Effects of Resistance Training on Strength, Power, and Selected Functional Abilities of Women Aged 75 and Older

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OBJECTIVE: To determine the effects of 12 weeks of progressive resistance strength training on the isometric strength, explosive power, and selected functional abilities of healthy women aged 75 and over.

DESIGN: Subjects were matched for age and habitual physical activity and then randomly assigned into either a control or an exercise group.

SETTING: The Muscle Function Laboratory, Royal Free Hospital School of Medicine, London.

PARTICIPANTS: Fifty-two healthy women were recruited through local and national newspapers. Five dropped out before and seven (4 exercisers and 3 controls) during the study. Pre- and posttraining measurements were obtained from 20 exercisers (median age 79.5, range 76 to 93 years) and 20 controls (median age 79.5, range 75 to 90 years).

INTERVENTIONS: Training comprised one supervised session (1 hour) at the Medical School and two unsupervised home sessions (supported by an exercise tape and booklet) per week for 12 weeks. The training stimulus was three sets of four to eight repetitions of each exercise, using rice bags (1–1.5 kg) or elastic tubing for resistance. The exercises were intended specifically to strengthen the muscles considered relevant for the functional tasks, but were not to mimic the functional measurements. No intervention was prescribed for the controls.

MEASUREMENTS: Pre- and posttraining measurements were made for isometric knee extensor strength (IKES), isometric elbow flexor strength (IEFS), handgrip strength (HGS), leg extensor power (LEP), and anthropometric indices (Body impedance analysis, arm muscle circumference, and body weight). Functional ability tests were chair rise, kneel rise, rise from lying on the floor, 118-m self-paced corridor walk, stair climbing, functional reach, stepping up, stepping down, and lifting weights onto a shelf. Pre- and posttraining comparisons were made using analysis of variance or analysis of covariance (using weight as a covariate) for normally distributed continuous data and one-sided Fishers exact test (2×2 table) for discontinuous data.

RESULTS: Improvements in IKES (mean change 27%, P = .03), IEFS (22%, P = .05), HGS (4%, P = .05), LEP/kg (18%, P = .05) were associated with training, but the improvement in LEP (18%, P = .11) did not reach statistical significance. There was an association between training and a reduction in normal pace kneel rise time (median change 21%, P = .02) and a small improvement in step up height (median 5%, P = .005). The other functional tests did not improve.

CONCLUSIONS: Progressive resistance exercise can produce substantial increases in muscle strength and in power standardized for body weight in healthy, very old women. However, isolated increases in strength and LEP/kg may confer only limited functional benefit in healthy, independent, very old women. **J Am Geriatr Soc 43:1081–1087, 1995.**

Cross-sectional studies have shown that across the age range of 65 to 89 years, even healthy men and women have differences in isometric knee extensor strength, isometric elbow flexor strength, and handgrip strength, consistent with losses of 1 to 2% per annum.[1] More importantly, the decline of explosive leg extensor power across this age range is about 3½% per annum.[1] It is important to maintain muscle strength in order to be able to continue to complete daily tasks successfully and to be able to do this with reasonable safety margins.[2]

Women should be the initial target for intervention to help maintain the ability to perform everyday tasks and activities. Not only is disability disproportionately more common in women,[3,4] but they also have lower strength and power standardized for body weight than do men of the same age.[1]

There have been more than 40 exercise training studies in older subjects that have considered one or more measures of strength as an outcome. Only 11 of these have been randomized and controlled, and until very recently (see below), these studies have considered only the youngest 'old,' those with mean ages between 66 and 75. Even fewer studies have considered functional ability. One recent randomized and controlled study examined older subjects (mean age 82, range

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All work reported in this typescript was performed within the Muscle Function Laboratory, University Department of Geriatric Medicine of the Royal Free Hospital School of Medicine, London.

