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CARDIOVASCULAR BENEFITS AND POTENTIAL HAZARDS OF PHYSICAL EXERCISE IN ELDERLY PEOPLE*

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The research project has taken not only money but also a lot of time. In the short story entitled ”Tulitikkuja lainaamassa” (”Borrowing matches”) by the famous Finnish writer (Lassila, 1910) a man goes out into the neighbourhood to borrow matches. The man forgets what he has gone out for because of the many interesting people he meets and the things that happen to him. The same thing has happened to me during this long research project. Producing a thesis is not my primary goal in life. It is to find new and interesting things.

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ABBREVIATIONS

ACSM	American College of Sports Medicine
ACE	Angiotensin-converting enzyme
AHA	American Heart Association
ANOVA	Analysis of variance
BMI	Body mass index
BP	Blood pressure
bpm	Beats per minute
β- blocker	Betablocking medication
C-ANP	Carboxyterminal atrial natriuretic peptide
CEE	Cycle ergometer exercise
CI	Confidence interval
CO	Control women
CMP	Exercise test completion group
Corp.	Corporation
ECG	Electrocardiogram
EDTA	Ethylenediamine tetraacetic acid
GH	Growth hormone
HDL	High density lipoprotein
HG	Holter (ambulatory ECG) group
HR	Hazard ratio
HR_{max}	Maximal heart rate
HRR	Heart rate reserve
IGF-1	Insulin like growth factor 1
Inc.	Incorporation
LBBB	Left bundle branch block
LBM	Lean body mass
LSD- test	Least Significance Difference- test
max.	Maximally exercised
MET	Metabolic unit
N, n	Number
N-ANP	N-terminal atrial natriuretic peptide
NEX	Non-exercise test group
PG	Population group
PA	Physically active
PI	Physical inactivity
PaO_2	Partial pressure of arterial oxygen
pH	Acidicity scale
RER	Respiratory exchange ratio
RM	Repetition maximum
RPE	Rating of perceived exertion
rpm	Revolutions per minute
RPP	Rate pressure product
SD	Standard deviation
SE	Standard error
submax.	Submaximally exercised
TER	Exercise test termination group
VO_2	Oxygen uptake
VO_{2max}	Maximal oxygen uptake
VO_{2peak}	Peak oxygen uptake
W	Watts
WHO	World Health Organisation
χ^2	Chi square
X-ray	Roentgen picture

This review is based on the following original publications, which will be referred to in the text as Studies 1-4:

1. Kallinen, M., Suominen, H., Vuolteenaho, O. and Alen, M. (1998) Effort tolerance in elderly women with different physical activity backgrounds. *Medicine and Science in Sports and Exercise* **30**, 170-176.

2. Kallinen, M., Kauppinen, M., Era, P. and Heikkinen, E. The predictive value of exercise testing for survival among 75-year-old men and women. Submitted for publication.

3. Kallinen M, Sipilä S, Alen M, Suominen H. (2002) Improving cardiovascular fitness by strength or endurance training in elderly women. A population-based randomized controlled trial. *Age and Ageing* **31**, 247-254.

4. Kallinen M, Era P, Heikkinen E. (2000) Cardiac adverse effects and acute exercise in elderly subjects. *Aging* **12**, 287-294.

CONTENTS

Kallinen, M. (2005) Cardiovascular benefits and potential hazards of physical exercise in elderly people**.** *Journal of Sports Science and Medicine* **4, Suppl. 7,** 1-51.

ABSTRACT

Large and consistent beneficial effects with few adverse effects have been found in relation to physical exercise in selected samples of elderly subjects. However, thus far, it has not been confirmed to what extent the effects of physical exercise among elderly people are beneficial or even harmful in population-based studies. Additionally, the role of exercise testing among elderly people remains unclear. Firstly, the effects of prolonged physical training on cardiovascular fitness in 66-85-year-old women were examined in a cross-sectional study. Secondly, the predictive value of exercise-test status and results, including exercise capacity for survival, were studied in 75-year-old men and women. Thirdly, the effects of an endurance and strength training programme were examined in women aged 76 to 78 years in a population-based randomized controlled trial. Finally, the cardiac-adverse effects of acute exercise in the form of a cycle ergometer test were clarified in 75-year-old men and women. In the maximal exercise tests the mean peak oxygen uptake was respectively 26.2 and 18.7 $ml \cdot kg^{-1} \cdot min^{-1}$ among the physically active and less active control women. High cycling power (Watts per kg body weight) in the completed ergometer test was associated with decreased risk for death (multivariate HR 0.20; CI 0.08 - 0.50). The 18-week strength training resulted in a 9.4% increase in peak oxygen uptake while the endurance training improved peak oxygen uptake by 6.8%. A significant increase in cycling power in W/kg was found in the strength and endurance training groups compared to controls. Five cases of cardio- or cerebrovascular health problems emerged in the exercise training groups. These health problems were not directly related to physical exertion. In the final study 23 and 7% of the exercise tests in men and women, respectively, were prematurely terminated because of cardiac arrhythmia or ST segment depressions. Using various study designs and methods the effects of physical training on cardiovascular fitness were found to be beneficial among the four different samples of elderly people. High exercise capacity was found to be strongly and independently associated with decreased mortality among elderly men and women. Exercise testing provides information on the risk of death that is incremental to clinical data and traditional risk factors for death. Cardiovascular monitoring during exercise testing is recommended as a safety precaution. Cardio- or cerebrovascular health problems can occur during exercise training programmes involving elderly people, although they may not be directly related to physical exertion. The dose-response relationships in relation to physical exercise among elderly people remain in need of further clarification in population-based trials.

KEY WORDS: Benefits and hazards of exercise, cardiovascular fitness, older people, exercise testing, predictive value, arrhythmia, ST segment depressions.

1. INTRODUCTION

”Ageing is the process that converts fit adults into frailer adults with increased risk of illness, injury, and death” (Miller, 1999). Ageing is neither a developmental process nor a disease, although a great proportion of older people have some overt or subclinical disease. It is useful but difficult to distinguish whether the age-related changes observed in the human beings are due to ageing itself or consequences of life-style factors, disease processes or genetic factors. These statements offer a basic definition of ageing. However, ageing is a process which individuals encounter in various ways and at different speeds. Ageing also influences different organ systems in varying ways and magnitudes. It is apparent that age-related changes in various physiological characteristics, for example, in cardiovascular fitness vary between the time periods (age cohorts). Studies on these age-related changes encounter problems of cohort and time-of measurement effects, and selection bias due to health (Ingram, 1999).

Physical exercise has effects counter those of age on many body structures and functions (Shephard, 1997a). Cardiovascular fitness, for example, has been found to be markedly higher among older endurance-trained men and women than among older less active subjects (Fitzgerald et al., 1997; Wilson and Tanaka, 2000). Cross-sectional comparisons in aerobic capacity between age groups usually tend to find minimal age-related changes in aerobic capacity because of enhanced selection by health and level of fitness in surviving older age groups. Older people who are fitter and healthier are more likely to survive than their frailer counterparts. Katzel et al. (2001) reported that longitudinal reductions in the absolute VO_{2max} (in $ml \cdot kg^{-1} \cdot min^{-1}$) among older endurance athletes were two to three times as large as those predicted by cross-sectional analyses or those found longitudinally in their sedentary counterparts.

However, Saltin (1986) have suggested that the decline in VO_{2max} in endurance athletes is comparable regardless of the athletes are studied cross-sectionally or longitudinally.

Since the publication of the origin of the species by Charles Darwin in 1859 it has been claimed that the fittest individuals of different species survive the longest (Balady, 2002; Darwin, 1859). This survival advantage among physically active and fit individuals has been thought to be true in older people (Goraya et al., 2000). Considerable beneficial effects of physical exercise on physical performance have been found in numerous longitudinal surveys and training studies. Recent training studies suggest that adaptation to endurance training is also preserved among the oldest old people (Binder et al., 2002; Malbut et al., 2002; Vaitkevicius et al., 2002). It has been suggested that the magnitude of the gain in aerobic capacity by endurance training is related to age of subject, duration of exercise bouts, length of training programme, and pretraining VO_{2max} (Green and Crouse, 1995). Most of these cross-sectional and longitudinal studies on cardiovascular fitness have, however, been performed among selected physically active and healthy older people. More data are needed to confirm the beneficial effects of training among the oldest old people aged 75 and over, especially among women, and among those having disabilities.

Strenuous exercise can also have deleterious effects. Few researchers have reported any adverse effects among elderly people both either during acute exhaustive exercise or prolonged physical training. Most of the adverse effects reported have been minor musculoskeletal problems. A large proportion of these studies, again, have been conducted among healthy people below age 75. Subjects with health problems have usually been excluded.

The standard guidelines issued by American College of Sports Medicine (ACSM, 2000) in exercise testing and prescription differ in a few details between elderly and younger people. Exercise testing under the supervision of a physician is recommended for most elderly people during maximal tests and prior to participation in vigorous exercise (ACSM, 2000; Fletcher et al., 1995). However, the value of exercise testing both for health screening and predictive purposes among elderly people has been questioned (Gill et al., 2000). It has been suggested that the safety margin in the case of physical exercise is narrower among older than younger people (Kallinen and Alen, 1995). Among older individuals the adverse effects of physical exercise may occur with a lower dose of exercise than among younger individuals. It may also be that older people benefit proportionally more from lower doses of exercise. A relatively few randomised controlled trials have been performed that address the issue of dose-response relationships among elderly people.

2. REVIEW OF THE LITERATURE

2.1. The factors behind age-related decline in physical performance

2.1.1. Muscular strength

Muscular strength is dependant on the amount of the contracting proteins actin and myosin present in the muscles. Loss of these proteins and muscle mass (sarcopenia) starts at the age of 25 and is mainly due to loss and reduction in size of type II muscle fibres. The fibres can change during ageing to types which are neither strictly type I nor type II (Andersen et al., 1999). The mean reduction in the area of the vastus lateralis muscle is 40% between the ages of 20 and 80 (Lexell, 1995). The most apparent decrease in isometric muscle strength is seen after the age of 50 (Larsson and Karlsson, 1978). A similar decline has been reported in isokinetic muscle force (Stanley and Taylor, 1993). The loss of strength seems to proceed more rapidly in women than in men, and is greatest around the menopause. Female sex steroids may play an important role in muscle strength in post-menopausal women (Sipilä et al., 2001; Skelton et al., 1999). Additionally, local growth factors (GH/IGF-I) influence muscle repair, adaptation and other age-related changes in muscles and their function (Harridge, 2003). Muscle satellite cells can form new muscle fibres in cases of muscular trauma and also in response to mechanical stimuli (Seale and Rudnicki, 2000). The age-related changes in skeletal muscle are listed in Table 1.

Table 1. Age-related changes in skeletal muscle.

Change	Authors
Loss of muscle fibres	Lexell, 1983
Atrophy of muscle fibres	Aniansson et al., 1981 Grimby and Saltin, 1983
Decrease in muscle mass	Lexell, 1988
Loss of muscle nerves	Grimby and Saltin, 1983
Loss of motor units	Brown et al., 1988
Increase in fat tissue	Borkan et al., 1983
Increase in connective tissue	Alnageeb et al., 1984
Decrease in muscle respiratory capacity	Coggan et al., 1993

Table 2. Age-related changes in cardiovascular system.

Effect	Authors
Decrease in number of cardiomyocytes	Olivetti et al., 1991
Hypertrophy of cardiomyocytes	Olivetti et al., 1991
Decrease in number of pacemaker cells	Davies et al., 1976
Increase in amount of connective tissue	Lakatta, 1987
Concentric and eccentric hypertrophy of cardiac muscle	Lakatta, 1987
Conversion of the contractile proteins of cardiomyocytes to slower isoforms	Holubarsch et al., 1985
Prolongation of calcium activation	Lakatta, 1987
Prolongation of depolarization of cardiomyocytes	Lakatta, 1987
Decrease in responsiveness of pacemaker cells to β- adrenergic stimuli	Folkow and Svanborg, 1993
Loss of Purkinje cells	Fleg, 1986
Decrease in maximal heart rate	Folkow and Svanborg, 1993
Increase in supraventricular arrhythmia	Garcia et al., 1992
Increase in ventricular arrhythmia	Garcia et al., 1992
Increase in diastolic volume	Gerstenblith et al., 1977
Decrease in cardiac ejection fraction	Fleg et al., 1993
Increase in cardiac afterload	O'Rourke, 1990
Pooling of venous blood	Fagard et al., 1993
Delayed filling of the atria and ventricles	Fagard et al., 1993

Older persons who engage in resistance exercise have higher muscle mass and strength than their sedentary counterparts (Sipilä and Suominen, 1993; 1994). Gains in muscular strength greater than 100% have been reported in elderly people after only a few months' strength training (Charette et al., 1991; Fiatarone et al., 1990; 1994; Frontera, 1988). Strength training has also increased muscle cross-sectional area in elderly people (Fiatarone, 1990; Frontera et al., 1988). However, other studies have reported considerably lower changes in muscular strength in elderly people after comparable training intensities and durations (Rice et al., 1993; Sipilä et al., 1996; Skelton et al., 1995). The differences in the gain in muscular strength between these studies may be due to differences in the measure of muscular strength used (1 RM versus isometric muscular strength measurements). Increase in the cross-sectional areas of all fibre types (I, IIA, and IIB) together with a decrease in percentage body fat have been detected after 16 weeks high-intensity resistance training (Hagerman et al., 2000). It has been suggested that age, sex, specific chronic conditions, depression, dementia, nutritional status and functional impairment do not influence adaptation to strength training (ACSM, 1998).

2.1.2. Cardiovascular fitness

The supply of oxygen to the contracting muscles is the most important limiting factor in endurance exercise lasting longer than minute or two. Oxygen uptake is a product of cardiac output and peripheral arteriovenous oxygen difference. Therefore maximal oxygen uptake (VO_{2max}) is the principal measure of aerobic capacity and cardiovascular fitness. Sustained muscular work leads to hydrogen ion accumulation inside the muscle and a decrease in intramuscular pH. Larger concentrations of inorganic phosphate and a reduced potassium concentration inside muscle cells cause decreased cross-bridge formation, decreased muscle membrane excitation and finally weakness of the muscles.

The ability to perform sustained muscular work is also dependant on the available energy resources, primarily on the muscular stores of glycogen. Although stored fat is substantially used for production of high energy phosphates, glycogen depletion leads eventually to muscle fatigue in prolonged muscular work. The supply of oxygen for oxidation of fat and glycogen and the removal of carbon dioxide are dependant on the cardiovascular (blood flow) and respiratory functions (ventilation).

Several changes occur in the human cardiovascular system during ageing. It is difficult to distinguish whether these changes are related to ageing per se or to the effects of pathological processes in the cardiovascular system, reduced total metabolic tissue mass or physical inactivity. The age-related changes in the human cardiovascular system are listed in Table 2. The most apparent effects of ageing on the human heart are elevated cardiac diastolic volumes and decreased myocardial contractility and maximal heart rates during heavy exercise (Fleg et al., 1995). These alterations are thought to be due to changes in the sympathetic nervous system. An increase in the plasma levels of norepinephrine and epinephrine together with reduced responses to beta-adrenergic stimulation are seen in older subjects (Lakatta, 1993). The increased expression of atrial natriuretic peptides, a marker of increased atrial load and dilatation, is reported to increase in the senescent rodent heart (Younes et al., 1995). Maximal oxygen uptake decreases inevitably with age. This decline in VO_{2max} is of the order of 5-22% per decade and 0.28 to 1.32 $ml \cdot kg^{-1} \cdot min^{-1}$ per year (Kasch et al., 1999; Posner et al., 1995). A similar decline in aerobic capacity has been reported for both sexes (Fleg and Lakatta, 1988). It has been suggested that the rate of decline in maximal oxygen uptake by age is 50% less in endurance-trained than sedentary adults (Heath et al., 1981).

Declined physical activity and reduced muscle mass account for a large proportion of the reduced maximal oxygen uptake observed during ageing (Ogawa et al., 1992). A smaller stroke volume, decreased maximal heart rate and arteriovenous oxygen difference are also involved in this decline (Fleg, 1994). A twenty-percent lower citrate synthase activity, a marker of aerobic metabolism, has been reported in the muscle of older untrained men aged 58-68 years men compared to corresponding groups of men aged 21 to 33 years (Coggan et al., 1993). In some studies older subjects have reversed a marked proportion of their reduced muscle respiratory capacity by endurance exercise training (Coggan et al., 1993; Meredith et al., 1989). Adaptation in both cardiac function and the peripheral circulation has been detected during exercise training among elderly persons (Beere et al., 1999; Stratton et al., 1994), but peripheral factors may play a major role in adaptation to endurance training in older people (Meredith et al., 1989). Regular intensive endurance exercise has been found to be associated with higher growth hormone and testosterone levels among older runners than their sedentary peers (Hurel et al., 1999). Both hormones are important in preserving fat-free mass during ageing.

2.1.3. Respiratory capacity

It is generally believed that respiratory function does not limit the individual's performance in endurance exercise except in top level athletes (Harms and Stager, 1995). This may not be the case among elderly people.

