Home Balance Training Intervention for People With Multiple Sclerosis

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This study investigated the effects of a home balance training intervention on people with multiple sclerosis (MS). This quasi-experimental repeated-measures study involved 14 ambulatory community-dwelling individuals with MS. Subjects were assessed on three separate occasions: before and after a 6-week control period and after a 6-week home exercise program. After the intervention, subjects demonstrated significant improvement in measures of balance, including the Berg Balance Scale and specific components of the Sensory Organization and Limits of Stability Tests. In conclusion, a multidimensional home exercise program can improve certain measures of balance in individuals with MS who have mild to moderate disability. Whether these improvements lead to improved quality of life or a reduction in fall risk is yet to be determined. Int J MS Care. 2007;9:111-117.
Environmental conditions such as lighting, support surface, and visual distractions can also influence balance strategies. The task itself (e.g., taking a leisurely walk or running to catch a cab) can impose various challenges to balance. Principles of motor learning such as transfer and specificity of training also demonstrate the important relationships among individual, environment, and task. Unfortunately, many balance tests and interventions do not adequately address these theoretical considerations and often fail to imitate the challenges to posture and balance routinely encountered in daily life. Whipple suggested that balance training should involve repeated exposure to diverse postural challenges that stimulate multiple sensory systems. Training programs should also involve various goal-directed activities performed under different environmental conditions.

Therefore, with an understanding that balance deficits are common in people with MS and that balance training interventions should be supported by current theories of motor learning and control, we designed a prospective study to investigate the effects of a multidimensional home exercise program on balance in individuals with MS.

Methods

Subjects

This quasi-experimental repeated-measures study involved one group of 14 individuals with MS. A convenience sample was recruited from a pool of ~100 subjects who had participated in previous unrelated research at Andrews University (Dayton, OH, USA). Subjects were also recruited through local MS support groups. Subjects were considered eligible if they (1) were able to ambulate independently a minimum of 10 meters (with or without an assistive device); (2) could maintain independent static standing balance with eyes open for 5 minutes without an assistive device; (3) were not experiencing an exacerbation of MS symptoms; (4) did not have the primary progressive form of MS; (5) were free of any significant known metabolic, cardiovascular, respiratory, renal, hepatic, or orthopedic conditions; (6) were currently not participating in a regular balance or strength training program; and (7) received medical clearance and a written verification of their MS diagnosis from their neurologist. Subject characteristics are summarized in Table 1. Before participation, all subjects gave informed consent that had been approved by the Institutional Review Boards at Miami Valley Hospital and Andrews University (Dayton, OH, USA).

Balance Measures

Multiple dimensions of balance were assessed using the Smart Balance Master with software version 7.01. This computerized system consists of dual force plates, a visual surround environment, a display monitor, and a safety harness. Force transducers measure ground reaction forces that are used to calculate center of pressure (COP) and center of gravity (COG) sway angles. Using the Smart Balance Master, subjects were evaluated on both the Sensory Organization Test (SOT) and the Limits of Stability Test (LOS).

SOT was used to evaluate each participant’s ability to maintain static standing balance under the following conditions: (1) eyes open on a fixed surface (EO), (2) eyes closed on a fixed surface (EC), (3) eyes open on a fixed surface with a sway-referenced visual surround (SV), (4) eyes open on a movable sway-referenced surface (EO/SS), (5) eyes closed on a movable sway-referenced surface (EC/SS), and (6) eyes open with a sway-referenced visual surround and movable sway-referenced surface (SV/SS). The term “sway referenced” indicates that during these conditions, the support surface and/or visual surround moves in reference to the subjects’ anterior and posterior changes in COG, reducing the subjects’ ability to use accurate somatosensory and/or visual input. Subjects performed three 20-second trials of each condition, which were scored as a percentage of maximum stability. A score of 0 indicated a fall, and a score of 100 indicated maximum stability.

