

# The Effects of Home-Based Resistance Exercise on Balance, Power, and Mobility in Adults With Multiple Sclerosis

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**ABSTRACT.** DeBolt LS, McCubbin JA. The effects of home-based resistance exercise on balance, power, and mobility in adults with multiple sclerosis. *Arch Phys Med Rehabil* 2004;85:290-7.

**Objective:** To examine the effects of an 8-week home-based resistance exercise program on balance, power, and mobility in adults with multiple sclerosis.

**Design:** Experimental group design.

**Setting:** General community.

**Participants:** Twenty-nine women (age,  $50.3 \pm 8.5$ y) and 8 men (age,  $51.1 \pm 7.1$ y) were stratified by disability level and age and were randomized into exercise ( $n=19$ ) and control ( $n=17$ ) groups.

**Intervention:** The exercise group had lower-extremity resistance training 3 times a week. The control group maintained current level of physical activity.

**Main Outcome Measures:** Primary outcome measures included balance, as measured by anteroposterior sway, mediolateral sway, and sway velocity using the AccuSway<sup>PLUS</sup> force platform; mobility as assessed with the Up and Go test; and leg power as assessed with the Leg Extensor Power Rig.

**Results:** Leg extensor power improved significantly in the exercise group (pretest,  $3.19 \pm 1.36$ W/kg; posttest,  $3.95 \pm 1.23$ W/kg;  $P=.004$ ), although measures of balance and mobility did not change.

**Conclusions:** The home-based resistance program was well tolerated by participants and offered a practical means to improve leg extensor power in a short period of time.

**Key Words:** Exercise; Multiple sclerosis; Rehabilitation.

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**M**ULTIPLE SCLEROSIS (MS) is a demyelinating disease of the central nervous system and is the most frequent form of neurologic disorder among adults. In the United States, approximately 300,000 to 350,000 persons have MS, with as many as 300 persons being diagnosed each week.<sup>1</sup> The demyelination of the nerve tissue causes a variety of symptoms that may affect physical activity. These symptoms include excessive muscle fatigue,<sup>2</sup> muscular weakness,<sup>3</sup> spasticity, impaired

balance, and impaired autonomic cardiovascular control.<sup>4,5</sup> Symptoms may lead to an abnormal gait or immobility and are frustrating for persons with MS because of the negative effects on daily activities.

Although the American College of Sports Medicine has guidelines for exercise with adults for MS,<sup>6</sup> the recommendations are derived from limited research that has been based primarily on aerobic capacity. The studies that have been completed have lacked results related to daily activities, including mobility. However, it is known that adults with MS are less physically active<sup>7</sup> and weaker than other adults.<sup>8</sup> Schapiro et al<sup>9</sup> determined that 12 weeks of home-based arm and leg cycle ergometry improved aerobic capacity by 10%; Petajan et al<sup>10</sup> determined that 15 weeks of community-based arm and leg cycle ergometry improved aerobic capacity by 22%. Although these data suggest that aerobic capacity may improve,<sup>9,10</sup> little is known about the effects of resistance exercise.

It has been suggested that adults with MS can improve strength with progressive resistance exercise<sup>11,12</sup> and aquatic exercise,<sup>13</sup> yet study design limits the generalizability of the results. Researchers have evaluated a 4- to 8-week resistance training program designed to improve the muscular endurance of the knee flexors in 5 adults with MS.<sup>11</sup> After training, 3 of the 5 participants increased the peak torque of the knee flexors and decreased perceptions of fatigue. Others<sup>11</sup> have examined the effects of progressive resistance exercise on muscular strength in 9 adults with MS. The 10-week community-based exercise program used machine-based resistance and free weights, 2 days a week. The results of the study indicated that the participants improved the peak torque of the knee flexors and extensors by 16% to 57%, elbow flexors and extensors by 6% to 29%, and shoulder abductors and adductors by 3% to 11%. The researchers concluded that although some participants did not improve, the results indicate that overall, most of the participants improved their muscular strength.<sup>12</sup> Although each of these studies is important to establishing the effects of resistance exercise on muscular strength and endurance, each had a small sample size (without a control group) and lacked results related to functional outcome measures.