Detrimental changes are seen during ageing in the chest wall, the bronchial tree, and the lungs (Table 3). These are followed by changes in pulmonary functions e.g. compliance, static lung volumes, pulmonary dynamics, gas exchange, and the oxygen cost of breathing. In some of the oldest persons the ventilatory equivalent, which describes the volume of air ventilated and needed for one litre of oxygen consumed, may exceed 30 $l \cdot l^{-1}$. During physical exertion an elderly person may soon approach the dyspnoea threshold in peak tidal volume, which is about 50% of vital capacity (Shephard, 1997a).

2.1.4. Diseases

Ageing is associated with disabling chronic diseases, co-morbidity being quite common. According a recent survey carried out among the Finnish population, 81% of people aged 65 or older have almost one chronic disease (Aromaa and Koskinen, 2002). Thirty percent and 21% of the older men and women have clinically evident myocardial infarction or angina pectoris. In addition to overt coronary heart disease, a large proportion of elderly people may have a symptomless coronary heart disease which it may be possible to detect by exercise ECG and/or thallium scan (Gerstenblith et al., 1980).The prevalence of chronic obstructive pulmonary disease in Finnish older people, according to spirometry, was 27% among older men and 14% among women, respectively. Hip or knee osteoarthritis is evident among 16 to 32% of older men and women (Aromaa and Koskinen, 2002). Psychological factors and cognitive impairment may influence further the management of daily tasks among elderly people (Laukkanen et al., 1993). Poor health was among the commonest obstacles to physical exercise reported

Table 3. Age-related changes in respiratory system.

Effect	Authors
Decrease in chest wall elasticity	Crapo, 1993
Increase in thoracic kyphosis	Crapo, 1993
Increase in diaphragmatic activity during breathing	Teramoto et al., 1995
Decrease in ciliary function	Tockmann, 1994
Attenuation of immune reactions	Abbas et al., 1995
Increase in resistance to airway passage	Dempsey and Seals, 1995
Decrease in lung elasticity	Reiser et al., 1987
Decrease in functional respiratory area	Thurlbeck, 1991
Decrease in vital capacity	Cotes, 1993
Worsening of gas exchange in the alveoli	Dempsey and Seals, 1995

in interviews with Finnish elderly men and women (Hirvensalo et al., 1998).

Arteriosclerosis of the coronary arteries decreases coronary blood flow and cause ischaemia in cardiac muscle and deterioration of the pumping power of the ventricles. Under extreme conditions necrosis of the cardiac muscle (myocardial infarction) and a markedly decreased ejection fraction (cardiac failure) follow. The symptoms limiting exercise tolerance in ischaemic heart disease are chest pain and/or dyspnoea. Low creatine phosphate concentrations, high phosphate, high lactate, and low pH values are seen in the skeletal muscles of heart-failure patients during exercise (Wilson et al., 1988). Patients with heart failure have increased sympathetic drive, skeletal and respiratory muscle atrophy and/or weakness, and hyperkinetic cardiovascular responses to physical exercise together with hyperventilation (Chua et al., 1995; Jondeau et al., 1992; Linderholm et al., 1969; Lindsay et al., 1996; Meyer et al., 2001).

The limiting physiological factors during exercise are similar in patients with pulmonary diseases and cardiovascular diseases. An altered ventilation perfusion ratio causes a decrease in PaO_2. Pulmonary hypertension and overload of the myocardium of the right ventricle are usually seen in severe pulmonary emphysema. Also, found among these patients there is reduced skeletal and inspiratory muscle strength together with impaired aerobic capacity of the muscles (Jones and Killian, 2000). In mild chronic bronchitis and bronchial asthma there is no decrease in PaO_2, and the ventilation perfusion ratio could even improve during physical exertion. In many cases the response to exercise is variable among patients with respiratory disorders and these responses are difficult to predict by measuring pulmonary capacity at rest (Jones and Killian, 2000).

Patients with musculoskeletal disorders may be obese, and have decreased muscular strength, endurance and cardiovascular fitness (Ries et al., 1995). A higher prevalence of coronary heart disease has been found among patients assessed before total knee arthroplasty (Philbin, 1995).

2.1.5. Medication

Age and morbidity increase drug use. Elderly women use medication more than elderly men. Diuretics, cardiac glycosides, nitroglycerides and beta-blocking agents as well as analgesics and sedatives are the types of medication most commonly used among the Finnish elderly (Laukkanen et al., 1992). Polypharmacia is also common among elderly people (Laukkanen et al., 1992). Medication may either increase or decrease physical effort tolerance.

Beta-adrenoceptor antagonists (beta-blocking agents) block the β- receptors through which the actions of the sympathetic nervous system are mediated. Two distinct receptors have been found: beta-1- and beta-2 -receptors. Non-selective β-blockers attenuate both beta-1- and beta-2-receptor stimulation leading to decreased heart rate, myocardial contractility, glycogenolysis, brochodilatation, vasodilatation and possibly fatty acid mobilisation during exercise. These alterations are advantageous for the patients with coronary heart disease as they decrease the myocardial oxygen demand and increase the myocardial ischaemia threshold. Non-selective beta-blocking agents may lead to central and peripheral limitations of effort tolerance and increased ratings of perceived exertion to external load (Head, 1999). Selective beta-1-blockers have minor negative effects on bronchial dilatation, vasodilatation and fatty acid mobilisation during exercise. Their effects, however, are dose-related, higher doses also having beta-2-blocking effects.

Digitalis increases myocardial contractility by increasing intracellular sodium and calcium (Peel and Mossberg, 1995). This drug is used to treat patients with heart failure and atrial fibrillation to improve left ventricular performance. Digitalis has a narrow therapeutic margin, higher doses causing bradycardia, arrhythmia and fatigue. Digitalis provokes ST segment depression in the ECG, misleadingly indicating myocardial ischaemia. Diuretics increase the excretion of the electrolytes sodium and potassium, and water by the kidneys. A decrease in blood volume results and therefore these drugs are beneficial in hypertension and heart failure. Hypokalemia related to diuretic medication can cause cardiac arrhythmia and muscle fatigue during physical exercise (Peel and Mossberg, 1995).

Calcium antagonists, ACE inhibitors, alpha-1 antagonists and centrally acting alpha-agonists decrease both systolic and diastolic blood pressure and are thus used in hypertension. No significant effects of calcium antagonist and ACE inhibitor medications on maximal oxygen uptake and work rate have been found with among relatively asymptomatic persons. Among patients with marked coronary heart disease or with heart failure these drugs improve hemodynamics and physical effort tolerance. ACE inhibitor use has been found to be associated with a lower decline in muscular strength among elderly hypertensive subjects (Onder et al., 2002).

Nitrates dilate both the system and coronary veins and arteries, reducing the preload of the heart and increasing coronary circulation. These effects are advantageous in patients with coronary heart disease as they increase their endurance work performance (Peel and Mossberg, 1995).

2.1.6. Physical activity

Heredity (Bouchard and Rankinen, 2001), physical activity, body composition and other factors such as life-style and personality contribute to health and health-related fitness (Bouchard and Shephard, 1994). Among physically active individuals the reserve capacity will remain high enough for the performance of the activities of daily living. It has been argued that the decline in the absolute values in cardiovascular fitness is more gentle among physically active than among sedentary persons (Heath et al., 1981; Kasch et al., 1993; 1999; Ogawa et al., 1992; Rogers et al., 1990). A large body of evidence exists to show that physical activity is associated with a reduction in all-cause mortality, cardiovascular disease, incidence of type 2 diabetes mellitus, and incidence of colon cancer and osteoporosis (Kesäniemi et al., 2001). A high level of physical activity has been shown to be associated with decreased risk of death in older people in several studies (Bijnen et al., 1999; Glass et al., 1999; Kaplan et al., 1987; Paffenbarger et al., 1986). It also seems evident that regular physical exercise protects against the triggering of cardiac events during vigorous exercise (Mittleman et al., 1993; Willich et al., 1993). On the other hand social and productive activities, such as church attendance, participation in social groups, shopping and gardening have been found to lower the risk of death as much as fitness activities among people aged 65 and older (Glass et al., 1999). Numerous other factors including genetic and socioeconomic factors are also involved in survival (Kujala et al., 2002; Lantz et al., 1998).

A polarisation phenomenon has been found in physical activity habits among elderly people with ageing (Marin, 1988). The proportion of physically very active older people tends to remain almost the same or to increase slightly during the later years of life. The remainder of the older population tend to reduce the amount of their physical activity. The proportion of 75- 84-old Finnish men exercising several times per week to the point of perspiring and heavy breathing was found to be about 17 percent (Hirvensalo et al., 1998). This proportion fell to about 7% over an 8-year follow-up. This declining trend in physical activity has also been seen among women. In a recent extensive survey on the health of Finns aged 30 years and older the most physically active individuals were men aged 65 to 74 years (Aromaa and Koskinen, 2002). Forty-three per cent of the men in this age group exercised at least 4 times per week to the point of light breathing and perspiring. The least physically active were women aged 75 to 84 years of whom fewer than 15% exercised so as to induce light breathing and perspiring at least four times per week. A declining proportion of people were physically active after the age of 74 in both sexes.

2.2. Cardiovascular benefits of physical exercise

2.2.1. Effects of physical training on cardiovascular fitness

A marked higher aerobic capacity has been found in several studies comparing older endurance-trained persons with their sedentary counterparts. Inconsistency in the results continues to characterize the results of cross-sectional studies concerning the rate of decline in aerobic capacity between physically active persons and sedentary persons. Fitzgerald et al. (1997) found a steeper decline in absolute maximal oxygen uptake among endurance-trained compared to sedentary women. Jackson et al. (1996) found no difference in the rate of this decline between two corresponding groups of women. In a large meta-analysis this was also true among men (Wilson and Tanaka, 2000). No difference in the relative decline of aerobic capacity has been detected between differently physically active groups of women or men (Fitzgerald et al., 1997; Wilson and Tanaka, 2000). Pollock et al. (1987), however, in a 10-year longitudinal study of runners aged 50 to 82 years reported a 13 percent reduction in maximal oxygen uptake among runners with reduced training intensity compared to a 2 percent loss in maximal oxygen uptake in a group of runners maintaining their habitual training intensity. Similar results have been found in other longitudinal studies among highly physically active subjects (Kasch et al., 1993; 1999; Trappe et al., 1996; Katzel et al., 2001). In the studies by Kasch et al., a lower decline in maximal oxygen uptake expressed in $ml \cdot min^{-1} \cdot kg^{-1}$ body weight was caused by a marked reduction in body weight during the intervention.

Katzel et al. (2001) reported that the longitudinal reductions in absolute VO_{2max} (in $ml \cdot min^{-1} \cdot kg^{-1}$) were two to three times as large as those predicted by cross-sectional analyses or those found longitudinally in their sedentary counterparts. The relative reduction in aerobic capacity was 22% in older endurance male athletes compared to 14% in sedentary men. The inconsistency of the results in studies comparing the decline in aerobic capacity between physically active and sedentary subjects may be due to differences in the training levels with ageing. It is also obvious that different conclusions can be drawn according to whether the absolute reductions in aerobic capacity are expressed in absolute values ($ml \cdot min^{-1} \cdot kg^{-1}$ or $l \cdot min^{-1}$), or as relative decline in aerobic capacity expressed as percentages of the baseline values.

It has been suggested that almost 100% of the age-related decline in aerobic capacity accumulated during 30 years among middle-aged men could be reversed by 6 months' endurance training (McGuire et al., 2001). Up to what age such a kind of reversal in aerobic capacity is possible remains unclear. Considerable increases (up to 38%) in cardiovascular fitness and other positive effects have been reported during endurance exercise programmes among older individuals. Only a few studies, where the exercise dose has been insufficient, have reported no change or even a decrease in cardiovascular fitness with endurance exercise training (Green and Crouse, 1995). The magnitude of the gain in aerobic capacity is dependant on the initial aerobic capacity and age of the subject, and on the duration of the exercise bouts/training programme. The youngest older subjects with the lowest baseline aerobic capacity increased their aerobic capacity most after training with exercise bouts and programme of sufficient duration (Green and Crouse, 1995). However, most studies have been performed among men and subjects younger than 75 years of age excluding subjects with disabilities.

Recent endurance training studies have also been performed among the oldest old and among frail subjects (Binder et al., 2002; Malbut et al., 2002; Vaitkevicius et al., 2002). Binder et al. (2002) found a 13% increase in VO_{2peak} (95% CI for the improvement 0.9 to 3.6 $ml \cdot min^{-1} \cdot kg^{-1}$) in 9 months' intensive exercise training compared to no increase in VO_{2peak} after a 9-month low-intensity home exercise program among 115 sedentary men and women aged 83 years (SD, ±4 years) with mild to moderate physical frailty. In this study 15% percent of the target group was excluded from the training programmes because they were considered too frail or ill for vigorous exercise. Furthermore, 27% of the randomized participants dropped out of the study because of medical problems unrelated to the training. Malbut et al. (2002) found a 15% increase in VO_{2max} after 24 weeks' endurance training in 12 elderly women aged 79 to 91 years, but no change in 9 men. The men in the study by Malbut et al. had a marked higher pretraining VO_{2max} than women (21.8 vs. 13.8 $ml \cdot min^{-1} \cdot kg^{-1}$) and therefore were not expected to show a large gain in aerobic capacity with endurance exercise training. A six-month community-based moderate endurance training programme resulted in a 6.5% increase in VO_{2peak} among 22 men and women aged 80 to 92 years in the study by Vaitkevicius et al. (2002). In the latter study the gain in aerobic capacity might have been even more limited had the subjects with submaximal exercise test results after training not been excluded.

Age, sex, specific chronic conditions, depressions, dementia, nutritional status and functional impairment have not been shown to influence adaptation to strength training (ACSM 1998). Some researchers (Hepple et al., 1997; Hagerman et al., 2000) have found beneficial effects of strength training on cardiovascular fitness among elderly people while others have not found any statistically significant differences in cardiovascular fitness with resistance training (Hagberg et al., 1989; Pollock et al., 1991).

2.2.2. Value of exercise-test result including exercise capacity in predicting mortality among elderly people

Exercise testing is widely used to diagnose cardiovascular disease or to evaluate its seriousness. Exercise testing is also recommended for screening purposes for older people starting a vigorous exercise training program (ACSM, 2000) to avoid exercise-triggered cardiovascular complications. Exercise test- results may further have prognostic value with respect to cardiovascular morbidity and mortality as well as all-cause mortality. Exercise capacity, exercise duration, positive exercise electrocardiogram, change in systolic blood pressure during exercise, marked cardiac arrhythmia, and heart-rate recovery have been found to be associated with the risk of death and cardiovascular morbidity even among apparently healthy and asymptomatic populations (Blair et al., 1995; Curfman and Hillis, 2003; Cole et al., 1999; Era et al., 2001; Glover, 1984; Goraya et al., 2000; Gulati et al., 2003; Jouven, 2000; Lakka et al., 1994; McHenry et al., 1984; Messinger-Rapport et al., 2003; Myers et al., 2002; Rywik et al., 1998; Sandvik. et al., 1993). However, relatively few studies have been examined this question among older people and among both sexes (Era et al., 2001; Goraya et al., 2000; Messinger-Rapport et al., 2003).

In the study by Goraya et al. (2000) after adjusting for clinical factors high workload in the treadmill test was the only factor associated with a decreased risk for death and cardiac events among the elderly subjects. One MET (metabolic unit) increase in workload resulted in an 18% reduction in risk for death in elderly persons and a 20% reduction in risk in younger persons. It was concluded that the treadmill exercise testing provided prognostic information that was incremental to the clinical data. The results also showed that the prognostic effect of workload in elderly subjects was of the same magnitude as in younger subjects. However, 72% of the exercise tests among the older participants were done for either the evaluation of documented coronary artery disease or its diagnosis. The participants were selected because of their high likelihood of having coronary heart disease. It is thus difficult to generalise the results of this study across the "normal" elderly population.

It has been suggested that the association of cardiac arrhythmia with subsequent coronary events among apparently healthy older people is weak (Fleg et al., 1993). However, in asymptomatic middle-aged men frequent premature ventricular depolarisations were associated with increased risk of death from cardiovascular causes in a mean follow-up of 23 years (Jouven et al., 2000). It is widely accepted that severe cardiac arrhythmia in relation to coronary heart disease and ischemia increase the risk of subsequent cardiac morbidity and mortality. An ischemic ST segment depression is a predictor of cardiovascular morbidity and mortality (Bruce et al., 1980). Changes in the ST segment are also usually seen in older people's exercise ECGs. The occurrence of ST segment changes is highly predictive of coronary artery disease in subjects with typical symptoms of the disease (angina pectoris). The predictive value, on the other hand, is low when the symptoms are not typical. It is also obvious that the possibility of having both a coronary heart disease and a positive exercise ECG is higher among population with high prevalence of disease i.e. among older people. In a population study Hedbad et al. (1989) found increased mortality among elderly men with ST segment depressions in their 24 hour ambulatory ECG recording. The risk of death was increased also among elderly men with non-symptomatic ST depressions. A high level of physical activity is associated with reduced risk for symptomatic ischemic heart disease. However, in the study of Katzel et al. (1998) the prevalence of exercise-induced silent myocardial ischemia in a maximal exercise test and in tomographic thallium scintigraphy was comparable among master male athletes and among healthy untrained men with no history of ischemic heart disease.

