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## Muscle function and functional ability improves more in community-dwelling older women with a mixed-strength training programme

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### Abstract

**Background:** supervised training can reach a limited number of elderly people.

**Objective:** to determine the impact of a 1-year mixed-strength training programme on muscle function (MF), functional ability (FA) and physical activity (PA).

**Setting:** twice-a-week hospital-based exercise classes and a once-a-week home session.

**Participants:** twenty-eight healthy community-dwelling men and women on the training programme and 20 controls aged over 75 years.

**Methods:** training with two multi-gym machines for the lower limbs at 60% of the repetition maximum (1RM). At-home subjects used elastic bands.

**Measurements:** maximum isometric strength of knee extensors (KE), ankle plantar flexors (PF), leg extensor power (LEP), functional reach (FR), chair rise 1 (CR1) and 10 times (CR10), bed rise (BR), six-minute walking test (6MWT), stair climbing (SC), get-up-and-go (GU&G), one-leg standing (1LS). PA was assessed with the Paqap<sup>®</sup> questionnaire.

**Results:** women were significantly weaker than men at baseline: -47% for KE and -59% for PF. Training induced significant gains in MF and FA in the training females; males improved significantly only in FA. PA levels increased non-significantly (2%) in all of the training group.

**Conclusions:** long-term mixed-strength programmes can improve MF and FA in elderly females, and FA in elderly males.

**Keywords:** *mixed-strength training, functional ability, elderly*

## Background

The majority of training studies in older subjects are of less than 4 months duration and have mostly considered (i) strength as an outcome, (ii) the age range 65–75 years and (iii) institutionalised elderly.

In recent times, greater attention has been focused on the need to increase muscle power in older populations [1–10]. In particular, women may reach levels below the threshold for tasks important for an independent life [1]. Impairments of muscle power are important factors limiting mobility in both nursing home residents [2] and community-dwelling elders [3, 4].

Few studies have considered functional ability together with muscle power [1, 2, 9, 10] and community-dwelling elderly as a population sample [11, 12]. There are few long-term studies [12, 13] and they mostly involve supervised training which could reach only a limited number of people. Partially supervised, home-based or mixed training programmes could potentially have a wider impact on the elderly population [14].

The aim of this study was to determine to what extent, and how differently, a long-term mixed-strength training programme can impact on muscle function, functional ability and physical activity profile in healthy community-dwelling men and women over 75 years of age. We also wanted to address the relationship of lower extremity strength–power and the ability to accomplish selected functional activities in order to identify the most influential determinant of performance in old age.

## Methods

### Subjects

We performed an observational study recruiting a total of  $n=60$  subjects over 75 years of age from (1) Social Services, (2) Age Concern, and (3) University of the Third Age in Pavia, Italy. The research study was approved by the local ethical committee and subjects gave written informed consent. They underwent a thorough medical examination and a stress electrocardiogram. Twenty-eight healthy elderly subjects (15 females, mean age  $76.42 \pm 3.58$  years, mean body weight  $59.42 \pm 11.82$  kg, mean body height  $160.71 \pm 5.34$  cm; and 13 males, mean age  $76.2 \pm 9.89$  years, mean body weight  $76.23 \pm 9.8$  kg, mean body height

$173.46 \pm 5.34$  cm) participated in a 1-year training programme and 20 elderly subjects (11 females, mean age  $77.2 \pm 3.4$  years, mean body weight  $62.3 \pm 9.5$  kg, mean body height  $160.2 \pm 4.45$  cm; and 9 males mean age  $77.8 \pm 6.3$  years, mean body weight  $72.3 \pm 8.6$  kg, mean body height  $171.2 \pm 4.4$  cm) served as controls. Twelve subjects were excluded on the basis of the following exclusion criteria: malignant disease, previous stroke, Alzheimer's disease, major lung pathology, motor neurone disease, Parkinson's disease, musculoskeletal disorders, endocrine disorders, severe diabetes mellitus and a history of hypertension, recent myocardial infarction, use of beta-blockers, and patients who were not in sinus rhythm, or who had had an acute febrile or systemic disease within the previous 2 years.

## Training programme

### Supervised programme

The supervised exercise classes were held twice weekly in the hospital gym. The participants started each class with a 15 minute warm-up that included light rhythmical, low-intensity aerobic activities, flexibility exercises and supported stretching exercises. Tai-Chi Yang style exercises involving slow, controlled movements in different planes of the upper and lower limbs were included.

