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Improving cardiovascular fitness by strength or endurance training in women aged 76–78 years. A population-based, randomized controlled trial

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Abstract

Background: there have been few population-based, randomized controlled trials on the effects of strength or endurance training on cardiovascular fitness in older women.
Objective: to study the effects of strength or endurance training on cardiovascular fitness in women aged 76–78 years.
Design: a population-based, randomized controlled trial.
Setting: exercise laboratory in a university faculty of sport and health sciences.
Subjects: we randomly assigned 42 medically-screened women aged 76–78 years, drawn from the population register to strength ($n=16$), endurance ($n=15$) or control ($n=11$) groups.
Methods: subjects in the two exercise groups performed a supervised, individually tailored 18-week strength or endurance training programme. Controls continued with physical activity at their normal level.
Results: the strength training group showed an increase in cycle ergometer peak power from 68.1 to 70.3 W ($P=0.035$ compared with controls). Their peak power per kg body weight increased from 1.02 to 1.05, while that of the endurance training group increased from 0.91 to 0.93 ($P=0.027$ and $P=0.049$ respectively). Peak oxygen uptake increased from 18.1 to 19.7 $ml \cdot kg^{-1} \cdot min^{-1}$ in the strength and from 17.1 to 18.2 in the endurance group (non-significant). Six subjects (19%) in the exercise groups withdrew from the study because of health problems.
Conclusions: even with its limitations, the study suggests that the effect of 18-week strength or endurance training on cardiovascular fitness among women aged $\geqslant 75$ is relatively small. Furthermore, health problems can emerge during training programmes in medically-screened elderly women.

Keywords: *aged, cardiovascular fitness, exercise, women*

Introduction

Considerable increases in exercise capacity have been reported following resistive or endurance exercise programmes for older individuals [1–14]. The magnitude of the gain in maximal oxygen uptake following endurance training depends on the initial level of physical capacity and the intensity and frequency of the training [15].

Age, sex, specific chronic conditions, depression, dementia, nutritional status and functional impairment have not been shown to influence adaptation to strength training [16]. However, the safety margin for physical exercise may be narrower among older people [17].

In older people, the beneficial and adverse effects of physical exercise may occur with a lower level and duration of exercise than among younger individuals. It has even been reported that the beneficial effects of moderate physical activity on mortality are evident up to the age of 80 and thereafter the prognosis of sedentary people is the same or better than that of physically active people [18].

Most previous exercise interventions have been carried out among selected older individuals aged <75 (mostly men) who had few health problems. Thus, the exercise dose–response relationships in the context of ageing and decreasing health need further clarification, especially in women aged $\geqslant 75$.

Our aim was to study the effects of 18-week strength or endurance training on cardiovascular fitness in a sample of older women, including documenting health problems that arose during the intervention.

Subjects

We sent a postal questionnaire about health, medication, physical activity level and functional status to a random sample of 76–78-year-old women ($n=240$), drawn from the population register of the city of Jyväskylä, Finland. Of the 157 who responded to the questionnaire (65.4%), 65 women reported no severe diseases or functional impairments which could exclude their performing strength or endurance exercise (on the basis of a physician's evaluation and the guidelines for exercise testing and prescription issued by American College of Sports Medicine [19]).

The study was approved by the ethical committees of the Jyväskylä Central Hospital and of the University of Jyväskylä. Written informed consent was obtained from all the subjects.

Fifty-four women participated in the laboratory examinations. The remaining 11 explained their non-participation by lack of time, difficulty in travelling to the centre or poor health. Forty-two women with no contraindications to physical exercise were randomly assigned to strength ($n=16$), endurance ($n=15$) and control ($n=11$) groups. The randomization was performed manually by drawing lots after deciding the number of subjects in each group. The number of subjects in the two exercise groups was intentionally larger than that in the control group to compensate for the possibility of a higher drop-out rate in the exercise groups.