The role and use of exercise testing among elderly people has been questioned by some authors (Gill et al., 2000; Fiatarone Singh, 2002). These authors criticize the routine use of exercise testing among elderly people, starting with a vigorous exercise training programme, as recommended by ACSM and AHA. The difference between vigorous and moderate exercise may be difficult to determine. Furthermore, the interpretation of exercise test results is problematic among elderly people because of non-specific signs and symptoms during testing. Intensive screening by exercise testing and other methods usually excludes a marked proportion elderly people from participating an exercise training programmes. In this way the oldest and frailest people who may obtain the largest benefit from physical exercise may be excluded from exercise training programmes (Fiatarone Singh, 2002).

2.3. Possible harmful effects of physical exercise

2.3.1. Effects of acute physical exercise on cardiac function

During heavy exercise plasma ionic concentration of potassium can double compared to the concentration at rest, the decrease in pH could be 0.4 units and increase in plasma catecholamines 15-fold (Paterson, 1996). Pulse rate and systolic blood pressure increase, while diastolic blood pressure tends to decrease slightly. In elderly person the capacity of the heart to increase the heart rate is limited. An aged heart compensates for the decreased left ventricular filling rate in the early diastole by enhanced atrial contraction (Swinne et al., 1992). The left ventricular diastolic volume normalized for body surface area does not differ much between younger and older healthy persons in the resting supine position (Fleg et al., 1995). However, during heavy exercise the diastolic volume of an elderly persons' heart increases suit to the cardiac minute volume to the demands of the working muscles. In younger persons diastolic volume drops to the seated rest level during exhaustive exercise (Fleg et al., 1995). The maximal ejection fraction during exhaustive upright exercise decreases with age due to difficulties in the ability to reduce end-systolic volume (Fleg et al., 1995).

Under the extreme biochemical conditions described above cardiac arrhythmia can be provoked. The heart is, however, protected against this chemical stress during exercise by mechanisms which are unclear. The heart seems to be at greatest risk in the post-exercise period when plasma potassium is low and plasma catecholamines are still at a high level (Paterson, 1996). It has been noticed that cardiac arrhythmia in physical exercise increase with age (Mayuga et al., 1996; Fleg, 1994). Most (about 80%) fatal cardiac arrhythmias are due to coronary atherosclerosis among adult population. Other causes of fatal arrhythmias include cardiomyopathy (10-15%) and among others (< 5%) are primary electrical and genetic ion-channel abnormalities, valvular or congenital heart disease (Huikuri et al., 2001).

2.3.2. General aspects of safety in physical exercise

Acute physical exercise increases the risk of cardiovascular events during the physical effort. The increase in risk is compensated for by a decrease in cardiovascular risk at other times. It is evident that regular physical exercise has beneficial effects on morbidity, mortality, functional decline, mobility, disability, coronary heart disease, and contributes to increase in active life expectancy (Gill et al., 2000). However, an important question is whether the immediate increase in risk during physical effort is age-related. In the epidemiological study by Vuori et al. (1995) both the absolute number of deaths during participation in various physical activities and the risk relative to activity were lower among persons aged 50 to 69 years than in middle-aged people. In contrast Mittleman et al. (1993) found that among people aged 70 years and over the relative risk of onset of myocardial infarction was over double that of younger age groups (< 50 years, 50 to 69 years), although this result did not reach statistical significance in the chi-square test. The researchers also found that the induction time for the onset of myocardial infarction was less than one hour. Furthermore, the corresponding relative risk of persons who were habitually sedentary was 100 compared to 2 among persons engaging in strenuous physical exertion 5 times or more per week (Mittleman, 1993). Similar results were reported by Willich et al. (1993).

Deposition of cholesterol, macrophage infiltration, enlargement of the necrotic core of the plaque, and the accumulation of erythrocyte membranes in an atherosclerotic plaque increase the risk of plaque rupture (Kolodgie et al., 2003). Acute risk factors for exercise-induced cardiac adverse effects are hemodynamic reactivity, hemostatic reactivity and vasoreactivity (Muller et al., 1994). The physical and mental stress quite often serves as an initial triggering mechanism producing hemodynamic changes which leads finally to plaque rupture in the coronary arteries (Muller et al., 1989). The end-point of this complex cascade would be myocardial infarction, cardiac arrhythmia or sudden cardiac death.

Surprisingly few adverse effects during exercise interventions among elderly people have been reported (Belman and Gaesser, 1991; Binder et al., 2002; Buccola and Stone, 1975; Carroll et al., 1992; Cunningham et al., 1987; Ehsani et al., 1991; Hamdorf et al., 1992; Kohrt et al., 1991; Malbut et al., 2002; Puggaard, 2000; Seals et al., 1984; Spina et al., 1993; Suominen et al., 1977a; 1977b; Tzankoff et al., 1972; Vaitkevicius et al., 2002). Most of these effects have been related to musculoskeletal problems. In strength testing Shaw et al. (1995) and Pollock et al. (1991) found some musculoskeletal injuries related to 1RM strength testing. In the study by Pollock et al. (1991) 19% of the elderly subjects sustained a joint injury during 1RM strength testing while 57% of the subjects who began to jog incurred an injury. Strength training resulted in only 2 injuries in 23 subjects (8.7%) and walking in only one injury in 21 subjects (4.8%). A few authors have reported harmful cardiac effects following exercise training among elderly people

Table 4. Components of physical examination prior the exercise testing and physical training programmes (adapted from ACSM 2000).

Body weight: body mass index (BMI), waist girth, body composition (percent body fat)
Apical pulse rate and rhythm
Resting blood pressure (seated, supine, standing)
Auscultation of the lungs (absence of rales, wheezes, and other breathing sounds)
Palpation of the cardiac apical impulse- PMI (point of maximal impulse)
Auscultation of the heart (murmurs, gallops, clicks, rubs)
Palpation and auscultation of carotid, abdominal, and femoral arteries
Evaluation of the abdomen (bowel sounds, masses, visceromegaly, tenderness)
Palpation and inspection of lower extremities (oedema, presence of arterial pulses, painful joints)
Palpation of the tendons (tendon xanthomas)
Evaluation of the skin (skin xanthelasma, diabetic ulcers, neuropathy)
Tests of neurologic function (including reflexes, cognition)
Oftalmoskopy (diabetic retinopathy)
Follow-up examination of any medical condition limiting exercise

(DeVries, 1970; Ehsani et al., 1991).

The best way to avoid cardiovascular complications and musculoskeletal problems is prevention. Pre-exercise screening by medical examination is important in this respect. The content of a clinical examination prior to exercise testing and physical training programmes is presented in Table 4. ECG and some blood tests may also be of value in such a pre-exercise evaluation (ACSM, 2000). Plasma N-ANP can be used as a marker of left ventricular dysfunction (Lerman, 1993). The role of plasma C-ANP in the assessment of cardiac function needs to be clarified. The ACSM recommends exercise testing under supervision of the physician in the case of older or sick people starting a heavy exercise training program (ACSM, 2000).

2.3.3. Exercise testing and its safety

The great individual variation in physical capacity and health among elderly people calls for an individual assessment of test modalities (ACSM, 1995; Spirduso, 1995). Methods of assessing endurance capacity can include self-reports, interviews or observations. Measuring cardiovascular fitness can include submaximal or maximal physical capacity tests. During maximal tests the measurement of direct oxygen uptake, carbon dioxide production, ventilation and respiratory exchange ratio (RER) produces accurate measures for aerobic capacity. The value of submaximal tests is limited due to wide individual variation in the maximal heart rates (ACSM, 1995). The most common methods used to asses cardiovascular function during exercise are 12-lead ECG and blood pressure monitoring. Supervision by a physician is recommended when maximal testing is performed with people at high risk (older or sick people) (ACSM, 2000). Exercise testing is used both for diagnostic purposes and to assess physical performance. The diagnostic and prognostic variables generally used during or after exercise testing are listed Table 5. A ≥1mm horizontal or downsloping ST segment depression in the early phases of exercise, angina pectoris, marked ventricular arrhythmia, inadequate blood-pressure or heart rate responses during exercise are obvious markers of cardiovascular disease and mean a poor prognosis (Curfman and Hillis, 2003).

Most of the studies related to exercise testing in elderly people have been performed among selected groups of healthy and physically fit elderly subjects. The adverse effects of heavy physical exercise in the form of exercise testing have been found to be minimal in these studies. Morbidity rates of 0 to 232 and mortality rates of 0 to 2.5 per 10 000 exercise tests have been reported (ACSM, 2000). These complication rates depend much on the age and health of the subjects tested. The safety of exercise testing has been studied specifically in the study by Gibbons et al. (1989). It can be calculated from the data given in this study that the complication rate among subjects older than 60 years was 10 times higher than that among the younger subjects. Gibbons et al. (1989) found that the complication rate decreased with time after a cooling-down period phase was added to the exercise protocol. They also found that most of the complications emerged in the immediate or late recovery period (Gibbons et al., 1989).

Table 5. Variables associated with coronary artery disease and poor prognosis (adapted from Curfman and Hillis, 2003).

During exercise
Low exercise capacity
ST segment depression
ST segment elevation (lacking the Q wave)
Angina pectoris
Blunted blood pressure response
Blunted heart rate response
Ventricular arrhythmia
During recovery
ST segment depression
Delayed slowing of heart rate
Ventricular arrhythmia

The American College of Sports Medicine has laid down widely used guidelines for exercise testing and prescription (ACSM, 1995; 2000). According to these recommendations medical clearance is advised prior to maximal exercise testing or participation in vigorous exercise. However, no specific indications for exercise test termination are given for the elderly population. The test modalities need to be modified for elderly populations because of the physiological effects of ageing and concomitant medical problems. It is recommended that exercise testing is started at low intensity, with small increments in work rate and longer stages. Among elderly individuals it is deemed best to keep the total exercise test time between 8 and 12 minutes. The cycle ergometer test is the preferred exercise test loading type (ACSM, 1995). The basic questions related to the safety of exercise testing are: When should the test not be performed? When should a test be stopped? Most of the contraindications for testing and indications for stopping a test are related to cardiovascular disease

Table 6. Predetermined contraindications for exercise testing (adapted from ACSM, 2000).

Absolute
A recent significant change in the resting ECG suggesting significant ischemia, recent myocardial infarction (within 2 days) or other cardiac event
Unstable coronary heart disease
Uncontrolled cardiac arrhythmias causing symptoms or hemodynamic compromise
Severe symptomatic aortic stenosis
Uncontrolled symptomatic heart failure
Acute pulmonary embolus
Aacute myocarditis or pericarditis
Suspected or known dissecting aneurysm
Acute infection
Relative
Left main coronary stenosis
Moderate valvular stenosis
Electrolyte abnormalities (hypokalemia, hypomagnesemia)
Systolic blood pressure at rest over 200 mm Hg, diastolic over 120 mm Hg
Tachyarrhythmias or bradyarythmias
Hypertrophic cardiomyopathy or other forms of outflow tract obstruction
Neuromuscular, musculoskeletal, or rheumatic disorders that are exacerbated by exercise
High degree atrioventricular block
Ventricular aneurysm
Uncontrolled metabolic disease (diabetes, thyrotoxicosis, myxedema)

and cardiovascular disturbances. The contra-indications for exercise testing and indications for test termination are presented in Tables 6 and 7.

2.3.4. Physical training and its safety

The responses to physical exercise are either beneficial or harmful. Improvement in cardio-vascular fitness and cardiovascular health are among the beneficial effects of an appropriate dose of exercise. High intensity endurance exercise is associated with cardiovascular complications such as cardiac arrhythmia, cardiac arrest and sudden cardiac death. Exercise of high frequency and long duration can provoke musculoskeletal problems.

Table 7. Predetermined indications for terminating exercise (adapted from ACSM, 2000).

Absolute
Decrease in systolic blood pressure by at least 10 mmHg or unchanged in spite of increased loading together with other evidence of ischemia
Moderate or severe angina
Increasing nervous system symptoms (ataxia, dizziness, near syncope)
Signs of poor perfusion: pallor, cyanosis, nausea, or cold and clammy skin
Systolic blood pressure rise over 260 mmHg, diastolic over 1115 mmHg
Technical difficulties in monitoring the ECG or blood pressure
Subject refuses to continue the exercise
Sustained ventricular tachycardia
ST elevation ($\geq$ 1.0 mm) in leads without diagnostic Q-waves (other than V_1 or aVR)
Relative
Drop in systolic blood pressure of $\geq$ 10 mmHg from baseline despite an increase in workload
ST or QRS changes such as horizontal or downsloping ST depression > 2mm or marked axis shift
Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block, or bradyarrhythmias
Fatigue, shortness of breath, wheezing, leg cramps, or claudication
Bundle branch block or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia
Increasing chest pain
Hypertensive response

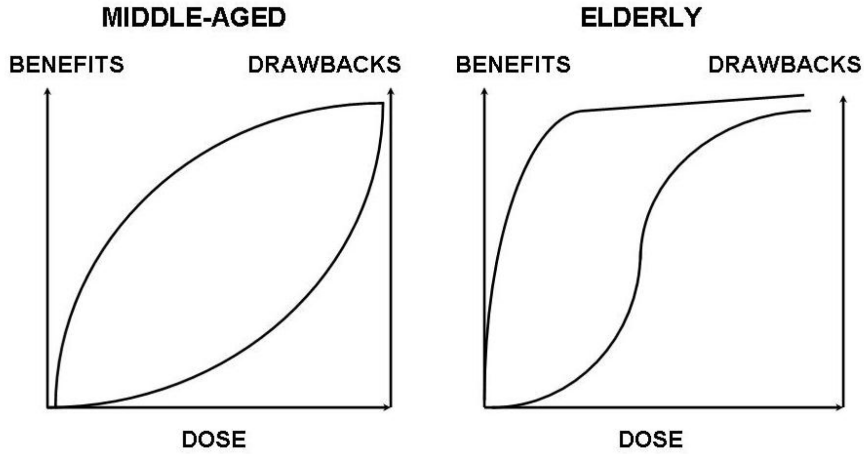


Figure 1. The dose-response relationships of physical exercise (Adapted from Kallinen and Alen, 1995).

Exercise type is also important with respect to responses. Aerobic exercise causes changes in the cardiovascular and metabolic body systems whereas anaerobic strength training imposes stress mainly on skeletal muscle. On the other hand the magnitude of stress should be sufficient to induce a process of adaptation in the body's systems, i.e. improvement in cardiovascular fitness or muscular strength.

The intensity of exercise can be defined in absolute terms or relative to the individual's maximal initial level. Usually the level of intensity in endurance exercise is expressed relative to maximal oxygen uptake (i.e. 50-85% VO_{2max}). The corresponding training heart rates are used by plotting them against the oxygen uptake level during an exercise test (direct method). The direct method is considered to be the best choice when setting an appropriate training intensity for persons with low fitness levels, for those with cardiovascular or pulmonary disease, and for those on some types of medication (e.g., beta-blockers). During exercise testing a safe level of exercise intensity can be established before the adverse effects of exercise arise (ACSM, 2000). Training heart rates expressed as a percentage of the heart rate reserve (i.e. 50-85% of heart rate reserve, HRR) plus resting heart rate (Karvonen et al., 1957) can also be used. The heart rate reserve is calculated by subtracting the maximal heart rate by the resting heart rate. Another way to calculate the training heart rate is to express it as a percentage of the maximal heart rate (i.e. 60-90% of the maximal heart rate, HR_{max}). The ACSM 2000 recommends the HRR method, which is comparable to the relative values of maximal oxygen uptake. However, among elderly people some authors favour using the percentage of maximal heart rate as it has been found to be accurately related to oxygen uptake in older women and men (Kohrt et al., 1993; Panton et al., 1996). Subjective ratings (rating of perceived exertion, RPE; Borg-scaling 6-20, Borg, 1970) of the intensity of exercise are also used alone or in the combination with other methods.

Muscular strength is best trained using near maximal weights with few repetitions while muscular endurance can be improved by light weights with a greater number of repetitions. Recent guidelines for resistance training among elderly people recommend 8-10 exercises of all the major muscle groups repeated 10-15 repetitions with RPE's of 12 to 13 (somewhat hard) and a training frequency of two times per week. The resistance training should be at low level during the first 8 weeks to allow adaptation of connective tissues. To maintain adherence to the training program resistance training exercise sessions should not last over 60 minutes. Normal breathing pattern should be maintained while exercising to avoid an excessive rise in systolic and diastolic blood pressure (ACSM, 2000). In addition, to appropriate modes, intensity, duration, frequency and progression of exercise, every exercise session should include warm-up and cooling down exercises to avoid harmful cardiac or musculoskeletal adverse effects (ACSM, 2000).

It has been suggested that the gain in aerobic capacity among elderly people achieved by endurance training is dependant on their initial aerobic capacity. Those with the lowest aerobic capacity have the largest relative potential augmentation of maximal oxygen uptake ($ml \cdot min^{-1} \cdot kg^{-1}$) (Shephard, 1997b). The gain in aerobic capacity is also dependant on the training intensity, frequency and duration. Figure 1 presents the hypothetical dose-response curves for middle-aged and elderly people. It has been suggested that among older individuals both the beneficial and adverse effects of physical exercise may occur with a lower

Table 8. Contraindications to progressive moderate or heavy endurance or strength training (adapted from ACSM, 1995; 2000; Fox et al., 1971; Shephard, 1997c; Van Camp and Boyer 1989).