LOS is more dynamic than the SOT in that it evaluates an individual’s ability to intentionally displace his or her COG toward eight different targets displayed on a
computer monitor. While keeping their feet in place, subjects leaned as far as possible toward each of the highlighted targets using an onscreen cursor that responded to changes in COG. These targets were positioned to require subjects to lean in anterior, posterior, and lateral directions. Targets were positioned at 100% of each person’s theoretical limit of stability, which was calculated by the computer and based on the person’s height. Measurements recorded during LOS were (1) movement velocity, indicating the average velocity of movement toward each target, measured in degrees per second; (2) maximum excursion (MXE), indicating the farthest on-axis distance the COG traveled during a trial, measured as a percentage of the total distance to the target; (3) endpoint excursion (EPE), denoting the farthest on-axis distance the COG traveled during the first sustained movement toward the target, also measured as a percentage of total distance to the target; and (4) directional control (DCL), calculated as a percentage of on-axis to off-axis movement of the COG during the initial movement excursion toward the target. For both SOT and LOS, the subject’s foot position was standardized based on height and checked routinely during testing. The Smart Balance Master has been shown to have moderate to good reliability and validity.18-22

The BBS was also used as an outcome measure to assess functional balance performance.23 This easily administered clinical assessment tool consists of 14 common functional tasks such as reaching, standing with eyes closed, stepping onto a step, picking up an object, and getting up and down from a chair. These activities require coordination of multiple systems involved in the control of balance. The scores of the balance scale range from 0 to 56 points, with a higher score indicating better balance. This test has shown excellent interrater and test-retest reliability.23,24

Disability Measure

All subjects were given a general neurologic evaluation and scored using the Kurtzke Expanded Disability Status Scale (EDSS).25 EDSS is a standardized assessment used extensively by MS clinicians and researchers to quantify level of impairment and disability and provide a common framework to describe patient status. Scores can range from 0 to 10, with a higher score indicating greater disability. Although EDSS has questionable reliability, validity, and sensitivity,26 it was used because it is one of the few disease-specific MS rating scales for clinical research. This scale was used only to help describe the subjects initially and not as an outcome measure. Subjects’ scores ranged from 1.5 (no disability, minimal signs of the disease) to 6.5 (constant bilateral assistance to walk ~20 meters without rest), with a mean of 4.5 (significant disability but fully ambulatory without device).25

Testing Protocol

All subjects were assessed on three different occasions with the described measures. An initial baseline measurement was taken for each subject, which was followed by a 6-week control period. During the control period, subjects were asked to resume their normal daily routine and not to start any new physical activities. Immediately after the control period, a preintervention measurement was taken, which was then followed by the 6-week home exercise intervention. A postintervention measurement was taken at the completion of the exercise program. On all three occasions, testing was conducted in the morning to reduce the potential effects of fatigue. To minimize the possible influence of early learning effects, subjects were given an opportunity to practice on the day of baseline testing and become familiar with the evaluation procedures before taking the initial measurements. During each testing session, all assessments were performed in the same order.

