Resistance Exercise and Physical Performance in Adults Aged 60 to 83

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OBJECTIVES: This investigation examined the effect of 6 months of high- or low-intensity resistance exercise on muscular strength and endurance and stair climbing ability in adults aged 60 to 83.

DESIGN: A randomized controlled trial.

SETTING: University of Florida Center for Exercise Science

PARTICIPANTS: Sixty-two men and women completed the study protocol. Subjects were matched for strength and randomly assigned to a control (n = 16), low-intensity (LEX, n = 24), or high-intensity (HEX, n = 22) group.

INTERVENTION: Six months of progressive, whole-body resistance training. Subjects trained at 50% of their one-repetition maximum (1RM) for 13 repetitions (LEX) or 80% of 1RM for eight repetitions (HEX) three times per week for 24 weeks using resistance machines. One set each of 12 exercises was performed.

MEASUREMENTS: One-repetition maximum was measured for eight different exercises. Muscular endurance was measured using leg press and chest press machines. Low back strength was measured using a lumbar extension machine. Stair climbing ability was assessed as the time to ascend one flight of stairs.

RESULTS: 1RM significantly increased for all exercises tested for the HEX and LEX groups ($P \leq .050$). The increases in total strength (sum of all eight 1RMs) were 17.2% and 17.8% for the LEX and HEX groups, respectively. Muscular endurance improved by 79.2% and 105.0% for the leg press, and 75.5% and 68.0% for the chest press for the LEX and HEX groups, respectively. The time to ascend one flight of stairs significantly decreased for both the LEX and HEX groups ($P \leq .050$). Lumbar extension strength increased by 62.6% and 39.5% for the LEX and HEX groups, respectively.

CONCLUSIONS: These data indicate that significant and similar improvements in strength, endurance, and stair climbing time can be obtained in older adults as a consequence of high- or low-intensity resistance exercise training. These findings may have an effect on how resistance exercise is prescribed to older adults. **J Am Geriatr Soc 50: 1100–1107, 2002.**

Key words: resistance exercise; older; strength; endurance; function

The proportion of older adults in the United States is steadily rising, such that the portion of the population aged 65 and older is expected to double in the next 30 years. Aging has been associated with a decrease in muscle mass and strength.[1,2] This decrease in strength is linked to decreased mobility, physical function, feelings of self-worth, and increased risk of falling.[3–5] As a result, appropriate exercise prescription guidelines to develop and maintain physical function and independence in this population are necessary. The Surgeon General's Report on Physical Activity and Health states that developing muscular strength can improve one's ability to perform tasks and reduce the risk of injury.[6] The American College of Sports Medicine has recognized that resistance training is important for quality of life and physical function for older and younger adults.[7,8] Numerous studies have demonstrated the beneficial effects of resistance exercise for older adults,[4,5,9–13] but there is no consensus on the appropriate quantity, quality, or intensity of resistance exercise necessary to promote improved health and function in this population.

Previous studies may not be generalizable to the older adult population because the programs used only high-intensity exercise or did not include exercises for all major muscle groups.[5,9–11] For example, these earlier studies had subjects perform three sets of eight repetitions at 80% of one-repetition maximum (1RM) for only the knee flexors and extensors.[5,9–11] It is not clear whether a regimen consisting of exercises emphasizing all major muscle groups at

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this intensity would lead to greater rates of injury or could be completed by the majority of older adults. Importantly, it is unclear whether this type of regimen is necessary to achieve health benefits or if a lower intensity or volume would be sufficient.

One current recommendation for level of difficulty for adults aged 50 and older corresponds to 14 to 16 (hard) on the Borg rate of perceived exertion (RPE) scale.[14] The difficulty level should be perceived as hard by the participant but should not be to voluntary failure, as is recommended for younger adults.[14] It is also recommended that older adults perform 10 to 15 repetitions per set instead of eight to 12, as is recommended for younger persons,[8] but it is not known whether performing exercises at eight or 10 repetitions achieves similar adaptations as performing sets with 12 or 15 repetitions. It is also not known whether older people need to work at the same intensity as younger adults to derive similar benefits or whether a lower intensity is sufficient. Intensity in resistance exercise refers to the percentage of 1RM lifted for each exercise, not the RPE scale, which is used to rate difficulty. Indeed, if evidence does not support an intensity threshold for optimizing improvements in strength and function, then the low-intensity exercise would be the better recommendation because it may be associated with a greater adherence and lower injury rates than high intensity. Therefore, the purpose of this investigation was to examine the strength and physical function responses to 6 months of high- (higher weight, lower repetitions) or low- (lighter weight, higher repetitions) intensity resistance training in older adults.