Acute infection
Unstable metabolic disorder
Significant locomotor's disturbance
Uncontrolled systemic hypertension; systolic blood pressure at rest over 200 mmHg, diastolic over 120 mmHg
Recent myocardial infarction
Unstable coronary heart disease
Manifest cardiac failure
Acute myocarditis or pericarditis
Significant aortic stenosis
Significant valvular disease
Pulmonary hypertension
Severe obstructive or restrictive lung disease
Recent systemic or pulmonary embolism
Recent deep vein thrombosis
Aneurysm or thrombosis in heart ventricle
Suspected or diagnosed aortic aneyrusm
Electrolyte abnormalities
Uncontrolled cardiac arrhythmia influencing cardiac functioning
Recent third degree atrioventricular block, left bundle branch block
Idiopathic long QT-syndrome
Cardiomyopathy
Fixed-rate cardiac pacemaker
Severe anemia (Hb under 100 $g \cdot l^{-1}$)
Any serious systemic disorder (e.g mononucleosis, hepatitis)
Severe psychological distribution
Subject refuses to exercise

dose of exercise than among younger individuals (Kallinen and Alen, 1995; Shephard, 1997b).

General rules for exercise prescription for elderly people are complicated to obtain because of great individual variation in fitness levels and health. Most of the training studies have been performed among elderly people less than 75 years old. Furthermore, most of these studies have been done among men and healthy people. The general exercise prescription differs in some aspects from that intended for younger age groups. The exercise type should be chosen to cause minimal orthopaedic stress among elderly people. If the effort tolerance of the elderly individual is very limited, one longer exercise session should be divided into several shorter bouts. Exercise duration in aerobic training and repetitions in strength training are the first factors to be increased before increasing training intensity among elderly people (ACSM, 2000). Acute infection, recent myocardial damage, unstable coronary heart disease or significant locomotor disturbances are standard absolute contraindications to progressive exercise training programmes. Other contraindications to progressive endurance or strength training are presented in Table 8. Some warning signs or symptoms, including angina or increased frequency of cardiac arrhythmias (Table 9) in relation to physical exertion, indicate that the exercise programme should be stopped or that the exercise dose, usually intensity, should be reduced.

Table 9. Signs and symptoms indicating excessive effort (adapted from Haskell, 1978).

Angina pectoris
Increased frequency of cardiac dysrhythmias
Inappropriate bradycardia
Inappropriate tachycardia
Ataxia, light headedness, confusion
Nausea
Claudication
Pallor, cyanosis
Inappropriate dyspnoea
Prolonged fatigue
Unusual insomnia
Weight gain due to fluid retention (oedema in the legs)
Musculoskeletal pain

3. SUMMARY OF THE LITERATURE

According to literature to date basic physiological factors and reduced muscle mass are involved in the age-related decline in aerobic capacity and effort tolerance among elderly people. A great proportion of the age-related decline in physical performance is due reduced physical activity. It is also clear that pathophysiological mechanisms (diseases) and medications influence this decline and also the trainability of older people. The physical capacity left over for managing everyday tasks has been found to be higher in physically active persons than in sedentary individuals in both cross-sectional and longitudinal studies. An appropriate dose of exercise can reverse the age-related decline in physical performance e.g. cardiovascular fitness. It is also apparent that the benefits of exercise do not come without some short-term risks, especially among persons not accustomed to regular physical exercise. It has been suggested that both the beneficial and adverse effects of physical exercise may occur with a lower dose of exercise among older than younger individuals. The existing guidelines for exercise testing and prescription have mostly been set for younger and middle-aged people with only minor modifications for elderly and sick individuals. Furthermore, the usefulness of exercise testing in the assessment of risks prior to physical training and its prognostic value among elderly people needs to be clarified.

Large beneficial effects of exercise training programmes have been found among older people in both cross-sectional and longitudinal studies. Most of these studies have, however, been performed among apparently healthy elderly people. Additionally, these studies have mostly been done among men aged less than 75 years. Data on effects of exercise on elderly women aged 75 and over is especially scarce. Thus, the over-all effects and safety of physical exercise among elderly people with health problems are inconclusively documented in the scientific literature. Few population-based randomised controlled studies have been done to address general statements of the benefits and adverse effects of physical exercise among elderly people.

4. AIMS OF THE STUDY

To address the issue of the overall beneficial or harmful responses of physical exercise, the effects of physical exercise on cardiovascular functions, fitness and health were examined among elderly people in cross-sectional and longitudinal population-based studies. The role of exercise testing was also clarified among elderly people.

The primary research objectives were the following:

1. To study the effect of physical activity level on cardiovascular fitness and effort tolerance in elderly women in a cross-sectional study.

2. To study whether exercise test status and exercise-test results, including exercise capacity, are predictive for risk of death in community-dwelling elderly men and women.

3. To study the beneficial and possible adverse effects of an 18-week strength and endurance training programme on cardiovascular functions, fitness and health among elderly women in a population- based randomised controlled trial.

4. To examine the acute and prolonged effect of acute exercise in the form of a progressive cycle ergometer test on cardiac arrhythmias, ST segment depressions and other cardiovascular adverse effects in community-dwelling elderly people.

5. METHODS

5.1. Effort tolerance in elderly people with different physical activity backgrounds (Study 1)

5.1.1. Study design

Sixty physically active women (PA) aged 66-85 years were selected from a sample of 600 members of Finnish sport organisations on the basis of a physical activity questionnaire. Most of them had a life-long training background and were still active in various sports (running, cross-country skiing, track and field, gymnastics). As a control group (CO) a random sample of 71 sedentary women aged 70-81 years was taken from the population register of the rural municipality of Jyväskylä. The control women performed light habitual physical activities (housekeeping, shopping, walking). None of them, however, reported regular endurance type training or other vigorous physical exercise.

Fifty-two (87%) of the PA and 42 (59%) of the CO took part in the laboratory examinations (Sipilä and Suominen, 1993). Those women who failed to attend the laboratory examinations were interviewed by phone about the reasons to their non-participation in the further examinations. Almost all of the control groups explained their non-participation by reference to health problems, and the physically active women failed to take part mostly because of travel arrangements. The ethical committee of the Central Finland Central Hospital approved the study protocol and all of the subjects gave their written informed consent.

Table 10. Predetermined contraindications for exercise testing in elderly women (adapted from ACSM, 1995).

Recent (under 3 months) myocardial infarction or suspected myocardial infarction
Unstable coronary heart disease, angina pectoris at rest or during light activities (dressing, eating, washing)
Premature ventricular beats (over 30%)
Uncontrolled atrial arrhythmia influencing cardiac functioning (atrial fibrillation, sustained supraventricular tachycardia)
Third degree atrioventricular block, left bundle branch block (LBBB)
Pacemaker (fixed rhythm)
Recent systemic or pulmonary embolia (under 6 months)
Ventricular aneurysm
Cardiomyopathy
Severe stenosis of aortic valve
Deep vein thrombosis in the extremities or thrombosis in the heart
Suspected or diagnosed aortic aneurysm
Suspected or active myocarditis or pericarditis
Acute infection
Severe psychological distribution (psychosis, dementia)
Systolic blood pressure at rest over 200 mm Hg, diastolic over 120 mm Hg
Uncontrolled metabolic disease (diabetes, thyreotoxicosis, myxedema etc.)
Anemia (hemoglobin under 100 $g \cdot l^{-1}$)
Disorders of neuromuscular system (hemiplegia, osteoarthritis), which make cycling difficult
The subject refuses to exercise

5.1.2. Laboratory examinations

Before the laboratory investigations questionnaires were sent to the subjects to elicit background data concerning their health, medication, and physical activity. The laboratory examinations consisted of various anthropometric and physiological measurements. A detailed physical examination was done to establish he contraindications for the exercise test (Table 10).

Blood pressure, body height and weight, body fat, and 12-lead ECG were taken before the exercise. The bioelectrical impedance measurements were performed at 10.00-10.30 h. The machine was calibrated daily with standard resistor. Before the measurements the subjects had fasted 3-4 h and not exercised for at least 12 hours. In our laboratory, the coefficient of variation between two consecutive bioelectrical impedance measurements has been in the order of 2-3%. In addition erythrocyte sedimentation rate and blood hemoglobin concentration were measured before the exercise. Serum gamma glutamyltransferace, alanine aminotransferase activities, and creatinine concentration were analysed afterwards to exclude hepatic or renal disturbances.

5.1.3. Cycle ergospirometry

Subjects were to perform an exhaustive cycle ergometer exercise to their volitional maximum. The subjects were asked to keep the pedalling frequency within the limits of 50-60 rpm as far as possible and a weight of 200-300 g was added after every 2 minutes to the cycle's basket connected to a mechanical braking system (Monark 814 E, Varberg, Sweden). The mean incremental loading after every 2 minutes was 18 W, depending on pedalling frequency.

The subjects were encouraged to continue pedalling the ergometer to their personal maximum unless they experienced any exceptional symptoms (chest pain, dizziness, severe breathlessness, musculoskeletal pain). ECG leads II, V_1, V_5 and the well-being of the subject were monitored continuously; 12-lead ECG, and brachial arterial cuff pressure were recorded at minimum intervals of 2 minutes. Oxygen uptake, carbon dioxide production, ventilation, and respiratory exchange ratio (RER) were measured after each 30 seconds with a gas analyser (Minjhardt Oxycon-4, Odijk, Holland). The indications for exercise cessation were based on the guidelines of ACSM 1995 (Table 11).

The point of maximal effort was evaluated by the laboratory personnel on the basis of objective signs of subject's exhaustion i.e. breathlessness, or, if, for example, the pedalling frequency and work power consistently decreased in spite of the subject's effort. On the other hand if the exercise was terminated for medical criteria (Table 11) or if the subject suddenly stopped without having reached exhaustion, the test was considered submaximal. According to their ability to perform the exercise

Table 11. Predetermined indications for terminating the exercise (adapted from ACSM, 1995).

Systolic blood pressure rise over 250 mmHg, diastolic over 120 mmHg
Decrease in systolic blood pressure by more than 10 mmHg or unchanged in spite of loading
Angina pectoris
2 mm horizontal decrease or down-sloping ST segment in the exercise ECG
Rise in number of the ventricular premature beats (over 30% of the QRS complexes)
R on T premature ventricular beats
Sudden fall in heart rate in spite of loading
Sustained supraventricular tachycardia
Second or third degree atrio-ventricular block
Subject confused, poor co-operation or movement co-ordination
Subject's pallor, bluish skin, nausea
Severe pain in musculoskeletal system
Subject refuses to continue the exercise

submaximally or maximally, the physically active subjects and controls were divided into submaximally exercised (submax.) and maximally exercised subjects (max.).

5.1.4. Analysis of plasma C-ANP and N-ANP

To evaluate the cardiac load a 10 ml blood sample from subject's (sitting) cubital vein was taken by venapuncture in EDTA tubes immediately before and within one minute after the ergometer test for the plasma C-ANP and N-ANP analysis (Thibault et al., 1987). The subjects were highly co-operative and thus good quality samples were obtained in all cases except in three cases in which we failed to get a blood sample within a minute after the exercise.

The blood samples were placed immediately in ice and centrifuged within 60 minutes at +4 °C. Plasma was separated and stored at -80 °C for further analysis. Plasma C-ANP and N-ANP radioimmunoassays were carried out by using the methods described previously (Vuolteenaho, 1985a; Vuolteenaho et al., 1985b; Vuolteenaho et al., 1992). For the C-ANP assay plasma samples were extracted with Sep-Pak C18 cartridges (Waters, Milford, MA) with a recovery of 82 ± 10%. N-ANP was measured directly from 25 µl plasma samples. The sensitivities of the C-ANP and N-ANP assays were 2 $pmol \cdot l^{-1}$ plasma and 30 $pmol \cdot l^{-1}$ plasma, respectively. The intra- and interassay coefficients of variation were < 10% and < 15%, respectively.

The two blood samples for C-ANP and N-ANP analysis were also taken at 15-20 minute intervals from those subjects (n= 13) excluded from the exercise to determine the normal variability of C-ANP and N-ANP over time. N-ANP was measured in all of the 42 exercising *PA* and in 19 out of the 22 exercising CO. The sample size of N-ANP was reduced because of problems in the venapuncture of three subjects. C-ANP was measured in 30 exercising PA and 16 exercising CO. The marked reduction of 15 in the sample size of C-ANP was due to technical problems (12 because of technical failure in the centrifuge thermostat and 3 because of problems in performing the venapuncture).

5.1.5. Statistical analysis

All data were expressed as means ± SD. The difference between the groups at the baseline was analyzed with one-way ANOVA. The effects of physical loading on the response of C-ANP and N-ANP were assessed using ANOVA with repeated measures. Pearson's product moment correlation test was done to determine connections between C-ANP and N-ANP with the physiological variables. Multiple linear regression analysis was used to determine connections between aerobic capacity and the other variables. Subjects with β- blocker were excluded for all statistical analyses concerning heart rate and rate pressure product (RPP) data. An alpha level of 0.05 was set to mark statistical significance. The statistical software package used was SPSS for windows version 6.0 (SPSS Inc., USA).

5.2. The predictive value of exercise testing for survival among 75-year-old men and women (Study 2).

5.2.1. Study design

The study population and the laboratory examination protocol are presented in Figure 2. Complete background, exercise test and mortality data were finally obtained from 282 persons. The ethical committee of the University of Jyväskylä approved the study protocol and all of the subjects signed a written informed consent. About two weeks before attending the research centre all the subjects were interviewed individually at home on the subject of their health, current medication and living habits, e.g. current smoking and physical activity.

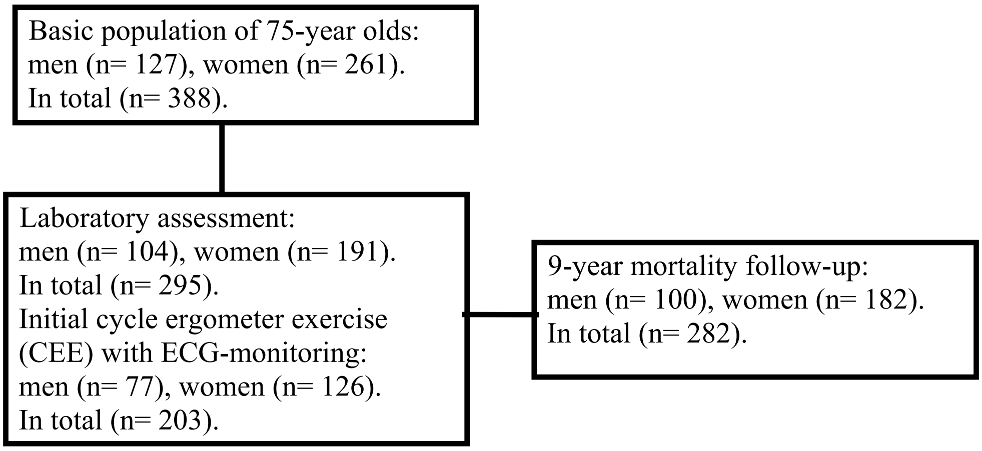


Figure 2. Design of the study (Study 2).

Physical activity was assessed by the question "Which of the following descriptions best corresponds to your current level of physical activity?" The subject selected one of six alternatives ranging from 1 (mostly light activities sitting in one place) to 6 (participating in competitive sports) (Grimby, 1986). Subjects were divided into three categories according to their physical activity level: category 1 (mostly light physical activities or activities sitting in one place), category 2 (moderate physical activities about 3 hours per week), category 3 (moderate physical activities or sports at least 3 hours per week or heavy physical activities at most 4 hours per week). Participation in competitive sports was excluded from the categories as it did not apply to any of the subjects. Physically inactive subjects were considered to belong to category 1, intermediately physically active to category 2, and physically very active to category 3. Current smoking status was categorized as non-smoking, smoking occasionally, or smoking daily.

At the research centre a standard physical examination was carried out by a physician to check general health and medication prior to the functional capacity tests. The number of chronic diseases was calculated according to physicians' diagnoses of chronic conditions lasted of over 3 months of duration. Blood pressure, body height and weight, and 12-lead ECG were recorded before attempting the cycle ergometer exercise. Body height and body mass were measured using standard procedures. Body mass index (BMI) was calculated as the relation of body mass (kg) to squared body height (m). In addition, blood hemoglobin, and glucose concentration were measured before the test. Hemoglobin A1c, total cholesterol and HDL-cholesterol concentrations were analyzed from serum samples afterwards. The contraindications for the cycle ergometer exercise were based on the guidelines issued by the American College of Sports Medicine 1986(a non-exercise test group).

A progressive cycle ergometer exercise was administered to 74.0% of the men and 66.0% of the women (77 men, 126 women). The indications for terminating the cycle ergometer exercise were assessed by the same physician (a specialist in sports medicine) on the basis of the guidelines issued by the American College of Sports Medicine 1986 (Tables 10 and 11).

The Ethical Committee of the University of Jyväskylä approved the study protocol and all of the subjects gave their written informed consent to participation in the study.

