Effects of physical training on aerobic capacity in frail elderly people (75+ years). Influence of lung capacity, cardiovascular disease and medical drug treatment: a randomized controlled pilot trial

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ABSTRACT. ***Background and aims:*** *Frail elderly people often suffer from a combination of unintentional weight loss and/or low body mass index, as well as a low physical activity level. No studies have investigated the effect of physical training alone or in combination with nutritional intervention on aerobic capacity in frail elderly people. The aim of this pilot study was to determine if a physical training program can affect aerobic capacity in frail elderly people.* ***Methods:*** *Ninety-six community-dwelling frail elderly people (58 women) were included in the study. Subjects were randomized to four different groups: i) physical training program (aerobic, muscle strength, balance), ii) a nutritional intervention program (individually targeted advice and group sessions), iii) a combination of these interventions, and iv) a control group. At baseline, subjects were screened for aerobic capacity, leg muscle strength, spirometry, heart disease and cardiovascular drugs. Aerobic capacity and leg muscle strength were analyzed immediately after the 3-month intervention period (1st follow-up), and after another 6 months (2nd follow-up).* ***Results:*** *Subjects mean age was 83 years. The mean compliance rate with the physical training program was 65%. There were no observed effects on aerobic capacity measured as maximal workload, or work time, with or without β-receptor blockade. Subjects in the training groups without lung disease significantly increased maximal work time when compared with subjects with lung disease. Physical training significantly increased lower extremity muscle strength compared with nutrition alone at the 1st follow-up. No serious adverse events occurred during assessment or physical training.* ***Conclusions:*** *Further studies with larger sample sizes and a more specific aerobic component in the training program are necessary before any further conclusions can be drawn.*
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INTRODUCTION

The population aged 65 and older will increase by 60% in the next 50 years in Sweden, and people above age 80 will represent half of this increase (1). A growing number of elderly people live just above the threshold of dependence, and a decline in aerobic capacity may render them dependent (2). Several studies have shown a heterogeneous body mass adjusted decline in VO_{2max} of 15-18% for men and 7-30% for women per decade after the age of 60 (3, 4).

Limitations in maximal oxygen uptake are assumed to be more complex in elderly than in younger subjects, where central hemodynamics, i.e., cardiac output, is regarded as the major limiting factor (5). The incidence of pulmonary and cardiovascular disease also increases with age, which may impair oxygen uptake (6, 7). When analyzing the age-related decline in work capacity, it is also important to consider the increase in medical drug treatment with age. Especially drugs with therapeutic effects on the cardiovascular system may influence VO_{2max}. The elderly commonly use various types of β-adrenoreceptor inhibitors. The effects of β-adrenoreceptor blockade on VO_{2max} have been thoroughly examined and many studies in healthy adults have shown a reduction in physical endurance capacity of 5-15%, more by non-selective β-blockade than $β_1$-selective blockade

Key words: Aerobic capacity, bicycle ergometry, frail, physical training, spirometry.

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(8). However, other studies, summarized in a review, have shown that a period of physical training provides a similar relative improvement in both healthy subjects and subjects with various cardiac diseases, in both cases with or without β-receptor blockade (9). Still, the outcome of physical training in elderly people with or without β-adrenoreceptor inhibitors is largely unknown.

Frailty has been defined as a clinical syndrome comprised of unintentional weight loss, self-reported exhaustion, muscle weakness, slow walking speed and low level of physical activity in men and women over the age of 65 (10, 11). However, there is no consensus regarding the definition of frailty in the literature. Few studies have examined the effect of physical training on the aerobic capacity of frail elderly people, and the evidence is limited and contradictory. Vaitkevicius et al. (12) showed an increase in endurance and VO_{2max}, and a decrease in resting heart rate and systolic blood pressure after six months of moderate-intensity aerobic training in community-dwelling people over the age of 80. One study showed significantly increased VO_{2max} after nine months of a combined muscle strength and endurance training program (13). Another study showed no effect of a muscle strength training program on endurance (6-minute walk) (14). None of the above studies investigated the combined effect of nutrition and physical training.

The present study was prompted by the strong need for controlled studies regarding the effect of physical training on the aerobic capacity of frail elderly people. We hypothesized that a physical training program, alone or in combination with a personalized nutritional intervention program, can positively affect aerobic capacity in frail elderly people aged 75 and older. The primary aim was to investigate this hypothesis. Secondary aims were to study the possible influences of compliance, leg muscle strength and lung capacity, as well as cardiovascular and pulmonary diseases, and drug prescriptions.

MATERIAL AND METHODS

Subjects

Subjects were recruited through a questionnaire (sent to all 6197 individuals over age 75 in the local municipality), advertisements in the local newspaper, primary care, and the home service administration organized by the local municipal authorities.