METHODS

Subjects

Eighty-four apparently healthy adults between the ages of 60 and 83 years volunteered for this investigation. Sixty-two of the volunteers completed the study protocol. Only participants that had not participated in regular resistance training for at least 1 year, but may have engaged in low-intensity aerobic training three or fewer times per week were eligible. To be eligible for study participation, subjects underwent a medical examination performed by a physician specializing in geriatric medicine, a resting 12-lead electrocardiogram (ECG), and a graded exercise test to symptom-limited maximum (SL-GXT). Blood pressure, oxygen consumption, heart rate, and ECG were monitored during the SL-GXT. Thus, the subjects in this study were healthy 60- to 83-year-olds with no signs of overt pathologies that would confound or compromise their responses to exercise training. After baseline testing, the subjects were rank ordered by composite strength (chest press 1RM plus leg press 1RM) and randomly stratified, using a random numbers table, to one of the two training groups (low-intensity (LEX) or high-intensity (HEX) exercise) or a control group (CON) that did not train. To be considered compliant and remain in the study, participants had to attend 85% or more of the possible exercise sessions. All participants received a comprehensive explanation of the proposed study and of its benefits, inherent risks, and expected commitments with regard to time. After the explanation, all participants signed an informed consent document approved by the Institutional Review Board at the University of Florida and in adherence with the guidelines of the American College of Sports Medicine.

Baseline testing was performed before the 6-month training period and included assessment of body composition, dietary intake, time to ascend one flight of stairs, and muscular strength and endurance. Before the training period, each participant was instructed as to the proper settings and movement techniques for each of the machines used during the 6-month training period.

Body Composition

Body composition was measured using skinfolds and dual energy x-ray absorptiometry (DEXA). The landmarks and techniques of Pollock et al.[15] were used for the skinfold measurements. Skinfold measurements were taken to the nearest 0.5 mm on the right side of the body using a Lange caliper (Cambridge Scientific Industries, Cambridge, MD). Seven sites were measured: chest, axilla, triceps, subscapular, abdomen, suprailiac, and anterior thigh. During the DEXA scan (Model DPX-L, Lunar Radiation Corp., Madison, WI), the subject was positioned in a supine position while the x-ray scanner performed a series of transverse scans, measured at 1-cm intervals from the top of the head to the ends of the toes. The DEXA machine was calibrated daily in accordance with the manufacturer's guidelines to ensure adequate quality control. DEXA scans were analyzed for body composition using the DPX-L Version 1.3Z program for body composition from the Lunar Radiation Corporation.

Diet Analysis

Three-day diet records were completed before and after training to determine whether any body composition or weight changes from pre- to posttraining were the result of changes in diet. To ensure standardization of the dietary records, a registered dietitian instructed the subjects individually on how to fill out the diet records and assess food servings and sizes. Diet records were analyzed using Nutritionist IV Software (First Data Bank, San Bruno, CA).

Strength Testing

The exercise testing equipment used in this investigation was MedX resistance machines (MedX Corp., Ocala, FL). Dynamic muscular strength was measured using eight resistance exercises: leg press, leg curl, knee extension, chest press, seated row, overhead press, triceps dip, and biceps curl. One-repetition maximum was determined for each dynamic exercise. Participants were properly positioned in the machine and performed a dynamic warm-up using a light weight. The participant began the test by lifting a light weight; then incremental increases were made according to how difficult it had been for the participant to execute the previous lift. Difficulty was measured by having the participant rate his/her exertion level using the RPE scale. Two- to three-minute rests were provided between trials to prevent premature fatigue. The investigator continued to increase the weight lifted until reaching the maximum weight that could be lifted in one repetition with proper form. This was usually determined in four to six trials. Maximal strength was defined as the maximum weight that could be lifted through a full range of motion with proper form.

Lumbar Strength Testing

Isometric lumbar extension strength was also tested. Before the test, participants performed a series of stretching exercises and dynamic variable resistance exercises designed to stretch and warm up the low back, hamstrings, and abdominal areas. For the dynamic exercise, participants were seated in the isolated lumbar extension machine, secured in place by restraints positioned under the feet, anterior thigh, and posterior pelvis. These restraints restrict movement of the pelvis, which facilitates isolation of the lumbar extensor muscles. The participants then moved from flexion to extension through a full range of motion (ROM). Men warmed up with 40 pounds and women with 20 pounds for 10 repetitions. This series of stretching and dynamic exercises lasted approximately 10 minutes. After the dynamic exercise session, participants completed an isometric test of lumbar extensor muscle strength. Seven testing points (0°, 12°, 24°, 36°, 48°, 60°, and 72° of lumbar flexion) were measured for participants who had a full range of lumbar motion. The specific angles were modified for participants with limited ROM. A maximum isometric contraction was generated at each of these angles, beginning with 72° of flexion. Participants were instructed to extend back slowly, building up tension over a 2- to 3-second period. Once maximal tension had been developed, participants were encouraged to maintain maximal force for an additional 1 to 2 seconds and then slowly relax. After each isometric contraction was a 10-second rest period while the next position was set. In this manner, a force curve was generated throughout the ROM for each subject. Participants were given verbal encouragement during the lifts to ensure maximal effort.