Strength training was carried out with multi-gym machines at 60% of the repetition maximum (1RM). Training was carried out on two variable-resistance machines for the lower limbs (Sitting Calf and Leg Press, TECHNO-GYM, Italy). Subjects performed one set of 12 repetitions on each machine at an intensity initially set at 40% of the 1RM value and gradually increased to 60% of 1RM within a month. A 2 minute rest between warm-up and training sets and between each set of repetitions was provided. The 1RM was measured on each machine every 2 weeks and the training load readjusted to keep the training stimulus constant at 60% of the 1RM. Subjects were asked to execute the concentric phase of each exercise over 2 seconds followed by the eccentric phase over 3 seconds. The range of motion was  $50^\circ$  on the Sitting Calf and  $90^\circ$  on the Leg Press. At the end of the session, the subjects performed a 10 minute cool-down including stretching of the trained muscles. The total duration of the session was approximately 60 minutes.

## Home programme

Once a week the training session was held at home using elastic bands (Theraband) reproducing the movements done on the two variable-resistance machines. Participants were familiarised with the elastic bands and were given clear instructions on how to reach the same intensity as with the machines [15]. Each home session consisted of 20 repetitions of horizontal squatting (Leg Press) and heel-rise from seated (Sitting Calf). Subjects were also encouraged to perform 30 minutes of outdoor aerobic exercise once a week. Monthly logs were completed to document their home activities and adherence to protocol.

## Measurements

The subjects were tested on two occasions at baseline and after 1 year.

### Muscle function (MF)

We measured maximum isometric strength of knee extensors (KE) and ankle plantar flexors (PF) with a Cybex Norm dynamometer. KE strength was measured with the subjects in a sitting position with hip flexed at 90° at five angles in the range 20–90° (full knee extension 0°).

PF isometric torque was measured with the participants lying prone with both hips and knees at an angle of 180° at five angles in the range –20° (dorsiflexion) to +20° (plantarflexion).

Leg extensor power (LEP) was measured with the Nottingham Power Rig equipment. This equipment measures the power (W) delivered by a seated subject in accelerating a flywheel from rest by pressing a footplate until the leg is extended [16].

### Functional ability (FA) tests

We used the following standardised tests.

#### *Functional reach (FR)*

The subjects had to stand and reach forward beyond arm's length as far as possible without taking their heels off the floor [17]. The reach distance was measured in centimetres from the initial to the final knuckles position. The longest reach out of three attempts was recorded.

#### *Chair rise 1 (CR1) and 10 times (CR10)*

The subjects had to rise as fast as possible, with the arms folded, from a seat at a height of 0.42 m from the floor [1]. The fastest out of two attempts was recorded with a 30 second stop watch. The CR10 consisted of rising 10 times consecutively and recording the total time [18].

#### *Bed rise (BR)*

Subjects had to rise to an upright position as fast as possible from a standard 0.72 m high hospital bed. The fastest out of two attempts was recorded with a 30 second stop watch.

#### *Six-minute walking test (6MWT)*

The 6MWT [19] measures the distance, in metres, walked at a preferred pace over 6 minutes along a measured walkway.

## Benefits of moderate-intensity strength training

Subjects were instructed to walk as fast and as far as possible during the 6 minutes and were given encouragement throughout the test.

#### *Stair climbing (SC)*

Subjects had to climb up a staircase (two flights of 12 steps each) as quickly as possible without stopping and without using the handrail as support, to turn around on the top platform and then walk down. Performance was recorded with a stop watch [20].

#### *Get up and go (GU&G)*

Subjects had to rise from a standard 42 cm high chair, walk to a wall 3 metres away, turn, and return to the chair to a seated position [21, 22]. The performance time was recorded with a stop watch.

#### *One-leg standing (1LS)*

Subjects had to stand on one leg for as long as possible with the contralateral knee flexed at 90°. The test was over when the subjects were not able to maintain their balance and the suspended leg touched the floor. The performance time was recorded with a stop watch [23].

### Physical activity (PA)

The physical activity (PA) profile was assessed with the Paqap<sup>®</sup> questionnaire [24]. The questionnaire records the subject's normal activities reported retrospectively over a duration of 1 week. It provides an evaluation of physical activity and energy expenditure (EE) in terms of mean daily EE, EE and duration for each activity and the oxygen consumption (VO<sub>2max</sub>) estimate.

### Statistical analysis

We used a two-factor ANOVA (gender and training) to analyse differences in strength values at baseline between training and control in both males and females. Results are expressed as mean values  $\pm$  standard deviation.

