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Aerobic training in the 'oldest old': the effect of 24 weeks of training

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Abstract

Objective: to determine the effects of aerobic training on the maximal aerobic power of healthy, very elderly people.
Design: a 12-week control period followed by 24 weeks of progressive, weight bearing, aerobic training.
Subjects: 26 men and women aged 79 to 91 years conforming to pre-determined health criteria.
Methods: we took measurements before and after a 12 week control period and following 24 weeks of training. These were maximal aerobic power (VO_2max), heart rate at an oxygen consumption of 10 ml.kg^{-1}.min^{-1} (HR at $VO_2$10), resting heart rate, isometric knee extensor strength, isometric elbow flexor strength and lower limb extensor power.
Main results: pre-control values of VO_2max for the women and men were 14.1 (SD 2.79) and 22.0 (5.12) ml.kg^{-1}.min^{-1} respectively. There was no significant change in the VO_2max of either group over the control period. After training, there was a 15% increase in the VO_2max of the women ($P<0.01$) but no change was observed in the men. In the women, there was no significant change in HR at $VO_2$10 over the control period but a 14% decrease ($P<0.01$) after training. In the men there was a 7% ($P<0.05$) increase in HR at $VO_2$10 over the control period and a 5% ($P<0.05$) decrease after training. No effect of training was seen on isometric knee extensor strength, isometric elbow flexor strength or lower limb extensor power of either group.
Conclusion: progressive aerobic training can increase the maximal aerobic power of very elderly women. A 15% increase in VO_2max may prevent many elderly women from crossing functionally important thresholds, thereby helping to maintain independence.

Keywords: *maximal aerobic power, aged, 80 and over, perceived exertion, endurance training*

Introduction

Maximal aerobic power (VO_2max) declines with advancing age [1, 2]. Many elderly people, in particular women, have such low values of VO_2max that it would need only a further small reduction to render some everyday activities either unpleasant or impossible to perform.

Aerobic training increases VO_2max in younger adults and in younger old subjects (mean ages 70–74 years) [3–6]. No controlled study has looked at the effects of training in subjects over 80 years of age, who are arguably those who would benefit most from an improvement in VO_2max. The purpose of the present study was to examine the effects of 24 weeks of aerobic training on VO_2max, and sub-maximal indicators of aerobic capacity in very elderly men and women.

Methods

Subjects and study design

The study received ethical approval and all subjects gave written informed consent. We recruited potential subjects, in their 80th year or older, from a volunteer database, through an article in a local newspaper and by word of mouth. We identified 34 subjects considered 'healthy' or 'medically stable' [7] from a health questionnaire, resting blood pressure and resting electrocardiogram (ECG). These subjects had a medically supervised exercise ECG and five were excluded. A further 3 subjects dropped out before the training began. Of the 26 subjects who commenced training, 5 failed to complete training; 2 dropped out due to illness unrelated to the study, 1 was diagnosed with

Alzheimer's disease during the study, 1 found the time commitment too great and 1 experienced aggravation of a previous knee problem. Characteristics of those completing the study are in Table 1.

All subjects were familiarised with the procedures on two visits to the laboratory. Each subject then performed a progressive maximal effort test on each of three separate occasions, separated by at least 3 days. The best of these tests was taken as the pre-control value. A single maximal effort test was performed after the 12-week control period and after 24 weeks of training. We measured height, weight, resting heart rate, isometric knee extensor strength (IKES) [8], isometric elbow flexor strength (IEFS) [8] and explosive leg power (LEP) [8] before and after the 12-week control period and after training.

Throughout the study subjects were asked to maintain their usual activities. To allow for time of year effects [5] half the group trained over the summer and half over the winter.

Aerobic power

Preliminary work had confirmed the feasibility, and reproducibility of maximal tests in very old age [9]. Subjects were asked to avoid caffeine for at least 2 hours before testing. For each individual subject, tests were performed at the same time of day on each occasion and at the same laboratory temperature. The same two investigators, both trained in cardiopulmonary resuscitation, supervised each test. Resting heart rate was taken after each subject had rested on a couch for 10 minutes.

Subjects pedalled an electrically braked cycle ergometer (Cybex) starting at a work rate of 25 W and progressing in 15 W or 25 W increments every 2.5 minutes until they could no longer continue, despite encouragement. Tests for each subject had been tailored from preliminary tests to try to get each subject to their limit in 10–12.5 minutes.