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71 to 97 years) and not only considered strength at the knee and ankle but also walking speed.[5] Another, looking at the effect of 10 weeks of training with leg press or wall-mounted pulleys in men and women more than 70 years old, found significant improvements in lower extremity strength, gait velocity and stair climbing power.[6] Only two controlled training studies have considered muscular power. One was a pilot study,[7] and in the other, the subjects were only 51–57 years of age.[8]

No study has examined the effects of strength training on strength, power, and functional ability in the same older subjects. The aim of this study was to determine if 12 weeks of progressive resistance strength training can produce an increase in strength and power in healthy women aged 75 and older and whether these increases in strength and power improve functional ability. Strict health criteria were chosen so that the results would be free of any effect of disease on strength or on the response to strength training and to avoid any possible interactions of different disease states with the response to training. Findings have been reported in abstract form.[9,10]

METHODS

Exclusion Criteria and Subjects

Volunteers were recruited through articles in local and national newspapers. Only those whose responses to a health questionnaire met previously defined criteria[11] for 'healthy' or 'medically stable' were included. Subjects had no recent history of cardiovascular, cerebrovascular, respiratory, systemic, muscular, or uncontrolled metabolic disease, or any impairment that interfered with mobility. All women lived independently and required no help with washing, cleaning, or cooking or help from external services. There were no selection criteria for habitual physical activity.

Fifty-two women were paired and matched for age and habitual physical activity.[12] Five withdrew, and the resulting unmatched subjects were paired, insofar as possible. Forty-seven subjects (median age 79.5 years, range 75 to 93 years) were allocated randomly, using a random numbers table, into the training or the control group.

Ethics

This study was approved by the Hampstead Health Authority Ethical Practices Sub-committee, and all subjects gave written informed consent.

Study Design

All tests were performed in the same order, with rests allowed to avoid fatigue. All measurements of an individual's performance were made on the same day; pre- and poststudy measurements were made at the same time of day and by the same observers without reference to the baseline values, but observers were not blind to the group in which the subject participated. Measurements were made during the 2 to 3 weeks before training and during the 2 weeks after training. All tests were demonstrated and fully explained to the subject, and practice of each test during the measurement session was encouraged.

Lifestyle

Each subject completed three questionnaires pre- and posttraining. One questionnaire graded habitual physical activity on a 6-point scale for each decade of their adult life.[12] Subjects also completed a 'Human Activity Profile' (HAP), which includes 94 questions about their current capability to perform very easy to very strenuous physical tasks.[13] The scoring allows calculation of a Maximum Activity Score (MAS), which gives an estimate of a subject's highest level of energy expenditure, and calculation of an Adjusted Activity Score (AAS), which is an estimate of the subject's average level of energy expenditure (a measure of usual daily activities). The Tokyo Metropolitan Institute of Gerontology Index of social competence (TMIG)[14] graded subjects' participation in social activities on a scale of 13 yes/no answers.

Anthropometry

Pre- and posttraining measurements were made of height (wall-mounted stadiometer), weight (heavy clothing and shoes removed), arm muscle circumference (AMC) (derived from mid arm circumference − (0.314 × triceps skinfold thickness)),[15] demi-span (distance from the sternal notch to the finger roots of one arm),[16] and phase angle (RJL Body Impedance Analyser BIA109), derived from the ratio of resistance (measure of fluid) and reactance (measure of body membranes) of the body.[17] Body impedance analysis (BIA) was performed without requiring subjects to have fasted.

Strength

Isometric knee extensor strength (IKES), isometric elbow flexor strength (IEFS), and handgrip strength (HGS) were measured bilaterally as reported previously.[1] Repeatability of strength and power measurements in older subjects has been reported elsewhere.[11] For all subjects who gave consent, electrically stimulated contractions were studied in the right quadriceps to measure relaxation rate[18] (training, $n = 9$; control, $n = 7$) and to assess the completeness of activation (using twitch interpolation (TI))[19] (training, $n = 14$; control, $n = 9$). Stimulation caused discomfort for most of the subjects.

Leg Extensor Power (LEP)

Explosive power was measured with a slightly modified version[20] of the Nottingham Power Rig,[21] as reported previously.[1] This method for power measurement allows the subject to remain seated and avoids impacts or excessive postural demands. It measures power exerted by a single explosive effort of the extensors of the lower limb to accelerate a flywheel from rest.

Functional Ability Tests

Functional Reach

The subjects were asked to stand with their feet slightly apart and then to reach forward as far as possible without taking their heels off the floor and without using the other arm for support.[22] They were asked to reach three times, and the longest reach was recorded.