Some of the subjects had chronic conditions (Table 1), but these did not exclude them from physical training. Nine subjects took no prescribed medications, 13 took nitrates, nine were on a β-blocker and six used calcium channel-blockers. Only one took digoxin. The mean level of physical activity in all of the groups studied was 3 on a 6-class scale (Table 1)—reflecting around 3 h moderate physical activity per week, involving domestic tasks such as cooking, cleaning, straightening up the room and making beds, and ordinary gardening, walking longer distances and cycling. None of the subjects reported regular vigorous physical exercise.

Twelve subjects in the exercise groups and 11 in the control group completed the intervention. Of the seven women who withdrew, six stopped because of illness; the remaining woman was unwilling to continue.

Methods

The study forms a part of a larger study that aims to clarify the effects of 18-week endurance or strength training on exercise capacity and health in elderly women.

Laboratory examinations

We measured body height, and body mass using standard procedures. Lean body mass and body fat were assessed by bioelectrical impedance (Spectrum II, RJL Systems, Detroit, MI, USA). The bioelectrical impedance measurements were performed at 1000–1030 h. The machine was calibrated daily with a standard resistor. Before the measurements, the subjects had fasted for 3–4 h and not exercised for at least 12 h. In our laboratory, the coefficient of variation between two consecutive bioelectrical impedance measurements has been in the order of 2–3%. Maximal isometric force was measured in a sitting position on a custom-made dynamometer [20].

A clinical examination, blood tests (glucose, haemoglobin and erythrocyte sedimentation rate), right brachial arterial cuff pressure after 10 min rest, resting and exercise ECG preceded the exercise capacity tests to set the contraindications for exercise on the basis of American College of Sports Medicine guidelines [19].

The subjects performed a symptom-limited cycle ergometer exercise to their volitional maximum to assess peak power and peak oxygen uptake. The exercise protocol and methods were the same as used in our earlier

Table 1. Baseline health and physical activity characteristics of the study subjects

	Group			
Variable	Endurance ($n=15$)	Strength ($n=16$)	Control ($n=11$)	P
Mean no. of medications (and SE)	2.2 (0.5)	2.8 (0.6)	3.2 (0.7)	0.535
Mean no. of chronic diseases (and SE)	2.4 (0.4)	1.9 (0.3)	2.7 (0.3)	0.267
No. of subjects with				
Ischaemic heart disease	5	3	6	0.153
Hypertension	4	4	3	0.990
Musculoskeletal problem	7	7	8	0.287
Respiratory disease	2	2	–	0.455
Diabetes	1	–	–	0.398
Mean physical activity score (and SE)	2.7 (0.3)	3.0 (0.2)	2.6 (0.2)	0.491

study [19]. The subjects were asked to keep their pedalling frequency within the limits of 50–60 revolutions/min as far as possible, and 200 or 300 g was added after every 2 min to the cycle's load basket, which was connected to a mechanical braking system (Monark 814E, Varberg, Sweden). The amount of work done during each minute was calculated afterwards on the basis of the load and the actual number of revolutions registered by a counter. At the pedalling frequency of 60 revolutions/min the average initial load was 29 W and the average incremental load 12 or 18 W.

We encouraged subjects to continue pedalling the ergometer to their personal maximum—unless they experienced any exceptional symptoms (chest pain, dizziness, severe breathlessness or musculoskeletal pain).

The point of maximal effort was evaluated by the test personnel on the basis of objective signs of exhaustion (e.g. breathlessness, or if the pedalling frequency and power fell consistently in spite of the pedalling effort). The test was considered as terminated if the exercise was stopped on medical grounds or if the subject suddenly stopped without having reached exhaustion. After termination, a 3-min cooling-down period was followed, during which the subject pedalled with a light load. A further cooling-down of 3 min followed, during which the subject sat on the ergometer without pedalling.