Expired gas was collected via a nasal and mouth breathing facemask (Hans Rudolph type 7930 or 7940) and passed into a mixing chamber from which samples were drawn through gas analysers. Heart rate (Hewlett Packard, UK), CO_2 concentration (infra red; PK Morgan, UK), O_2 concentration (paramagnetic; PK Morgan) and inspired volume (Harvard dry gas meter) were measured during the last minute of a 2.5 minute rest period, every 30 seconds during exercise and at peak exercise. ECG was monitored continuously (Datascope, Cambridge, UK). The CO_2 and O_2 analysers were calibrated using room air and two different gas mixtures. The dry gas meter was calibrated with a 1 litre syringe (PK Morgan).

We measure lactate concentration in fingertip samples (intact whole blood) taken (where possible) at the highest work rate and 5–7 minutes post exercise (LM5 Analox Instruments, London, UK). The analyser was calibrated with a lactate/pyruvate quality control serum and a lactate standard (both Analox Instruments).

The highest value for VO_2 during a test was accepted as VO_2max only if the respiratory exchange ratio (RER) was >1.0 [9, 10] and the subject was judged subjectively to have made a 'maximal effort' test.

The heart rate at an oxygen consumption of 10 $ml.kg^{-1}.min^{-1}$ (HR at $VO_2$10) was calculated with an equation derived by linear regression (for each individual subject).

Table 1. Pre-control characteristics of the subjects who completed training

	Age (years)	Height (m)	Weight (kg)
Men (*n*=9)			
Range	80–87	1.6–1.8	58.5–85.5
Median	80	1.69	68
Mean	81	1.69	68
(SD)	(2.28)	(0.06)	(8.3)
Women (*n*=12)			
Range	79–91	1.5–1.65	44–65.5
Median	80	1.56	55.9
Mean	83	1.58	56.5
(SD)	(4.58)	(0.05)	(6.0)

Exercise training

We asked each subject to attend three of six exercise sessions per week over a 24-week period. The exercise sessions consisted of a consistently formatted progressive exercise to music programme. Each session comprised warm up (13–15 minutes), weight-bearing aerobic training (13 increasing to 20 minutes), warm down (10 minutes), and strength training, flexibility and relaxation components (10–15 minutes). The aerobic component was built up gradually over the first 6 weeks, lasting 13 minutes at week two, 17 minutes at week four and 20 minutes by week six. After week six, the intensity of the aerobic exercise was increased progressively.

Training intensity was a rating of perceived exertion (RPE) [11–14] between 13 and 15. All subjects were thoroughly familiarised with the RPE scale during their pre-control tests and at regular intervals throughout the training programme. During the aerobic component of each session subjects were shown the RPE scale and asked to rate how hard they were working. If necessary the intensity of the exercise was adjusted, by giving alternatives, for individual subjects.

We monitored heart rate (Polar Sportstester) in each subject in at least one session per week, in order to compare RPE levels with the percentage of their maximal heart rate (%HRmax) and therefore %VO_2max (see below), in those subjects who had performed a maximal pre-training test.

Resistance for strength training was provided initially by body weight and the use of different grades of theraband (Nottingham Rehab, Nottingham, UK). Later, these were supplemented by the use of body bars (Forza Fitness International, London, UK).

Statistical analysis

We examined data in the way described by Sokal and Rohlf [15]. If analysis of variance (ANOVA) identified the presence of a significant treatment effect we tested the percentage changes over the control period for statistical significance (Wilcoxon signed rank test [16]). If there was no significant change over the control period, the changes (%) over the training period were calculated from the individual means of pre- and post-control. If the change over the control period was significant, however, we used post-control data as the starting point for calculating the changes (%) over the training period. We then tested training changes for statistical significance (Wilcoxon signed rank test).

Results

Attendance

There was no significant difference between the number of sessions attended by the men (median 71% range 44–100) and the number attended by the women (median 65% range 46–88) (unpaired *t*-test) [16].

Exercise intensity

The mean RPE for the older women was within the desired training zone by week 2 but the men did not achieve this until week 4. Although after week 4 the mean RPE of both the men and women was within the desired training zone, overall the women were found to have worked at a slightly higher RPE than the men (mean RPE, averaged over the training period, 14.4 and 13.6 respectively, $P<0.01$).