Chair Rise

The subjects were asked to rise with their arms folded, at a comfortable pace, from a stool with a level seat 0.42 m from the floor.[1] The test was performed twice, and the faster rise (timed with a 30-second stop watch) was recorded. The subjects were then asked to repeat the test, as fast as they could. The subjects were then asked to rise 10 times consecutively, with their arms folded, at their own comfortable pace.[23]

Lifting a Bag onto a Surface

Subjects were asked to lift a shopping bag (46 cm handle to base) containing, progressively, 2 to 8-kg laboratory weights (1-kg increments) onto a 0.72-m surface.[1] The test was performed once per arm at each weight, and the mean best weight lifted recorded.

Box Stepping

The subjects were asked to step up onto and down from boxes of heights progressing in 5-cm increments from 5 to 55 cm; there were no handrails.[1,24] At each height, the subject was allowed two attempts at stepping up and two attempts at stepping down, and the maximal height achieved for each was recorded.

Kneel Rise

Subjects started the test from a kneeling position, with their hands on the floor in front of them. They were asked to rise to standing in their own time without the use of a hand hold (although one was provided for safety). The test was performed twice, and the faster rise was recorded. Subjects were then asked to repeat this test, rising as fast as they could.

Floor Rise

Subjects started the test lying on their side on the floor. They were asked to rise to standing in their own time without the use of a hand hold. The test was performed twice, and the faster rise was recorded.

Corridor Walk

Subjects were asked to walk once, at their own pace, along a 118-m corridor.[25] Heart rate was measured telemetrically and averaged every 5 seconds (Sports Tester PE3000), and the mean of the final 60 seconds of the walk was recorded. The number of steps taken in 20 seconds was recorded at half way.

Stair Walking

Subjects were asked to climb up a staircase (6 flights of 12 steps each, 1.885 m per flight) as far as they could without stopping, moving at a comfortable pace but without using the handrail as support. Performance was recorded as flights per second (flights/sec). Heart rate was measured telemetrically as the mean of the final 15 seconds.

Interventions

To encourage participation and to ensure that the only training stimulus imposed on the training group was the prescribed exercise, taxi-cabs were provided to and from the Medical School for each of the supervised exercise sessions. Only two women would have been unable to commute to the laboratory had taxi-cabs not been provided.

Control Group

No active or placebo intervention was prescribed for the control group. They were asked to perform no more or less activity than before the study and were asked to complete an exercise diary each day of the study. This diary was to include any moderately strenuous activity (and length of activity time) that involved the use of major muscle groups, e.g., stair climbing, gardening, walking to and from shops, sports, dancing.

Training Group

These subjects attended an exercise class at the Medical School, in groups of four to six, once a week for 12 weeks. The subjects were also asked to complete two unsupervised 'home sessions' per week, following an exercise prescription. Each subject had an illustrated exercise booklet and an audio cassette explaining the exercises. Each subject kept an exercise diary for home sessions (number of sets and repetitions managed for each exercise) and for any other exercise related activities they did apart from the prescribed exercise. No subject missed more than 2 consecutive weeks of training or performed fewer than 30 complete sessions.

Exercise Class

Each class began with a 10-minute warm-up and stretch of the main muscle groups being trained; correct posture was stressed. The 30 to 40-minute strengthening component of the class involved exercises chosen for their expected effectiveness, safety, and ease of learning. The exercises did not mimic any of the pre-study measurements of strength, power, or functional ability but were aimed at increasing the strength of those muscles considered necessary for the tests. The muscles trained were shoulder and hip abductors, adductors, flexors and extensors, elbow flexors and extensors, and knee flexors and extensors. Following a typical progressive resistance protocol, each exercise was performed as three sets of four to eight repetitions, with body weight, rice bags (1–1.5 kg), or elastic tubing (6 resistances of 'Theraband' (Nottingham Rehabilitation)) for resistance. Initially, resistances were chosen so that the subject could almost complete three sets of four repetitions. As soon as a subject could complete three sets of eight repetitions of an exercise, the resistance was increased and the number of repetitions reduced. There was a 10-minute 'warm-down' component at the end of the class. Heart rate telemetry (Polar Sports Tester) on at least one person each week showed that at no time did the heart rate rise above 70% of estimated maximum heart rate. The exercises used can be obtained from the authors.