The definition of frailty used in the present study was chosen on the basis of previous findings that a combination of low physical activity and weight loss significantly predict mortality (14).

Inclusion criteria were: a) unintentional weight loss ≥5% during the last year and/or body mass index (BMI) ≤20 kg/m^2 and b) low physical activity level (≤ grade 3 in the 6-graded classification of physical activity according to Mattiasson-Nilo et al. and Frändin and Grimby (15, 16)).

Exclusion criteria were: age under 75, non-walkers, people with recent cardiac problems requiring hospital care, recent hip fracture or surgery in the last six months, present cancer treatment, stroke within the last two years, less than 7 of a 9-point score on the short form of the Mini Mental State Examination (17), and being institutionalized.

Detailed information concerning successive recruitment and drop-out of participants is shown in Figure 1. All subjects (n=437) who fulfilled the inclusion criteria regarding unintentional weight loss and/or BMI ≤20 kg/m^2 were contacted by telephone for screening. Ninety-six subjects were included in the study.

Procedure

The 96 subjects were randomized consecutively into four different groups: 1) Training (T) (n=23): specific physical training plus general diet advice; 2) Training and nutrition (T+N) (n=25): specific physical training plus specific personalized diet counseling and group session education; 3) Nutrition (N) (n=25): specific personalized diet counseling and group session education plus general physical training advice; 4) Control (C) (n=23): general physical training advice and general diet advice.

The randomization procedure was conducted in an open manner by the study personnel with instructions from a statistician. For each new included group, randomization started with the oldest individual, to avoid age differences between groups. Three of the randomized subjects could not perform the bicycle ergometry test due to knee pain (n=2), together with an electrocardiograph (ECG) recording showing recent silent myocardial infarction (n=1) and were therefore excluded from the analyses (Fig. 1). Thus, a total of 93 subjects remained for the final analysis. Subjects were assessed at baseline (0 months), 1st follow-up (3 months) and 2nd follow-up (9 months, i.e., 6 months after the end of the intervention). The study protocol was approved by the Ethical Committee at the Karolinska Institutet. All participants were informed about the study procedures and gave their written informed consent for participation. A portable defibrillator, oxygen gas equipment, and the Karolinska University Hospital pharmacy standard drug emergency kit, containing adrenalin, atropine, hydrocortisone, etc. were available during all measurements and training occasions, in case of adverse events.

Examination of baseline characteristics

All patients had a thorough anamnesis and physical examination completed, with analysis of ECG and results of spirometry, including inspection of all air flow-air volume curves. All available medical records from primary care and hospital care since the late 1980s were examined. A combined ECG and spirometer (AT-2PLUS, Schiller AG, Switzerland) was used to register ECG and lung capacity. Total slow (SVC) and forced (FVC) vital capacity and forced expiratory volume during the first second (FEV_1)