Muscular Endurance

Assessment of muscular endurance was performed on the chest press and leg press resistance machines. The participants were properly positioned in the appropriate machine and allowed a dynamic warm-up with a light weight. They then performed as many repetitions as possible with proper form using 60% of their previously determined 1RM. Participants performed the endurance test for the leg press first.

Stair Climbing Time

The time to walk up one flight of stairs was measured by having the participants walk up one flight of stairs consisting of 23 steps as quickly as possible. The stairs were 16.5 cm high and 29.2 cm wide. After 14 steps, the participants made a left-hand wrap-around turn and then completed the remaining nine steps. The participants were not allowed to use the handrails. The time to complete this task was recorded to the nearest hundredth of a second using a handheld stopwatch. Participants were required to step on all of the steps; taking two steps at a time was not permitted. This test was repeated after a 2- to 3-minute rest period, and the faster of the two trials was used for data analysis.

Resistance Exercise Training

The exercise training equipment used in this investigation was MedX resistance machines. These machines were selected because their design allows each exercise to be performed in a seated position so that the participant can enter and exit each machine easily. Additionally, resistance loads can be increased in 2-pound increments, allowing the resistance used to be tailored to each participant. Participants were oriented to the proper positioning and movement on each machine using a light load (20 ft-lb). The machines used for this study were abdominal crunch, leg press, leg extension, leg curl, calf press, seated row, chest press, overhead press, biceps curl, seated dip, leg abduction, leg adduction, and lumbar extensions.

Participants in the LEX and HEX groups were asked to report to the training facility three times per week for 6 months (24 weeks) to perform dynamic variable resistance exercise under the supervision of trained personnel for all exercises except the isolated lumbar extension exercise. Isolated lumbar extensions were performed once per week under the supervision of personnel certified especially in the use of MedX rehabilitation equipment. The rationale for training the lumbar extensor muscles only 1 day per week is derived from previous research indicating that training more than once per week does not provide superior results to training once per week.[16] Each subject received appropriate instruction concerning warm-up and cool-down techniques and on how to monitor the intensity of the exercise using the RPE scale. Each subject performed one set on each of the resistance exercise machines. There was a 2-minute rest period allowed between each machine. Each set consisted of eight repetitions for the HEX group and 13 repetitions for the LEX group at the appropriate resistance load. The LEX participants trained at an intensity equivalent to 50% of their 1RM, whereas the HEX participants used loads corresponding to 80% of their 1RM. This regimen was chosen because 80% of 1RM for eight repetitions is commonly used in studies using older adults and corresponds to the lower repetition limit of the American College of Sports Medicine (ACSM) reccomendations.[8] The intensity of 50% of 1RM for 13 repetitions was chosen for two reasons: one, because it represents the upper repetition limit of the ACSM recommendations, and two, it approximates the training volume of the regimen of 80% of 1RM for eight repetitions. This allowed the groups to perform at different training intensities while completing comparable volumes of work. For the LEX and HEX groups, the load was increased by 5% when RPE dropped below 18. RPE was noted immediately after each exercise during each training session. The training logs were reviewed daily and the necessary adjustments in workload made. The HEX group performed 10 lumbar flexion-extension repetitions; the LEX group performed 15 repetitions.

Statistical Analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences software, version 9.0 (SPSS Inc., Chicago, IL). Experimental analysis was performed with a 3×2 repeated-measures analysis of variance model to determine differences within and between groups over time. If a significant (group $\times$ time) interaction was found, the appropriate post hoc procedures were applied. The post hoc procedure used for this investigation was a Scheffé post hoc test to determine whether and where there was a difference between the group means. Although no statistical differences were observed between groups at study entry, an analysis of covariance (ANCOVA) was performed on outcome variables at conclusion of the study. The covariate used was the baseline value for each subject for the particular outcome variable being analyzed. When the ANCOVA revealed that the covariate significantly contributed to the outcome, then the predicted means generated by the ANCOVA were analyzed with a Scheffé post hoc test. A priori alpha levels were set at .05, and power was set at 80%.