Statistical Analysis

Preliminary work indicated that a training group size of 23 would give an 85% probability of detecting a 20% decrease in chair rise and kneel rise time, a 10 to 15% increase in leg extensor power, and a 10 to 15% increase in isometric knee extensor and elbow flexor strength ($\alpha < .05$, two-tailed). Results are expressed, unless otherwise stated, as means and standard deviations, and all calculations were made with the bilateral mean of each subject's strength or power values. Correlations between variables were assessed by calculating Pearson's product moment r or Spearman's ρ.[26] Pre- and posttraining comparisons were made using analysis of variance or analysis of covariance (using weight as a covariate), as appropriate,[27] for continuous data and one-sided Fishers exact test (2×2 table)[28] for discontinuous data. Some subjects' pretraining values were at the upper limit of the stepping and bag-raising tests (55 cm and 8 kg, respectively, being considered as the upper limit of stepping or lifting in everyday life) and, therefore, they could not show improvement. Unless these subjects deteriorated in their stepping or bag-lifting ability, their data for that test were excluded from further analysis.

RESULTS

Seven women, four from the training group and three from the control group, dropped out during the 12 weeks of the study because of ill health (not related to the exercise). Results are reported from the 20 exercisers (median age 79.5 years, range 76–93 years) and 20 controls (median age 79.5 years, range 75–90 years) who completed the study.

Compliance:

Three subjects attended extra class sessions because they were unable to complete home sessions, and nine completed extra home sessions because they were unable to attend the class. Eight of 20 subjects attended all classes and completed all (or more) home sessions. No one attended fewer than nine class sessions (range 9–14, median 10.5 (10 or 11) classes). According to the exercise diaries no one performed fewer than 20 home sessions (range 20–30, median 24 classes). The median total number of sessions completed was 35.5 (range 31–40). Except for the first 2 weeks of the study where a number of people felt stiff after training, the exercises caused no discomfort, and there were no untoward occurrences.

Lifestyle and Anthropometry

The training and control groups did not differ in their pretraining levels of habitual physical activity on any of the three scales used. Both groups had a median score of 3 (range 3–5) on a 6-point scale,[11] corresponding to light exercise for 2–4 hours per week. On the HAP scale,[12] the training group had a median maximum activity score (MAS) of 76.5 (range 60–85) and a median adjusted activity score (AAS) of 73 (range 48–81), and the control group had a median MAS of 76 (range 71–82) and a median AAS of 71 (53–80). Unfortunately, age-matched normal values for these scores are not available, but a MAS of 76.5 is approximately the 74th percentile, and an AAS of 73 is the 67th percentile of 70 to 79 year women.[12] Pre-and posttraining questionnaire answers showed no difference for either group. On these scales, activity score would not be influenced by the training program itself. Subjects scored highly on the TMIG Index (controls: median 13, range 11–13; exercisers: median 13, range 11–13).

The control group was heavier than the training group (mean 61.5 kg vs 54.1 kg; $P < .05$). Over the study period, neither group varied in its body weight, height, arm muscle circumference, demi-span or phase angle (Table 1).

Strength

Before training, mean HGS for the control and the training group did not differ significantly. The members of the control group were stronger than those of the training group for mean IKES ($P < .05$) and mean IEFS ($P < .01$) (Table 2). Analysis of variance (with weight as a covariate) showed an association of improvements in IKES, IKES/kg, HGS, and IEFS with training (Table 2, Figure 1).

The maximal voluntary contraction (MVC) performed during twitch interpolation (TI) was frequently less than 95% of the best MVC. This may have been attributable to the discomfort caused by the stimulation. As a result, interpretable TI data (both pre-and posttraining) were obtained for only one control and three training group subjects. The control subject and two of the three training subjects had evidence of incomplete activation both pre- and posttraining. There was an association of faster relaxation rates with training (mean 15%, $F = 4.56$, $P = .05$)

Leg Extensor Power

Before training, the control and training groups did not differ significantly in their mean LEP (Table 2). There was an association of an increase in LEP/kg with training (Table 2, Figure 1), but the association between increase in LEP and training was not statistically significant ($P = .11$). Analysis of variance (without weight as a co-variate) also showed no association between increase in LEP and training ($P = .07$). When the Student's t test was used on pre- and posttraining data in the training group alone, LEP significantly increased ($P < .05$).