A two-factor ANOVA (gender and training) for repeated measures was used to analyse pre–post training differences in trained individuals and controls, and differences following training according to gender.

The relationship between the time to complete the FA tests and the strength and power variables was determined using Pearson product moment correlations. The level of significance was set at  $P < 0.05$ .

## Results

The overall adherence rate to the programme (number of sessions actually performed divided by the total number of home and hospital-based sessions) was 65% (12–89% in males and 17–89% in females).

At baseline women showed significantly lower mean KE values (–47%) and mean PF values (–59%) than men.

Significant differences in PF were also evident between training and control subjects at baseline (Table 1).

**Table 1.** Baseline KE and PF data (mean  $\pm$  standard deviations)

		KE right (Nm)	KE left (Nm)	PF left (Nm)	PF Right (Nm)
Females	Training	95.3 $\pm$ 21.8	93.6 $\pm$ 16.4	57.2 $\pm$ 11.1*	67.2 $\pm$ 15.8*
	Control	68.1 $\pm$ 22.4	66.0 $\pm$ 16.6	42.6 $\pm$ 17.0*	41.3 $\pm$ 16.8*
Males	Training	148.9 $\pm$ 23.5	143.8 $\pm$ 21.7	104.4 $\pm$ 22.6	111.6 $\pm$ 14.0**
	Control	136.1 $\pm$ 51.3	150.4 $\pm$ 28.6	86.1 $\pm$ 24.4	84.9 $\pm$ 21.6**

Non-significant baseline differences were found for KE data between training and control group; significant differences in PF values ( $P < 0.05$ ) are evident between training and control group in the female (\*) and male (\*\*) subgroup.

**Table 2.** Percentage increases in MF (KE, PF, LEP), FA (FR, 1LS, CR1, CR10, BR, GU&G, SC, 6MWT), PA (Paqap) in the training females (Tf) and training males (Tm) and controls (Cf and Cm)

	Tf	Cf	Tm	Cm	Pre-post T-C	Gender
PF -20°	+21.5%	-5%	+8%	-4%	$P < 0.001$	$P = 0.023$ (f $P = 0.001$ , m $P = 0.17$ )
KE 90°	+12%	-2%	+4%	-5%	$P < 0.001$	$P = 0.006$ (f $P = 0.019$ , m $P = 0.04$ )
LEP	+22.5%	-9%	+4%	-8%	$P < 0.001$	$P = 0.006$ (f $P = 0.001$ , m $P = 0.04$ )
FR	+85%	-1.7%	+60%	+1%	$P < 0.001$	n.s. (f $P < 0.001$ , m $P = 0.003$ )
1LS	+29.1%	-11%	+25%	-4.8%	$P < 0.001$	n.s. (f $P = 0.007$ , m $P = 0.017$ )
CR1	+29%	-11%	+17%	-2%	$P < 0.001$	n.s. (f $P = 0.002$ , m $P = 0.052$ )
CR10	+28%	-8%	+20%	-7%	$P < 0.001$	n.s. (f $P < 0.001$ , m $P = 0.018$ )
BR	+29%	-4%	+8%	-3%	$P < 0.001$	n.s. (f $P < 0.001$ , m $P = 0.02$ )
GU&G	+20.5%	-0.6%	+18.6%	-2%	$P < 0.001$	n.s. (f $P < 0.001$ , m $P < 0.001$ )
SC	+12%	-3.3%	+12%	-2%	$P < 0.001$	n.s. (f $P < 0.001$ , m $P = 0.034$ )
6MWT	+4.7%	-2.7%	+4.5%	-2%	$P < 0.001$	n.s. (f $P = 0.016$ , m $P = 0.026$ )
Paqap	+2%	-1%	+2%	-1%	n.s.	n.s.

The significance of pre-post training differences between trained and control subjects (pre-post T-C) are reported. The significance of the different effects of training according to gender is reported in the last column and, in brackets, the significances in females (f) and males (m).

We observed significant pre-post training differences between trained and control subjects in all of the parameters studied except Paqap (Table 2).

The effect of training was significantly different between trained females and males for strength and power values. In particular, females showed significantly higher gains than males.

The effect of training on functional parameters and level of physical activity (Paqap) did not show significant differences between females and males (Table 2).

We observed significant gains in MF and FA in the training females, with larger differences in LEP values than in FA values (Figure 1a).

The training males improved significantly in only FA and to a lesser extent than in females (Figure 1a, b).

