Self-Paced Resistance Training and Walking Exercise in Community-Dwelling Older Adults: Effects on Neuromotor Performance

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Background. Resistance-training intervention studies have demonstrated meaningful health benefits in older adults; however, most have used exercises performed at specific intensities on expensive equipment, which limit their widespread applicability. We tested whether two self-paced, less expensive exercise protocols could be effective and safe for modifying neuromotor performance and functional capacity in community-dwelling adults 65-95 years of age.

Methods. One hundred and thirty-one subjects were randomized to a novel resistance training, walking, or control group. Subjects determined their level of resistance or walking intensity (self-paced) on a session-by-session basis. Muscle strength, balance, reaction time, stair climbing speed, and a timed pen pickup task were measured before and after the intervention period. Exercisers met three times per week for 10 months.

Results. Significant improvements in tandem stance and single-legged stance with eyes open times and stair climbing speed were seen in both exercise groups. In addition, resistance trainers improved their muscle strength and ability to pick up an object from the floor and reduced the number of missteps taken during tandem walking, and walkers reduced tandem walking time. Controls showed no significant improvement in any variable.

Conclusions. The two self-paced exercise protocols were effective at improving neuromotor performance and functional capacity in the study sample and show promise as a safe, effective, cost-efficient, acceptable exercise model for primary and secondary prevention in the general population of community-dwelling older adults.

Neuromotor performance declines with age and is exacerbated by inactivity and disease. Deterioration of muscle strength, balance, and reaction time is associated with an increased incidence of falls (1–3), a loss of mobility (4), and disability (5), all of which place a heavy demand on our health care and long-term care systems (6). With the current environment of health care, there is an urgent need to prevent injury and disease and maintain functional autonomy in older adults. One approach to this problem is to shift a greater portion of responsibility to the individual for her/his own health and well-being. To this end, many feel that increasing the number of persons involved in regularly scheduled physical activity, or exercise, will promote better health and reduce the incidence of injury (7–9).

In recent years, investigators have reported specific beneficial effects of resistance-training exercise interventions on aging muscle (10–13), bone (14), neuromuscular performance (10,15,16), metabolism (17), body composition (18), ability to perform daily tasks (16,19), falls, and hip fracture (9–11,15). Even though resistance-training protocols have been effective, their use has been limited in the general population.

To increase markedly the number of older exercisers in this country, issues of cost, safety, acceptability, and accessibility, in addition to effectiveness, must be addressed. In most resistance-training studies involving older adults, subjects exercise on expensive equipment at set intensities that require regular reassessment by trained personnel (10,13,14,18–20). While effective, the costs of implementing these interventions deter their general use. To overcome these obstacles of widespread participation in exercise by community-dwelling older adults, we tested whether a novel, self-paced resistance-training intervention requiring less expensive equipment and a self-paced walking program could modify muscle strength, balance, reaction time, and functional capacity, while being safe and enjoyable for long-term participation.

Methods

Subjects. Subjects were 131 independent-living elderly persons from 12 suburban communities north of Boston, MA. Volunteers were included if they were age 65 years or greater, could climb a flight of stairs, participated regularly in activities (social, volunteer, recreational, employment) outside of their home a minimum of twice a week, had transportation (private or public) to the community center where the exercise program was held, and had received written approval from their primary care physician. Volunteers were excluded based on the identification by physicians of unsta-
ble or uncontrolled chronic conditions (e.g., angina) and the use of medications that could compromise their safety or ability to complete the testing or training protocols.

One hundred and forty-four of the 146 volunteers qualified for participation. Two female volunteers were excluded from the study because one was younger than she initially reported and the second withheld information regarding a history of three myocardial infarctions during the previous 12 months. Between the sign-up date and the scheduled testing date, 13 persons decided not to participate. Therefore, 131 volunteers participated in the initial testing.

**Design**

This was a three-armed, randomized, controlled clinical trial. Subjects were randomized at the time of initial testing into one of three groups: resistance training, walking, or waiting list control. A waiting list control was used because it was felt that controls should be offered the option to exercise after completion of the study. Prior to subject enrollment a decision was made to use unbalanced randomization to assign more individuals to the control group than the treatment groups because of the length of the intervention and an expected higher attrition rate in the control group. We altered the three-group block randomization protocol slightly by placing every thirteenth volunteer into the control group. The study protocol was approved by the Committee on Clinical Investigations at Beth Israel Hospital, Boston. Written informed consent was obtained from each subject.