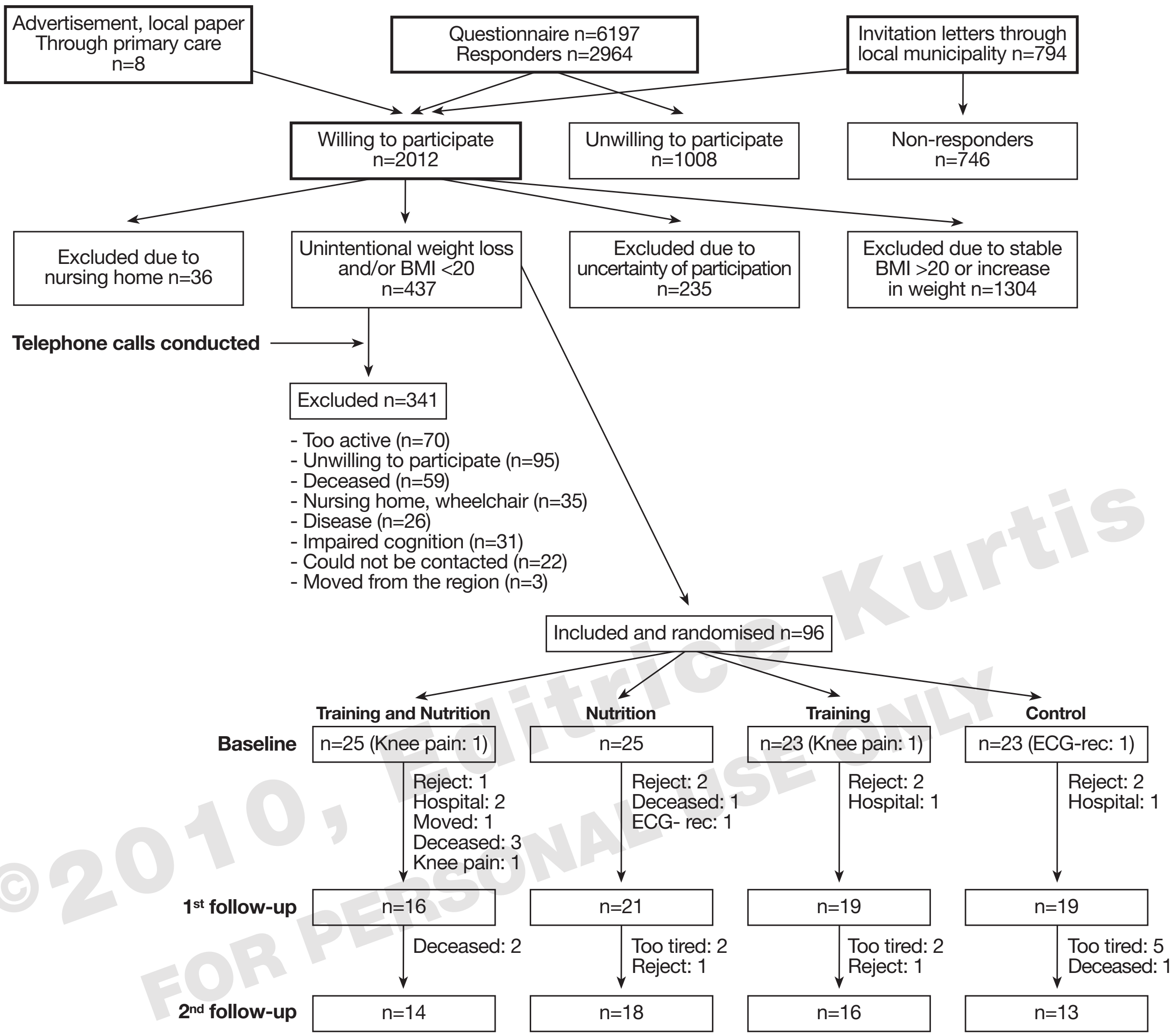

Fig. 1 - *Flow chart for recruitment, inclusion/exclusion and drop-outs of subjects from baseline to 2nd follow-up.*

was measured. The lowest ratio between FEV_1/SVC or FEV_1/FVC was calculated and expressed as FEV%. Tests were performed while subjects were seated, and the best of three attempts was recorded. On this basis, patients were classified according to existing heart disease: no heart disease, congestive heart failure (certain, probable), previous myocardial infarction (certain, probable), cardiac arrhythmia (persistent or intermittent) or angina pectoris (certain or probable). Similarly, patients' pulmonary functions were classified as normal, obstructive or restrictive, based on the flow volume curve, the highest value of FEV%, FEV_1 and VC.

All continuous drug prescriptions were recorded. Blood hemoglobin was analyzed according to standard procedures at the Department of Clinical Chemistry, Karolinska University Hospital. Smoking habits and tobacco consumption, total number of years of smoking, former smoking habits, and years after smoking cessation were recorded.

Body weight and height were measured by standard procedures and the body mass index (BMI) was calculated by dividing the body weight (kg) by height^2 (m).

Physical activity level was estimated according to a 6-graded ordinal scale including both physical training/exercises and household activities (15, 16).

Outcome measures

For aerobic capacity, a bicycle ergometry test was conducted according to Wetterqvist et al. (18). The procedure started with a resting period of approximately 5 minutes in a supine position, the ECG electrodes were applied and heart rate and blood pressure were recorded. A resting ECG was recorded and assessed by the geriatrician before the subjects were allowed to start the test. Before the test was initiated, subjects were screened again for heart rate and blood pressure, in an upright position on the bicycle.

All subjects started at 25W, and the load was increased by 25W every 4 minutes if possible. After 3 minutes on each load, subjects were checked for heart rate, systolic blood pressure and estimated effort, breathlessness and pain, according to the category-ratio perceived exertion scale (CR-10 scale) (19). ECG recordings continued throughout the test. Subjective (chest pain, dizziness, etc.) and objective (ECG recording) adverse events were recorded.

The test was interrupted when the subject i) could no longer perform at a speed sufficient to maintain load, ii) when the subject refused to continue due to the appearance of symptoms, iii) chest pain, or iv) for safety reasons, as determined by the geriatrician. If subjects interrupted the test before the end of a 4-minute stage, the maximal workload was calculated as follows: if the subject worked for ≤2 minutes on maximal load, the difference between the two last loads was divided by 2 and added to the lower load. This resulted in maximal workloads such as 37.5, 62.5, 87.5 and 112.5 W (18).