It has been shown that adults with MS have less leg strength than their peers,<sup>8</sup> as well as impaired balance,<sup>14</sup> which has led to an increased prevalence of falls in this population.<sup>15,16</sup> When differentiating between fallers and nonfallers with MS, balance was identified as a key component, along with cane use and ability to walk.<sup>16</sup> Researchers have also found a relationship between mobility and tasks related to gait speed as a predictor of recurrent falling in older adults.<sup>17</sup> On tests of clinical balance, adults with MS scored significantly lower for tandem stance, functional reach, and arm raise.<sup>15</sup> However, research related to the effects of resistance exercise, which has been shown to improve balance in middle-aged and older adults, seniors,<sup>18,19</sup> and poststroke participants,<sup>20</sup> has not been done on adults with MS.

Rehabilitation programs for adults with MS are often designed to help maintain independence and optimize physical functioning. Some researchers<sup>21,22</sup> have found lower-extremity power to be the number 1 predictor of physical functioning in

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elderly persons. Other researchers<sup>23,24</sup> have concluded that leg power may be a better predictor of physical performance and function than muscular strength in older adults. A minimum level of leg power has been shown to be required for daily activities such as lifting objects, rising from a chair, and climbing stairs.<sup>22,25,26</sup> A resistance training program specifically designed to improve leg power was well tolerated in a group of healthy older adults. The high-velocity training program used weighted belts 3 times a week, in addition to 45 minutes of walking. Peak leg power improved an average of 22%.<sup>23</sup> Leg extensor power was also found to be a key predictor of mobility problems in very old people living independently.<sup>27</sup> Researchers have examined leg power and mobility in older adults and in the elderly, but the effects of resistance training on these variables related to physical functioning have not been examined in adults with MS.

Although many adults with MS are interested in exercise, often it is difficult to find available community-based programs that are at a nominal cost with a support staff trained to provide guidance for persons with MS. Transportation may be difficult for those adults with vision impairments or paralysis due to the disease. Those adults who are still working part-time and/or raising children may find that committing to an exercise program in the community is difficult. Thus, home-based exercise may be an appropriate tool for many adults with MS. Presently, it is not known if adults with MS are capable of training at home at levels that will improve lower-leg power or mobility. Research has shown that participants had a high rate of compliance when training at home with electric stimulation (to improve muscle fatigue ability of the dorsiflexors)<sup>14</sup> and arm and leg cycle ergometry.<sup>7</sup> An effort to create a feasible exercise program that may be easily replicated is essential. Because of the lack of participants available to commit to a 14-week community-based program<sup>28</sup> and because of the need for appropriate study design in the area of resistance training, our study examined the efficacy of a home-based resistance training program in adults with MS.

Our primary objectives were to determine whether, after a 6-session instructional phase, an 8-week home-based resistance training program would improve balance, power, and mobility in adults with MS. Two questions were examined: (1) Would participants adhere, without complications, to an 8-week home-based resistance training program? and (2) Would an 8-week home-based resistance training program increase balance, power, and mobility in adults with MS?

## METHODS

### Study Design

Our study used a pretest–posttest experimental group design. Type of MS, neurologic score (as determined by the Expanded Disability Status Scale<sup>29,30</sup> [EDSS]), balance, power, and functional mobility were measured before and after the 8-week intervention. Before testing, each participant completed a familiarization period, which included testing on all the dependent measures: mobility, balance, and power. The scores during the familiarization period were not used in the analysis, because this period was designed to decrease the effects of learning on the dependent measures. After the familiarization period, participants completed pretesting (at least 48h apart) on balance, power, and mobility before the start of the intervention. The scores for balance, power, and functional mobility on the pretest day were used in the final analysis.

### Participants

The participants included 29 female volunteers with MS (mean age  $\pm$  standard deviation [SD], 50.3 $\pm$ 8.5y) and 8 male volunteers with MS (mean age, 51.1 $\pm$ 7.1y). Inclusion criteria for this study were healthy adults with MS and the ability to walk (with or without assistive devices) at least 20m without rest. Subjects were recruited through all the local chapters of the National Multiple Sclerosis Society's support group meetings within a 60-mile radius of the university. Within this area were 3 cities with populations that ranged from 40,000 to 60,000. To assist in the recruitment of subjects from the surrounding communities, some participants were transported for testing, and others were reimbursed for mileage, according to university guidelines, for the testing and/or training sessions. Volunteers signed informed consent that was approved by the Institutional Review Board for the Protection of Human Subjects of Oregon State University.