5.2.2. Cycle ergometer exercise

Subjects were to perform an exhaustive cycle ergometer test to their volitional maximum pedalling at a frequency of 50 to 60 rpm for as long as possible, and a weight of 300 or 600 g was added after every 2 minutes to the a load basket which was connected to the mechanical braking system of the ergometer (Monark 814E, Varberg, Sweden). The amount of work achieved during each minute was then calculated on the basis of the load and the actual number of revolutions, the latter registered by a counter. The average initial load was 29 watts, and the average incremental load 18 or 36 W. Oxygen uptake was not measured directly in this study.

The point of maximal effort was evaluated by the test personnel on the basis of objective signs of the subject's exhaustion, e.g., breathlessness, or when pedalling frequency and work power fell consistently in spite of the subject's efforts to maintain them (exercise test completion group). On the other hand the test was considered to have been

Table 12. The groups of subjects by gender (Study 2).

Group	Men n (%)	Women n (%)	Overall n (%)
Non-exercise test (NEX)	23 (23.0)	56 (30.8)	79 (28.0)
Exercise test termination (TER)	44 (44.0)*	51 (28.0)*	95 (33.7)
Exercise test non-termination (CMP)	33 (33.0)	75 (41.2)	108 (38.3)

* Statistically significant ($p < 0.05$) difference between genders (χ^2- test).

prematurely terminated if the exercise was stopped for medical reasons or if the subject suddenly stopped without having reached exhaustion (exercise test termination group). All the exercise tests were performed with the subjects on their current medication. Thirty-seven percent of the subjects were taking nitrates and 12% β- blockers. Digitalis and diuretics were being used by 21% and 27%, respectively.

The number of the subjects in the non-exercise test group (NEX), exercise test termination group (TER), and exercise test completion group (CMP) are presented in Table 12. The proportion of subjects whose exercise test was prematurely terminated was higher among men than among women (Table 12).

5.2.3. Analysis of mortality

Time of death for all participants who died during the nine-year follow-up was obtained from the official register of the province of Central Finland and from hospital records. The principal causes of death were classified and registered up until the year 1994 in accordance with the 1977 International Classification of Diseases (WHO, 1977) and thereafter in accordance with the 1992 International Classification of Diseases (WHO, 1992). Mortality was followed up from the baseline studies (1989 and 1990) until the end of 1998. Complete mortality data was obtained for all the deceased subjects. The most frequent causes of death were cardiac-related and ranged between 28 and 49% of cases in the different groups. The figures of deaths from cancer ranged between 12 and 36%.

5.2.4. Statistical analysis

Standard methods were used to calculate the means and standard deviations of the variables. Students t-test (two-tailed) or analysis of variance (ANOVA, Least Significance Difference test, LSD- test) were used in comparisons of means for continuous variables. Contingence tables and χ^2-test were used to compare categorical data.

Survival distributions were analyzed by using statistics D (Lee and Desu, 1972) for the non-exercise test group, exercise test termination group, and exercise test completion group. The Cox proportional hazards model (Cox, 1972) was used to estimate the relative risk for mortality in terms of exercise-test status, sex, various physical characteristics, health status, physical activity, and physical performance. Subjects who did not die during the follow-up were assigned a survival time of 9 years. For those who died during the follow-up, survival time was calculated as the time from the beginning of the study to the day they died.

Three main models were created to calculate the hazard ratios for death: Model 1 with unadjusted hazards ratios for all three study groups, Model 2 with adjusted hazards ratios for all three study groups, and Model 3 with adjusted hazards ratios for the exercise test completion group. The adjusted models were controlled by sex, number of chronic diseases, physical activity level, and, additionally in the exercise test completion group, cycling power. The adjustment was done step by step by adding one factor after another into the new model. The covariates included in the models were selected on the basis of their known or suspected association with mortality. Covariates not having a significant association with mortality were excluded from the main three final models presented in the results. The excluded covariates were BMI, smoking, blood hemoglobin, blood glucose, hemoglobin A1c concentrations, total cholesterol and HDL-cholesterol ratio. Cumulative models were created to calculate the hazard ratios between three groups: two sub-groups of the exercise test termination group, i.e., termination for cardiovascular reasons, and termination for other reasons, and an exercise test non-termination group.

The computations were done with SPSS 10.0 software (SPSS Inc., Chicago, IL).

5.3. Improving cardiovascular fitness by endurance and strength training (Study 3)

5.3.1. Study design

A postal questionnaire about health, medication, physical activity level, and functional status was send to a random sample of 76- to 78-year-old women (n= 240) drawn from the population register

Table 13. Baseline health and physical activity characteristics of the study subjects (Study 3).

Variables	**Endurance group (n = 15)**	**Strength group (n = 16)**	**Control group (n = 11)**	**p**
Number of medications (mean, SE)	2.2 (.5)	2.8 (.6)	3.2 (.7)	.535
Number of chronic diseases (mean, SE)	2.4 (.4)	1.9 (.3)	2.7 (.3)	.267
Ischemic heart disease (n)	5	3	6	.153
Hypertension (n)	4	4	3	.990
Musculoskeletal problem (n)	7	7	8	.287
Respiratory disease (n)	2	2	-	.455
Diabetes (n)	1	-	-	.398
Physical activity score	2.7 (.3)	3.0 (.2)	2.6 (.2)	.491

of the city of Jyväskylä, Finland. Of the 157 women (65.4%) who responded to the questionnaire, 65 women reported no severe diseases or functional impairments which could exclude their performing the cycle ergometer test and the subsequent strength or endurance exercise programme on the basis of a physician's evaluation and the guidelines for exercise testing and prescription issued by ACSM (Table 10).

Fifty-four women participated in the laboratory examinations. The remaining 11 who did not attend the laboratory examinations explained their non-participation by lack of time, travelling, and poor health. Forty-two women with no contraindications for physical exercise were randomly assigned to strength (n= 16), endurance (n= 15), and control (n= 11) groups. The randomisation 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 overcome the possible higher drop-out in the exercise groups. Some of the subjects had chronic conditions (Table 13) which, however, did not exclude them from physical training. Nine subjects had no prescribed medications, 13 subjects had a nitrate as medication, 9 subjects had a ß-blocker, and 6 subjects used calcium channel-blockers respectively. Only one person used digitalis. The level of physical activity in all of the groups studied averaged 3 in six class scale (Table 13), i. e. around 3 hours moderate physical activity per week, involving domestic tasks such as cooking, cleaning, straightening up the room, 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 eleven in the control group completed the intervention. Of the seven women who withdrew from the study, six stopped because of illness and one was unwilling to continue. The study was approved by the ethical committees of the Central Finland Central Hospital and of the University of Jyväskylä. A written informed consent was received from all the subjects.

5.3.2. Laboratory examinations

Body height and body mass were measured using standard procedures. Lean body mass (LBM), and body fat were assessed by bioelectrical impedance (Spectrum II, RJL Systems, Detroit, MI). Maximal isometric force was measured in a sitting position on a custom-made dynamometer (Sipilä et al., 1996).

A clinical examination, blood tests (glucose, haemoglobin, erythrocyte sedimentation rate), right brachial arterial cuff pressure after 10 minutes' rest, resting and exercise ECG preceded the exercise capacity tests to set the contraindications for exercise (Table 10).

5.3.3. Cycle ergospirometry

The subjects performed a symptom-limited cycle ergometer exercise to their volitional maximum according to the protocol described in the methods section of study 1. Oxygen consumption, carbon dioxide production, ventilation and respiratory exchange ratio were assessed by a gas analyser (Minjhardt Oxycon-4, Odijk, The Netherlands). The cycle ergometer and the exercise test were done at the baseline and after the 18-week intervention in all subjects. The strength measurements were additionally performed after 9 weeks of the intervention.

5.3.4. Physical training

Both exercise groups participated in an 18-week progressive physical training program which consisted of a 2-week orientation phase and a 16-week training phase. The subjects had supervised 1-hour training sessions twice a week during the orientation phase and three times a week during the training phase. At the beginning of each training session, both groups had a warm-up period of 10 minutes, including brisk walking and stretching. At the end of the session, stretching exercises for the major muscle groups were performed. The subjects in strength and endurance groups participated in 85-95% of the exercise sessions.

Strength group trained the major muscle groups (muscles of the thigh, calf and trunk) on equipment using compressed air as a resistance (HUR, Kokkola, Finland). The intensity of the training was gradually increased from 60% (first 3 weeks) of the 1 RM (repetition maximum) to 75% of the 1 RM (last 4 weeks). 1 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 one-repetition maximum test (1 RM) measured at 2-wk intervals. To obtain the 1 RM, the initial resistance was set close to the previous 1 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 5kg in the combined knee-hip extension.

After the 18-week training period, the 1RM values increased on the average 19 - 60 % depending on the muscle group tested. The individual variation between the two final 1 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 the repetitions.

The endurance group walked on an indoor track twice a week and had step aerobics 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 controlled by 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 walking distance during indoor walking increased from the average value of 1500 m (range 1200-2200 m) to the 2700m (range 2400-3300 m) in the end of the training period. The step-aerobics session lasted for 40 min, during stepping on a bench 0.10 m or 0.15 m in height.

Controls were instructed to continue their habitual physical activity levels. All subjects, including the subjects in the control group kept a diary concerning their physical activities during the intervention to detect possible changes in physical activity level. A routine clinical examination was repeated after 9 and 18 weeks of the intervention to 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 registered in 3 subjects in the training groups because of chest pains in order to exclude possible cardiac disease or dysfunction behind the symptoms.

5.3.5. Statistical analysis

Standard statistical procedures were performed to calculate means and standard errors (SE). The differences between the groups at the baseline were analysed using either the one-way ANOVA or chi-square test. The effects of training were assessed using two-way ANOVA with repeated measures. An alpha 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 was $p < 0.10$, the training effect was localised utilising simple contrasts with a $p < 0.05$. The statistical power of detecting a significant interaction was 0.614 for peak power ($W \cdot kg^{-1}$) and 0.238 for peak oxygen uptake ($ml \cdot kg^{-1} \cdot kg^{-1}$). The statistical software package used was Sigma Stat program version 2.0 (Jandel Scientific Corp, USA) or SPSS for windows (SPSS Inc., Cary, NC).

5.4. Cardiac adverse effects and acute exercise (Study 4)

5.4.1. Study design

The general design of the study is presented in Figure 3. The study population was the same as in study 2. The target population consisted of all 75-year-old residents of the city of Jyväskylä, Central Finland (n= 388). Of them 295 (76%) entered the laboratory for the assessment of their health and functional capacity (Heikkinen, 1997). Before entering the laboratory all of them were interviewed individually at home about their background data of health, functional capacity and living conditions. A questionnaire of health and physical activity was given to t he subjects to fulfil before entering to the laboratory examinations. Physical activity was assessed with the question "Which of the following descriptions best corresponds to your current level of physical activity?" The subject selected one of 6 multiple-choice alternatives (Grimby, 1986).

A detailed physical examination was done in the laboratory by a physician to check general health and medication prior to the functional capacity tests. Blood pressure, body height and weight, body fat

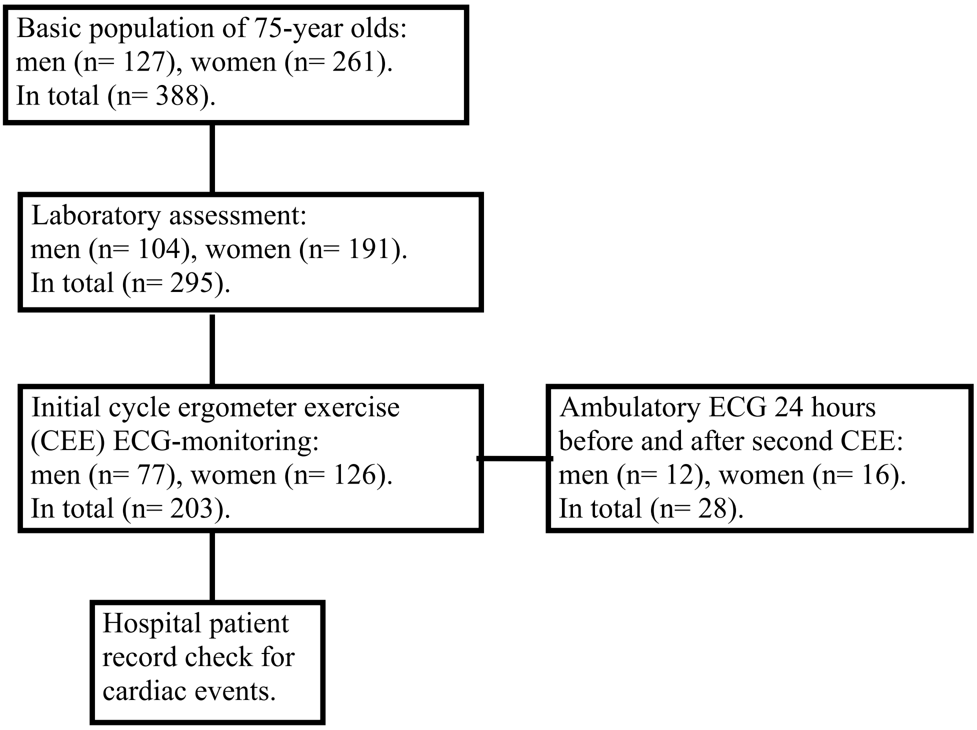


Figure 3. Design of the study (Study 4).

(by bioelectrical impedance, Spectrum II, RJL Systems, Detroit, MI), and 12-lead ECG were recorded before cycle ergometer exercise. In addition, the erythrocyte sedimentation rate, blood haemoglobin and glucose concentration were measured before the exercise. Total cholesterol and HDL-cholesterol concentrations were analysed from serum samples afterwards. The contraindications for cycle ergometer exercise were based on the guidelines issued by ACSM 1986 (Table 10).

A progressive cycle ergometer exercise was then administered to 74.0% of the men and 66.0% of the women (77 men, 126 women) (population group, PG). The indications for terminating the cycle ergometer exercise were assessed by the same physician (a specialist in sports and exercise medicine) on the basis of the guidelines issued by ACSM 1986 (Table 11). Maximal isometric strength measurements, 10-meter walking test, and stair-mounting test were performed by the subjects on the same day as the cycle ergometer exercise. Additionally, some psychological tests were administered in the intervals between the physical capacity tests. The subjects stayed in the laboratory for the assessments for an average of 6 hours on the same day.

Any possible contact by the subjects with the central hospital, to which all acute cardiac cases are referred, during the 24-hour period after the laboratory examinations was to be obtained from the hospital's patient records. Thirty-six subjects out of the PG were invited to the ambulatory ECG recordings and the second cycle ergometer exercise on the basis of the prior clinical examination, laboratory tests (blood hemoglobin and glucose, ECG) and initial exercise test on the cycle ergometer. Of this number 28 subjects (16 women and 12 men) with no contraindications to heavy physical exercise participated in the second cycle ergometer exercise and ambulatory ECG recordings (holter group, HG).

The primary inclusion criterion for the subjects in the HG group was that they were able to attain their peak physical effort in the initial cycle ergometer test. The second criterion was that the subjects should not have had any regular medications influencing on the amount of heart arrhythmia and ST segment changes. Thus, the subjects of the HG were free of any observable limitations on physical loading and were apparently healthy and asymptomatic of cardiovascular diseases. One person, however, had previously suffered myocardial infarction and one had mild bronchial asthma and medicated hypothyreosis.

The ethical committee of the University of Jyväskylä approved the study protocol and all of the subjects signed a written informed consent.

5.4.2. Cycle ergometer exercise

The subjects (both in PG and HG) were to perform

Table 14. Selected characteristics of the exercised physically active women and control women (Study 1). Values are means (±SD).

Charasteristic	Physically active women (n = 42)	Control women (n = 22)	*P* value
Age (yr)	73.9 (4.5)	74.3 (2.7)	.681
Height (m)	1.58 (.05)	1.58 (.05)	.579
Weight (kg)	59.7 (8.8)	73.0 (11.5)	< .001
Body fat (%)	25.1 (6.5)	34.2 (6.2)	< .001
Lean body mass (kg)	44.4 (4.3)	47.5 (4.9)	.012
Blood hemoglobin ($g \cdot l^{-1}$)	144 (9)	145 (8)	.524
SBP at rest (mmHg)	178 (25)	181 (21)	.504
DBP at rest (mmHg)	87 (11)	88 (11)	.737
Peak power (W)	95.6 (36.1)	68.2 (23.1)	.002
Peak power ($W \cdot kg^{-1}$)	1.61 (.62)	0.98 (.43)	< .001
Peak oxygen uptake ($l \cdot min^{-1}$) [a]	1.37 (.43)	1.15 (.19)	.023
Peak oxygen uptake ($ml \cdot kg \cdot min^{-1}$) [a]	22.6 ± 6.7	15.1 (3.0)	< .001
Peak RER [a]	0.91 (.09)	0.85 (.13)	.077
Physical activity ($km \cdot year^{-1}$) [b]	823 (705)	310 (285)	< .001

[a] n = 35 for physically active women, n = 13 for control women. [b] A weighted sum index was computed from self-reported annual walking (weighted by 0.6), running (1.0), cross-country skiing (0.7), swimming (4.0), cycling (0.3) on the basis of their relative energy expenditure and the average distance traveled within the time unit. Abbreviations: SBP= systolic blood pressure, DBP= diastolic blood pressure, RER= respiratory exchange ratio.

an exhaustive cycle ergometer exercise to their volitional maximum, as described in the methods section in study 2. All the exercise tests were performed with the subjects under their current medications. Thirty-seven per cent of the subjects were taking nitrates and 12% β-blockers. Digitalis and diuretics were being used by 21% and 27%, respectively.