LEP showed higher correlations than KE-PF with GU&G, SC, CR10 and 6MWT (Figure 1a and b).

The 1LS and CR1 tests showed higher correlations with KE and PF than LEP.

PA levels increased by 2% in the male and female training subjects and were statistically non-significant.

## Discussion

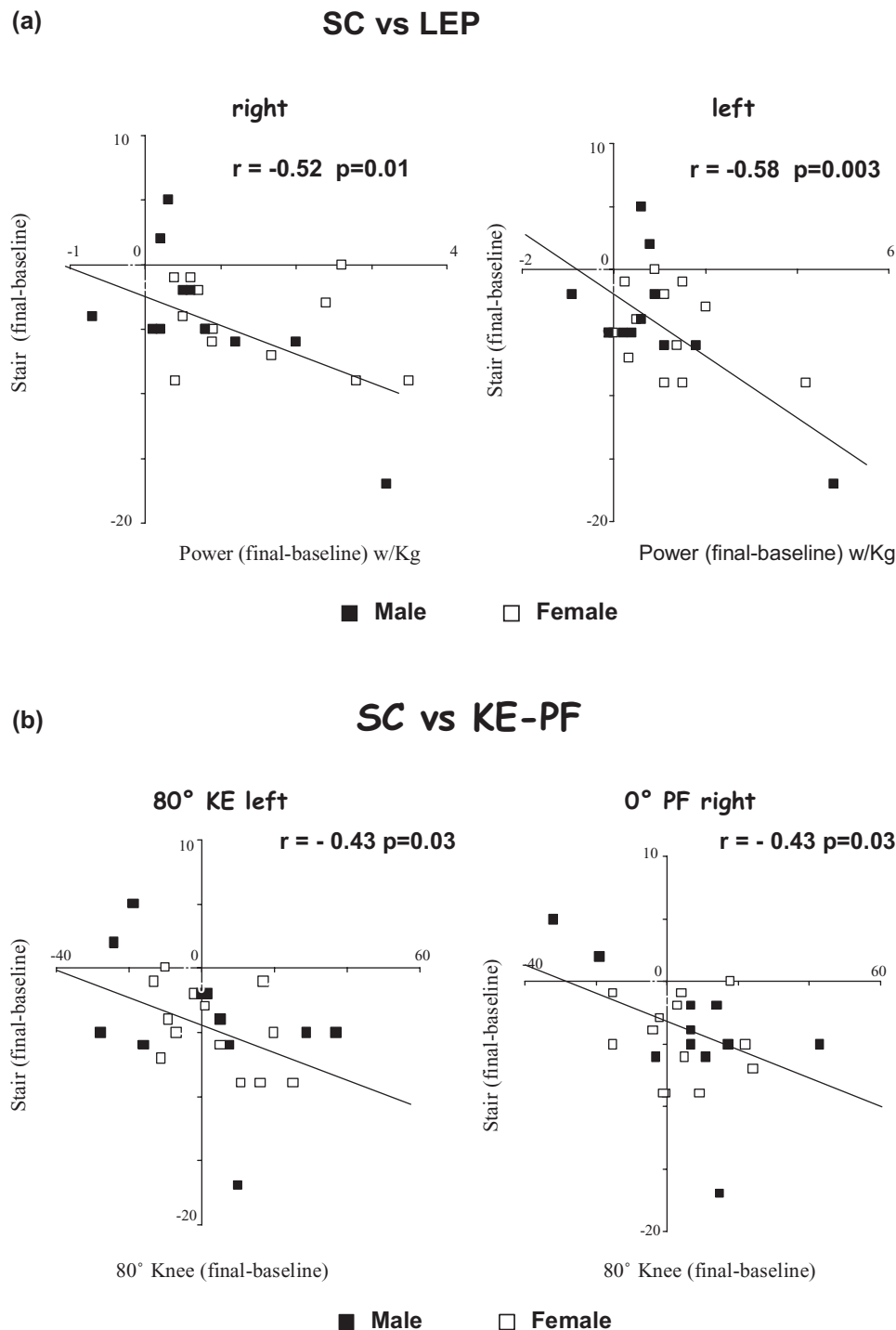
There is only little evidence [25–27] for the effectiveness of partially supervised or home-based training programmes. Our mixed training showed beneficial and significant effects on MF and FA in the female group. The training intensity appears insufficient for the men to significantly improve their MF but enough to improve FA. Another possible

reason for non-significant MF changes in males could be that their age values were more scattered around the mean value than in women and it is known that both strength and power in men are noticeably age-related: KE declines by 4.5 Nm per annum while LEP decreases by 5.4 W per annum [1, 28].