RESULTS

Subjects

Sixty-two of the original 84 subjects completed the study (CON = 16, LEX = 24, HEX = 22). Of the 22 who did not finish, 11 (CON = 1, LEX = 6, HEX = 4) were dropped by the investigators for not adhering to the training protocol or dropped out voluntarily for reasons of inconvenience. The other 11 (CON = 3, LEX = 6, HEX = 2) dropped out for one of the following reasons: moved out of the area, financial difficulties, or surgery/injury (detached retina, atrial fibrillation, liver cancer, renal stenosis, prostate cancer) not related to the study protocol. Six of the training subjects experienced joint discomfort (3 knee, 2 back, 1 elbow) and had to reduce training for 2 weeks. The six subjects were distributed as follows: LEX; 1 knee, 1 back, HEX; 2 knee, 1 back, 1 elbow. Characteristics of those who completed the study are listed by group in Table 1. There were no statistically significant differences between groups for age, height, or weight before or after the study ($P \geq .050$).

Body Composition and Dietary Analysis

The results of body composition and dietary analysis are shown in Table 1. There were no significant differences in body composition among the three groups at study entry or from pre- to poststudy for either of the techniques ($P \geq .05$). Fat-free mass (FFM), presented in Table 1, was calculated using the DEXA data. Correlation between pretraining percentage of body fat measured by skinfold and DEXA was 0.86 ($P \leq .01$), with no significant difference between methods. Correlation between posttraining percentage of body fat measured by skinfold and DEXA was 0.91 ($P < .01$), with no significant difference between methods.

Analysis of 3-day diet records revealed that there were no significant changes in total caloric intake (kcal) or grams of fat consumed ($P \geq .05$), but the percentage of the diet contributed by fat significantly increased from 23.7% to 29.6% and 26.3% to 30.7% for the CON and HEX groups, respectively ($P \leq .05$).

Muscle Strength

There were no statistically significant differences between groups at baseline. The 6 months of resistance training significantly ($P \leq .05$) increased 1RM in all eight tested exercises in LEX and HEX when analyzed in absolute and relative terms (Tables 2 and 3). Relative changes in strength were calculated by dividing force in Newton meters (Nm) by kilograms of FFM. Muscular strength significantly ($P \leq .05$) increased for the chest press, leg press, leg curl, biceps curl, seated row, overhead press, leg extension, and triceps dip. Total strength, calculated by summing the 1RMs from the eight tested exercises, is shown in Tables 2 and 3. The results show that total strength increased significantly from pre- to posttraining ($P \leq .05$) in LEX and HEX but was not different between the two training groups ($P \geq .05$).

Training logs were examined to determine whether subjects from the LEX and HEX groups were training at similar volumes. During the last week of exercise, the training volumes were 13,839 ± 4,364 and 14,307 ± 4,740 Nm, corresponding to 52.4% and 79.0% of posttraining 1RMs for the LEX and HEX groups, respectively ($P \geq .05$).

Muscle Endurance

Muscle endurance, measured as the number of repetitions that could be performed with 60% of the 1RM in the leg press and chest press, increased significantly ($P \leq .05$) and similarly in the two training groups (Table 4).

Table 1. Subject Characteristics

	CON (n = 16)		LEX (n = 24)		HEX (n = 22)	
	Pre	Post	Pre	Post	Pre	Post
Variable	mean ± standard deviation					
Age, years	71.0 ± 4.7		67.6 ± 6.3		66.6 ± 6.7	
Height, cm	169.9 ± 10		167.2 ± 11.5		167.1 ± 9.7	
Weight, kg	73.1 ± 13.8	71.0 ± 14.3	77.4 ± 19.3	74.4 ± 16.5	74.1 ± 14.8	74.8 ± 15
Skinfold, %fat	30.3 ± 7.5	28.9 ± 7.4	30.9 ± 6.0	29.0 ± 5.1	32.0 ± 7.8	29.9 ± 7.8
DEXA, %fat	33.5 ± 7.4	34.4 ± 7.2	34.1 ± 8.9	34.1 ± 8.4	35.9 ± 8.6	36.2 ± 9.0
FFM, kg	46.5 ± 10.5	46.0 ± 10.6	50.5 ± 14.6	48.7 ± 13.3	47.7 ± 12	47.9 ± 12
Kcal/day	1,537 ± 269	1,500 ± 272	1,940 ± 468	1,709 ± 512	1,431 ± 235	1,415 ± 277
Protein, g/day	62.6 ± 21.7	65.6 ± 18.2	82.5 ± 12.6	75.2 ± 11.3	59.5 ± 17.2	64.3 ± 18.5
Fat intake, g/day	39.3 ± 11	49.5 ± 13	55.7 ± 24.8	56.4 ± 23	42.4 ± 15	47.8 ± 15
Fat intake, % of total daily calories	23.7 ± 8	29.6 ± 5*	25.8 ± 10	29.8 ± 9	26.3 ± 7	30.7 ± 8*

Note: *$P < .050$ vs PRE.
CON = control group; LEX = low-intensity exercise group; HEX = high-intensity exercise group; DEXA = dual energy x-ray absorptiometry; FFM = fat free mass.