Before assignment, all participants underwent baseline testing on all measures. After baseline testing, participants were separated by gender and stratified by disability level (EDSS) and age. First, each participant was matched with another participant with a similar EDSS score (1.0, 2.0, 3.0, 4.0, etc) and then by age. Age was grouped by decades (20s, 30s, 40s, 50s). Participants with EDSS scores of 1.0 or 1.5 were grouped together, then 2.0 or 2.5, then 3.0 or 3.5, and so on. Next, participants were matched for age (same decade). A coin toss determined which participant was in the exercise group and which was in the control group. There was 1 remaining participant without a match, and she was assigned to the exercise group (because of potential loss of participants from disease-related issues). Thus, after assignment there were 19 exercisers and 18 controls (tables 1, 2).

For all participants, level of disability was determined by using the Kurtzke functional system scales<sup>29</sup> and the EDSS.<sup>30</sup> The EDSS instrument has been determined to be reliable and valid<sup>2</sup> and is frequently used for evaluating neurologic impairment in research involving adults with MS.<sup>31</sup> This scoring system is performed by skilled professionals to rate the level of neurologic impairment due to MS lesions in the 8 functional systems and ambulation. The final score ranges from 0 (normal) to 10 (death due to MS).<sup>24</sup> A trained physical therapist evaluated participants at baseline and at the conclusion of the intervention. Although the visual portion of the EDSS was not measured and could have a direct bearing on balance, no participant reported changes in vision during the study. Because each functional system is mutually exclusive in terms of neuroanatomy, the capacity for this tool to rate level of disability in all the other areas remained intact.

Participants' EDSS scores ranged from 1.0 to 6.5. Ambulatory status ranged from the ability to walk 500m without rest to the ability to walk 90m without rest (with an assistive device). Twenty-six of the 37 participants had the ability to walk more than 500m without rest, and only 2 participants walked less than 100m without rest (with an assistive device). Thus, our study included participants at various levels of ambulatory ability.

A health and history questionnaire was used to collect information regarding type of MS (benign, chronic-progressive, progressive, relapsing-remitting), year of diagnosis, current health status, level of physical activity, and demographic information. This questionnaire was also used to determine whether other serious comorbidities (eg, cancer, coronary heart disease) existed. Participants were excluded from the study if they had an exacerbation within the last 3 months.

Table 1: Demographic and Disability Measures for Exercise Group

Subject	Sex	Age (y)	Height (m)	Weight (kg)	Type of MS	Duration of MS (y)	EDSS Score	MAS Score
1	F	46	1.61	65.3	RR	7	2.5	0.0
2	F	59	1.59	57.4	RR	38	1.0	0.0
3	F	47	1.66	97.1	CP	17	6.0	3.0
4	F	56	1.72	80.1	RR	10	2.0	0.0
5	F	41	1.59	69.7	P	5	6.0	1.0
6	F	48	1.73	88.6	RR	7	4.5	0.0
7	F	52	1.56	53.6	RR	8	1.5	0.0
8	F	50	1.67	49.0	RR	21	3.0	0.0
9	F	42	1.64	54.0	RR	1	1.5	0.0
10	F	47	1.64	76.7	CP	21	6.0	2.0
11	F	61	1.69	101.9	RR	6	4.5	0.0
12	F	67	1.59	63.0	CP	30	5.0	0.0
13	F	40	1.67	79.6	P	5	6.0	0.0
14	F	51	1.59	83.3	CP	11	4.0	0.0
15	F	57	1.57	72.1	CP	5	6.0	1.0
16	M	55	1.75	82.4	CP	22	6.5	1.0
17	M	55	1.83	87.3	RR	2	3.5	1.0
18	M	59	1.79	85.1	B	40	2.0	0.0
19	M	48	1.82	64.5	CP	30	4.0	1.0

Abbreviations: B, benign; CP, chronic progressive; F, female; M, male; MAS, Modified Ashworth Scale; P, progressive; RR, relapsing-remitting.