Satisfactory pre- and post-training calibration of RPE against VO_2max and HRmax was achieved for 7 men and 5 women. In their pre-training tests an RPE of 14 corresponded to 83% of VO_2max, 86% HRmax in the men, and 82% VO_2max, 85% HRmax in the women. These figures were virtually unchanged after training, *viz* 81%, 84% in the men, and 79%, 85% in the women.

In the weekly checks of RPE against HR during the aerobic component of the training, an RPE of 14 corresponded to 79% HRmax in the men, and 81% HRmax in the women. This suggests that a training RPE of 14 might have corresponded to a slightly lower $\%VO_2$ max (perhaps about 76%, in both men and women) than during the pre- and post-training tests. This, in turn, would suggest that the overall mean training RPE values (13.6 for the men and 14.4 for the women) would be consistent with the men training at an average of about 74% VO_2max and the women at 80% VO_2max.

Weight

ANOVA showed the presence of a 'treatment' effect in the women and Wilcoxon signed rank test showed no significant difference over the control period. Taking the mean of the pre- and post-control values as the baseline, however, the small decrease in weight over the training period (Table 2) did not reach statistical significance. There was no evidence of a 'treatment' effect in the men.

Maximal oxygen uptake

Collection of expired gas for analysis was not possible in one subject after either 12 or 24 weeks of training because of increasing intolerance of the facemask.

We obtained VO_2max data from nine women and eight men (Table 2). ANOVA confirmed a treatment effect in the VO_2max of the women ($P<0.05$) but not the men. In the women there was no significant change in VO_2max over the control period, but there was a 15% mean increase, when expressed as $ml.kg^{-1}.min^{-1}$, ($P<0.01$), and a 13% mean increase when expressed as $l\ min^{-1}$ ($P<0.02$) in VO_2max following training (Figure 1).

ANOVA failed to demonstrate a treatment effect in either the men or women in terms of HRmax, RERmax or lactate max (LAmax) (Table 3).

Table 2. Weight, VO_2max, HRmax, RERmax and Lactate max (LAmax) values for the 8 men and 9 women who performed maximal tests. (See Methods for defining criteria for 'maximal'.) Expressed as mean (standard deviation)

	Pre-control	Post-control	Post-training
Weight (kg)			
Men	67.6 (8.7)	69.6 (8.8)	67.9 (9.3)
Women	57.4 (5.6)	57.7 (6.1)	56.4 (6.4)
VO_2max ($ml.kg^{-1}.min^{-1}$)			
Men	22.2 (5.8)	21.8 (5.4)	22.2 (6.2)
Women	14.5 (2.5)	13.8 (3.7)	16.2 (3.1)[a]
VO_2max ($l\ min^{-1}$)			
Men	1.51 (0.29)	1.49 (0.30)	1.47 (0.28)
Women	0.83 (0.14)	0.79 (0.20)	0.91 (0.17)[a]
HRmax (bpm)			
Men	143 (20)	138 (17)	137 (20)
Women	130 (16)	126 (14)	129 (17)
RERmax			
Men	1.08 (0.05)	1.1 (0.10)	1.07 (0.07)
Women	1.06 (0.05)	1.02 (0.08)	1.03 (0.11)
LAmax ($mmol\ l^{-1}$)			
Men[b]	4.3 (0.7)	4.6 (1.4)	4.9 (1.5)
Women[c]	3.5 (1.0)	3.3 (0.7)	3.3 (1.4)

[a]Significantly different from mean of pre- and post-control.
[b]$n=7$.
[c]$n=6$.

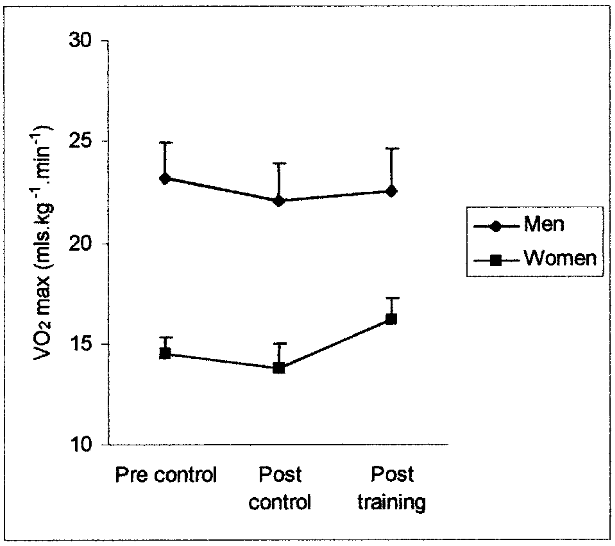

Figure 1. Maximal oxygen uptake (8 men and 9 women) (Mean + 1 SEM).