Muscle strength was measured in the lower extremities with combined knee and hip extension (Leg Press Scandinavian Mobility, Norway). One repetition maximum (1RM) was performed in the individual full range of motion after a warm-up session (20). Subjects performed two repetitions on each load until the maximum load was achieved. The procedure was conducted according to the recommendations of the American College of Sports Medicine (21). The test was performed in a sitting position, and subjects were instructed to hold on to the bars next to this seat.

Intervention

Physical training. Subjects randomized to the physical training program participated in organized regular physical training group lasting 60 minutes twice a week for 12 weeks, with the emphasis on aerobic capacity, muscle strength and balance (Qigong). The physical training program has been described in detail (22). Briefly, it consists of three corresponding sections: aerobic training, including warm-up (see below); individually prescribed progressive muscle strength training with an intensity of 60%, increasing to 80% after the two initial weeks, on stationary equipment for the upper and lower extremities, as well as functional muscle strength training (chair-stand, step up and toe raise); and Qigong, including balance exercises on different degrees of the area of support, and cool-down. The aerobic section was performed in a standing position. Exercises included walking on the spot at different speeds, walking sideways, forward and backward. Arm movements were performed at different speeds and in different directions. The arm and leg movements were separated, to decrease the difficulty of coordination, and subjects with balance deficits were allowed to use hand support if necessary, to facilitate increases in heart rate. Halfway through the aerobic section, range of motion and stretching exercises were performed. Directly after each section, subjects were asked to score this effort on the CR-10 scale (19) and heart rate was measured. The program was performed in groups of 5-8 subjects.

The mean compliance rate to participation in the physical training program was 65% (range 4-100%). Subjects estimated the effort to a median level of 4 (q1-q3=3-5), 4 (3-5) and 3 (3-5) during the aerobic, muscle strength training and balance training sections, respectively. The corresponding results for percentage of predicted maximal heart rate measures (220 minus age) were on average 73% (SD=15), 72% (13) and 71% (13), respectively.

The training program was planned by a physiotherapist and led by a trained instructor with the help of a trained physiotherapy assistant. The trained instructor was not involved in assessments of outcome measures.

Nutritional treatment. The nutritional treatment has been described in detail (22). Briefly, it consisted of personalized dietary counseling based on individual baseline food record data and body weight changes over time. A dietician/nutritionist tested different options that would cover the estimated needs of each subject, and then gave advice on food intake in a personal session lasting about one hour. The nutritional treatment included five group sessions that covered such topics as nutritional needs for elderly people, meal frequency, and cooking methods. At each session, an example of a nutritionally well-balanced between-meal snack was served. Forty-six out of 49 eligible subjects (one was excluded due to missing data on energy intake) completed personalized dietary counseling, and the mean compliance rate for the N and T+N groups during group sessions was 73% (range 20-100%).

General advice. The general physical training advice for the N and C groups was to take walks 3 times per week for at least 20 minutes, to use staircases instead of elevators from time to time, and to follow the WHO recommendation of a total of 30 minutes of physical activity per day.

The general diet advice for the T and C groups was to eat three main courses and 2-3 between-meal snacks, including meat, fish or egg, fruit and vegetables, dairy products and dietary fiber in combination with fluid, every day.

Statistical analysis

Statistical analysis was conducted in JMP 6.0.0 (SAS Institute, USA). Continuous data include means (m) and standard deviations (SD) and ordinal data with median (md) and first and third inter-quartile distances (q1-q3). Since maximal workload (watt) only was measured at fixed levels, these data are presented with median and first and third inter-quartile distances. Scatter plots for baseline variables against the difference between baseline and follow-ups in outcome variables were used to determine whether the baseline values had any impact on the magnitude of change. No consistent patterns were noted and, therefore, baseline values were not used as covariates in the analysis. An intention-to-treat analysis, including all subjects regardless of compliance, was conducted with the differences between baseline and 1st and 2nd follow-up, respectively, by One-way ANOVA analyses and Tukey-Kramer HSD as *post-hoc* tests for continuous data with normal distribution, and Wilcoxon/Kruskal-Wallis tests for ordinal data and continuous data with skewed distribution. Associations were calculated with Pearson Product Moment correlation for continuous data and Spearman's Rho for ordinal data. The analyses of compliers and improvers were conducted with Student's *t*-test for continuous data, Wilcoxon Kruskal-Wallis tests for ordinal data, and Fischer's Exact Test for nominal data.