Balance Intervention

After the 6-week control period, each subject was instructed in a home exercise program that was designed to address multiple dimensions of balance. Table 2 gives a summary of the exercise program, including rationale for the various activities. The program was based on common exercises used in balance training but designed to address common impairments found in individuals with MS. Participants performed the exercise program on 3 nonconsecutive days per week for 6 weeks. The exercise program consisted of 11 different exercises and was designed to minimize the risk of injury yet sufficiently challenge balance. Most of the exercises were performed seated or standing in a corner with a chair placed in front of the subject; if a subject were to lose his/her balance, it could quickly be regained by touching the walls or chair. All subjects completed the same exercises, but the difficulty of individual exercises could be modified to appropriately challenge the balance of each subject. Each person was given an instruction booklet and a video demonstrating the training program. Subjects were called by the investigator during Weeks 1, 3, and 5 to answer questions and advance the exercise program as
<table>
<thead>
<tr>
<th>Treatment activity</th>
<th>Exercise progression</th>
<th>Time/reps</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing with eyes closed</td>
<td>FS/NS, FS/STa, FS/Ta, US/NS, US/STa, US/Ta</td>
<td>1–2 min</td>
<td>Improve static postural control using vestibular and somatosensory systems</td>
</tr>
<tr>
<td>Tossing ball between hands</td>
<td>FS/NS, FS/STa, FS/Ta, US/NS, US/STa, US/Ta; also, increase distance between hands and speed of ball movement</td>
<td>1–2 min</td>
<td>Improve static postural control using vestibular and somatosensory systems</td>
</tr>
<tr>
<td>Standing with head movement</td>
<td>Rotation, flexion/extension and side bending, increasing speed as able, attempt with eyes open then closed</td>
<td>6 reps in each direction</td>
<td>Improve static postural control during vestibular and visual challenge</td>
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<tr>
<td>Marching in place</td>
<td>With 10-s pause in unilateral stance every 5 steps, progress from FS to US</td>
<td>2 min</td>
<td>Improve dynamic postural control and single-leg stance ability</td>
</tr>
<tr>
<td>Visual fixation on stationary target with head movement</td>
<td>Increase speed of movement as tolerated; progress from seated to standing position</td>
<td>1–2 min</td>
<td>Improve use of vestibuloocular reflex and cervicoocular reflex for gaze stability</td>
</tr>
<tr>
<td>Visual fixation on moving target with head movement</td>
<td>Increase speed of movement as tolerated; progress from seated to standing position</td>
<td>1–2 min</td>
<td>Facilitation of eye/head coordination</td>
</tr>
<tr>
<td>Eye movement between stationary targets</td>
<td>Increase speed of movement as tolerated; progress from seated to standing position</td>
<td>1–2 min</td>
<td>Facilitate use of saccadic eye movement</td>
</tr>
<tr>
<td>Ankle sways</td>
<td>Anterior, posterior, medial, and lateral; increase amount of sway as able</td>
<td>1–2 min</td>
<td>Improve use of ankle strategy, increase ankle flexibility</td>
</tr>
<tr>
<td>Partial squats</td>
<td>Reduce upper-extremity support; increase repetitions and depth of squat as tolerated</td>
<td>Reps until moderate fatigue</td>
<td>Increase lower-extremity strength, improve dynamic postural control</td>
</tr>
<tr>
<td>Heel raises and toe raises</td>
<td>Reduce upper-extremity support; increase repetitions as tolerated</td>
<td>Reps until moderate fatigue</td>
<td>Increase lower-extremity strength, improve dynamic postural control</td>
</tr>
<tr>
<td>Anterior chest and gastrocnemius stretch</td>
<td>Increase stretch as tolerated</td>
<td>30–60 s/2 reps</td>
<td>Increase flexibility of anterior chest muscles and gastrocnemius for improved posture and range of motion</td>
</tr>
</tbody>
</table>

FS, firm surface; NS, normal stance (2–4 inches between feet); reps, repetitions; STa, semitandem stance; Ta, tandem stance; US, unstable surface (3-inch foam pad)
needed. Each subject maintained a daily log of exercise compliance.

**Data Analysis**

Descriptive statistics were calculated for each of the baseline characteristics and outcome measures. A one-way repeated-measures analysis of variance (ANOVA) was used to compare the results of SOT and LOS for baseline, preintervention, and postintervention measurements. When a significant main effect resulted from the ANOVA, a Newman-Keuls multiple comparisons test was used to establish which group means were statistically different. Friedman’s repeated-measures ANOVA on ranks was used for the ordinal data of the BBS. All statistical analyses were performed with SigmaStat Statistical Software, version 1.0 (Jandel Scientific Software, Chicago, IL, USA), and significance was defined at \( P < .05 \).

**Results**

Thirteen of the 14 subjects completed the study. One subject dropped out after the baseline testing because of transportation difficulties. Table 3 displays the mean baseline, preintervention, and postintervention values for each of the outcome measures. BBS scores improved 12.3% \((P < .001)\) after the exercise program. Performance on SOT showed significant improvement in the EO/SS condition of 6.0% \((P < .05)\) and the SV/SS condition of 32.4% \((P < .05)\). A 12.2% \((P < .001)\) improvement in the comprehensive SOT score was evident after the intervention. LOS results demonstrated that MXE increased by 8.9% \((P < .05)\) and EPE by 13.7% \((P < .001)\). Movement velocity was unchanged.