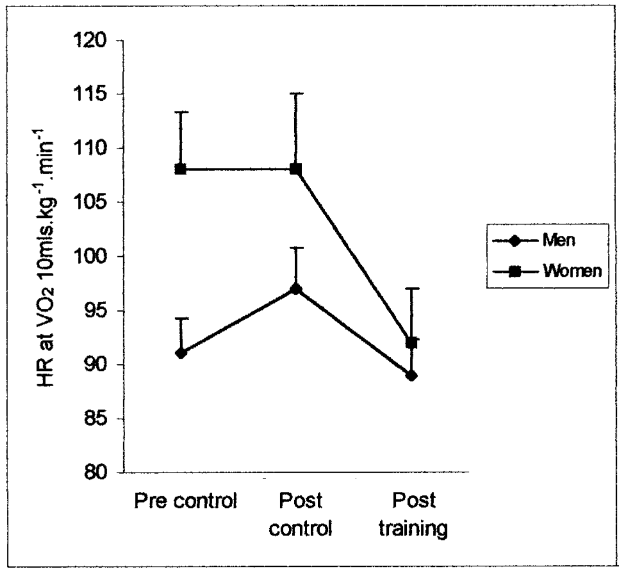

Figure 2. Heart rate at VO_2 of 10 ml.kg^{-1}.min^{-1} (9 men and 9 women) (Mean + 1 SEM).

Table 3. Heart rate at VO_2 of 10 ml.kg^{-1}.min^{-1}, resting heart rate, isometric knee extensor strength (IKES), isometric elbow flexor strength (IEFS) and lower limb explosive power (LEP) at each time point. Expressed as mean (standard deviation)

	Pre-control	Post-control	Post-training
HR at VO_2 10 ml.kg^{-1}.min^{-1}			
Men (n=9)	91 (10)	97 (11)[a]	89 (10)[b]
Women (n=9)	107 (12)	108 (21)	92 (15)[c]
Resting heart rate (bpm)			
Men (n=9)	74 (10)	75 (12)	71 (13)
Women (n=11)	75 (8)	73 (7)	61 (20)[c]
IKES (N)			
Stronger leg at pre-control			
Men (n=9)	356 (115)	359 (135)	340 (74)
Women (n=11)	239 (54)	250 (74)	264 (60)
IEFS (N)			
Stronger arm at pre-control			
Men (n=9)	194 (35)	179 (51)	209 (62)
Women (n=10)	138 (29)	134 (29)	136 (21)
LEP (W)			
More powerful leg at pre-control			
Men (n=9)	139 (46)	138 (46)	144 (48)
Women (n=11)	75 (24)	71 (33)	79 (25)

[a]Significantly different from pre-control.
[b]Significantly different from post-control.
[c]Significantly different from mean of pre- and post-control.

Heart rate at an oxygen consumption of 10 ml.kg^{-1}.min^{-1} and resting heart rate

In two of the women it was not possible to calculate the HR at $VO_2$10 as tests were too short to perform linear regression.

ANOVA confirmed a treatment effect in the men ($P<0.01$) and in the women ($P<0.005$) (Table 3). In the women there was no significant change in the HR at $VO_2$10 over the control period, but there was a 14% mean decrease ($P<0.01$) following training. In the men there was a 7% mean increase ($P<0.05$) in the HR at $VO_2$10 over the control period and a 9% mean decrease ($P<0.05$) following training (Figure 2).

ANOVA confirmed a treatment effect in the resting HR of the women ($P<0.001$) but not of the men. In the women, there was no significant change in resting heart rate over the control period but there was a 13% decrease ($P<0.01$) after training (Table 3).

Muscular strength and power

We present data for the limbs which were stronger or more powerful at the pre-control time point. ANOVA failed to demonstrate a treatment effect in IKES or LEP of the men or of the women (Table 3). ANOVA also failed to demonstrate a treatment effect in the IEFS of the women but a treatment effect was demonstrated in the men ($P<0.05$). There was no significant change in IEFS of the men over the control period, but there was a 22.5% increase in IEFS following training which approached significance (P=0.1).