The adherence rate was comparable in the training females and males. At baseline women were 47% and 59% weaker than men in KE and PF, respectively, in line with previous data [29]. Anthropometric characteristics and strength values of our subjects were comparable to the data of Skelton [1]. The PA baseline data showed that males devoted an average of 17 hours a week to physical activities while females reported only 7 hours/week. Initial level of frailty seems, therefore, to affect the impact of strengthening.

Other studies have reported gender differences in response to training [27, 29, 30]. Roth [30] has shown significant increases in muscle cross-sectional area in females over 70 but not in males after 6 months of training. Vincent *et al.* [13] have reported significant functional changes either after training at 80% or 60% of the 1RM in males and females between 60 and 83 years of age.

In our study, FA significantly improved for the training participants with no gender differences. These improvements can be explained by the MF increases and, in particular, by task-independent LEP increases in the females, and possibly by enhanced movement co-ordination, motor control and higher velocity of execution in the males. LEP appears to be a crucial determinant of performance for women,



**Figure 1.** (a) The correlations between differences in LEP values and in SC values. Differences are between final–baseline values (average for both legs) in males (filled squares) and females (empty squares). Training effect is slightly more pronounced in the female group (see also text). (b) The correlations between differences in KE values (at 80° flexion) or in PF values (at 0° flexion) and SC values. Symbols as in (a).

whereas men seem to have ‘safety margins’ of muscle power for daily functional activities.

The potential effect of age on increase in performance following training was not addressed in our study due to the small age range of the subjects.

Consistent with prior investigations [31, 32], we found that the relationship between MF and FA was best characterised by the equation  $y = a \cdot \log x + b$ . The curvilinear trend of the function suggests that factors other than MF improvements contribute to the results of the FA tests. In



tests involving the rapid execution of complex movements there were various neuromuscular factors that were not under investigation in our study.

LEP appears to be highly correlated with GU&G, SC, CR10 and 6MWT, describing more of the variance than does isometric strength (KE and PF) in these tasks. On the other hand, short-term performance measures, such as 1LS, BR and CR1, showed higher correlations with KE–PF rather than LEP. This is probably due to the fact that strength *per se*, rather than the rate at which force is generated, is important in these tasks. These results are in line with the conclusions of the InCHIANTI study [12], which used the same equipment to measure LEP. Validity and reliability of the method have been shown [12]. The method provides a relevant functional assessment, since the angles of the hip, knee and ankle during the push are somewhat similar to those occurring during daily tasks. We used average LEP values from both legs, since they are used simultaneously in chair-rising or walking, and we did not analyse right–left asymmetry. Since both legs are used to move the body mass against the force of gravity, it seemed most appropriate to relate the performance measures to the ratio of LEP (W) to body mass (kg).

Females showed a significant improvement in the 6MWT. In this test, the intensity is self-selected and participants are allowed to stop and rest during the test. Therefore, it appears to be an adequate means to reflect the demands of daily tasks. In our study, the baseline 6MWT values for males were higher than the reference values [33], whereas the female ones were 20% lower.

The 2% increase in PA in the whole training group could mostly be due to longer time devoted to physical activity rather than to increased intensities of exercise. The questionnaire, completed using a 30 minute personal interview, has been shown to be reproducible and to provide a valid estimate of daily EE [23]. It has also been validated in elderly subjects [34] and on the Italian population (P. Capodaglio, unpublished results).

The biases in our study are represented by the non-randomised allocation of the subjects into training and control groups, and by the baseline significant differences in PF strength between training and control subjects. In general, the recruitment of elderly groups matched in terms of physical activity and fitness appears quite difficult to achieve. In our study a spontaneous enrolment of the subjects in the training and control group occurred depending on personal motivation, difficulties reported in reaching the training facility on a regular basis, level of fitness or subjective perception of physical status. Therefore, it could not be excluded that the more fit subjects formed the training group.

In conclusion, the main finding of this study is that a mixed training programme is effective in improving MF and FA in healthy elderly women. The men probably require intensities of training higher than 60% 1RM to improve MF, but even so moderate training has been shown to improve their FA.

LEP appears a more relevant measurement than strength for important mobility tasks. FA tests, namely

GU&G, SC, CR10 and 6MWT, can be used to assess elderly subjects and their muscle power capacity in both ambulatory care or home setting.

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