Effect of Age or Number of Sessions Attended on Training Changes

There was no association between age and the training-induced change in strength or power, but this study was not designed to study the effect of age on the training change (the ages of the subjects were not evenly distributed over the age range). There was no association between the number of sessions attended and the training-induced change in strength or power.

Effect of Habitual Physical Activity on Training Change

Again, this study was not designed to answer this question. There was no association between training-induced changes in strength or power and pre-study levels of habitual physical activity.

Table 1. Anthropometric Indices Pre- and Posttraining in the Training and Control Group

	Training			Control			F Ratio
	Pre	Post	%Δ	Pre	Post	%Δ	P
Body weight (kg)	54.1 (9.1)	54.1 (9.3)	0	61.5 (11.4)	62.2 (11.8)	0	0.712
Body height (m)	1.54 (0.07)	1.54 (0.07)	0	1.57 (0.07)	1.57 (0.06)	0	0.987
Demi-span (cm)	72.1 (2.9)	72.3 (3.0)	0	73.9 (4.2)	73.3 (3.4)	−1	0.231
AMC (cm)*	23.0 (2.9)	22.5 (2.6)	−2	24.8 (3.8)	24.1 (2.8)	−1	0.929
Phase angle†	5.7 (0.7)	6.2 (1.1)	9	6.0 (0.7)	6.3 (0.7)	8	0.778

Values expressed as mean (SD). $\overline{\%\Delta}$ = mean % change in variable. n = 20 for each group, except † as measured from resistance and reactance (Body Impedance Analyser) (n = 18 for training group, n = 17 for control group). * AMC = Arm muscle circumference. P-values are calculated from the F-ratio as derived from analysis of variance.

Table 2. Strength and Power Measurements

	Training			Control			F Ratio	
	Pre	Post	%Δ	Pre	Post	%Δ	P	P_w
IKES (N)	199.9 (55.9)	239.7 (76.3)	27	243.3 (66.7)	242.9 (63.7)	3	0.031*	0.829
IKES/kg (N/kg)	3.8 (1.2)	4.7 (1.8)	27	4.0 (1.0)	4.0 (1.1)	2	0.019*	0.832
HGS (N)	212.2 (33.6)	218.4 (38.1)	4	209.3 (49.3)	204.0 (44.9)	−3	0.050*	0.361
IEFS (N)	106.6 (28.3)	127.0 (35.2)	22	133.8 (28.0)	127.4 (25.0)	−3	0.049*	0.278
LEP (W)	61.7 (23.0)	79.3 (18.7)	18	69.8 (31.4)	71.2 (31.4)	4	0.112	0.489
LEP/kg (W/kg)	1.2 (0.5)	1.4 (0.4)	18	1.1 (0.5)	1.2 (0.5)	−1	0.049*	0.453

Values expressed as mean (SD), $n = 20$ for all. P = the P value for the F-ratio. P_w = P value for the co-variate weight. IKES = Isometric knee extensor strength; IKES/kg = Isometric knee extensor strength/body weight; HGS = Handgrip strength; IEFS = Isometric elbow flexor strength; LEP = Leg extensor power; LEP/kg = Leg extensor power/body weight. $^*P \leq .05$ as obtained from analysis of variance using body weight as a co-variate.

$$\overline{\%\Delta} \text{ in strength and power} = \frac{100 \times \text{posttraining} - \text{pretraining}}{\text{pretraining}}$$

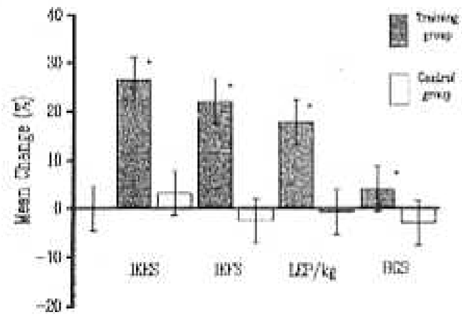

Figure 1. Mean percentage change after training. IKES=isometric knee extensor strength, IEFS=isometric elbow flexor strength, LEP/kg=leg extensor strength standardized for body weight, HGS=handgrip strength. The error bars denote = 1 standard error. $^*P \leq .05$.