5.4.3. Ambulatory ECG

Ambulatory ECG recordings were taken 24 hours before and after the cycle ergometry (HG). Portable two-channel tape recorders (Marquette Electronics Inc., USA) were used with electrode placement to obtain modified V_1 and V_5 leads. Before final electrode placement the height of the calibration signal and R-signal were checked (minimum 10 mm in the modified V_5) and the electrodes were replaced if necessary.

The recorders were applied between the hours 8-11 a.m. and were removed at the same time the following day. The subjects went home wearing the recorder on a waist belt and continued with their normal daily activities. They were asked to maintain the daily activities performed over the two consecutive 24-hour periods comparable. The subjects kept a diary of their activities and symptoms. They were also asked to push the 'event' button of the holter device if they had any exceptional symptoms, i.e. severe breathlessness, dizziness, feelings of arrhythmia or chest pains.

The ECG tapes were analyzed in the routine scanning mode with a Marquette Laser Holter (Marquette Electronics Inc., USA) electrocardioscanner by the same technician. The number of ventricular premature beats (isolated, couplets, runs), supraventricular beats (isolated, runs) and ST segment depressions were compared between the two consecutive time-matched recordings before and after the maximal exercise. Rhythm strips were obtained to document the complexity of arrhythmia and the nature of each ST segment depression.

The criteria for calculating ST segment depressions were as follows: every ST segment depression was checked and registered if it was ≥ 1.0 mm from the baseline at 60 milliseconds after the J-point and lasted at least 1.0 minute. There should also be an interval of at least 2 minutes between two separate ST segment depressions. In relative ST segment depressions the basal time constant was 2 hours. Slowly ascending, horizontal or downsloping ST segment depressions were taken into account for comparison. The recordings of 5 subjects were excluded from the data analysis, two because of poor quality of the ECG signal in the ambulatory ECG recordings, one because of incomplete exercise data, one because of left bundle branch block, and one because of β-blocker medication. Altogether the ambulatory recordings of 12 men and 11 women were available for the statistical analysis.

Table 15. Health status of the submaximally or maximally exercised subjects (Study 1).

	Physically active women		Control women	
	Submax. (n = 22)	Max. (n = 20)	Submax. (n = 19)	Max. (n = 3)
Age [mean (SD)]	75.5 (4.2)	72.2 (4.3)*	74.2 (2.9)	74.8 (2.4)
Chronic diseases per subject [mean (SD)]	2.1 (2.1)	1.8 (1.6)	4.3 (2.7)	4.7 (0.6)
Hypertension (n)	1	1	12	1
Cardiac valve disease (n)	1	1	-	-
Cardiac insufficiency (n)	-	1	4	1
Myocardial infarction (n)	-	-	-	-
Heart arrhythmias (n)	1	-	5	-
Angina pectoris (n)	1	1	6	-
Diabetes (n)	1	-	2	-
Osteoarthritis (n)	7	5	5	1
Back pain (n)	4	5	9	2

* $p < 0.05$ differs significantly from submaximally exercised subjects.

5.4.4. Statistical analysis
Standard statistical procedures were performed to calculate means and standard errors (SE). The differences between the men and women in the PG and HG were analysed doing T-test, Mann- Whitney Rank Sum test or Chi-Square test. The effects of physical loading on cardiac arrhythmia and ST segment depressions among both sexes were assessed using two-way ANOVA with repeated measures. An alpha level of 0.05 was set to mark statistical significance. The statistical software package used was SigmaStat program version 2.0 (Jandel Scientific Corp, USA).

6. RESULTS

6.1. Effort tolerance in elderly people with different physical activity backgrounds (Study 1)

6.1.1. Background data
The exercised physically active women (PA) and control women (CO) were comparable in age. PA were leaner than CO (Table 14). Submaximally exercised PA were somewhat older than maximally exercised PA. Cardiovascular and musculoskeletal problems were common in the groups studied especially among CO in submax. group (Table 15). Three of the exercised controls used digitalis medication and 4 used beta-blocker. Among the physically active elderly women 4 used digitalis and 2 used beta-blocker, respectively.

6.1.2. Cycle ergospirometry and aerobic capacity
Twenty-two of the 42 PA terminated the ergometer exercise before objective exhaustion, and of the CO only 3 out of the 22 went to the maximum. The most common reasons for termination among *PA* were the subject's own wish to stop or abnormal cardiovascular reactions. Among CO tiredness of the legs was also a common reason for termination (Table 16). In submaximal exercise PA differed from CO in aerobic performance characteristics only when expressed in relation to body weight. In maximal exercise the difference in peak heart rate and rate pressure product (peak RPP) reached statistical significance (Table 17).

Table 16. Reasons for early exercise termination in physically active (PA) and control (C) women (Study 1).

	PA women (n = 42)	CO women (n = 22)
Subject's own wish to stop	7	3
Feeling of exhaustion	0	1
Tiredness of legs	1	5
Breathlessness	0	1
Musculoskeletal pain	0	1
Heart arrhythmia	7	3
Abnormal blood pressure	7	3
Other	2	6

Aerobic capacity expressed in peak power and peak oxygen uptake was higher among PA than CO. This difference was more pronounced when the aerobic capacity figures were expressed in relation to body weight. The RER values tended to be lower among CO than PA (Table 17).

6.1.3. Assessment of cardiac load during exercise by C-ANP and N-ANP
Both C-ANP and N-ANP increased during physical loading in submaximal and maximal exercise (Figure 4a and 4b). No significant differences

Table 17. Selected characteristics in submaximal and maximal exercise among physically active and control women (Study 1). Values are means (SD).

	Submaximal exercise		**Maximal exercise**	
	Physically active women (n = 22)	**Control women (n = 19)**	**Physically active women (n = 20)**	**Control women (n = 3)**
Age (yr.)	75.5 (4.2)	74.2 (2.9)	72.2 (4.3)	74.8 (4.2)
Exercise duration (min.)	8.7 (3.5)	6.8 (2.4)*	12.5 (2.1)	10.7 (2.1)
Peak HR (bpm)	137 (23)	120 (18)*	152 (17)	127 (4)*
Peak RPP (beats$\cdot$mm^{-1} Hg$\cdot$min^{-1})	29030 (5840)	26430 (5620)*	33470 (5010)	25900 (3380)
Peak power (Watts)	76.8 (30.8)	63.7 (20.4)	116.3 (30.1)	96.3 (22.1)
Peak power (W$\cdot$kg^{-1})	1.27 (.48)	.86 (.31)**	1.99 (.54)	1.66 (.52)
Peak oxygen uptake (l$\cdot$min^{-1})[a]	1.17 (.37)	1.18 (.17)	1.56 (.41)	1.22
Peak oxygen uptake (ml$\cdot$kg$^{-1}\cdot$min^{-1}) [a]	19.1 (5.3)	15.2 (2.4)*	26.2 (6.2)	18.7
Peak RER [a]	.88 (.10)	.85 (.12)	.96 (.05)	.91

[a] n = 17 in submaximal exercise and n = 18 in maximal exercise for physically active women and N = 13 and N = 1 for control women. * $p < 0.05$ between the physically active and control women, **$p < 0.01$ between the physically active and control women. Abbreviations: Peak HR = peak heart rate in exercise, Peak RPP = peak value of multiple of SBP and HR in exercise, peak RER = peak respiratory exchange ratio.

between the groups were found in the effect of exercise on either C-ANP or N-ANP (ANOVA with repeated measures). The basal level of N-ANP among PA before submaximal exercise was, however, significantly higher than before maximal exercise among PA and higher than before submaximal exercise among CO (Figures 4a and 4b).

6.2. Exercise test outcome and mortality (Study 2)

6.2.1. The survival of the subjects

Of the 282 subjects, 117 (42%) died during the 9-year follow-up. In the non-exercise test group 49 subjects (62%) died, in the exercise test termination group 32 (34%) and in the exercise test completion group 36 (33%). The most frequent causes of death were cardiac-related and ranged between 28 and 49% of cases in the different groups. The figures of deaths from cancer ranged between 12 and 36%. The non-exercise test group had significantly higher mortality than the exercise test termination group. A similar difference was found between the non-exercise test group and exercise test completion group. No statistically significant difference was found in survival between the exercise test termination group and exercise test completion group either over the whole 9-year follow-up or after 4, 5, and 6 years of observation.

6.2.2. Cox proportional hazards models for mortality

The multivariate hazard ratio (HR) for death was 1.87 times higher among the subjects in the non-exercise test group than in exercise test completion group. A similar difference was found between the non-exercise test group and exercise test termination group (HR 1.97, CI 1.24 - 3.13). No statistically significant difference was found in the risk for death between the exercise test completion group and exercise test termination group.

The high peak cycling power in W$\cdot$kg^{-1} body weight was associated with reduced risk for death in Model 3 (multivariate HR 0.20; CI 0.08 - 0.50). In both models a high number of chronic diseases per subject was independently associated with an increased risk for death. Males were at increased risk for death in Model 3. Physical inactivity was independently associated with increased risk for death in Model 2. In this model the risk for death in relation to physical inactivity was defined as risk for death among the physically inactive subjects (category 1) compared to physically very active subjects (category 3). The risk for death among the intermediately physically active subjects (category 2) compared to risk for death among the physically inactive subjects (category 1) did not reach statistical significance.

The hazard ratio for death among subjects whose tests were terminated for cardiovascular reasons was 1.185 (CI 0.71 - 1.99) compared to the exercise test completion group in a non-adjusted model (data not shown). When both gender and cycling power were controlled the corresponding hazards ratio was 0.78 (CI 0.45 - 1.36). In the latter model male gender resulted in a hazard ratio of 2.33 (CI 1.36 - 3.98) and cycling power in W/kg of 0.31 (CI 0.17 - 0.55).

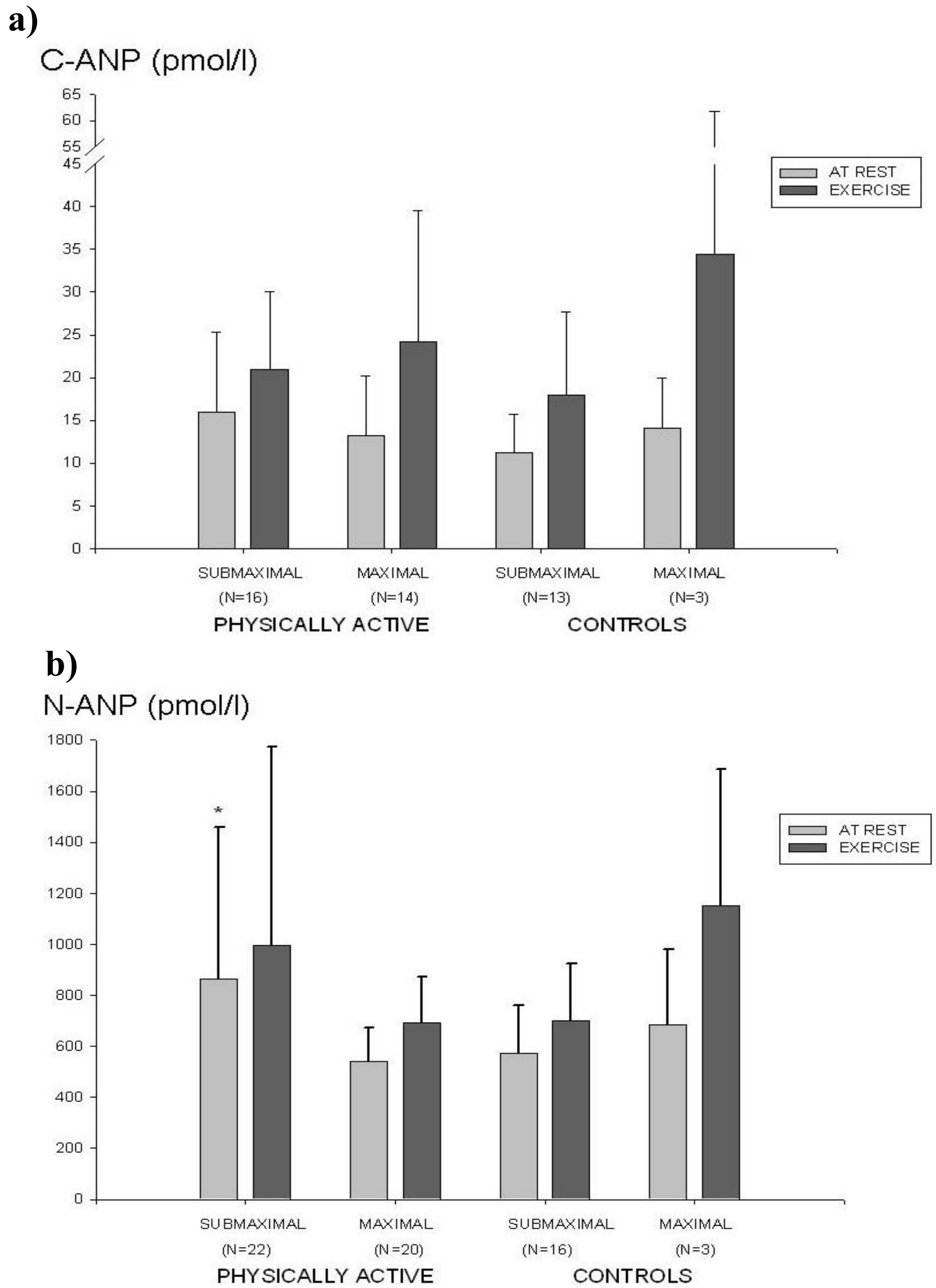


Figure 4. a) The plasma concentration of C-ANP at rest and after submaximal and maximal exercise (exercise) among two groups of elderly women (Study 1), **b)** The plasma concentration of N-ANP at rest and after submaximal and maximal exercise (exercise) among two groups of elderly women (Study 1). *Significant difference compared with the resting values of physically active maximal and control submaximal ($p < 0.05$).

6.3. Improving cardiovascular fitness by endurance and strength training (Study 3)

6.3.1. Background data

The medications, health characteristics, and physical activity level of the subjects at the baseline are presented in Table 13. No significant differences were found in these variables or in the baseline values of physical characteristics between the groups. Beyond the training induced in the trial, the study groups did not differ with respect to the initial level of physical activity, which remained constant throughout the experiment. Body fat decreased significantly among the subjects in the strength training group compared to the controls (Table 18).

6.3.2. Effects of training on aerobic capacity

Table 18. Physical characteristics of the study groups before and after the 18-week intervention (Study 3). Values are means (SE).

Variables	Endurance group (n = 12)		Strength group (n = 12)		Control group (n = 11)		ANOVA		
	Baseline	18 wk	Baseline	18 wk	Baseline	18 wk	Group	Time	Interaction
Body height (m)	1.57 (.02)	1.57 (.02)	1.60 (.01)	1.60 (.01)	1.59 (.02)	1.59 (.02)	.337	< .001	.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)	.972	< .001	.519
LBM (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)	.728	.706	.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)	.572	< .001	.078 *

Abbreviations: LBM = lean body mass; ANOVA = analysis of variance.
* Significant difference in the effect of time between the strength and control groups (p = 0.031).

There was a significant increase in peak power in Watts (W) in the strength training compared to control group (Table 19). Peak power in Watts·kilogram^{-1} body weight increased in both the endurance and strength training groups compared to controls. No interaction of group by time was found for peak oxygen uptake (Table 19). The respiratory exchange ratio (peak) did not differ between the baseline and after the 18-week intervention in any of the groups (Table 19). The mean percentage changes in peak oxygen uptake (ml·kg^{-1}·min^{-1}) in the endurance, strength, and control groups, respectively, were +6.8 %, +9.4 %, -6.2 %. The mean respective percentage changes in power (in W·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 5a and 5b).

6.3.3. Health problems emerged during the exercise intervention

Six subjects (19%) in the exercise groups withdrew

Table 19. Physiological characteristics of the study groups before and after 18-week intervention (Study 3). Values are means (SE).