**Neuromotor Assessments**

The battery of neuromotor performance measures assessed several intrinsic parameters identified as risk factors for falling and future disability in older adults (1,2,5). Testing was spread across 2 consecutive days and took approximately 1.5 hr per subject to complete. Measurements were taken prior to beginning and within 5 days of completing the 10-month exercise program. Testing was conducted by trained personnel who had administered identical tests to an average of 450 subjects in prior studies. In an attempt to standardize the testing environment, the same instructions were issued to all subjects during both testing periods. All test-retest values. All tests, both pre- and postintervention, were administered by a single individual who did not participate in the training yet was not blinded to the intervention grouping of all subjects, because some subjects talked about their group assignment during the follow-up visit.

**Strength.** A bilateral knee extension movement was used in the one-repetition maximum (ORM) protocol to assess muscle strength. After a 5-min warm-up period involving walking and climbing two flights of stairs, subjects were tested on a knee extension machine (Nautilus Sports Medicine, Independence, VA). Subjects familiarized themselves with the testing movement by performing five repetitions without resistance. The maximal knee extension angle was determined by manual goniometry. Knee extension strength was defined as the greatest amount of weight a subject could lift from 90° of knee flexion to within 5° of the maximal knee extension angle. Weight was added in .23-kg increments. The first weight a subject was unable to lift within the 5° range was repeated after a 45-sec rest period to ensure accuracy of the strength measurement. Rest periods of 45 sec, or longer if needed, were given between efforts. Verbal encouragement for maximal effort was given during each trial. This testing protocol was highly reliable in this population (r = .95) comparing test-retest values. All tests, both pre- and postintervention, were administered by a single individual who did not participate in the training yet was not blinded to the intervention grouping of all subjects, because some subjects talked about their group assignment during the follow-up visit.

Hand grip strength was assessed in dominant and nondominant hands by dynamometer (Model 78010, Lafayette Instruments, Lafayette, IN). Subjects sat in a straight-backed chair with feet on the floor and the testing extremity positioned in zero degrees shoulder flexion, 90° elbow flexion, and the forearm supinated with palm upward. The subject’s fingers gripped the handle of the dynamometer while the thumb was positioned in partial extension so it would not contribute to the force generated by finger flexion. Tests were performed on alternating hands after each trial. The mean of three trials was used for comparison.

**Balance.** Balance was assessed using a battery of field tests. Static balance was quantified as the number of seconds a subject could perform the following: (1) tandem stance, with the heel of one foot touching the toe of the other and the feet maintained in a straight line; (2) single-legged stance with the eyes open, and (3) single-legged stance with the eyes closed. Single-legged stance time was the length of time in seconds the subject maintained the posture without repositioning the support foot, touching the floor or support leg with the suspended foot, or requiring assistance from the tester. The maximum time measured was 60 sec. Dynamic balance was assessed by a timed forward tandem walk along a 10-ft solid line. The time (in seconds) it took to complete the test and the number of times the subject stepped completely off the line during the test (missteps) were the measured outcomes. Testing consisted of one practice and three recorded trials for each test. The mean of the three recorded trials was used for analysis. Subjects were given 20- to 30-sec rest periods between trials, and additional rest if necessary.

**Reaction time.** Simple reaction time was measured using the right lower extremity. Subjects were seated at a table with the left foot flat on the floor, the right foot depressing a foot pedal switch (Model 741, Dekan Timing Devices, Chicago, IL), and their hands folded on their lap or resting on the table. A verbal “ready” was given followed by a latency period of 1–10 sec before the presentation of a red light (visual stimulus). Latency times of 1–10 sec were changed for each trial to prevent anticipation by the subject. Subjects were instructed to lift their foot off the depressed foot pedal in response to the visual stimulus as quickly as they could. The right foot was used to simulate releasing the accelerator of an automobile to reduce the chance of a learning effect. All subjects performed 30 trials (5 practice/25 recorded) with an intertrial interval of 6 sec. The mean of the recorded trials was used as a single reaction time score.