Functional Ability

The training group did not differ from the control group in the pretraining functional ability data. Functional ability did not change in the control group during the study. In the training group, functional reach, self-paced stair climbing speed (flights/sec), self-paced walking rate, step rate, heart rate during stair climbing or corridor walk, bag lifting, chair rising, or floor rising did not change with training (Table 3).

Kneel Rise

Two different data sets, normal pace and fast pace, were obtained for kneel rise. There was an association between training and a reduction in kneel rise time (normal pace) (P = .02), but not between training and a change in kneel rise time (fast pace) (P = .29) (Table 3).

Box Stepping

Two of the training group and three of the control group were at the 'ceiling' of our stepping-up measurements (55 cm) pretraining, and two of the training group and five of the control group at the 'ceiling' of stepping down. None decreased their stepping-up performance and their data, therefore, have been excluded from analysis. In the training group, nine of the 18 not at our 'ceiling' improved their stepping up ability (5–15 cm), and four decreased their stepping-up ability (5 cm). Using Fishers exact test, there was an improvement in stepping-up ability with training, P = .005 (2-sided), corresponding to a median increase of 2.5 cm. The probability of an improvement in stepping-down ability with training was not significant (P = .34).

DISCUSSION

Twelve weeks of progressive resistance strength training significantly increased strength and LEP/kg in very old women. The improvements in muscle strength in our subjects are at least equal to those seen in studies with younger subjects.[29,30] Cross-sectional data suggest that muscle strength is lost at a rate of 1 to 2% per annum, and muscle power even faster at 3½% per annum, in healthy women older than the age of 65.[1] It is likely that at the end of training, the subjects were stronger than they had been for many years. Although increases of IEFS and IKES in the training group were large, the increase in HGS was not (4%) and is unlikely to be biologically significant.

Strength may be an important limiting factor in the maintenance of an independent lifestyle. Whipple et al.[31] have documented that nursing home dwellers with a history of falls had only 62% of the quadriceps strength of fellow residents not experiencing falls and only 37% of the strength of community dwellers. An intervention that would increase strength and power may help in the prevention of falls.

The present study did not directly examine mechanisms of strength gains. Nevertheless there was no change in the measured phase angle or arm muscle circumference, implying no increase in lean body mass. An increase in muscle cross-sectional area smaller than the increase in strength is a common finding of strength-training studies.[29,30] It has been considered that most untrained older subjects can fully activate their muscles in a voluntary contraction.[32,33] Our twitch interpolation data, although very limited, suggest that this may not be so; we are unable to exclude the possibility that our subjects' strength gains were the result of a change in the completeness of activation achieved.

Although the results for quadriceps relaxation rate are for only a small number of subjects, they do suggest that training can increase relaxation rates. Muscle power is determined by the velocity of shortening and the overall size and strength of the muscle. With an increase in strength and 'speed' of the muscle after training, we would perhaps expect