Table 1 - *Baseline characteristics. Significant differences in bold. Regarding "certain", "intermittent" and "probable", numbers in square brackets are included in numbers without square brackets.*

	T group (n=22)	T+N group (n=24)	N group (n=25)	C group (n=22)	Total group (n=93)
Age, m	83.6 (3.8)	83.3 (4.1)	83.1 (4.5)	83 (4.1)	83.3 (4)
Sex	M=12, W=10	M=8, W=16	M=10, W=15	M=7, W=15	M=37, W=56
Heart and lung diseases (n)					
No heart disease	7	**12**‡*	1	3	23
Congestive heart failure [certain]	2 [2]	2 [1]	7 [7]	7 [5]	18 [15]
Previous myocardial infarction [certain]	5 [1]	9 [4]	13 [7]	11 [10]	38 [22]
Arrhythmia [intermittent]	3 [1]	4 [1]	4 [4]	8 [1]	19 [7]
Angina pectoris [certain]	5 [1]	5 [1]	7 [1]	3 [0]	20 [3]
No lung disease	17	17	14	17	65
Obstructive	3	6	4	5	18
Restrictive [probable]	4 [2]	0	5 [0]	1 [1]	10 [3]
Medication					
Continuous (m)	7 (3)	6 (3)	7 (3)	6 (4)	6 (3)
Cardiovascular drugs (m)	1 (1) (n=10)	1 (1) (n=11)	2 (1) (n=19)	2 (1) (n=16)	2 (1) (n=56)
Non-selective β-blockade (n)	1	3	2	1	7
Selective β-blockade (n)	7	6	12	8	33
Blood hemoglobin	132 (13)	131 (15)	128 (10)	128 (19)	130 (14)
Blood pressure					
Systolic	142 (20)	148 (33)	144 (27)	144 (28)	144 (27)
Diastolic	77 (11)	81 (15)	75 (14)	80 (14)	78 (14)
Resting electrocardiogram					
Pathological [certain]	12 [8]	12 [7]	19 [10]	16 [15]	59 [40]
Sinus rhythm	14	16	22	13	65
Pacemaker	2	0	2	3	7
Spirometry					
Functional vital capacity (FVC) (m)	2.26 (1.12)	2.16 (0.67)	2.2 (1.06)	2.29 (0.71)	2.23 (0.9)
Slow vital capacity (SVC) (m)	2.21 (0.69)	2.19 (0.5)	2.17 (0.87)	2.3 (0.72)	2.22 (0.7)
Forced expiratory volume 1 sec (FEV_1) (m)	1.61 (0.74)	1.53 (0.52)	1.68 (0.71)	1.72 (0.64)	1.63 (0.6)
FEV_1/VC (FEV%) (m)	68.7 (15.3)	66.3 (13.7)	70.8 (10)	71.6 (13.4)	69.4 (13.1)
Smoking					
Current smokers (n)	0	**8**‡§	2	3	13
1-10 cigarettes per day (n)	0	5	1	2	8
11-20 cigarettes per day (n)	0	3	1	1	5
Total number of years (m)	32 (17) n=11	47 (20) n=15	31 (19) n=12	44 (21) n=11	39 (20) n=49
Stopped smoking (n)	11	7	10	8	36
Number of years since smoking cessation (m)	29 (18)	37 (14)	36 (15)	27 (14)	32 (16)
Body mass index (m)	21.9 (3.8)	21.9 (3.4)	21.8 (3.4)	21.6 (3.6)	21.7 (3.4)
Physical activity level (md)					
Last summer	2 (2-3) n=14	2 (1-3) n=19	2 (2-3) n=16	3 (2-3) n=17	2 (2-3) n=66
Last winter	2 (2-2) n=19	2 (1-3)	**2 (2-3)**¤§	**3 (2-3)**¤§	2 (2-3) n=90

m=mean (SD), md=median (q1-q3), n=number of subjects, M=men, W=women. *Significant difference compared with C group; ‡significant difference compared with N group; ¤significant difference compared with T+N group; §significant difference compared with T group, $p<0.05$.

RESULTS

Baseline characteristics

Table 1 shows a description of subjects at baseline, for each of the four groups and for the total group. The number of subjects with probable or certain cardiovascular diseases are listed ("certain" is indicated in square brackets in Table 1). The T+N group had significantly more subjects without heart disease compared with the N and C groups. There were significantly more current smokers in the T+N group compared with the T and N groups. Several subjects with a BMI >20 kg/m^2, suffered from unintentional weight loss. Since inclusion criteria were unintentional weight loss and/or BMI <20 kg/m^2, this resulted in mean levels of BMI above >20 kg/m^2 in all groups.

There were significant correlations between maximal workload at baseline for the total group and SVC [r=0.39 (p<0.01)] and total years of tobacco consumption [r=-0.28 (p<0.05)], respectively. When analyzing women and men separately, there were only significant correlations for men, SVC [r=0.42 (p<0.01)], FVC [r=0.50 (p<0.01)], FEV_1 [r=0.35 (p<0.05)]. There were no significant correlations between maximal workload and either leg muscle strength or blood hemoglobin in either sex.