Variables	Endurance group (n = 12)		Strength group (n = 12)		Control group (n = 11)		ANOVA		
	Baseline	18 wk	Baseline	18 wk	Baseline	18 wk	Group	Time	Interaction
HR at rest (bpm)	66 (3)	62 (3)	66 (4)	64 (3)	69 (2)	67 (2)	.809	.046	.530
Peak HR (bpm)	135 (4)	123 (4)	140 (3)	135 (6)	130 (7)	121 (5)	.144	.002	.478
SBP at rest (mmHg)	174 (15)	164 (16)	184 (15)	167 (14)	182 (15)	167 (15)	.577	< .001	.597
DBP at rest (mmHg)	83 (3)	80 (2)	80 (3)	78 (3)	84 (2)	81 (2)	.971	.054	.550
Peak power (W)	61.1 (3.2)	61.9 (3.2)	68.1 (3.1)	70.3 (4.1)	64.5 (4.3)	58.2 (3.9)	.972	.208	.077 [a]
Peak power (W·kg^{-1})	.91 (.04)	.93 (.06)	1.02 (.05)	1.05 (.07)	.98 (.07)	.88 (.06)	.260	.490	.053 [b]
VO_{2peak} (l·min^{-1})	1.15 (.05)	1.20 (.06)	1.21 (.07)	1.27 (.06)	1.15 (.08)	1.10 (.05)	.728	.706	.477
VO_{2peak} (ml·kg^{-1}·min^{-1})	17.1 (.1)	18.2 (.1)	18.1 (.1)	19.7 (.1)	17.3 (.1)	16.9 (.1)	.364	.102	.207
RER	.88 (.06)	.93 (.09)	.94 (.11)	.93 (.93	.89 (.07)	.89 (.08)	.297	.351	.335

Abbreviations: HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; VO_{2peak}, peak oxygen uptake; RER, respiratory exchange ratio; ANOVA, analysis of variance.

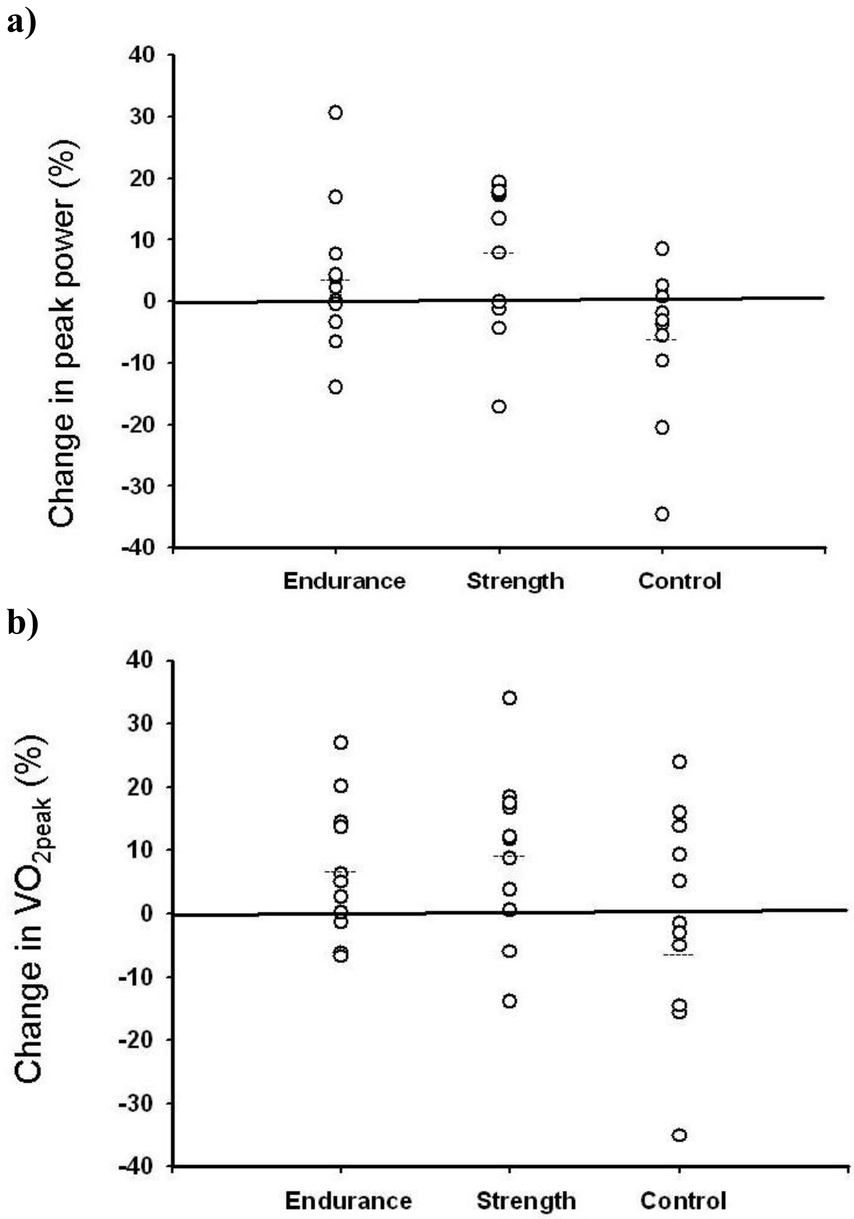


Figure 5. a) Individual percentage changes in peak power ($W \cdot kg^{-1}$) after 18-week programme (Study 3), **b)** Individual percentage changes in peak oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) after 18-week programme (Study 3).

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 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 two 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 ischemia. Another subject in the strength group sustained an unstable angina pectoris at 4 weeks into the intervention starting 2 days after the exercise session. She was operated successfully for three- vessel coronary heart disease. In her medical history she had been treated in the hospital 2 years before the exercise intervention for a chest pain attack, but this event was considered non-cardiac. A small painless and horizontal 1mm 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 suffer from occasional angina pectoris and dyspnoe when walking at 8 weeks into the intervention. No actual ST segment changes were seen in her resting ECG and the chest X-ray was normal. ST segment depressions were detected in her initial exercise ECG neither. A nitrate was prescribed for evident angina pectoris and the symptoms 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 dysartria 2-3 hours after the strength measurements at 9 weeks into the intervention. A neurologist made a clinical diagnosis of infarction of the brainstem. The symptoms gradually disappeared. Her exercise intervention 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 diameter of 5 cm was confirmed by ultrasonography. The subject was excluded from the final measurements and she was successfully operated 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.

6.4. Cardiac adverse effects and acute exercise (Study 4)

6.4.1. Cardiac disturbances during cycle ergometer test and cardiac adverse events after the test

In the population group (PG) the cycle ergometer exercise (CEE) was terminated in 23.4% of the men and 6.4% of the women because of cardiac arrhythmia or deep ST segment depression (gender difference, χ^2 = 10.93, p < 0.001). Almost twelve percent (11.7%) of the men were stopped because of deep ST segment depression compared to 5.6% of the women (gender difference, χ^2 = 1.70, p = 0.192). An increasing number of ventricular premature beats or multifocal ventricular premature beats was the reason for exercise cessation in 6.5 and 5.2% (men) and 0.8 and 0.8% (women) of the subjects (gender difference for the arrhythmia, χ^2 = 9.90, p= 0.002). No episodes of nonsustained ventricular tachycardia were detected in our subjects. One subject in the PG was referred to hospital immediately after the cycle ergometer exercise because of acute atrial fibrillation while performing it. The subject was treated successfully in the local hospital.

No other subject in the PG was referred to hospital within the 24 hours following the laboratory examinations. Seven performances (3 men and 4 women) out of 23 in the HG were submaximal. Five out of these seven were terminated for medical reasons, 3 cases because of deep ST segment depression and 2 because of bundle branch block.

6.4.2. Cardiac disturbances in the 24-hour ambulatory ECG recordings

As expected, the sum duration of the ambulatory ECG recordings was similar in time-matched pre-exercise and post-exercise periods in both the men and the women (holter goup, HG). Similarly, no gender differences were found in the minimal, average or maximal heart rates.

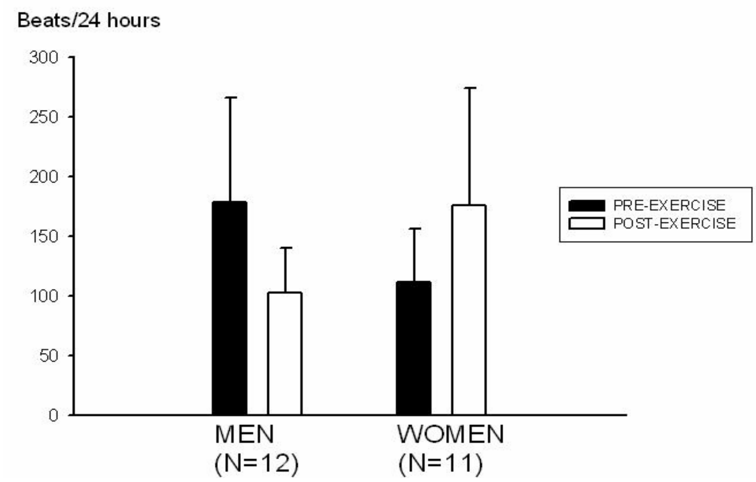
The men had a lower mean number of isolated ventricular premature beats in the post-exercise than pre-exercise period, whereas among the women the opposite was true (HG). However, the effect of exercise on isolated ventricular premature beats (p = 0.309) and isolated supraventricular premature beats (p = 0.251) did not differ significantly between the sexes in the HG.

Also, there were no statistically significant intragroup differences in isolated ventricular beats between the pre- and post-exercise recording periods among either in men (p = 0.665) or in women (p= 0.555) in the HG (Figure 6a). The same was true in isolated supraventricular premature beats (p = 0.795 and p = 0.896) respectively (Figure 6b). A corresponding result was found with the number of ventricular couplets, runs, and supraventricular runs, respectively (data not shown). Ventricular runs occurred in 2 men and 2 women having 1-5 episodes of ventricular runs with 3-5 consecutive beats at a rate of 121-147 beats per minute.

Totally of forty-five ST segment depressions (range -1.0 - - 7.1mm and 1.10- 41.50 minutes) meeting the criteria mentioned earlier were found among three men and four women in the HG during the two recordings. No angina pectoris was reported in relation to these ST segment depressions. The number of ST segment depressions was comparable between these two recordings, with 24 in the pre-exercise and 21 in the post-exercise period. In four subjects (three women and one man) the number of depressions, however, increased in the post-exercise period. In two subjects the number of ST segment depressions decreased (one woman and one man) in the post-exercise period and remained the same in one subject (a man).

Exercise had no significant effect in either gender on the variables related to ST segment depressions (Table 20). Men in the HG showed significantly more severe ST segment depressions than women as expressed in peak absolute ST depressions and ST-deviation time. Men tended also to have longer periods of ST segment depressions than women. There also was a tendency among men and women to have deeper ST segment depressions during the pre-exercise period than the post-exercise period (Table 20).

a)



b)

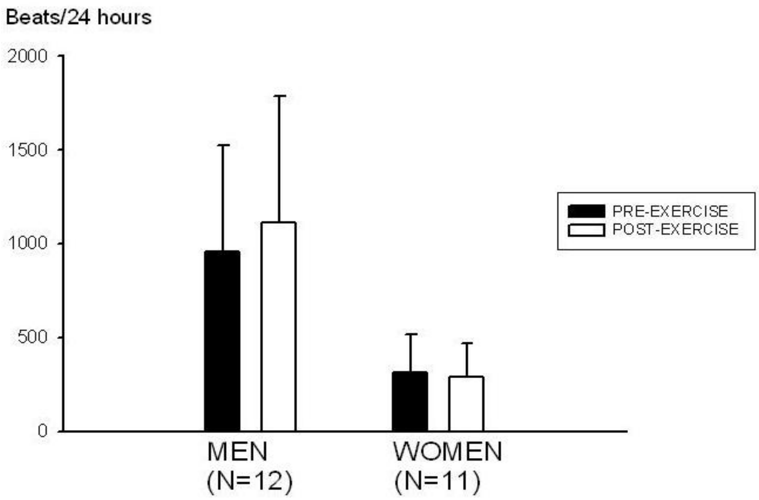


Figure 6. a) Isolated ventricular premature beats during pre-exercise and post-exercise ambulatory ECG recordings (Study 4) (mean, SD), **b)** Isolated supraventricular premature beats during pre-exercise and post-exercise ambulatory ECG recordings (Study 4) (mean, SD).

When looking at the time period surrounding the acute physical exercise (from 0,1, 2 hours pre- and post-exercise) the number of isolated ventricular premature beats increased considerably in relation to exercise in 5 cases in the men and in 4 cases among the women in the HG (data not shown). The number of isolated supraventricular premature beats increased in 6 cases among the men and 1 case among the women. Furthermore, the ST-deviation time was more pronounced in 7 cases among the men during the observation period (0, 1, 2 hours pre and post-exercise); a similar effect was seen in 2 cases among the women (data not shown).

In general, the cases of more marked arrhythmia and ST segment depressions occurred usually in the exercise hour, and during the pre- or post-exercise hour in both men and women. According to the two-way ANOVA, no significant gender differences were found in the HG in the effect of exercise on these variables. Differences in these variables between the recording hours and sexes did not reach statistical significance either.

7. DISCUSSION

It has been suggested that both beneficial and harmful effects result at a lower dose of exercise among elderly people than among younger people (Kallinen and Alen, 1995). The existing recommendations with respect to exercise doses differ between older and younger people, however, rather little (ACSM, 1998; 2000). Most of the former studies have found exercise to have substantial beneficial effects among selected groups of elderly people. In the present research the beneficial effect of physical exercise on cardiovascular fitness and effort tolerance was studied first, and the cardiovascular fitness among

Table 20. Basic characteristics of ST segment depressions in pre- and post-exercise ambulatory ECG. Values are means (±SE) (Study 4).

Variables	Men (n = 12)		Women (n = 11)		ANOVA significance		
	Pre-ex	**Post-ex**	**Pre-ex**	**Post-ex**	**Gender**	**Time**	**Interaction**
Number	3.33 (1.30)	2.00 (1.30)	3.50 (1.23)	3.70 (1.23)	.423	.698	.574
Duration (min) [a]	50.1 (12.5)	30.7 (12.5)	10.7 (10.9)	12.4 (10.9)	.090	.384	.308
Peak absolute (mm)	-4.3 (.9)	-2.2 (.9)	-1.7 (.8)	-1.2 (.8)	.002	.309	.510
ST-deviation time (mmmin) [b]	-110.8 (8.0)	-59.3 (28.0)	-11.8 (24.2)	-13.8 (24.2)	.052	.344	.310
HR at onset (bpm) [c]	91.1 (4.7)	83.9 (6.2)	93.1 (4.1)	99.9 (5.0)	.162	.975	.210
Peak HR (bpm) [c]	113.1 (7.6)	114.6 (8.0)	114.4 (6.6)	112.8 (6.8)	.982	.977	.614
HR-change (%)	25.0 (5.8)	36.6 (7.6)	26.0 (5.0)	16.6 (6.1)	.216	.854	.147

[a] Sum of the duration of all ST segment depressions. [b] Sum of the ST-deviation time. [c] Heart rate at onset (HR at onset), peak heart rate (Peak HR) and change in heart rate (HR-change) during ST segment depressions.

physically active women compared to that among less active sedentary women in a cross-sectional study. Secondly, the beneficial effect of an 18-week endurance and strength training programme on cardiovascular fitness was further studied among women aged 76 to 78 years in a population based randomized controlled trial. Possible harmful effects of physical loading were evaluated in relation to acute exercise in the form of a cycle ergometer test and in relation to 18-week endurance and strength training programmes. Furthermore, the value of exercise testing among community-dwelling elderly people was clarified.

7.1. Cardiovascular benefits of exercise

7.1.1. Cardiovascular fitness and effort tolerance among physically active women and less active control women (Study 1)

Physically active women had superior aerobic performance and effort tolerance compared to the less active control women (study 1). The physically active women had a peak oxygen uptake (in $ml\cdot kg^{-1}\cdot min^{-1}$) 25 and 40% higher than that of the control women in the submaximal and maximal cycle ergometer exercise tests. Forty-eight percent of the physically active women reached the objective maximum in the exercise test. The corresponding proportion in the less active control women was only 15%. In the large meta-analysis by Fitzgerald et al. (1997) and Wilson and Tanaka (2000) a comparable difference in aerobic capacity between physically active and sedentary subjects aged 18 to 89 years was found. Sixty-three and 75 percent higher aerobic capacity was, however, reported in the endurance trained men and women aged 18 to 89 years compared to sedentary controls (Fitzgerald et al., 1997; Wilson and Tanaka, 2000).

In the two meta-analysis (Fitzgerald et al., 1997; Wilson and Tanaka, 2000) physically active persons were defined as those who participated in occasional or irregular (≤ 2 times per week) performance of aerobic exercise (walking, basketball, dancing, stairmaster exercise, etc.). Sedentary subjects were defined as performing no aerobic exercise. Endurance-trained persons regularly performed vigorous endurance exercise (e.g. running, cycling, cross-country skiing) ≥ 3 $sessions\cdot wk^{-1}$ for ≥ 1 yr. Most of the physically active subjects in study 1 had a life-long physical training background and were still active in various sports (running, cross-country skiing, track and field, gymnastics). Additionally, a weighed sum of the annual training kilometres (walking, running, cross-country skiing, swimming, cycling) of the physically active persons was 2.7 times of the less active control women. The control women in study 1 performed only light physical activities (housekeeping, shopping, walking) and none of them reported regular endurance-type training or other vigorous physical exercise. The control women in study 1 were, however, not totally sedentary because of this physical activity during the activities in their daily living. The differences in defining the physical activity level make the comparisons of the magnitudes of the effect of physical exercise on aerobic capacity between the studies difficult. Nevertheless, physical exercise was found to have a marked beneficial effect on cardiovascular fitness in all age-groups in these cross-sectional studies.