Table 2. Means and Standard Deviations for Absolute One-Repetition Maximum Values: Dependent Variables

Group	Chest Press (Nm)	Leg Press (Nm)	Leg Curl (Nm)	Biceps Curl (Nm)	Seated Row (Nm)	Overhead Press (Nm)	Triceps Dip (Nm)	Leg Extension (Nm)	Total Strength (Nm)
CON									
Pretest	191.7 ± 92	329.1 ± 78	180.3 ± 55	113.8 ± 48	252.6 ± 92	176.1 ± 74	219.8 ± 69	234.0 ± 75	1,697 ± 537
Posttest	184.9 ± 90	329.2 ± 82	179.2 ± 59	107.1 ± 44	268.0 ± 101	169.5 ± 79	217.7 ± 68	222.9 ± 75	1,678 ± 535
% Change	−1.2 ± 20	1.5 ± 22	−0.7 ± 10	−3.8 ± 16	6.5 ± 16	−3.6 ± 18	−0.7 ± 6	−4.6 ± 8	−1.1 ± 6
LEX									
Pretest	223.7 ± 116	401.0 ± 120	174.5 ± 59	118.4 ± 50	276.2 ± 137	215.3 ± 98	263.2 ± 96	276.2 ± 102	1,719 ± 696
Posttest	258.8 ± 130*†	469.1 ± 159*†	217.1 ± 74*	138.8 ± 58*	318.9 ± 126*†	251.6 ± 111*	310.5 ± 111*†	305.6 ± 114*	2,029 ± 818*
% Change	17.5 ± 14‡	15.7 ± 16	25.3 ± 13‡	17.8 ± 10‡	19.2 ± 11‡	18.8 ± 12‡	18.5 ± 9‡	10.8 ± 7‡	17.2 ± 10‡
HEX									
Pretest	254.3 ± 141	375.4 ± 171	209.5 ± 83	114.4 ± 45	228.8 ± 109	220.5 ± 113	265.2 ± 100	298.1 ± 123	1,909 ± 850
Posttest	287.7 ± 157*†	469.1 ± 197*	246.8 ± 109*	143.9 ± 66*	376.5 ± 140*†	257.1 ± 135*	307.9 ± 123*	347.1 ± 167*	2,263 ± 1078*
% Change	16.0 ± 16.6‡	27.6 ± 18.3‡	17.3 ± 10‡	24.6 ± 14‡	22.1 ± 16‡	16.6 ± 10‡	16.1 ± 10‡	14.6 ± 12‡	17.8 ± 8‡

*$P < .05$ vs PRE; †$P < .05$ vs CON (analysis of covariance); ‡$P < .05$ vs. CON.
CON = control group, LEX = low-intensity exercise group, HEX = high-intensity exercise group.

Stair Climbing Time

The time to ascend one flight of stairs consisting of 23 steps was measured to the nearest hundredth of a second (Table 4). The time required to ascend one flight of stairs decreased for the LEX ($P \leq .05$) and HEX groups (Table 4). There were significant inverse correlations of −0.73, −0.67, −0.78, and −0.64 between stair climbing time and leg press, leg curl, and leg extension 1RMs and total strength, respectively, but stair-climbing time was not correlated with leg press endurance ($r = -.09$, $P \leq .05$).

Lumbar Extension Strength

Mean isometric strength values at pre-and posttraining for each of the seven angles are shown by group in Tables 5 and 6. There were no statistically significant differences between groups at baseline. Both training groups showed a significant ($P \leq .05$) increase in force production at each of the seven angles. Percentage increases in force production at 60° and 72° of lumbar flexion were significantly greater in the LEX group than in the CON and HEX groups ($P \leq .05$). Total lumbar extension strength increased significantly ($P \leq .05$) for the LEX and HEX groups, respectively (Table 5) but was not significantly different.

DISCUSSION

This study was the first to investigate the effects of two different intensities of resistance exercise on muscular strength and endurance and stair climbing ability in older adults. The results demonstrated significant improvements, but the most noteworthy finding is that there were no major differences between the improvements achieved by high or low intensity exercise regimens in this population. These data suggest that older persons using high- or low-intensity resistance exercise may derive similar benefits when total volume is held constant.