**Discussion**

As recommended previously, the training program for this study included various tasks designed to challenge multiple components of balance under different sensory conditions. The exercise program was also designed to address specific impairments that are common with MS (ie, vestibular dysfunction, weakness, sensory disturbances, decreased range of motion). The rationale for choosing a home-based program with the specific parameters used in this study was based on several factors. First, with any learned skill, balance training needs to be performed on an ongoing basis to be maintained. Therefore, a home-based program was the only realistic option for continued training outside of the clinic environment. Second, the choice of exercise time and frequency was based on a realistic expectation of what an individual with MS could perform on a regular basis given time constraints imposed by other daily activities, in addition to fatigue. Although the subjects in our study were highly motivated volunteers, the fact that only one person was unable to complete the study supports the potential long-term feasibility of the program.

Current understanding of postural control and motor learning indicates that a maximum training response would be elicited by the most aggressive exercise pro-

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**Table 3. Baseline, pretraining, and posttraining outcome measures**

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Baseline (mean [SD])</th>
<th>Pretraining (mean [SD])</th>
<th>Posttraining (mean [SD])</th>
<th>Percent change pre/post</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Berg Balance Scale</strong></td>
<td>49.0 (5.7)</td>
<td>47.3 (7.3)</td>
<td>53.1 (4.0)</td>
<td>12.3</td>
<td>.001</td>
</tr>
<tr>
<td><em>Sensory Organization Test,</em> %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO</td>
<td>90.8 (6.1)</td>
<td>92.1 (4.1)</td>
<td>93.2 (2.8)</td>
<td>9.0</td>
<td>NS</td>
</tr>
<tr>
<td>EC</td>
<td>82.3 (5.5)</td>
<td>78.7 (24.4)</td>
<td>85.8 (5.5)</td>
<td>1.0</td>
<td>NS</td>
</tr>
<tr>
<td>SV</td>
<td>84.3 (13.9)</td>
<td>89.1 (5.2)</td>
<td>90.0 (5.6)</td>
<td>6.0</td>
<td>NS</td>
</tr>
<tr>
<td>EO/SS</td>
<td>80.7 (11.4)</td>
<td>84.0 (7.8)</td>
<td>89.0 (5.6)</td>
<td>33.0</td>
<td>.002</td>
</tr>
<tr>
<td>EC/SS</td>
<td>19.0 (25.0)</td>
<td>31.4 (30.3)</td>
<td>41.8 (26.6)</td>
<td>32.4</td>
<td>NS</td>
</tr>
<tr>
<td>SV/SS</td>
<td>57.5 (22.3)</td>
<td>51.1 (30.2)</td>
<td>67.7 (17.8)</td>
<td>12.2</td>
<td>.040</td>
</tr>
<tr>
<td>Composite score</td>
<td>64.8 (11.2)</td>
<td>66.5 (15.0)</td>
<td>74.6 (10.1)</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td><strong>Limits of Stability Test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement velocity, deg/s</td>
<td>3.2 (1.0)</td>
<td>3.1 (0.7)</td>
<td>3.1 (0.9)</td>
<td>0.0</td>
<td>NS</td>
</tr>
<tr>
<td>Maximum excursion, %</td>
<td>73.0 (11.7)</td>
<td>72.1 (13.7)</td>
<td>78.5 (13.8)</td>
<td>8.9</td>
<td>.021</td>
</tr>
<tr>
<td>Endpoint excursion, %</td>
<td>57.8 (12.8)</td>
<td>58.5 (12.9)</td>
<td>66.5 (13.8)</td>
<td>13.7</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Directional control, %</td>
<td>66.4 (13.0)</td>
<td>65.4 (15.6)</td>
<td>70.1 (12.8)</td>
<td>7.2</td>
<td>NS</td>
</tr>
</tbody>
</table>

EO, eyes open; EC, eyes closed; SV, sway-referenced vision; SS, sway-referenced support; SD, standard deviation; NS, not significant

Note: Sensory Organization Test values measured as percentage of maximal stability.
gram a patient could safely tolerate. Ideally, this would include activities with both self-imposed and externally applied perturbations that destabilize the patient, causing him or her to repeatedly lose balance. If a patient is not being challenged sufficiently, the opportunity for development of new and enhanced postural control strategies might be diminished. Because this study used an unsupervised home exercise program, safety was a primary concern. With this in mind, the training program needed to be safe while providing enough stimulus for a training effect. Consequently, higher-functioning individuals who were already scoring near normal ranges may not have been challenged adequately to demonstrate significant improvement. These higher-level patients may have benefited from a more challenging clinically based program with close supervision and fall protection.