We monitored ECG leads II, V_1 and V_5 and the supervising physician (a specialist in sports and exercise medicine monitored the well-being of the subject continuously; 12-lead ECG (Case 12, Marquette Electronics, Milwaukee, WI, USA), and brachial arterial pressure were recorded at minimum intervals of 2 min during exercise and at intervals of 3 min during the 6-min cooling-down period. The indications for stopping the exercise were based on the guidelines issued by American College of Sports Medicine [19]. Oxygen consumption, carbon dioxide production, ventilation and respiratory exchange ratio were assessed by a gas analyser (Minjhardt Oxycon-4, Odijk, The Netherlands).

All subjects undertook the cycle ergometer and exercise tests at baseline and after the 18-week intervention. The strength measurements were also performed halfway through the intervention.

Training

The training protocol is described in detail elsewhere [20–23]. Both exercise groups participated in an 18-week progressive physical training programme which consisted of a 2-week orientation phase and a 16-week training phase. The subjects had supervised 1-h training sessions twice a week during the orientation phase and three times a week during the training phase. Each training session started with a 10-min warm-up period, including brisk walking and stretching, and finished with stretching exercises for the major muscle groups. The subjects in the exercise groups participated in 85–95% of the exercise sessions.

The strength group trained the major muscle groups (thigh, calf and trunk) on equipment that used compressed air as a resistance (HUR, Kokkola, Finland). The intensity of the training was gradually increased from 60% (first 3 weeks) of the repetition maximum (RM) to 75% of the RM (last 4 weeks). The RM was defined as the heaviest load the subject could move in acceptable way throughout the complete range of motion. The resistance was individually adjusted according to the RM test measured at 2-week intervals. To obtain the RM, the initial resistance was set close to the previous RM result. The resistance increment was 0.25 bar, which corresponded to 2.5 kg in knee flexion, 3 kg in the knee extension and 5 kg in the combined knee–hip extension.

After the 18-week training period, the RM values increased on average by 19–60%, depending on the muscle group tested. The individual variation between the two final RM measurements averaged 2%. During the strength training sessions, the subjects performed three to four sets of 8–10 repetitions with a 30-s pause between sets. Each repetition lasted for 4–6 s, with no more than 2 s rest between repetitions.

The endurance group walked on an indoor track twice a week and had a step-aerobics class once a week. The training heart rate was individually adjusted on the basis of the initial cycle ergometer test. The training intensity was gradually increased from 50% (first 5 weeks) to 80% (last 4 weeks) of the initial heart rate reserve. The training heart rates were monitored using heart rate monitors (Sport Tester, Polar Electro, Kempele, Finland) during the training sessions. The walking session lasted 20 min in the first 2 weeks and 30 min in the subsequent 16 weeks. The average distance walked increased from 1500 m (range 1200–2200 m) to 2700 m (range 2400–3300 m) over the training period. The step-aerobics session lasted for 40 min and required participants step up onto a bench that was either 10 or 15 cm in height.

Controls were instructed to continue their habitual levels of physical activity. All subjects, including those in the control group, kept a diary of their physical activities during the intervention to detect possible changes in physical activity level. The clinical examination was repeated after 9 and 18 weeks for all subjects. Any new symptom was examined by the supervising physician and the training stopped if necessary. Brachial arterial cuff pressure was measured before exercise sessions. Ambulatory ECG was performed in three subjects in the training groups who reported chest pains in order to exclude underlying cardiac disease.

Statistics

We used standard statistical procedures to calculate means and standard errors. We analysed the differences between the groups at the baseline using either one-way ANOVA or the χ^2 test. The effects of training were assessed using two-way ANOVA with repeated measures. An α level of 0.05 marked statistical significance in the group comparisons for independent samples. If the significance of the interaction of group by time in ANOVA with repeated measures had a P value of <0.10, the training effect was localized using simple contrasts with a $P<0.05$.

With the present sample size, the statistical power of detecting a significant interaction was 0.614 for peak power per kg body weight. The statistical software package used was Sigma Stat programme version 2.0 (Jandel Scientific, Chicago, IL, USA) or SPSS for windows (SPSS, Cary, NC, USA).