There were significant differences in maximal workload at baseline between men with restrictive lung disease, with or without obstructive lung impairment [md=37.5 W (37.5-50)], compared with men without lung disease [md=62.5 W (50-75)] (p<0.05), but no differences for women or for the whole group. Heart disease in general, as well as chronic heart failure in particular, did not affect maximal workload at baseline.

The main causes of interruption of the bicycle ergometry test were similar at baseline and follow-ups as well as between groups. General fatigue (40%) and leg fatigue (30%) were the most common causes of interruption, followed by a combination of fatigue and breathlessness (12%).

Subjects reached on average 77% (SD=14) of predicted maximal heart rate during the bicycle ergometry test. This level was similar between groups and test occasions (data not shown).

Effects of intervention

Aerobic capacity. The effects of the intervention on different outcome measures are listed in Table 2. There were no significant differences between groups regarding maximal workload (watts) or time (minutes) between baseline and follow-ups. A similar analysis excluding subjects with ongoing β-receptor blockade gave the same results (data not shown).

Estimated effort. The median level of estimated effort on the CR-10 scale for the whole group was 6 (5-7) at baseline and 1st follow-up and 7 (5-7) at 2nd follow-up during bicycle ergometry. There were no significant differ-

Table 2 - Effect of physical training program on aerobic capacity, estimated effort, blood pressure and leg muscle strength at baseline (B) and follow-ups (F1-F2). Significant differences in bold.

	T group			T+N group			N group			C group		
	B (n=22)	F1 (n=18)	F2 (n=16)	B (n=24)	F1 (n=16)	F2 (n=14)	B (n=25)	F1 (n=21)	F2 (n=18)	B (n=22)	F1 (n=19)	F2 (n=13)
Aerobic capacity												
Maximal load, watts (md)	50 (37.5-62.5)	50 (50-62.5)	50 (37.5-62.5)	50 (37.5-62.5)	50 (37.5-62.5)	44 (37.5-62.5)	50 (37.5-62.5)	50 (37.5-50)	50 (37.5-50)	50 (50-62.5)	50 (37.5-62.5)	50 (37.5-62.5)
Maximal time, minutes (m)	7.4 (2.9)	8.3 (3.4)	8.1 (3.9)	7.9 (2.3)	7.9 (2.7)	6.7 (2.4)	7.7 (3.2)	7.5 (2.7)	7.4 (3)	8.3 (2.7)	8.2 (3.2)	8.2 (3.2)
Estimated effort												
25W (md)	3 (1-5)	2 (0-3)	3 (1-3)	3 (1-4)	3 (2-5)	4 (2-5)	3 (1-3)	2 (1-3)	1 (1-3)	2 (1-3)	2 (1-3)	2 (2-3)
50W (md)	5 (4-7)	5 (3-5)	4 (3-7)	5 (3-7)	5 (3-6)	6 (5-7)	5 (3-6)	5 (5-5)	6 (3-7)	5 (3-5)	5 (3-5)	4 (3-5)
Blood pressure (BP) (mmHg)												
Systolic BP at rest before test (m)	142 (20)	141 (26)	147 (24)	148 (33)	149 (29)	148 (21)	144 (27)	148 (27)	139 (23)	144 (28)	149 (27)	141 (21)
Diastolic BP at rest before test (m)	77 (11)	77 (12)	**84 (13)***‡¤	81 (15)	79 (12)	76 (7)	75 (14)	75 (13)	78 (8)	80 (14)	83 (13)	77 (8)
Leg muscle strength												
Leg press, kg (m)	71 (20)	**87 (24)**‡	81 (19)	70 (21)	**81 (23)**‡	67 (16)	76 (28)	75 (30)	77 (34)	78 (26)	86 (27)	85 (31)

m=mean (SD), md=median (q1-q3), n=number of subjects. *significant difference compared with C group; ‡significant difference compared with N group; ¤significant difference compared with T+N group, p<0.05.

ences between the groups regarding estimated effort at 25 or 50W between baseline and follow-ups.

Blood pressure. There were no significant differences between groups regarding resting systolic blood pressure between baseline and follow-ups. Between baseline and 2nd follow-up, there was a small but significant increase in resting diastolic blood pressure for the T group - 6.4 mmHg (CI 95% 0.8-12) compared with the other groups ($p<0.05$).

Muscle strength. There was a significant increase in leg muscle strength (Leg press) in the T and T+N groups compared with the N group at 1st follow-up, with mean differences of 14.3 kg (CI 95% 4.4-24.1) and 11.4 kg (0.8-21.9), respectively ($p<0.01$). This increase did not remain at 2nd follow-up.

Associations

In the following section, only the combined training group (T and T+N groups) was included in the analyses. There were no differences in the outcome of maximal workload/time in relation to sex, β-blockade or tobacco consumption between baseline and follow-ups.