The Modified Ashworth Scale (MAS) was used to determine the level of spasticity in participants.<sup>32</sup> The MAS is a 5-point ordinal scale designed to grade the level of resistance encountered during manual passive muscle stretching.<sup>32</sup> It is the most widely used scale to grade the degree of spasticity and has a high rate of interrater reliability. Its validity has been determined with the use of electromyographic recordings of muscle activity in patients with spinal cord injury.<sup>33</sup>

### Primary Outcome Measures

Balance was measured using the AccuSway<sup>PLUS</sup> force platform.<sup>a</sup> The force platform measures the 3-dimensional forces (Fx, Fy, Fz) and 3-dimensional moments (Mx, My, Mz) involved in balance. These provide center of pressure coordinates, which allow postural sway and sway velocity to be

measured (AMTI, 1995). During assessment, participants were asked to stand on the platform for 10 seconds and to focus on a large red target placed 4ft (1.2m) away on the wall. For our study, the primary outcome measures of balance were antero-posterior (AP) sway, mediolateral (ML) sway, and sway velocity.

Leg power was measured using the Leg Extensor Power Rig.<sup>b</sup> The power rig was designed to provide a measurement for leg extensor power in older adults with poor mobility, as well as in adults of all ages. The design and setup of the power rig has been described.<sup>22,25,34</sup> This device measured the power delivered in watts during a single-leg extension. For each test, participants were seated in a semirecumbent position with the knees flexed approximately 90° to 96° and the hips flexed at approximately 45°. The seat position was marked, so the setup

Table 2: Demographic and Disability Measures for Control Group

Subject	Sex	Age (y)	Height (m)	Weight (kg)	Type of MS	Duration of MS (y)	EDSS Score	MAS Score
1	F	43	1.68	59.3	RR	3	2.0	0.0
2	F	52	1.73	78.5	CP	14	3.0	0.0
3	F	62	1.56	62.8	CP	33	2.0	0.0
4	F	48	1.70	68.0	CP	18	1.5	0.0
5	F	54	1.67	62.9	CP	29	3.5	0.0
6	F	49	1.61	55.1	RR	11	4.0	0.0
7	F	40	1.71	64.8	RR	14	4.0	0.0
8	F	48	1.58	48.6	RR	4	2.5	0.0
9	F	57	1.56	73.0	CP	1	4.5	0.0
10	F	43	1.79	99.2	RR	3	1.5	0.0
11	F	33	1.66	107.8	P	8	5.0	0.0
12	F	69	1.63	73.3	B	35	6.0	0.0
13	F	45	1.70	79.8	RR	21	4.5	0.0
14*	F	25	1.60	57.3	RR	1.50	2.0	0.0
15	M	36	1.70	68.7	RR	9	5.5	1.0
16	M	53	1.85	115.1	CP	4	2.5	0.0
17	M	55	1.75	70.3	CP	3	3.0	0.0
18	M	48	1.95	123.2	CP	24	6.0	2.0

\*Withdrew from study because of MS exacerbation.

was identical for posttesting. With arms across the chest, participants were asked to push down by extending their leg "as hard and as fast as they could." During assessment, participants alternated legs and performed 8 to 9 trials per leg, at their own pace, or until power values plateaued. The primary outcome measure was the sum of the maximal power from the right and left legs divided by body weight. The summation of power for both legs divided by body weight has been used previously.<sup>25,34</sup> This device was determined to be safe, reliable, and valid for all age groups (20–86y) and levels of physical capability.<sup>22</sup>

The precision error of this tool, when used with adults with MS, has not been evaluated. For our study, the precision error was 9.5% (n=30) and was evaluated by comparing the highest scores of the right and left legs obtained during the familiarization session and the highest scores during the pretest session. The precision error was calculated by dividing the SD of the scores by the average. This was similar to the coefficient of variation determined by Bassey et al<sup>22</sup> in control participants with an average age of 27 years.

The Up and Go test was used to evaluate functional mobility. This test measured, in seconds, the time taken by a person to stand up from a standard arm chair, walk a distance of 3m, turn, walk back to the chair, and sit down again.<sup>35</sup> This test has been widely used with adults and has been determined to be a reliable and valid index of functional mobility.<sup>35</sup> If assistive devices were used during typical ambulation, then those devices were used for each testing session. This test was administered 2 times, and the best (or lowest) score for each test session was used in the analysis. For our study, the precision error for the Up and Go was 5.6% (n=31), which was calculated using the same technique as was used to determine leg extensor power.