Discussion

The 15% increase in the VO_2max of the women, and the decreases in their resting HR and HR at $VO_2$10, indicate that the ability to respond to a progressive aerobic training programme is maintained in women even in their 80s.

The women's mean pre-training value of VO_2max of 14.0 ml.kg^{-1}.min^{-1} is similar to that reported by Foster *et al.* [17] in a group of 8 women of mean age 81 years *viz* 13.6 ml.kg^{-1}.min^{-1}. The subjects in the present study were all relatively healthy and were all still living independently; such a low VO_2max would suggest that even in health, most women aged over 80 would experience difficulties in the performance of everyday tasks.

The mean increase in VO_2max of 15% seen in the women of the present study is similar to that reported in studies of younger old women. Warren *et al.* reported an increase in VO_2max of 12.6% in women with a mean age of 74 years in response to 12 weeks of training [6] while Cress *et al.* reported an increase of 16% in women of mean age 72 years in response to 50 weeks of training [5]. Foster *et al.* reported a 15% increase in response to a moderate exercise programme lasting 10 weeks in women of a mean age (78 years) nearer to that of the women in the present study, but their study was not adequately controlled [18].

It is unclear why the men in this study showed no changes in VO_2max or in resting HR. They did show a reduction in HR at $VO_2$10, suggesting a response to training, but this is difficult to interpret as it followed an increase in this variable during the control period. It seems unlikely that older women, but not men, are able to respond to training. There was no significant difference between the men and the women in attendance levels and, although the men may have trained at a slightly lower %VO_2max than the women, their average aerobic training intensity was still probably greater than 70% VO_2max.

There is nothing published on changes in VO_2max in response to training in men aged 80 or over. In 'younger' old age groups increases in VO_2max have been reported in response to training in men and in mixed groups, *viz* Cunningham *et al.* in men of mean age 63 years [19], Tonino and Driscoll in 5 men and 4 women, mean age 70 years [3], Seals *et al.* in 24 men and women of mean age 63 years [20] and Hagberg *et al.* in men and women of mean age 72 years [4]. (The percentage of the subjects who were men was not reported for either of the last two studies).

The pre-training VO_2max of the men (22.2 ml.kg^{-1}.min^{-1}) was significantly higher than that of the women. Data from the English National Fitness Survey [21] for people aged 50–74 suggest that, on average, a woman's VO_2max (expressed as ml.kg^{-1}.min^{-1}) will be about 78% of a man's. In this study the VO_2max of the women was 64% of the men's. Perhaps the men were already more highly trained than the women. There are few data on the VO_2max of octogenarian men. Harridge *et al.* report a VO_2max of 27 ml.kg^{-1}.min^{-1} in five men (mean age 85) who were still highly active in endurance walking or running [22], and de Wild *et al.* [23] report a VO_2max of 27 ml.kg^{-1}.min^{-1} in active men (mean age 77) participating in the Nijmegen 4-day march. It therefore seems unlikely that our men were already very highly trained.

One other possible explanation is that some of the men may have dropped some of their regular physical activities to accommodate the training classes. Although all subjects were asked to maintain current activities throughout the study, no written record of activity levels was made. However, verbal feedback throughout the training programme from subjects indicated that those who participated in regular activities (mainly golf and swimming), continued to do so throughout the training period.

Although the primary aim of the study was to determine the effects of training on VO_2max, a small strength training component was also included in the programme. It seems that including 10 minutes of strengthening exercise in an aerobic programme is not sufficient to improve strength in healthy, very elderly people.

We conclude that 24 weeks of predominantly aerobic training can increase the maximal aerobic power of very elderly women. The relative increases seen are similar to those reported for younger subjects. This finding could have major implications for older women; increasing VO_2max may well prevent them from crossing functionally important thresholds, thereby helping them to maintain their independence and avoid fatigue in everyday activities.

Key points

- Even healthy women aged over 80 have very low values for maximal aerobic power, *viz* around 14 ml.kg^{-1}.min^{-1}.
- 24 weeks of predominantly aerobic training can increase the maximal aerobic power of women aged over 80 by 15%.
- This increase may improve their ability to sustain sub-maximal tasks, thereby helping to maintain independence.

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