The results indicate that both training regimens used for this study were effective in increasing muscular strength, as evidenced by the improvements in 1RM values for each exercise. These data are in accord with those presented by Brown et al.,[17] Fiatarone et al.,[9] Frontera et al.,[10,11] and Hagberg et al.,[18] who all reported increased strength after resistance training in older adults. The strength increases in this study (~17%) are of the same magnitude as those reported in the Hagberg[18] study (~13%). This is most likely because our study and the Hagberg[18] study used similar one-set exercise regimens with a similar repetition range. Our results are lower than reported in Brown et al.,[17] Fiatarone et al.,[9] and Frontera et al.[10,11] (48–113%), who used multiple set protocols. The greater training volume used in those studies possibly resulted in greater strength gains. Additionally, Fiatarone et al.[9] used frail older subjects, who displayed greater percentage improvement because they had more room to improve than the participants in this study.

There is little evidence regarding what intensity is necessary to achieve significant improvements in muscular strength and endurance in older adults. One recent study examined the effects of high- (80% of 1RM for seven repetitions) or low-intensity (40% of 1RM for 14 repetitions) resistance exercise activity on strength, thigh cross-sectional area (CSA), and bone mineral density.[19] Female subjects (aged 65–79) trained 3 days per week for 52 weeks at one

Table 3. Means and Standard Deviations for Relative* 1-RM Values: Dependent Variables

Group	Chest Press (Nm)	Leg Press (Nm)	Leg Curl (Nm)	Biceps Curl (Nm)	Seated Row (Nm)	Overhead Press (Nm)	Triceps Dip (Nm)	Leg Extension (Nm)	Total Strength (Nm)
CON									
Pretest	4.1 ± 1	7.0 ± 1	3.8 ± 1	2.3 ± 1	5.4 ± 1	3.7 ± 1	4.7 ± 1	5.0 ± 1	36.0 ± 4
Posttest	3.9 ± 1	7.2 ± 2	3.8 ± 1	2.3 ± 1	5.8 ± 1	3.6 ± 1	4.8 ± 1	4.9 ± 1	36.0 ± 7
LEX									
Pretest	4.1 ± 1	7.9 ± 2	3.5 ± 1	2.2 ± 1	5.9 ± 1	3.9 ± 1	4.8 ± 1	5.3 ± 1	32.2 ± 9
Posttest	4.9 ± 1†	9.3 ± 2†‡	4.4 ± 0.4†‡	2.7 ± 1†	7.2 ± 1†‡	4.8 ± 1†‡	5.9 ± 1†‡	5.8 ± 1†	38.5 ± 9†
HEX									
Pretest	5.0 ± 2	7.7 ± 2	4.3 ± 1	2.4 ± 1	6.3 ± 1	4.5 ± 1	5.4 ± 1	5.9 ± 1	38.5 ± 9
Posttest	5.6 ± 2†‡	9.7 ± 2†‡	5.0 ± 1†‡	3.0 ± 1†‡	7.6 ± 1†‡	5.2 ± 2†‡	6.2 ± 1†‡	6.8 ± 2†‡	45.3 ± 12†‡

*Nm/kg FFM.
†$P < .05$ vs PRE; ‡$P < .05$ vs CON (analysis of covariance).
CON = control group, LEX = low-intensity exercise group, HEX = high-intensity exercise group.

of the two intensities, performing three sets of leg press, knee extension, and knee flexion. The authors reported a mean increase in strength of 59% and 41% for the high and low groups, respectively. Nevertheless, the limitations in experimental design, such as the use of only three exercises and restriction to female subjects, precludes its applicability to exercise prescription. It is unknown whether the greater intensity (80% 1RM), performed for three sets using exercises for the entire body, would have lead to increased rates of injury or noncompliance.

Although this investigation did not determine the mechanisms for an increase in strength, other investigators have examined several possibilities, including increased muscle CSA and neural adaptations. First, increased muscle CSA after resistance training in older adults has been reported by Brown et al.,[17] Fiatarone et al.,[9] and Frontera et al.[11] Unfortunately, none of these studies attempted to examine the relationship between the increase in strength and the increase in muscle CSA. Second, Brown et al.[17] and Hakkinen et al.[20] examined electromyographic adaptations to resistance exercise in older adults. Hakkinen indicated that neural adaptations were more important than increases in CSA for the development of muscular strength in this population, as evidenced by a 20% to 30% increase in muscular strength with only a 2% to 6% increase in muscle CSA.[20]

Table 4. Changes in Chest Press Endurance, Leg Press Endurance, and Stair Climbing Time Following Six Months of Resistance Training for CON, LEX, and HEX Groups