### Resistance Training Intervention

After group assignment and before the home-based experimental treatment, the exercise group participated in 6 exercise instructional sessions. The instructional sessions took place at 3 different locations near the homes of the participants. The sessions were designed to teach participants the correct form for each exercise and proper exercise recording procedures. The exercise sessions included instruction on the warm-up stretches, resistance training exercises, and cool-down activities. The sessions occurred 3 times a week, on alternating days, for 2 weeks. Weighted vests were worn without weight during the last session of the instructional phase of the program, so that participants could get used to them before beginning home-based exercise. After the 2-week instructional phase, the exercise group received all the equipment (vest, ankle weights, step, data recording sheets) needed to perform the exercises at home. Also, during the instructional phase of the program, an exercise video was produced that was specific for this study. Instructions and cues were given to remind participants of the correct positioning and form during the exercise. The video was approximately 6 minutes in length and was mass-produced and given to each participant. Participants were asked to watch the video before or during each exercise session.

**Home-based resistance training.** The 8-week resistance training intervention began after the instructional phase. The exercise program focused on activities that were designed to be functional in nature and that had been shown in other studies<sup>36,37</sup> to increase strength and power in the lower extremities. Each participant performed 5 to 10 minutes of warm-up activities (walking) and stretches, 25 to 30 minutes of strengthening exercises, and 5 to 10 minutes of whole-body stretching, 3 times a week. During all the strengthening exercises, a wall, a chair, or a stable structure was located to the left or right of

subjects, so that they could grasp it if balance was compromised. The exercises included chair raises, forward lunges, step-ups, heel-toe raises, and leg curls. Participants were asked to perform the exercises at their own pace and to take rest breaks between sets if necessary. Because of the variability in ability levels, the exercise programs were individualized so that each participant would be able to perform the exercises safely and effectively.

**Chair raises.** Participants were asked to rise from an armless chair that allowed for about a 90° knee angle, with their arms crossed on the chest. The volunteers positioned their feet a shoulder-width apart, toes pointed out. The participants were asked to "look straight ahead, chest up, and to stand straight up." Participants were asked to perform the raises at their own pace and to avoid putting their knees in front of their toes. Chair raises were performed in sets of 10.

**Forward lunges.** Lunges were performed in a forward direction. Participants were asked to step forward, bend the opposite knee toward the ground, and then to push back off the lunged leg to the starting position. Participants were instructed not to touch the opposite knee to the ground and not to have their lunged knee go in front of their toe. One set of lunges consisted of 10 lunges with the right leg and 10 with the left leg.

**Step-ups.** Step-ups were performed on a 4-, 6-, or 8-in (10.2-, 15.2-, 20.3-cm) step, depending on the ability level of the participant. Participants were asked to "step up, up, down, down." They were to step up with the first foot, step up with second foot, then down with second foot, and finally down with the first foot. One set of step-ups consisted of 10 repetitions with the right foot first and 10 repetitions with the left leg first.

**Heel-toe raises.** Lower-leg musculature was developed through the use of heel-toe raises. These required participants to rise up on the toes and rock back onto the heels while lifting the toes for 1 repetition. Heel-toe raises were performed in sets of 10.

**Leg curls.** Leg curls were performed with the use of adjustable ankle weights. Participants were instructed to stand up and hold onto a wall or door jam and to lift their lower leg up to their buttocks. Often, more weight would be used on the strong side, and less weight would be used on the weak side. Leg curls were performed in sets of 10.

**Intensity of training.** The 8-week home-based exercise program was based on strength training periodization models, which included the 2 weeks of instructional sessions and 8 weeks of home-based exercise. The experimental phase was based on research by Stone et al,<sup>38</sup> which included a 4-week hypertrophy phase, a 4-week strength phase, and a 2-week power phase. These periodization techniques have been used with athletes as well as untrained persons.<sup>39</sup> This program used weighted vests to increase the intensity of the training. Although the intensity of the training and the volume of exercise varied with each individual, the progression of the study was designed as follows: (1) the initial vest resistance was set at 0.5% of body weight and increased by percentages of body weight (.05%–1.5%) every 2 weeks; (2) during the first and third weeks of the study, participants were instructed to perform 2 sets of 8 to 12 repetitions, and during the second and fourth weeks of the study, participants were instructed to perform 3 sets of 8 to 12 repetitions for each exercise (hypertrophy phase); and (3) during weeks 5 through 8, participants decreased the number of exercises to 2 sets of 8 to 10 repetitions (strength and power phase). The initial weight and progression were based on an 11-week pilot study using the weighted vests and the same exercises, 3 times a week in a university setting.<sup>28</sup>