**Functional capacity.** Due to the generally higher level of functional ability of our population, we used a timed
stair climb and a pen pickup task to assess functional capacity. Starting at the bottom of a flight of 14 steps, subjects were instructed to ascend the flight of stairs "at their usual pace," turn around at the top, and descend to the starting position. Subjects were instructed to use the railing as they normally would. The mean of the two trials was used as the score. Time was recorded from the word GO ("On your mark, get set, GO") until both feet were on the floor at the base of the stairs (starting position). Two trials were given with a 30-sec rest between efforts.

The pen pickup task assesses multiple body systems by requiring the simultaneous use of lower extremity strength, balance, vision, and the range of motion of several joints. Standing with feet comfortably apart and toes on a line, the subject bent down and retrieved a pen that was 12 inches in front of the line. Time was measured from the word GO ("On your mark, get set, GO") until the person was standing upright in the starting position with the pen and had stopped moving.

Interventions

Each exercise group met three times per week, alternating a day of exercise with a day of rest. Exercise classes were led by one of two research assistants. Heart rate was measured immediately before and after each exercise session. Blood pressure was recorded before and after exercise sessions for at least the first month of exercise, then biweekly due to time and personnel constraints. Blood pressure was used as a safety measure only and was not recorded as an outcome. A change in blood pressure alerted training personnel to a possible change in health status and prompted further inquiry into the individual’s physical condition.

Resistance training. — The resistance training program was designed to strengthen hip and knee extension and ankle plantar flexion and dorsiflexion. A 5-min warmup period of walking at a normal pace and ascending a flight of stairs preceded exercise. Three sets of each exercise were performed during an exercise session. Subjects climbed a set of stairs using a weighted nylon skin-diving belt around their waists for added resistance. A set was composed of twice ascending and descending a flight of 14 stairs. One- to 2-min rest periods were taken between sets. Every subject started with no weight on the belt during the first 2 weeks. Weight was added to the waist belt in increments of ninety-one hundredths (.91) of a kilogram when subjects felt they could handle the additional weight. Subjects were queried as to their choice of more weight once a week during weeks 2–4, and at each exercise session after that. A seated knee extension exercise working one leg at a time (Fitness Chair, NordicTrack, Chaska, MN) provided a form of accommodating resistance where the resistance increased as the subject exerted more effort. Each repetition was performed to a verbal cadence of 1 sec for the concentric phase and 4 sec for the eccentric phase. Verbal encouragement to maintain a high level of effort was given continuously during exercise. Sixty-second rest periods were taken between each of the three sets of eight repetitions. Three sets of 15 repetitions of standing plantar flexion were completed using the weight belts for added resistance. Subjects were encouraged to hold on to a wall for stability. Three sets of 10 repetitions of standing knee raises without added resistance were also performed. Eight repetitions per set of the standing biceps curl were performed using plastic 1-gallon containers (milk, water, laundry detergent) and hand-held weights for resistance. The weight used for resistance in the biceps curl began at 1 lb and increased to a maximum of 8 lb. Resistance training sessions were led by one instructor, performed in groups of five or six subjects per class, and were 1 hour in length.

Walking. — Walking was selected as the other exercise intervention because of its low cost, accessibility, and previously reported benefits in older adults (21–23). Subjects began walking for 12 min per session and increased weekly to 14, 17, 20, 23, 27, 32, 38, and 45 min. Walking time was maintained at 45 min per session for the remainder of the intervention period. Subjects walked at their own pace on level ground throughout the intervention program. After 3 weeks, the walkers were encouraged to increase their walking speed daily. Walking sessions were run by one or two instructors, included more than 15 persons per class, and were held outside in a parking area, along a wooded path, or in a gymnasium depending on weather conditions.

Controls. — Controls were told they were on a waiting list for enrollment into the exercise program and were requested to not alter their current exercise habits. Subjects in the control group had contact with a staff person by phone or in person every other week. At the biweekly contact, subjects were asked about their health and well-being and about the occurrence of a fall.