Table 3. Functional Ability Data Pre- and Posttraining

	Training				Control				F-Ratio	
	n	Pre	Post	%Δ	n	Pre	Post	%Δ	P	P_w
Chair rise-normal (sec)	20	1.0 (0.5–3.5)	0.9 (0.5–1.6)	−16	19	1.0 (0.5–2.0)	1.0 (0.6–1.6)	9	0.821	0.767
Chair rise-fast (sec)	20	0.7 (0.3–2.3)	0.6 (0.4–1.2)	−14	19	0.7(0.4–1.4)	0.7 (0.4–1.2)	0	0.131	0.833
Chair rise X 10 (sec)	20	28.2 (7.8–63)	28.8 (15–62.5)	2	18	30 (6.1–52.6)	29.8 (15.5–43.6)	−2	0.348	0.062
Kneel rise-normal (sec)	17	2.8 (1.0–13.8)	2.2 (1.0–4.5)	21	15	2.9 (1.1–9.2)	2.2 (1.4–7.1)	−12	0.021‡	0.252
Kneel rise-fast (sec)	15	1.8 (0.6–3.0)	1.7 (0.9–2.5)	−10	15	2.0 (0.7–4.1)	1.6 (1.0–5.5)	−15	0.289	0.403
Floor rise (sec)	17	4.1 (2.0–17.0)	4.0 (1.9–18.5)	−2	18	4.5 (2.5–8.5)	4.5 (1.8–9.2)	4	0.443	0.848
Functional reach (cm)*	20	94.7 (4.5)	96.0 (5.0)	1	20	95.6 (5.5)	95.0 (8.1)	0	0.169	0.321
SP walking speed (m/s)*	20	1.4 (0.5)	1.2 (0.3)	−7	20	1.2 (0.2)	1.2 (0.2)	1	0.389	0.832
SP stair speed (flights/s)*	17	0.10 (0.03)	0.11 (0.04)	14	20	0.10 (0.02)	0.10 (0.03)	0	0.230	0.391
Corridor heart rate (b/m)*	12	94.1 (9.6)	98.7 (11.1)	5	14	91.8 (12.4)	92.5 (10.9)	1	0.509	0.688
Stair heart rate (b/m)*	12	117.0 (11.2)	116.4 (11.0)	0	14	114.9 (14.1)	113.2 (16.2)	−4	0.790	0.693
Step up height (cm)	18	40 (20–50)	45 (25–55)	5	17	40 (20–50)	40 (20–50)	0	0.006§	
Step down height (cm)	18	40 (20–50)	45 (25–55)	0	16	40 (20–50)	40 (20–50)	0	0.341†	
Bag raise (kg)	12	6.75 (6–7.5)	8 (6–8)	14	7	5.5 (3–7.5)	5.5 (5–8)	0	0.178†	

Values expressed as median (range), except * mean (SD). SP = self paced. b/m = beats per minute. † = P value obtained from Fishers exact test after exclusion of subjects unable to show improvement (see *Statistical Methods*). ‡ = $P < .05$; § = $P < .01$ as obtained fromanalysis of variance using body weight as a covariate. %Δ = median change (except * mean change).

an increase in muscle power. LEP/kg and LEP both increased by 18% in the training group, but only LEP/kg showed a statistically significant increase. We would suggest that the training subjects have received a significant biological effect.

There have been two other fully randomized, controlled training studies that have considered functional ability and strength in older people. One showed that 12 weeks of a combination of strength and balance training increased both strength and chosen gait velocity.[5] Fiatarone et al., looking at the effect of 10 weeks of training with leg press or wall-mounted pulleys in men and women more than 70 years old, found significant improvements in lower extremity strength, gait velocity, and stair climbing power.[6] The subjects in these studies were either not as healthy as those in this study[5] or were very frail and had functional difficulties.[6] Neither chosen gait velocity nor stair-climbing power was improved in the present study, where the volunteers were functionally more able than in Fiatarone's study. No other strength-training study has considered muscle power and functional ability in older people.

Only two of the functional tasks, stepping up and rising from the kneeling position on the floor (normal pace), improved with strength training. Step-up height is related to LEP/kg,[1] and this is supported by the fact that stepping-up ability did improve, with training, in this study. Kneel rise time is also related to LEP/kg and IKES/kg (unpublished data). Both step height and bag raise involved a cut-off height or weight beyond which the task was no longer considered functional. A number of women were able to step our highest step or lift our heaviest bag. These women were excluded from the analyses because they could not improve (see *Statistical Methods*). This reduced the statistical power of this analysis. However, of the 11 functional ability tasks that showed no improvement, only two had reduced statistical power. We conclude that task-independent increases in strength and LEP/kg can produce only limited improvements in functional ability in healthy, independent, older women. Perhaps improving functional ability requires training that includes practice of the functional tasks.

Women in the training group also reported subjective benefits. Many suggested that they felt better able to cope with the demands of daily life (shopping, use of public transportation, etc.), five reported that movement in the shoulders had improved, three that their balance was much improved, and one that she could now cut her toe-nails and have a bath rather than a shower.

The enthusiasm of the volunteers for the exercise classes was apparent from their expressed hope that the program could be continued. At follow-up 6 months later, one weekly class had been set up in a subject's front room (3 women attending), two women had joined classes elsewhere, and 12 reported that they continued to practice at home, at least once a week, the exercises used in the study.

We conclude that a simple-to-follow program of progressive resistance exercise can produce substantial increases in muscle strength and power, standardized for body weight, in healthy, independent, older women. Isolated improvements of strength and power standardized for body weight may not be sufficient to improve functional ability in such people.

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