Group	Chest Press (repetitions)	Leg Press (repetitions)	Stairs (seconds)*
	mean ± standard deviation		
CON			
Pretest	17.6 ± 6	32.2 ± 16	9.1 ± 1
Posttest	16.9 ± 5	29.4 ± 18	9.0 ± 1
% Change	−0.05 ± 32	−5.0 ± 44	−0.58 ± 7
LEX			
Pretest	16.9 ± 5	26.3 ± 9	9.4 ± 2
Posttest	28.6 ± 8†‡	45.0 ± 20†‡	8.7 ± 1†
% Change	75.5 ± 47§	79.2 ± 81§	−7.3 ± 6§
HEX			
Pretest	17.1 ± 8.7	25.1 ± 13	8.23 ± 2
Posttest	27.4 ± 12†‡	48.3 ± 25†‡	7.8 ± 2†‡
% Change	68.0 ± 35§	105.0 ± 94§	−5.8 ± 8

*Time to ascend one flight of stairs.
†$P < .05$ vs PRE; ‡$P < .05$ vs CON (analysis of covariance); §$P < .05$ vs. CON.
CON = control group, LEX = low-intensity exercise group, HEX = high-intensity exercise group.

The subjects in the present study demonstrated significant improvements in muscular endurance. Improvements in endurance for the chest press and leg press ranged from 68% to 105% for both training groups ($P < .05$) compared with the CON group (Table 4). These results are in accord with those of Brown et al.,[17] who also reported increased muscular endurance after 12 weeks of resistance training in older adults (63 ± 3). The increased endurance could be the result of several factors. First, because the weight lifted for the endurance test was the same for the pre- and posttest, the overall increase in strength would make the load relatively easier during the posttest, facilitating the performance of more repetitions. Second, the adaptations reported by Brown et al.,[17] such as increased half-relaxation time, indicate that there are neural alterations that could contribute to increased resistance to fatigue. Finally, it is possible that the increased endurance may be partially the result of increased concentrations of glycogen, adenosine triphosphate, and creatine phosphate that have been documented with chronic resistance training.[21,22]

The subjects in this investigation did not demonstrate a significant increase in FFM or a significant decrease in body mass or fat mass (Table 1), but this result is fairly consistent with previous reports in the literature for this type of exercise regimen and study duration. Typical circuit training regimens in younger and older subjects have shown only modest alterations in body composition. Gettman et al.[23] summarized the effects of five weight training and six circuit weight training studies on changes in body composition. The studies showed a mean decrease in body weight of 0.12 kg, an increase in lean body mass of 1.5 kg,

Table 5. Means and Standard Deviations for Absolute Lumbar Extension Strength for the CON, LEX, and HEX Groups: Dependent Variables

Group	0° (Nm)	12° (Nm)	24° (Nm)	36° (Nm)	48° (Nm)	60° (Nm)	72° (Nm)	Total Strength (Nm)
CON								
Pretest	137 ± 76	185 ± 83	217 ± 104	235 ± 108	237 ± 100	240 ± 84	241 ± 75	1342 ± 400
Posttest	104 ± 91	160 ± 102	191 ± 88	218 ± 104	226 ± 107	259 ± 113	249 ± 96	1245 ± 550
% Change	−33.3	−13.9	−10.0	−5.8	−5.7	7.0	−7.1	−8.0
LEX								
Pretest	103 ± 69	135 ± 71	146 ± 85	175 ± 102	201 ± 99	201 ± 99	197 ± 89	1100 ± 494
Posttest	165 ± 75*	207 ± 79*	238 ± 84*	259 ± 94*	274 ± 92*	267 ± 87*	262 ± 83*	1613 ± 495*
% Change	141.4†	87†	136†	76.5†	53.0†	48.0†‡	45.3†‡	62.6†
HEX								
Pretest	93 ± 74	138 ± 106	187 ± 115	207.0 ± 114	233 ± 134	249 ± 138	254 ± 125	1364 ± 796
Posttest	172 ± 107*	229 ± 118*	254 ± 125*	270 ± 125*	273 ± 134*	278 ± 134*	289 ± 138*	1772 ± 887*
% Change	130.3†	112.0†	57.0	40.4†	27.0	18.0	17.0	39.5†

*$P < .050$ vs PRE; †$P < .050$ vs. CON; ‡$P < .050$ vs. HEX.
CON = control group, LEX = low-intensity exercise group, HEX = high-intensity exercise group.

and a decrease in fat mass of 1.7 kg. The diet record analysis showed that total caloric consumption remained similar from pre- to posttraining. Based on this and the increased caloric expenditure caused by the resistance exercise, it seems reasonable to expect that body mass would have decreased. The lack of response may be the result of inaccurate reporting of dietary intake such that the subjects underestimated their true caloric intake. It is interesting to note that the percentage of the diet contributed by fat increased significantly for the CON and HEX groups ($P \leq .05$), but that this did not result in an increase it body fat for either group (Table 1).