Statistical analysis. — All analyses were performed with SAS (24) statistical software using intention-to-treat analyses for all variables evaluated. Subjects were not randomized by gender, which resulted in a gender imbalance between the control group and intervention groups (Table 1). Because an analysis of covariance showed no significant gender effect, the data reported here are unadjusted mean values. The success of randomization was assessed by analysis of variance (ANOVA) to compare mean baseline scores of all measured variables of the intervention groups. Repeated measures ANOVA was used to compare changes in test performance between time points (within group) and between interventions at identical time points (between groups). During the intervention period, 13 control subjects started exercising on their own. To identify any effect of the noncontrolled exercise, we also performed the analysis considering this group of noncomplying controls separate from the control group and found no difference in significance status. Therefore, the significance levels from the intention-to-treat analyses are presented. All $p$-values < .05 were considered statistically significant.

RESULTS

Baseline Characteristics of the Subjects

Baseline values were similar for each group in demographic characteristics (Table 1) and in all but one neuro-motor measure (Table 2). Dominant handgrip strength was considered statistically significant.
Effect of Exercise on Neuromotor Measures

Muscle strength. — Knee extension strength increased 65% (p < .0001) in the resistance-trained group, while walkers and control group subjects demonstrated small losses of 6% and 7%, respectively, over the intervention period (Table 2, Figure 1). Resistance training was superior to both walking exercise (p < .05) and the control intervention (p < .05) for improving lower extremity muscle strength. No significant changes in handgrip strength were seen in any of the study groups.

Balance. — Exercise intervention groups significantly improved their performance compared to baseline on all of the balance measures, except for the one-legged stance with eyes closed test (p < .05). Resistance trainers improved 16% (p = .03) from baseline in resistance-trained subjects and 23% (p = .02) in walkers, while controls declined 14% (p = .05). Changes in performance of the two exercise groups were significantly different when compared with controls (p < .05). Resistance trainers improved 98% (p < .0001), walkers 39% (p = .04), and controls 26% (p = .13) on the one-legged stance with eyes open measure (Figure 2B). The mean increase in performance on the one-legged stand with eyes open measure in the control group was influenced by the 13 subjects who exercised on their own during the intervention period. Without their inclusion (n = 31 vs 44), mean performance declined 17%. Regardless of their inclusion, no difference in statistical significance was found. In addition to significant changes over time, significant between-group differences were seen between the resistance-trained group and both walkers and controls. The one-legged stance with eyes closed test was the most difficult for subjects to perform. Resistance-trained subjects showed a 9% improvement (p = .47) while walkers and con-

Table 1. Demographics of Subjects

<table>
<thead>
<tr>
<th></th>
<th>Resistance Training</th>
<th>Walking</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>72.7 ± 4.6</td>
<td>72.9 ± 5.4</td>
<td>75.1 ± 6.0</td>
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<tr>
<td>Height (cm)</td>
<td>165.7 ± 8.0</td>
<td>167.1 ± 8.2</td>
<td>162.5 ± 7.6</td>
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<tr>
<td>Weight (kg)</td>
<td>68.6 ± 9.3</td>
<td>68.7 ± 11.8</td>
<td>65.6 ± 10.1</td>
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<td>Body mass index (kg/m²)</td>
<td>24.9</td>
<td>24.5</td>
<td>25.2</td>
</tr>
<tr>
<td>No. of medications</td>
<td>2.1 ± 1.7</td>
<td>2.6 ± 1.9</td>
<td>2.3 ± 1.7</td>
</tr>
<tr>
<td>No. of diagnoses</td>
<td>2.0 ± 1.5</td>
<td>2.2 ± 1.3</td>
<td>2.0 ± 1.3</td>
</tr>
<tr>
<td>% female</td>
<td>59</td>
<td>52</td>
<td>82</td>
</tr>
<tr>
<td>% perceived excellent good health*</td>
<td>86</td>
<td>85</td>
<td>94</td>
</tr>
<tr>
<td>Depression score*</td>
<td>2.1 ± 1.8</td>
<td>2.8 ± 2.1</td>
<td>2.1 ± 2.1</td>
</tr>
</tbody>
</table>

*OARS Multidimensional Functional Assessment Questionnaire (25).