Results

The medications, health characteristics, and physical activity level of the subjects at baseline are presented in Table 1. We found no significant differences in these variables or in the baseline values of physical characteristics (Table 2) between the groups. Aside from the training induced in the trial, the study groups did not differ with respect to initial level of physical activity, which remained constant throughout the experiment. Subjects in the strength training group had a significant decrease in body fat compared with the controls (Table 2).

There was a significant increase in peak power in the strength training compared with the control group (Table 3). Peak power per kg body weight increased in both the endurance and strength training groups compared with controls. No interaction of group by time was found for peak oxygen uptake (Table 3). There was no difference in peak respiratory exchange ratio between baseline and 18 weeks in any of the groups (Table 3).

The mean percentage changes in peak oxygen uptake per kg body weight in the endurance, strength and control groups were +6.8%, +9.4% and −6.2% respectively. The mean percentage changes in power (in $W \cdot kg^{-1}$) were +3.8%, +8.1% and −5.9 %. There was wide inter-individual variation in all groups in percentage change in peak power and peak oxygen uptake (Figure 1).

Medical problems and drop-outs

Six subjects (19%) in the exercise groups withdrew from the study because of health problems. One subject in the endurance group dropped out of the intervention because she was unwilling to continue. Two subjects in the exercise groups were not able to take part in the final exercise tests. Five cases of cardio- or cerebrovascular problems emerged during the intervention in the exercise groups.

One subject in the strength group died because of large myocardial infarction 8 weeks into the intervention. The symptoms of the myocardial infarction started 2 days after the exercise session. No cardiac problems or hospital contacts because of heart problems before the intervention were documented. The initial exercise ECG showed no cardiac ischaemia. Another subject in the strength group suffered unstable angina at 4 weeks into the intervention, starting 2 days after the exercise session. She had successful surgery for three-vessel coronary heart disease. She had been treated in hospital 2 years before the exercise intervention for chest pain, but this event was considered non-cardiac. A small, painless, horizontal 1 mm ST segment depression in leads V_5 and V_6 was detected in her initial exercise ECG at peak exercise.

One person in the strength group began to have occasional angina and dyspnoea when walking 8 weeks into the intervention. No ST segment changes were seen on her resting ECG or on her initial exercise ECG. Her chest x-ray was normal. A nitrate was prescribed and the symptoms of angina disappeared. Her exercise intervention was terminated.

A member of the endurance group had slight weakness of the limbs in the right side, together with mild dysarthria 2–3 h after the strength measurements 9 weeks into the intervention. A neurologist made a clinical diagnosis of infarction of the brainstem. The symptoms gradually disappeared. Her exercise intervention

Table 2. Physical characteristics of the study groups before and after the 18-week intervention

	Mean value (and SE), by group								
	Endurance (n=12)		Strength (n=12)		Control (n=11)		ANOVA		
Variable	Baseline	18 weeks	Baseline	18 weeks	Baseline	18 weeks	Group	Time	Interaction
Body height, cm	156.7 (1.6)	156.9 (1.6)	159.5 (1.0)	159.9 (1.0)	158.7 (1.7)	159.1 (1.7)	0.337	<0.001	0.768
Body mass, kg	67.3 (2.8)	65.9 (2.6)	66.9 (2.7)	65.3 (2.7)	67.6 (3.9)	66.7 (4.0)	0.972	<0.001	0.519
Lean body mass, kg	44.4 (0.8)	44.2 (0.8)	45.3 (1.1)	45.8 (0.9)	45.0 (1.5)	45.0 (1.5)	0.728	0.706	0.477
Body fat, %	34.4 (1.9)	32.9 (1.7)	31.9 (1.9)	29.2 (2.3)	32.2 (2.4)	31.2 (2.4)	0.572	<0.001	0.078[a]

ANOVA, analysis of variance.
[a]Significant difference in the effect of time between the strength and control groups (P=0.031).