Heart and lung disease

There were no differences in subjects with or without heart disease concerning changes in workload/time. There was a significant difference in work time ($p<0.05$) between subjects with or without lung disease regarding changes between baseline and 1st follow-up (Fig. 2), with a mean difference of 1.5 minutes.

There were, however, no differences when analyzing women and men separately, and there were no differences between maximal workload/time in subjects with or without obstructive lung impairment.

Leg muscle strength

There were no significant correlations between differences in leg muscle strength and in maximal workload/time between baseline and 1st follow-up, either for the combined group, or for women/men, respectively.

Compliance *vs* improvers

The correlation between compliance with the physical training program and difference in work time between baseline and 1st follow-up was [r=0.31]; however, this did not reach significance ($p<0.07$). There were no significant or near-significant differences between compliance and improvement in workload or heart disease, lung disease and spirometry measurements, respectively.

Adverse events

Subjective. At baseline, four subjects experienced dizziness and two chest pain during or directly after the test.

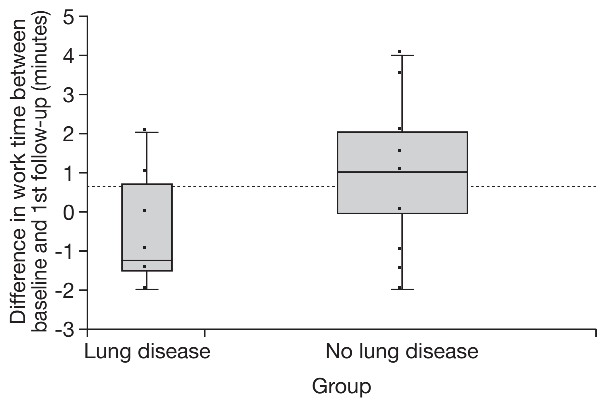

Fig. 2 - *Subjects in combined training group without lung disease significantly increased work time between baseline and 1st follow-up, compared with subjects with lung disease, p<0.05.*

At 1st follow-up, two subjects experienced dizziness and one had chest pain. Of these, one subject experienced dizziness both at baseline and 1st follow-up, and one had chest pain at both measurements. At 2nd follow-up, one subject experienced dizziness and one chest pain. None of the subjects experiencing chest pain or dizziness at both baseline and 1st follow-up had pathological ECG recordings (see below). One subject experiencing chest pain at 1st follow-up had a non-assessable ECG recording, due to a pacemaker.

Objective. No adverse events occurred requiring emergency equipment (e.g., defibrillator, oxygen or medication) during or after the tests. During the bicycle ergometry test at baseline, four subjects had certain and five had probable pathological ECG recordings (ST-T changes, occurrence of atrial fibrillation, AV-block II and sinus arrest). Ten subjects were non-assessable, due to bundle branch blocks or pacemaker treatment. This may be summarized as 4/5/10. The corresponding results for 1st and 2nd follow-ups were 2/5/10 and 1/5/7, respectively.

DISCUSSION

This study did not show any effects of a combined physical training program on aerobic capacity, measured as maximal workload or time during bicycle ergometry, in frail elderly people aged 75 and older. This observation clearly highlights the difficulties both of assessing and improving aerobic capacity in this group. An exception was represented by subjects without lung disease in the combined training group, who significantly increased work time between baseline and 1st follow-up compared with subjects with lung disease. This observation reveals the influence of diseases and medical drugs in evaluating the outcome of a physical training program. Since all subjects based on unintentional weight loss and/or low BMI were included, a nutritional intervention program was added, and we hypothesized that this would enhance the effect of the physical training program. However, we did not find any amplified effect on either aerobic capacity or leg muscle strength. A separate analysis comparing the combined T and T+N groups with the combined N and C groups did not alter the results. The effects of the nutritional intervention program have been described and discussed previously (22).

In the present study, the physical training program comprised three different sections to ensure diversified training effects. The aerobic section lasted for 20 minutes during which subjects on average reached 73% of predicted maximal heart rate at the end of the section. Exercise training at this intensity level is well documented to enhance oxygen uptake in young individuals. Nonetheless, no increase was observed in aerobic capacity measured as workload or time during bicycle ergometry in either of the two training groups. A meta-analysis concluded that aerobic training of >80% intensity and duration >30 minutes for people aged 46-90 yields a significantly greater effect on VO_{2max} compared with lower intensity and duration (23). Despite the effort to facilitate heart rate increases, the intensity of the aerobic section of the training program may still have been too low and the duration too short (23) to produce any effects. An indication which may support this assumption is that heart rate levels were similar during the aerobic and balance training sections. The method for predicting maximal heart rate (220 minus age) is well established, but has disadvantages due to the large variations in the applied prediction formula at individual level (24).