Table 2. Performance on Neuromotor Measures at Baseline and 10 Months (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Resistance Training (n = 37)</th>
<th>Walking (n = 25)</th>
<th>Control (n = 44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee extension (kg)</td>
<td>20.9 ± 4.9</td>
<td>34.5 ± 7.1*</td>
<td>21.4 ± 5.7</td>
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<tr>
<td>Handgrip (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>12.5 ± 4.4</td>
<td>12.4 ± 4.0</td>
<td>9.2 ± 2.3</td>
</tr>
<tr>
<td>Nondominant</td>
<td>10.9 ± 4.1</td>
<td>10.7 ± 3.7</td>
<td>9.4 ± 2.3</td>
</tr>
<tr>
<td>Tandem stance (sec)</td>
<td>46.9 ± 20.2</td>
<td>54.3 ± 14.5**</td>
<td>46.1 ± 19.8</td>
</tr>
<tr>
<td>One-legged stance (sec)</td>
<td>19.7 ± 17.6</td>
<td>39.1 ± 22.8**</td>
<td>17.9 ± 19.0</td>
</tr>
<tr>
<td>Eyes open</td>
<td>3.3 ± 3.1</td>
<td>3.6 ± 2.4*</td>
<td>3.1 ± 2.7</td>
</tr>
<tr>
<td>Eyes closed</td>
<td>15.7 ± 16.2</td>
<td>21.8 ± 19.3*</td>
<td>17.9 ± 22.5</td>
</tr>
<tr>
<td>Tandem walk</td>
<td>13.7 ± 16.5</td>
<td>10.2 ± 6.2</td>
<td>12.2 ± 4.7</td>
</tr>
<tr>
<td>Time (sec)</td>
<td>13.7 ± 16.5</td>
<td>10.2 ± 6.2</td>
<td>12.2 ± 4.7</td>
</tr>
<tr>
<td>Missteps (no.)</td>
<td>2.7 ± 2.8</td>
<td>1.7 ± 1.9*</td>
<td>2.7 ± 3.0</td>
</tr>
<tr>
<td>Reaction time (msec)</td>
<td>281 ± 41</td>
<td>245 ± 29*</td>
<td>299 ± 64</td>
</tr>
<tr>
<td>Stair climb (sec)</td>
<td>17.9 ± 3.4</td>
<td>13.9 ± 3.3*</td>
<td>18.5 ± 7.1</td>
</tr>
<tr>
<td>Pen pickup (sec)</td>
<td>1.7 ± 0.5</td>
<td>1.3 ± 0.4*</td>
<td>1.8 ± 0.9</td>
</tr>
</tbody>
</table>

Notes: Within-group differences: *p < .05; **p < .01; ***p < .0001. Between-group differences: *p < .05 (different from the control group); ^p < .05 (different from the walking group).
SELF-PACED EXERCISE IN OLDER ADULTS

TANDEM STANCE

Resistance Training Walking Control

Resistance Training Walking Control

Resistance Training Walking Control

Resistance Training Walking Control

ONE-LEGGED STANCE - EYES OPEN

ONE-LEGGED STANCE - EYES CLOSED

TANDEM WALKING SPEED

Figure 2. Tandem stance (A), one-legged stance with eyes open (B), one-legged stance with eyes closed (C), and tandem walking speed (D) times for the resistance-training, walking, and control groups. Empty bars represent baseline values, and solid bars represent postintervention values. Significant within-group changes are identified by an * over the solid bar (\(*p < .05, \**p < .01, \***p < .0001\)). The * over the horizontal line that courses across intervention groups signifies between-group differences of \(p < .05\). Values are mean ± SEM.

trols had significant declines of 23% \((p = .03)\) and 39% \((p = .004)\), respectively (Figure 2C). The change seen in the resistance-trained group was significantly different from that of the control group \((p < .05)\). Tandem walking time improved in both exercise groups, by 26% \((p = .06)\) in the resistance-trained group and 23% \((p = .002)\) in the walkers. No change was seen in the control group (Figure 2D). Reductions in the number of missteps were seen in the resistance-trained group \((37\%,\ p = .006)\) and the walking group \((21\%,\ p = .15)\), while the control group mean increased by 11% \((p = .50)\) (Table 2).