Table 3. Physiological characteristics of the study groups before and after 18-week intervention

Variable	Mean value (and SE), by group						ANOVA		
	Endurance ($n=12$)		Strength ($n=12$)		Control ($n=11$)				
	Baseline	18 weeks	Baseline	18 weeks	Baseline	18 weeks	Group	Time	Interaction
Heart rate, beats.min^{-1}									
At rest	66 (3)	62 (3)	66 (4)	64 (3)	69 (2)	67 (2)	0.809	0.046	0.530
Peak	135 (4)	123 (4)	140 (3)	135 (6)	130 (7)	121 (5)	0.144	0.002	0.478
Resting blood pressure, mmHg									
Systolic	174 (15)	164 (16)	184 (15)	167 (14)	182 (15)	167 (15)	0.577	<0.001	0.597
Diastolic	83 (3)	80 (2)	80 (3)	78 (3)	84 (2)	81 (2)	0.971	0.054	0.550
Peak power, W									
Total	61.1 (3.2)	61.9 (3.2)	68.1 (3.1)	70.3 (4.1)	64.5 (4.3)	58.2 (3.9)	0.972	0.208	0.077[a]
per kg body weight	0.91 (0.04)	0.93 (0.06)	1.02 (0.05)	1.05 (0.07)	0.98 (0.07)	0.88 (0.06)	0.260	0.490	0.053[b]
Peak oxygen uptake									
Total, l.min^{-1}	1.15 (0.05)	1.20 (0.06)	1.21 (0.07)	1.27 (0.06)	1.15 (0.08)	1.10 (0.05)	0.728	0.706	0.477
per kg body weight, ml.kg^{-1}.min^{-1}	17.1 (0.1)	18.2 (0.1)	18.1 (0.1)	19.7 (0.1)	17.3 (0.1)	16.9 (0.1)	0.364	0.102	0.207
Respiratory exchange ratio	0.88 (0.06)	0.93 (0.09)	0.94 (0.11)	0.93 (0.93)	0.89 (0.07)	0.89 (0.08)	0.297	0.351	0.335

ANOVA, analysis of variance.
[a]Significant difference in the effect of time between strength and control group ($P=0.035$).
[b]Significant difference in the effect of time between strength and control group ($P=0.027$), and between endurance and control group ($P=0.049$).

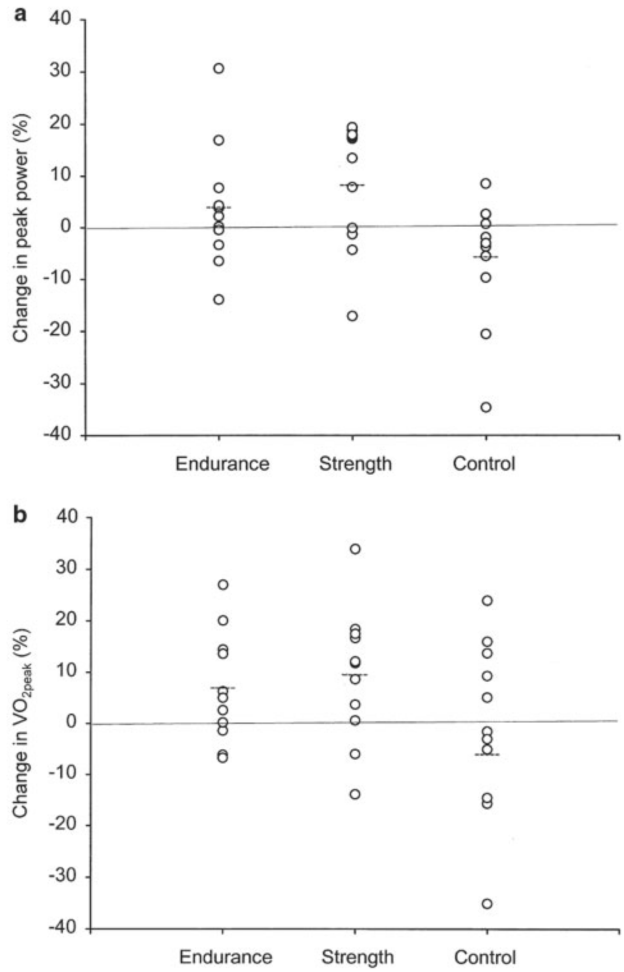

Figure 1. Individual percentage changes in (**a**) peak power (W.kg^{-1}) and (**b**) peak oxygen uptake (VO_{2peak}; ml.kg^{-1}.min^{-1}) after 18 weeks of strength or endurance training.