Table 3: Summary of Primary Outcome Measures at Pretesting and Posttesting

	Exercise Group		Control Group		Time Effect ( <i>P</i> )	Group Effect ( <i>P</i> )	Group by Time Effect ( <i>P</i> )
	Pretest	Posttest	Pretest	Posttest			
Power (W/kg)	3.19±1.36	3.95±1.23	3.52±1.32	3.68±1.22	<.001*	.941	.040*
Power (W)	227.67±83.29	282.00±65.44	272.48±101.24	290.04±110.23	<.001*	.375	.017*
Balance (cm/s)							
AP sway	0.477±0.253	0.382±0.212	0.440±0.334	0.412±0.256	.101	.965	.361
ML sway	0.261±0.165	0.212±0.130	0.300±0.311	0.235±0.129	.137	.567	.834
Velocity sway	1.690±0.605	1.727±0.778	1.644±0.775	1.748±0.490	.480	.972	.791
Mobility (s)	11.28±4.71	9.15±2.26	11.09±4.74	11.08±5.21	.090	.522	.092

NOTE. Values are mean ± SD.

\**P*<.05.

Bimonthly home visits and weekly phone contact were made for both groups. During contact, the researcher discussed participants' fatigue levels and asked about changes in physical activity, medical status, medications, or home- or work-related stress. The researcher then adjusted the intensity of the individual exercise programs. At the end of the intervention, both groups returned for posttesting.

### Control Group Training

At the conclusion of posttesting, the control group had an opportunity to learn the home-based resistance exercises. The 2-week instructional phase for the control group was held at the same locations, 3 times a week for about an hour. All participants in the control group were given the home exercise video either at posttesting or at the beginning of this training.

### Statistical Analysis

The statistical analyses were carried out using SPSS, version 11.5.<sup>c</sup> Characteristics of the participants at baseline were compared between the exercise and the control group by Mann-Whitney *U* tests for the type of MS and EDSS and the MAS scores. Mean scores ± SD are presented for pretesting and posttesting sessions for the primary outcome measures (table 3). A 2×2 repeated-measures analysis of variance (ANOVA) was used to examine the group, time, and group by time interaction. The main effects were group (exercise, control) and time (pretest, posttest), and interaction was used to determine differences in the groups during the intervention (group by time). Level of significance was set at *P* less than or equal to .05 for all statistical tests.

Before the study, power analysis indicated that, with an expected effect size of 0.5, changes in the dependent measures<sup>22</sup> would be detected with 80% power by evaluating 25 subjects per group.<sup>40</sup> However, participant availability was limited to 37 participants, which lowered the estimated power to 60%. The impact of the exercise program effect size<sup>41</sup> ( $M_1 - M_2 / SD$ ) will also be discussed.

## RESULTS

After data collection, all variables were entered for analysis and were screened to determine whether statistical assumptions were met. This screening included examinations for distribution linearity and outliers. All statistical assumptions were met for the primary outcome measures. One outlier<sup>40</sup> from the exercise group was excluded from the mobility analysis because of an extreme score (>2 SDs from the mean). This person used the only front-wheeled walker for ambulation in the study; therefore, we removed this score from the mobility analysis. Before the intervention, there were no significant differences between groups on the type of MS (*U*=148.00,

*P*=.637). For the EDSS scores, the Mann-Whitney *U* test showed no significant differences between groups before (*U*=133.5, *P*=.545) or after the intervention (*U*=142.5, *P*=.552). Similarly, the results from the Mann-Whitney *U* tests showed no significant difference between groups on the MAS scores before (*U*=131.5, *P*=.346) or after the intervention (*U*=105, *P*=.572).