Reaction time. — Lower extremity reaction times improved in all three groups (Table 2, Figure 3). Within-group changes in reaction times were similar in the resistance trainers \((13\%,\ p < .0001)\) and walkers \((11\%,\ p < .0001)\), but not in the control group \((4\%,\ p = .30)\). Between-group differences were seen between the resistance-trained and control groups \((p < .05)\).

Functional capacity. — Stair climbing speed improved in both exercise groups and declined in the control group \((9\%)\) (Table 2, Figure 4A). Resistance trainers and walkers demonstrated similar reductions in stair climbing time \((22\%\ vs\ 20\%)\, both of which were significant changes from baseline \((p < .0001)\), and were different from that seen in the control group \((p < .05)\). Significant improvement in the pen pickup task was observed in the resistance-trained group \((24\%,\ p < .0001)\) but not in the walking \((6\%,\ p = .30)\) or control \((0\%,\ p = .62)\) groups (Figure 4B). Between-group differences were seen between the resistance-trained and control groups \((p < .05)\).

Intervention Safety and Compliance

None of the subjects was injured during the testing or training periods. Five subjects in the resistance-training group admitted to experiencing mild, transient soreness in their thigh muscles during the first week of exercise. Soreness was resolved by the second week of exercise.

Of the 131 subjects who started the study, 106 completed retesting \(81\%)\. Three subjects \(7\%) were lost from the resistance-training intervention group during the 10-month period because of a fractured patella \(1\), a cervical spine condition \(1\), and influenza \(1\), resulting in a final sample of 37 completers. Fifteen walkers \(37\%) were lost during the study; 10 subjects \(25\%) after 7 months of the 10-
Resistance Training Walking Control

Figure 3. Lower extremity reaction times for the resistance-training, walking, and control groups. Empty bars represent baseline values, and solid bars represent postintervention values. Significant within-group changes are identified by an * over the solid bar (**p < .0001). The * over the horizontal line that courses across intervention groups signifies between-group differences of p < .05. Values are mean ± SEM.

A

STAIR CLIMB

Figure 4. Stair climbing (A) and pen pickup task (B) times for the resistance-training, walking, and control groups. Empty bars represent baseline values, and solid bars represent postintervention values. Significant within-group changes are identified by an * over the solid bar (**p < .0001). The * over the horizontal line that courses across intervention groups signifies between-group differences of p < .05. Values are mean ± SEM.

DISCUSSION

In this study, we have demonstrated that 10 months of a self-paced resistance-training protocol using low to moderately expensive equipment can safely improve muscle strength, static and dynamic balance, lower extremity reaction time, stair climbing speed, and the ability to pick up an object from the floor in community-dwelling older adults. Furthermore, a self-paced walking program of similar duration can safely improve static and dynamic balance, lower extremity reaction time, and stair climbing speed. In contrast, control subjects showed no significant improvement in any variable and, in fact, significantly declined in performance on muscle strength, balance, and stair climbing tasks over the intervention period. While the physiological findings are similar to those of other studies, the resistance-training and walking protocols examined in this study are unique because they offer the freedom of exercising at a self-determined intensity, use less expensive or no equipment, are performed in groups with a low staff-to-participant ratio, and are safe and enjoyable over an extended period of time.

Self-paced exercise is not commonly used in research studies, due in part to the concern that such a format does not ensure an adequate stimulus for significant physiological gain. The magnitude of neuromotor changes seen in this study is similar to or greater than that reported in several previous studies using exercise interventions of moderate to high intensities requiring expensive equipment (14,18,26,27) or nonconventional, less expensive modes of exercise (15,28). These observations suggest that the self-paced resistance-training and walking protocols used in this study can provide a physiological stimulus sufficient to elicit improvements in the neuromotor performance and functional capacity of active, community-dwelling older adults.