was terminated. In the last medical screening (after the 18 weeks endurance training), a suspected abdominal aortic aneurysm was found in one asymptomatic woman. An abdominal aortic aneurysm with a diameter of 5 cm was confirmed by ultrasonography. She was excluded from the final measurements and successfully operated on after the intervention.

Six cases of musculoskeletal problems emerged in the exercise groups, but these complaints were minor and did not lead to premature termination of the exercise intervention. One subject in the strength group, however, fractured her clavicle when she fell off a bicycle during her free time.

Discussion

Large and excessive increases of oxygen uptake (up to 38%) have been reported in older subjects after endurance training [15]. Strength training has similar effects on endurance work capacity and peak oxygen uptake in older subjects [1, 24]. We performed a population-based, randomized and controlled trial in women aged 76–78 years, using standard criteria for medical screening [19]. We found limited and individually variable responses, together with unexpected health changes. These results call into question the claims made for large beneficial effects of strength and endurance training on cardiovascular fitness in women aged $\geqslant 75$.

The increase in peak power in the two exercise groups was significant and limited. There was also a gain in knee extension torque in both groups [20, 22, 23]. By walking and undertaking step-aerobics, women can thus improve the strength of their legs and reduce the constraints of local factors during cycle ergometric testing. With more powerful muscles in the legs, higher work power in the cycle ergometer test is achieved. Walking and step-aerobics were chosen as training types for practical reasons: they were easier and more economical to arrange for group training than cycle ergometric training.

The effect of strength and endurance training on peak oxygen uptake was non-significant. This may be due to the training types (strength training, walking, step-aerobics) which may not be specific to induce an increase in aerobic capacity in the cycle ergometer test. The latter was used in this study because it allows higher quality in monitoring cardiovascular responses than walking on a treadmill, where poor balance among subjects with chronic conditions makes blood pressure measurements and ECG monitoring difficult. Technical problems may also exist when measuring oxygen uptake directly in elderly subjects [19], leading to an increase in the variation in the responses larger and thus a loss in statistical power.

The dose and duration of the strength and endurance exercise used in the present study is adequate on the basis of the earlier studies [3, 15, 24, 25]. The large variation in the responses and the small number of subjects may limit the statistical power of these exercise effects. The initial exercise capacity and physical activity level will modify the gain in exercise capacity. In the present study no significant correlation was, found between relative increase in aerobic capacity and the initial exercise capacity or physical activity level.

The effects of strength and endurance training on cardiovascular fitness may be modified by differences in the maximal levels reached in the initial and later exercise tests. The peak respiratory exchange ratio values were, however, comparable during the initial and later cycle ergometer tests. Another question which arises is: how maximal were the initial exercise tests as indicators for dose setting in the endurance training? The respiratory exchange ratio values shown in Table 3 suggest that many of the exercise tests were submaximal and prematurely terminated because of abnormal cardiovascular responses. The low effort tolerance and decreased health may result in elderly women being prescribed insufficient amounts of exercise, so that it is difficult for them to make significant gains in cardiovascular capacity during endurance exercise training.

In contrast to the respiratory exchange ratio values, the peak heart rates were lower during the final ergometry test in all groups. After careful evaluation of the individual exercise tests between the initial and final measurements, we found no tendency towards terminating the test for medical reasons during the latter measurements.