### Intervention Compliance

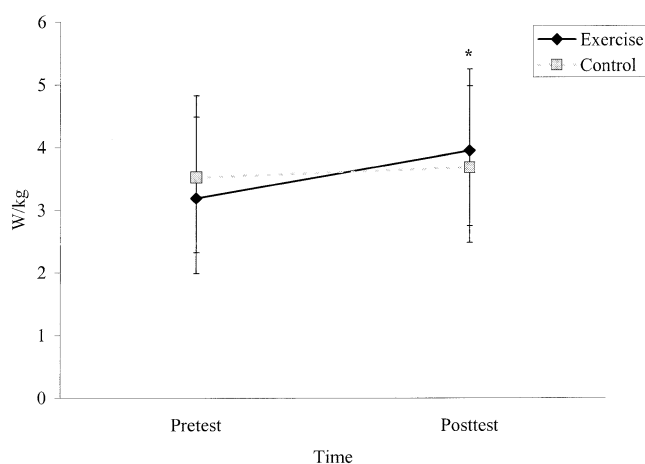
During the study, 1 participant from the exercise group was unable to complete the study because of an MS exacerbation. Therefore, for the final analysis, there were 19 in the exercise group and 17 in the control group. The adherence to the home-based program was successful, with participant reports of 95% of the 24 exercise sessions completed (mean, 22.9±0.43 sessions). The participants in the exercise group successfully increased the weight in their vests by 0.5% to 1.0% of body weight during the 8-week intervention. All participants were visited a total of 4 times during the study period, with the exception of 1 participant who had an exacerbation and dropped out of the study.

### Balance

After the intervention, the repeated-measures ANOVA showed that there were no significant differences between groups for any of the balance measures. Although AP sway decreased by -10.3% in the exercise group and the control group increased AP sway by 6.4%, the group by time interaction was not significant. ML sway in the exercise group saw a similar decrease of -4.0%, whereas the control group had an increase of 9.4%. For sway velocity, the exercise group increased by 2.5%, and the control group increased by 25.1%. Although it appears that balance test data were improving for the experimental group, the final results for the balance tests indicated that the adults in the exercise group did not significantly improve their AP sway, ML sway, or sway velocity by the intervention (table 3). The main effects for group and time were also not significant.

### Leg Extensor Power

After the intervention, the group by time interaction showed a significant difference ( $F_{1,34}=6.23$ , *P*=.004, effect size=.22) in leg extensor power (fig 1). The exercise group (pretest mean, 3.19±1.36W/kg; posttest mean, 3.95±1.23W/kg) improved their leg power by 37.4%, and the control group (pretest mean, 3.52±1.32W/kg; posttest mean, 3.68±1.22W/kg) improved their power by 6.7%. Although the experimental group had slightly less lower-extremity power than the control group at baseline, the main effect for group was not significant. The main (within-group) effect for time was statistically significant,



**Fig 1. Lower-extremity power corrected for both groups. Significant group by time effects: \* $P < .05$  significantly different from control at posttest.**

which indicates changes in leg extensor power during the intervention (table 3).

### Mobility

The final results for the Up and Go test indicated that the 18 adults in the exercise group decreased their time by 12.7%, whereas the control group showed little improvement (1.0%). Although the exercise group decreased their time by an average of 2.13 seconds, the group by time interaction was not significant. Also, the main effects for group or time were not statistically significant.

## DISCUSSION

The first research question was positively addressed. The resistance-training program did not cause any injuries or increases in MS symptoms due to the intervention, and the participants maintained compliance to the home-based exercise program. This 8-week home-based resistance exercise program significantly improved leg extensor power in adults with MS. The home-based exercise program offered a practical means for ambulatory adults with MS to improve leg power by more than 30% in a short time. Our study did not support the entire portion of the second research question for an improvement in balance, leg power, and mobility. Although there were changes in the exercise group's balance and mobility scores, they did not reach statistical significance.

Lower-extremity power is a major determinant of functional ability in older adults.<sup>22,27,42</sup> Researchers<sup>22</sup> have examined the relationship between functional measures and lower-extremity power in very old adults. Bassey et al<sup>22</sup> found in 13 very old women (mean,  $86.5 \pm 6$ y) that the relationship between leg extensor power in both legs (W/kg) and functional performance was significant for stair rising speed and for 6.1-m walking speed. Leg extensor power was also found to be a key predictor of mobility problems in very old people living independently.<sup>27</sup> Research<sup>8,11-13</sup> involving strength training and adults with MS has not addressed outcomes related to mobility or independence.

Researchers<sup>42</sup> have examined a large cohort of seniors and found measures similar to those used in our study to be predictors of maintaining functional independence. The Senior Fitness Test uses a modified version of the Up and Go test, whereby participants are asked to walk 2.4m and then to return.