While the resistance-training protocol had a greater effect on neuromotor and functional performance than walking, we found the degree of improvement in balance, reaction time, and stair climbing speed in the walking group of particular interest. Several investigators have reported improvements in muscle strength, balance, and reaction time.
These findings highlight the importance of exercise selection when developing an intervention program or recommending exercises to older adults for the purpose of improving functional capacity in older adults (10, 16, 19). However, there is a paucity of data available on the effects of long-term walking on functional tasks. Our findings of improved stair climbing speed in both resistance-training and walking groups support the concept that factors other than muscle strength, such as balance, account for improved functional mobility (29,30), and suggest that these factors are modifiable by long-term resistance-training or walking exercise. In this study we focused on exercising the lower extremities and found a localized effect (training specificity) with positive changes in tasks involving the lower extremities and no effect on tasks requiring isolated use of the upper extremities (handgrip strength). These findings highlight the importance of exercise selection when developing an intervention program or recommending exercises to older adults for the purpose of improving specific functional capabilities. Additional functional tasks, such as those where the upper body musculature plays a key role (i.e., carrying a bag of groceries) were not assessed in this study. The clinical implications of gaining significant neuromotor benefit from walking are noteworthy, as walking can be performed at a self-determined pace, at any age, in any safe environment, requires little or no special equipment, has a low rate of injury, is a highly familiar activity, and is an integral part of mobility and functional independence.

The significant improvements in lower extremity reaction times observed in the exercise groups are consistent with findings of previous exercise intervention studies (15, 28) and cross-sectional studies of exercising and nonexercising older adults (31,32). While our findings of improvement agree with those of Lord et al. (15), there is a sizable difference in the magnitude of change in reaction time performance (31-34 msec, 11-13% vs 5 msec, 2%) between the two studies. Differences in our findings could be due to the mode and intensity of the exercise interventions used. Lord and colleagues (15) used “structured general exercise” relying on body weight and isometrics as resistance during their 12-month intervention, compared to our self-paced, progressive resistance and walking approach. The modest strength gains they report reflect the probable differences in exercise intensity.

Stair climbing while wearing a weighted nylon skin-diving belt is a safe and comfortable method of providing resistance to the muscles of hip and knee extension, hip and knee flexion, and ankle plantar flexion in older adults. Toward the end of the 10-month period, most subjects carried belts of more than 20 lb during the stair-climbing exercise, while several subjects carried belts of more than 30 lb. When fitted properly, the belt distributes the weight across the pelvis and muscles of the lower extremities. At the higher weights, padding under the belt makes it more comfortable for very thin individuals to wear. The weight belt complements the self-paced paradigm by providing a visible measure of success. This supplies important positive feedback that motivates individuals to progressively increase resistance.

Cost effectiveness was not an outcome measure in this study. However, we propose that based on costs associated with most previous studies: (a) initial investment in equipment, (b) the staff-to-exerciser ratios to administer the classes (dollars paid to staff per hour per participant), and (c) number of paid staff hours required to complete non-exercise-related responsibilities (i.e., periodic retesting of ORM), the model presented here is less costly than most exercise programs presented in the research literature. An accurate comparison of program costs between this and other studies in the literature requires additional data to those collected here. Program cost effectiveness is critical when assessing the feasibility of a community-based model aimed at stimulating widespread involvement and is an important outcome to include in future studies.

A limitation intrinsic to any exercise intervention trial is the lack of double blinding. Such a limitation raises the possibility that participation in the interventions may have motivated exercisers to extend more effort than controls during retesting. Furthermore, because test personnel were not completely blinded to subjects’ group assignments, it is impossible to completely exclude the possibility of bias. We attempted to reduce these influences by standardizing the testing protocols and environment, using personnel experienced in administering these tests, and including an outcome measure in an untrained area (handgrip strength) as an indicator of potential bias. Our finding of no change in handgrip strength performance strongly suggests that the performance-based findings are not biased by the fact that subjects knew whether they were exercisers or controls.

Clinical implications of the findings of this study center on the potential applicability of these relatively inexpensive, safe, enjoyable, and effective exercise programs of self-paced resistance training and walking, as models for health promotion and disease prevention in community-dwelling older adults. Moreover, the exercise protocols presented here accommodate the financial and space limitations of many senior housing centers, assisted living facilities, other forms of group housing, and community centers. Much more work is needed to identify and promote exercise protocols that are cost efficient, safe, acceptable, accessible, and effective at improving health and modifying risk factors for injury and disease in community-dwelling older adults.

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This article is dedicated to the memory of Lottie Berman (1909-1995), who began exercising at the age of 82. Her enthusiasm for and belief in the exercise program, kindness, encouragement of others, and determination to enjoy life regardless of often debilitating illness continue to inspire those who knew her.

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