Accompanying the training-related increases in strength and endurance was a significant decrease in the time required to ascend one flight of stairs. These data are in agreement with Rooks et al.[24] and Fiatarone et al.,[9] who reported an increase in stair climbing speed and an increase in stair climbing power after resistance training, respectfully. Stair climbing time inversely correlated to leg press, leg curl, and leg extension 1RM and total strength with *r*-values ranging from −.64 to −.78 ($P < .01$). Because there were no significant changes in body weight and the same set of stairs was used for both the pre-and posttesting, the improvement in time is not attributable to a decrease in the work necessary to complete the task. Therefore, the improvement in stair climbing time can be largely attributed to increased muscular strength. However, it is also possible that in the LEX group the nonsignificant decrease in body mass combined with increased muscle strength contributed to improved stair climbing ability.

Lumbar extensor strength improved significantly as a consequence of training with a machine specifically designed to strengthen the lumbar extensors. It is interesting to note that the magnitude of increase was greater for the lumbar extensors than for the sum of the rest of the body, 62.6% ver-

Table 6. Means and Standard Deviations for Relative* Lumbar Extension Strength for the CON, LEX, and HEX Groups: Dependent Variables

Group	0° (Nm)	12° (Nm)	24° (Nm)	36° (Nm)	48° (Nm)	60° (Nm)	72° (Nm)	Total Strength (Nm)
CON								
Pretest	2.6 ± 1	3.7 ± 1	4.3 ± 1	4.6 ± 1	4.7 ± 1	4.8 ± 1	4.9 ± 2	28.2 ± 5
Posttest	1.8 ± 1	3.1 ± 1	3.8 ± 1	4.3 ± 1	4.5 ± 1	5.2 ± 1	5.1 ± 2	25.8 ± 6
LEX								
Pretest	2.2 ± 2	2.7 ± 1	2.9 ± 2	3.4 ± 2	3.7 ± 2	3.9 ± 2	4.2 ± 2	22.3 ± 9
Posttest	3.6 ± 1†‡	4.4 ± 1†‡	5.0 ± 1†‡	5.3 ± 1†‡	5.5 ± 1†‡	5.6 ± 1†	5.7 ± 1†	34.3 ± 6†‡
HEX								
Pretest	1.8 ± 1	2.7 ± 2	3.8 ± 2	4.2 ± 2	4.7 ± 2	5.1 ± 2	5.3 ± 1	27.5 ± 10
Posttest	3.4 ± 1†‡	4.6 ± 1†‡	5.2 ± 1†‡	5.5 ± 1†‡	5.5 ± 1†‡	5.7 ± 1†	6.0 ± 1†	35.9 ± 9†‡

All values are mean ± SD.
*Nm/kg FFM.
†$P < .05$ vs PRE; ‡$P < .05$ vs CON (analysis of covariance).
CON = control group, LEX = low-intensity exercise group, HEX = high-intensity exercise group.

sus 17.2% and 39.5% versus 17.8% for the LEX and HEX groups, respectively. The greater magnitude of improvement may be due to the lack of isolated lumbar exercise during daily activity or in routine training. Decreased lumbar extensor strength has been associated with increased rates of low back pain and injuries.[16,25] The magnitude of improvement for the lumbar extensor muscles when compared with the rest of the body would seem to indicate that they are in a greater state of detraining. These data suggest that exercises that isolate the lumbar extensor muscles should be incorporated into a comprehensive exercise regimen. Such exercise could be beneficial for treating and preventing low back pain and injury.

This investigation demonstrated similar results for LEX (50% of 1RM) as for HEX (80% of 1RM) when total volume was held constant. This finding is important when prescribing exercise regimens to older adults. Lighter loads may allow the exerciser to obtain adequate benefits while reducing the possibility of injury. It is also important to note that the regimen used in the current study consisted of one set per exercise. This volume allows for the entire circuit to be completed in 15 to 30 minutes depending on the length of the rest period.[8] Protocols similar to the one used in this investigation using one set per exercise have been associated with high rates of adherence/compliance and decreased rates of injury.[8,26]

In summary, this investigation examined the effects of two different intensities of resistance exercise on muscular strength and endurance and stair climbing ability in older adults. The results demonstrated significant and similar improvements in muscular strength and endurance and stair climbing ability for both of the training groups. These data indicate that older adults may derive similar benefits using high- or low-intensity resistance exercise.

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