Of the seven subjects using β-blockers who managed to do both exercise tests, two were in the endurance training group, three in the control group and two in the strength group. One of the two β-blocker users in the endurance group showed a considerable increase in maximal oxygen uptake (from 1.11 to 1.37 l/min) and the other one showed a slight decrease (from 1.14 to 1.03 l/min). Unfortunately, two β-blocker users (one in the endurance training group and one in the strength training group) took their tablets so close to the final exercise test that the blocking effect was assumed to be much stronger in that test. In these two subjects the peak heart rates were 149 and 127 beats per minute in the initial exercise tests and 98 and 91 beats per minute in the final exercise tests. One subject in the control group had to stop the final exercise test suddenly because of deep ST segment depression and was unable to attain her initial exercise test heart rate level (164 beats per minute in the initial test, 120 beats per minute in the final test). These cases will have affected the mean peak heart rate values due to the small number of subjects.

There were also some subjects who had lower peak heart rate values and higher respiratory exchange ratio values in the final exercise test than in the initial tests. Most of these showed a marked increase in peak oxygen uptake and working power. This may be an indication of cardiac adaptation to exercise—i.e. exercise had blunted the increase in the subject's heart rate.

The subjects were medically screened according to standard criteria, the training supervised and the exercise programmes individually tailored. In spite of these procedures, five subjects in the exercise groups had cardio- or cerebrovascular health problems. Whether physical training caused these health problems is difficult to answer with certainty. Health problems of these kinds were likely to emerge in a larger group of subjects in these exercise groups. Health changes in elderly women often manifest themselves within a relatively short period. In no cases were the incidents directly related to physical effort. In addition, the distribution of clinical findings in the exercise tests did not indicate any adverse effects of exercise training on the cardiovascular response, and nor was there any indication of cardiovascular complaints during the exercise sessions. Nonetheless, taking these facts into account, the possibility remains that physical training could have contributed to these health problems.

Most of our subjects were slightly hypertensive and had overt or latent atherosclerosis. This may increase the likelihood of cardio- or cerebrovascular events. An abrupt increase of aortic pressure caused by a reflecting pressure wave component from the abdominal aorta meeting the systolic pressure wave has been shown in elderly subjects [26]. Holding one's breath when making a physical effort considerably increases the arterial pressure. These factors may have contributed to arterial wall damage and the incidence of disease. After the case of myocardial infarction and death, the strength training programme was modified by excluding training to the trunk muscles. In addition, the subjects were asked not to hold their breath during physical effort when doing the strength training.

In earlier studies from our institution, functional capacity tests (isometric strength measurements, cycle ergometer tests) have been performed with minimal cardio- or cerebrovascular adverse effects (except for one case of exercise-induced atrial fibrillation) on large groups of elderly subjects aged 66–85 years [19, 27, 28]. In all of these studies, we used the same testing methods, exclusion criteria and medical screening. In the present study all of the cardio- or cerebrovascular problems occurred unexpectedly in subjects who had not initially had that particular health problem.

Are elderly women aged $\geqslant 75$ more prone to problems with repeated physical exercise than has been thought previously, how can we prevent such events, and what are the exact dose–response relationships among older women? These remain important questions to be addressed in future studies.

In conclusion, 18-week strength training led to an increase in peak work power in women aged 76–78 years. Similar but more limited effects were found after endurance training. Although statistically significant effects were found, the responses in practice are limited. We also detected wide individual variation in the responses. Five women in the training groups developed cardio- or cerebrovascular health problems. Although these problems were not immediately related to physical exercise, adverse effects of repeated physical exercise cannot be ruled out. Appropriate screening methods, and the dose–response relationships of physical exercise need further clarification in elderly populations.

Key points

- The effect of 18-week endurance or strength training on cardiovascular fitness among women aged 76–78 years is relatively small.
- Health problems can emerge during training programmes in medically-screened elderly subjects.
- More population-based, randomized controlled studies are needed to clarify the exact dose–response relationships and safety of physical exercise among women aged $\geqslant 75$ years.

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