In our study, the Up and Go test asked participants to stand up from a seated chair, walk 3m, turn around a cone, walk back to the chair, and sit down.<sup>42</sup> However, after the resistance-training intervention, the women in the exercise group decreased (positive change) their average time from 11.5 to 8.3 seconds, which corresponds to moving from the "at risk for loss of functional independence" category to "below average," even when comparing this group to a longer test and with women aged 60 to 64 years. Although it is difficult to compare the participants of this study (mean, 49.67y) with the research on older adults, the importance of functional performance and the ability to remain independent and mobile may be just as great.

### Limitations

One limitation of our study may be sample size. For the group by time mobility measure, the effect size and observed power were .084 and 39%, respectively. However, when looking at leg extensor power, the effect size was .22, and the observed power was equal to 86%. When looking at the measures of balance, for ML sway and sway velocity the observed power was 6%, with an effect size of .001 and .002; for AP sway the power was 15%, with an effect size of .03. To avoid a type II error, an attempt was made to recruit 25 subjects per group, while estimating the effect size of 0.5 for all dependent measures. Future research should address this limitation by increasing the number of participants in the study and by using a smaller effect size (0.2) to estimate the number of participants needed per group.

A second limitation of the study may be the length of the intervention. The home-based resistance training program included 2 weeks of instructional sessions and 8 weeks of home-based exercise. Although the length of the intervention was sufficient to impact lower-extremity power, it may not have been long enough to determine statistically significant changes in balance or mobility. Other researchers have found improvements in postural control,<sup>18</sup> functional reach, and gait<sup>19</sup> with 10 weeks of resistance training. Lengthening the intervention by 2 to 4 weeks may improve the ability to determine the effects of resistance training on balance or mobility. Then again, when Judge et al<sup>43</sup> used a force platform to measure improvements in balance, single-leg stance improved with 6 months of exercise, whereas double-leg stance did not. Therefore, the interpretation of the balance results for this study (double-leg stance) and for future research should consider the instrument and procedures used to measure balance. An additional limitation of this study was the lack of visual assessment in the EDSS. This may have affected the balance performance in this population. Finally, the difference in baseline lower-extremity power may have provided the exercise group with a greater potential for improvement.

### Applications and Implications

An important application of the study may be the nature of the home-based exercise program. The intervention consisted of functional exercises, which could be performed at home with inexpensive equipment (weighted vest, \$45; ankle weights, \$15) and relatively little supervision. Over a longer period of time, such as 3 to 6 months, the functional nature of the exercises may also transfer specifically to activities of daily living (ADLs). Activities such as getting out of a chair and step ups were performed as part of the intervention. Participants often claimed that others noticed how much easier it was for them to get in and out of the car and to get up and down stairs. Also, during the intervention, 4 participants stopped using their canes for daily ambulation. These anecdotal results are important to consider, as is the impact of the improvements in

lower-leg power. These outcomes may have a bigger impact on the ADLs in adults with MS than the improvements in lower-extremity power.

### Recommendations for Future Research

The recommendations for future research are derived from the implications and applications. One recommendation is to extend the project and to systematically decrease the amount of contact. A possible alternative to the present format might include instructional sessions in a clinical setting or in a community-based setting, followed by 1 home visit and a phone call each month thereafter. The researchers found that the initial home visit was valuable and important to ensure that the participants were performing the exercises safely and correctly in their setting. These suggestions may be applicable for physical therapy and/or home health care workers. Furthermore, an alternative format would be to initiate the training sessions in a clinical setting and to use telephone contact for 3 to 6 months. Participants could return to the clinical setting for retesting and, subsequently, continue with the exercise program without phone contact for 1 year. Last, functional ADL measures should be included as dependent measures in future research.

### CONCLUSIONS

The purpose of our study was to examine the effects of an 8-week home-based resistance training program in adults with MS. This resistance-training intervention was implemented without injury or increases in MS symptoms. The results indicate that participants were compliant with the home-based resistance program, and the program improved lower-extremity power in a short period of time. Although there were no statistically significant changes in balance or mobility, the exercise group's mobility scores improved, and the balance data indicated more stability. The nature of the home-based exercise program may provide a viable solution to adults with MS who would like to exercise at home and at a reasonable cost.

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