The results of this study are consistent with previous research that has shown a high incidence of balance impairment in people with MS. Evaluation of our subjects’ SOT scores revealed that they had the greatest deficits in maintaining postural control during conditions that required maximal dependence on vestibular and/or somatosensory input (EC/SS and SV/SS conditions). In contrast, most of our subjects achieved near-normal scores under conditions with accurate visual input (EO, EO/SS), indicating that they could effectively use vision to compensate for their vestibular or somatosensory deficits. With a high incidence of vestibular dysfunction and a potential overdependence on visual feedback, many people with MS may have difficulty maintaining balance during conditions where vision is compromised (eg, inadequate lighting, glare, complex visual environments). Therefore, treatment activities involving both specific vestibular training and compensation strategies (eg, use of a cane outdoors at night, proper home lighting) might prove useful.

During LOS, our subjects also scored below normative values for similar age groups in all categories. LOS predominantly requires the use of an ankle strategy to shift the center of gravity toward the various targets on the computer screen. Because this activity requires adequate strength and range of motion at the ankle, the lower scores may indicate that the subjects had limitations in one or both of these areas. Prior research has shown a relationship between balance ability, ankle strength, and range of motion. Although ankle range of motion was not measured in this study, the results indicate that subjects had the greatest difficulty reaching the targets positioned anteriorly. Muscular tightness and spasticity of the plantar flexors could reduce the ability to perform this task. Because lower-extremity muscle weakness is common in MS, muscle strength at the ankle could have also played some part in the lower-than-normal LOS scores. Several of the activities (ie, plantar flexor stretching, heel and toe raises, ankle sways) in the exercise program were designed to address these impairments specifically and could have led to the improvements observed in MXE and EPE.

In addition to SOT and LOS, the BBS was used to identify potential balance impairment. This measurement tool was chosen because it uses common functional activities and can be performed quickly and easily in the clinic. The results of this study show that the BBS may be a useful tool for measuring balance in people with MS who have more significant balance impairments. However, it may not be appropriate for higher-functioning patients because of a “ceiling effect.” This was evident in five of our subjects who scored the highest possible score of 56 despite having abnormal scores on the computerized balance assessment. Two subjects achieved the maximum score during all phases of testing, leaving no ability to document improvement with the BBS. Baseline scores on the BBS for our subjects ranged from 34 to 56, with a mean of 47. Previous research indicated that for older adults scoring in the 46–54 range on the BBS, a 1-point increase in score corresponded to a 6–8% decrease in fall risk. Our subjects improved an average of 6 points on the BBS, suggesting a possible reduction in fall risk.

One limitation associated with this study was the use of a repeated-measures design. With this type of design, the potential of learning effects during testing exists, although efforts were made to reduce the effects by allowing the subjects to become familiar with the testing procedures before actual data collection. Also, no significant differences were noted between the baseline and preintervention performance for any balance measures. Another limitation was that the progressive and variable nature of MS could influence performance over the 12-week study period. Although people with recent exacerbations and those with the primary progressive form of the disease were excluded, those with secondary progressive, relapsing-remitting, and benign disease courses could participate. Subjects in these categories could have experienced a decline or improvement in function over a
12-week period unrelated to the exercise program. Third, all tests were administered by the same unblinded investigator. Although this may have improved reliability, it also introduced the possibility of evaluator bias. Furthermore, a small sample of highly motivated subjects with mild to moderate disability may not have been representative of the typical person with MS. These factors make generalizing the results to the MS population at large difficult.

Future studies would benefit from a larger sample of randomly selected individuals and the use of a true control group. In addition, long-term documentation of continued exercise adherence, fall reduction, and balance improvement would be beneficial. Comparing results of this research with a more aggressive supervised program might clarify whether long-term clinically based interventions would be justified.

Conclusion
This study has shown that a multidimensional home exercise program can improve some measures of balance in people with MS who have varying levels of disability. It has also demonstrated that a home training program is safe and feasible. Moreover, the findings support the current recommendation that balance training include various activities that challenge multiple dimensions of balance. Whether these improvements lead to an increase in functional ability or a reduction in fall risk is yet to be determined.

References

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