The very few studies that have examined the effects of a physical training program on aerobic capacity in frail elderly subjects show contradictory results (13, 14). Perhaps degrees of frailty to various extents prevent the positive effect of physical training on aerobic capacity. However, since one study that combined muscle strength training with aerobic training showed a positive effect (13), we believe that it was the design of our intervention rather than the frailty syndrome that explains the lack of a positive outcome.

Our physical training program included a muscle strength training section, since some studies suggest that this would enhance aerobic capacity; however, different studies demonstrate diverse results. One study showed no effect in frail elderly people (14), while another showed positive effects in healthy elderly people (25). In the present study, there were no significant correlations between increases in muscle strength and increases in aerobic capacity. Still, the significant increase in muscle strength supports training effects and is in line with other studies investigating the effects on frail community-dwelling older people and older people living in institutions (26, 27).

One important aspect is the test protocol used to evaluate physical training-induced changes. Unfortunately, due to the clinical setting and research conditions, a maximal oxygen uptake test could not be performed. The 4-minute stages and 25 W intervals were suggested by Wetterqvist et al. (18), who reported hemodynamic responses and average workloads in 355 participants aged 70-75, both male and female. However, the usefulness of this test in measuring physical training induced changes may be questioned with regard to the subjects' estimated maximal work capacity, in relation to the size of suggested incremental workload steps (28). Indirect support for this possibility is that the estimated effort during the tests was quite low, which is in line with a previous study in healthy elderly people showing that only 41% of the women and 36% of the men who exercised less than 8 minutes rated their maximal effort as "hard" to "very, very hard" (29). Alternative explanations are that the applied CR-10 scale is difficult for elderly people to understand, and that it is difficult to rate perceived exertion when participants are not accustomed to experiencing total fatigue. Nonetheless, our subjects reached an average level of 77% of predicted maximal heart rate at the end of the ergometry tests, without any observed relation to use of β-receptor blocking drugs. Perhaps, a physical endurance test such as the six-minute walk would have been more suitable for capturing clinically relevant changes.

To investigate whether a more complex analysis could predict aerobic capacity and training responses, various associations were calculated. Reduced pulmonary function explained some of the variance in maximal workload for men at baseline. No such relationship was found for women, which is in contrast with the suggestion of Harms (30) that elderly women are more prone to pulmonary limitation during exercise than men. We further hypothesized that leg muscle strength, heart disease, β-receptor blockade for both sexes and lung disease, also in women, would explain some of the variance, but this could not be shown in this study. Maximal leg muscle strength was measured with 1RM; perhaps a muscle endurance test would have been more appropriate in comparison with aerobic capacity. The lack of correlation between heart disease and aerobic capacity may be explained, as most of the subjects (75%) had some type of heart disease. The observation that β-receptor blocking medication did not affect changes in aerobic capacity is in line with the results of other studies (9).

From a safety perspective, it is important to note that very few adverse events were observed and no severe complications occurred, even though many participants had verified heart disease. In fact, only 34 out of 93 participants had a normal ECG, but additional pathological changes were uncommon during the tests. Although two participants experienced slight to moderate chest pain during the test, they had no simultaneous ECG signs of coronary ischemia. Thus, even though these frail elderly subjects certainly constitute a population at substantial cardiac risk, it was safe to conduct the submaximal bicycle ergometry presented here.

There are several limitations in the present study, such as clinical heterogeneity among subjects, small sample size, non-blinded evaluation, and non-stratification. However, the groups were comparable at baseline regarding aerobic capacity, which was the primary outcome. Still, several factors that may affect aerobic capacity, such as the presence of heart disease, were not comparable between groups. Stratification may have solved this issue for some factors, but there are many other potential factors that might have affected the outcome and it was impossible to stratify them all because of the small sample size. Clinical heterogeneity and unknown treatment effect(s) of physical training on aerobic capacity in frail elderly people made it difficult to conduct a formal power analysis beforehand. We therefore decided to conduct this pilot randomized controlled trial in order to provide both methodological and clinical information as a basis for future studies on frail elderly subjects. The research conditions made it impossible to use blind evaluations.

CONCLUSION

Our intervention and outcome measurements did not allow us to detect any effects on the aerobic capacity of frail elderly people. Subjects without lung disease improved more than subjects with lung disease. Submaximal bicycle ergometry in this frail group was conducted safely. There is a strong need for further studies with larger sample sizes, more specific and progressive aerobic training (including higher levels of intensity, longer durations and higher compliance) and the development of procedures and types of measurements regarding aerobic capacity for frail elderly people. Moreover, in order specifically to address the effect of aerobic training in frail elderly people, an additional age-matched non-frail control group should be used.

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