In the meta-analyses by Wilson and Tanaka, 2000 age explained 65 to 75% of the total variance in the reduction in aerobic capacity. Body mass explained an additional 3 to 10% of the variance. In the two meta-analyses (Fitzgerald et al., 1997; Wilson and Tanaka, 2000) training dose (running mileage) was inversely associated with age in both men and women. This suggests a significant decrease in training dose with advancing age. However, the number of the subjects aged 70 years and over was limited in both meta-analyses and the associations between age, body mass, training kilometres and cardiovascular fitness in elderly people remained rather obscure. In study 1 among the women aged 66-85 years, age correlated negatively with cardiovascular fitness only in the physically active women, but no association between lean body mass and cardiovascular fitness was found. There was neither a significant association between age and physical activity (in kilometres) among the physically active women. Among the control women no association emerged between age and cardiovascular fitness. Lower lean body mass did not explain the higher peak oxygen uptake per body weight ($ml \cdot kg^{-1} \cdot min^{-1}$) among the physically active women as the absolute values ($l \cdot min^{-1}$) were also higher. It is suggested that the higher peak oxygen uptake in physically active women was due to their higher level of physical activity. However, the analysis concerning the associations between age, lean body mass, physical activity, and aerobic capacity suffer from a limited number of subjects and relatively narrow age range in study 1.

Chronic diseases and medication can also influence cardiovascular fitness and effort tolerance (see introduction). In study 1 the control women had twice as many diseases as the physically active women. It is evident that the higher prevalence of cardiovascular diseases among the control women than among their physically active age-peers had an impact on the difference in cardiovascular fitness between these two groups. The prevalence of musculoskeletal disorders was higher in the control than in the physically active women. Musculoskeletal problems may hamper the function of the lower extremities and thus be a limiting factor in a cycle ergometer test. The cycle ergometer test was used in these studies because it allows better control of movement and balance together with more precise monitoring of ECG and blood pressure. No difference in the respiratory exchange values between the physically active and control women was found. Also, the cardiac load assessed by N-and C-ANP increase during the exercise tests was comparable between the study groups. The cardiovascular and metabolic demand was thus comparable between the study groups during the cycle ergometric loading.

The results of cross-sectional studies usually suffer from selection bias. The most fit and healthy physically active persons are likely to continue their training into the later years of life. Those who get sick usually stop their training or decrease their level of physical activity. Thus cross-sectional comparisons between physically active persons and less active persons may, because of this selection bias, overestimate the benefits of physical training. Rogers et al. (1990) found, however, in their longitudinal study with a mean follow-up of 8 years one-half the rate of decline in aerobic capacity among those master athletes (mean age 62 years) engaged in regular vigorous endurance exercise than that prevalent among age-matched sedentary subjects.

7.1.2. High exercise capacity as a protective factor for survival (Study 2)

In study 2 peak cycling power (in $W \cdot kg^{-1}$ body weight) was a strong and independent predictor of death. In the non-adjusted models (not shown in the results) an increase in cycling power of one $W \cdot kg^{-1}$ decreased the risk for death by 97% during the 9-year period. 0.2 $W \cdot kg^{-1}$ cycling power is approximately equivalent to one MET (oxygen uptake 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ at rest). An increase in cycling power of 0.2 W/kg (approx. one MET) corresponded a 19% decrease in mortality risk. In the study by Goraya et al. (2000) an increase of 1 MET in maximal workload in a treadmill exercise test was associated with an 18% reduction in the risk for death among elderly persons. The decrease in the risk for death for every increase of 1 MET in exercise capacity was almost the same in younger persons (Goraya et al., 2000). Gulati et al. (2003) found a 17% reduction in the risk for death for every 1 MET increase in treadmill exercise capacity among middle aged women.

The magnitude of the association between high exercise capacity and low mortality found in this study conducted among elderly people is well in line with that reported in the scientific literature (Goraya et al., 2000; Gulati et al., 2003). Both men and women seem to benefit from this reduction in risk. In the study by Era et al. (2001) maximal cycling power in an ergometer test was associated with risk for death among 70-year-old men but not among women. Messinger-Rapport et al. (2003) reported that heart rate recovery and exercise capacity independently predicted mortality not only in older patients in general, but also in those aged 75 and older and among both sexes.

The association of physical activity and exercise capacity with mortality in elderly people can be explained in several ways. First, physical activity and fitness are closely related to each other. People with a latent or prevalent disease are evidently more passive as well as less fit than their healthier counterparts and thus more prone to die. The reason for this association could therefore arise from the selectivity of the study subjects rather than from the causal relationship between physical activity and physical performance and mortality. The protective effect of physical activity and exercise capacity on the progression of disease, and thus on premature death, could be another explanation for this association. Most of this protection is assumed to result from the beneficial effects of physical exercise on blood lipids, blood pressure, glucose metabolism, vascular function, autonomic tone, blood coagulation, and inflammation (Balady, 2002). This assumption is supported by research findings which show that among middle-aged and older men less fit and less active persons can improve their prognosis by increasing their level of physical activity or fitness (Dorn et al., 1999; Paffenbarger et al., 1995).

A consistent dose-response relationship between physical activity and mortality was not found. There was no difference in mortality between the physically very active and intermediately active subjects. Neither was there a significant difference in mortality between the intermediately and inactive subjects (not shown in the results). This may be due to our way of assessing the amount of physical activity, which may not be accurate enough. It is also possible that a certain exercise threshold is needed before the beneficial effects of exercise on mortality become evident.

7.1.3. Effects of endurance and strength training on cardiovascular fitness (Study 3)

Substantial and beneficial gains in cardiovascular fitness have been reported in most of the training studies conducted among elderly people. An increase in aerobic capacity of up to 38% with endurance exercise training has been reported among older people (Shephard, 1997b) depending on baseline aerobic capacity, exercise duration and frequency, and training modality. However, Benestad (1965) found no increase in VO_{2max} in elderly subjects following endurance training for 6 weeks. In this study the duration of the training bouts was less than 15 minutes and the subjects trained three times per week. Sidney and Shephard (1978) found a decrease in VO_{2max} following low-intensity and low frequency training. Other studies have also reported low gains in VO_{2max} following endurance exercise training among elderly people (DeVries, 1970; Foster et al., 1989).

Most of the former studies showing a substantial increase in VO_{2max} following endurance training have been conducted among selected samples of healthy elderly people, mostly among men under 75 years of age. The gain of 6.8% in cardiovascular fitness from endurance training found in study 3 is among the lowest reported. Study 3 was a randomised controlled trial carried out among elderly subjects age 76 to 78 years and with health problems. Considerable variation in individual gains in cardiovascular fitness was also found (Figure 5b). Kohrt et al. (1991) reported a mean increase of 26 (men) and 23% (women) in VO_{2max} with a range from 0 to 58% following 9-12 months endurance training among elderly persons aged 60 to 71 years. Age was not significantly associated with the gain of aerobic capacity in their study as the age range of the subjects was limited. In the meta-analysis by Green and Crouse (1995) both pretraining VO_{2max} and gain in VO_{2max} was inversely related with age among subjects aged 61 to 78 years. They also found that the length of the training intervention correlated with age the shortest training programmes been performed among older subjects. It was suggested that the lower gain in older people was because of the shorter duration of their programmes. In the meta-analysis 14 out of 29 studies were conducted without a control group and only 3 out of 29 studies were done among subjects older than 75 years. Furthermore, exercise intensity and VO_{2max} was variously reported in the studies included in this meta-analysis (Green and Crouse, 1995).

Exercise intensity, duration, frequency and length of exercise regimen are critical factors for the size of the gain in aerobic fitness following endurance exercise training among elderly people. In the meta-analysis by Green and Crouse (1995) mean duration of exercise was 32 minutes (range 12.5 – 60 min) per session and mean frequency of exercise was 3 times per week (range 2.5 -5.0). The mean length of the training regimen was 26 weeks (range 6 – 60 weeks). Unfortunately, the authors were unable to precisely quantify and code the exercise in these training studies. In the discussion the authors mention that eight different methods of prescribing intensity were used in these studies.

The frequency of the training in study 3 was 2 times per week in the 2-week orientation phase and 3 times per week in the 16-week training phase. The intensity of endurance exercise in study 3 was gradually increased from 50 to 80 of the initial heart rate reserve. The heart rate reserve method was used because it served to set reasonable training limits when compared to the corresponding oxygen uptake levels. It has been recently suggested that the percentage of maximal heart rate is the preferred method as it has been found to be more accurately related to oxygen uptake than the HRR method in older women and men (Kohrt et al., 1993; Kohrt et al., 1998; Panton et al., 1996). Puggaard et al. (2000) found an 18% improvement in VO_{2max} among 55 women aged 85 years following 8 months' endurance exercise training at an intensity of 69% of the HR_{max}. Morey et al. (1999) reported an 11% increase in VO_{2max} after 3 months' aerobic-only training at 70% of HRR among 134 subjects (both men and women) aged over 64 years. Malbut et al. (2002) found a 15% increase in VO_{2max} among women and no gain in men aged 79 to 91 years with a combined 24-week endurance and strength training programme at an RPE between 13 and 15. The women's initial mean VO_{2max} was only about 14 $ml \cdot kg^{-1} \cdot min^{-1}$, and therefore a further gain was likely to occur.

The gain in cardiovascular fitness was low in the training groups in study 3 when compared to results of earlier studies. It is probable that the low increase in aerobic capacity was due to the shorter duration of the exercise training programme in study 3. However, cardiovascular fitness declined during the intervention in the control group. The overall effect of training on cardiovascular fitness can be thus considered beneficial and significant. The basal peak oxygen uptake among the subjects in study 3 was 17-18 $ml \cdot kg^{-1} \cdot min^{-1}$. Even a small increase in elderly people may be enough to offset the deleterious effects of ageing. In the oldest old people maintaining a constant level of physical capacity over the final years of life may be an acceptable aim.

The effects of endurance and strength training on cardiovascular fitness may be more pronounced at the submaximal than maximal level of effort. In study 3 the average distance walked during the training sessions (endurance group) increased from 1500m (range 1200-2200m) to 2700m (range 2400-3300m) over the training period. Walking time increased from 20 to 30 min and training intensity from 50 to 80% of the initial heart rate reserve. When these facts are taken into account there is no clear evidence that submaximal working capacity increased in our subjects in the endurance group. In addition, our peak oxygen uptake values would represent submaximal aerobic capacity if RER (respiratory exchange) figures are taken into account (Table 19). It should also be kept in mind that present peak oxygen uptake values do not represent a pure measure of cardiovascular fitness but a combined measure of cardiovascular fitness, function and health. This is because a considerable number of the exercise tests were stopped for medical or other reasons. Peak HR was lower in the final exercise test in all 3 study groups. This was found not to be an indication of submaximal exercise levels in the endurance and strength training groups but due to the increased effect of β- blocking medication. One subject in the control groups stopped the exercise test in the early phase because of deep ST segment depression.

Strength training increased cycling power in study 3. Strength training may also stimulate the cardiovascular system and type I muscle fibres (slow-twitch) resulting in an increase in aerobic capacity. Other studies have also found an increase in endurance working capacity following strength training (Ades et al., 1996; Hepple et al., 1997). An increase in muscular endurance in the lower extremities makes it possible to achieve a higher work load in a cycle ergometer test. These findings suggest that improved endurance is not a function of cardiovascular fitness alone but can be significantly enhanced by increased muscular strength. The subjects in the endurance group also showed increased strength in the lower extremities. This could be due to the step aerobic training performed in the endurance group inducing a significant resistive stimulus in the muscles of the lower extremities.

7.2. Possible adverse effects of exercise

7.2.1. Adverse cardiac effects in exercise tests among elderly men and women (Study 4)

Acute physical exertion increases the likelihood of cardiovascular disturbances and sudden cardiac death. These adverse effects seem to be more pronounced among older than younger people (Gibbons et al., 1989; Mayuga et al., 1996).

A low frequency of cardiovascular complications in relation to exercise testing has mostly been reported in various study populations (ACSM, 2000). These studies have mostly been performed among selected groups and among subjects younger than 75 years. In study 2 the exercise tests were stopped in a considerable proportion of cases because of cardiac arrhythmia or ST segment changes. No complex cardiac arrhythmia or cardiovascular disturbances were detected. Cardiac arrhythmia and ST segment depressions were principally seen in close temporal proximity to exercise, i.e. during or 2 hours before or after exercise. These findings are well in line with earlier studies (Kennedy et al., 1977; Mittleman et al., 1993).

An increasing number of ventricular premature beats or multifocal ventricular premature beats were a more common reason for exercise test cessation among men than women. The same gender difference has also been found in another study (Hollenberg et al., 1998). It is suggested that this gender difference is due to the longer duration of the exercise test among men than among women. No exercise test- related complex arrhythmia or symptomatic ST segment depression was seen among elderly men and women. One subject in the population group, however, was referred to hospital because of acute atrial fibrillation when doing the test. This subject was treated successfully in the hospital. No other referrals to hospital were found in the hospital register check. The relatively high number of cases of cardiac arrhythmia events in relation to exercise tests generally calls for cardiac monitoring and careful clinical supervision both during exercise and in the immediate post-exercise cooling down period.

7.2.2. Medical problems during strength and endurance training programmes (Study 3)

Our subjects were medically screened according to standard criteria, the training supervised and the exercise programs individually tailored. In spite of these procedures there were five cases of cardio- or cerebrovascular health problems in the exercise groups. The rate of these health problems is among the highest reported in the existing exercise training studies among elderly people. Whether it was the physical training that caused these health problems is a difficult question to answer with any degree of certainty. Health problems of these kinds were likely to emerge in a larger group of subjects in exercise groups. Health changes in elderly women quite commonly manifest themselves within a relatively short period of time during normal life. It is more probable that declining health and symptoms of disease are detected better in elderly individuals engaging in physical training than among sedentary subjects. This is because the symptoms of the disease tend to become evident during physical exertion. In no cases among the present subjects were the incidents directly related to physical effort. In addition, on the basis of the distribution of the clinical findings in the exercise tests no adverse effects of exercise training on cardiovascular response were detected. However one subject in the control group had to stop the final exercise test suddenly because of deep ST segment depression. No cardiovascular complaints during the exercise sessions were detected. When asked by questionnaire, almost all of the subjects in the training groups considered the training beneficial to their fitness and health.

Most of the health problems emerged in the strength training group. The safety of strength training among healthy individuals seems to be well established. However, the effectiveness and safety of strength training among older subjects with low aerobic capacity has not been clarified (Pollock et al., 2000). Most of our subjects were slightly hypertensive and suffering from prevalent or latent atherosclerosis. This may increase the likelihood of cardio- or cerebrovascular events. An abrupt increase in aortic pressure due to the reflecting pressure wave component from the abdominal aorta meeting the systolic pressure wave has been shown in elderly subjects (O'Rourke 1990). Holding one's breath when making a physical effort considerably increases arterial pressure. These factors may have contributed to arterial wall damage and the incidence of cardio- or cerebrovascular disease. After one case of heart infarction and death the strength training programme was modified to exclude training directed at the trunk muscles. In addition, the subjects were asked not to hold their breath when performing the strength training exercises.

At the beginning of the programmes a 2-week orientation phase was used in which the frequency and intensity of the training was reduced. The newly revised ACSM guidelines for strength training in the elderly recommend a minimal resistance for the first 8 weeks to allow for connective tissue adaptations (ACSM, 2000). This is to avoid the kinds to musculoskeletal problems which also emerged during the training programme. It is unclear whether this is also of importance in avoiding cardiovascular problems.

With reference to the dose-response curves (Kallinen and Alen, 1995, Figure 1) it seems that among elderly people the beneficial and adverse effects of exercise emerge at lower doses of exercise than in younger people. Nevertheless, it is questionable whether a general dose-response curve could be set for a rather heterogeneous group of elderly people. The results of the training study showed that the responses of physical exercise on cardiovascular fitness, and perhaps on health as well were individually very variable and non-predictable. It is possible that both genetic, age- and disease-related factors determine the responses to physical exercise and that these effects can be quite fortuitous as far as the individual is concerned.

7.3. Value of exercise testing among elderly people (Study 2, 4)

The research results suggest that exercise testing was found useful from two points of views. At first, high occurrence of cardiac arrhythmia in relation to exercise testing, especially in elderly men, calls for cardiac monitoring during exercise testing and the immediate post-exercise recovery period (study 4). Although the data did not confirm that these cardiac disturbances were serious manifestations of an underlying cardiovascular disease, the data neither support the omission of ECG and blood pressure monitoring during maximal exercise testing among elderly people. Moreover, in some of elderly subjects, exercise ECG may reveal complex and life-threatening arrhythmias. These can be treated with modern medical technology or drugs. In accordance with the guidelines issued by ACSM and AHA , for safety reasons exercise testing with cardiac monitoring remains a recommendation for elderly people embarking on a vigorous exercise programme.

The most noteworthy finding in study 2 was that low exercise capacity in relation to cycle ergometric testing was a strong and independent predictor of death. Exercise testing provides prognostic information and is thus useful for elderly people in risk stratification. The usefulness of this information is, however, unclear. Whether we can prevent premature death in elderly people by increasing exercise capacity through exercise training or more active medical treatment remains an open question.

Elderly people are not a homogenous group in their physical capacity and health. A considerable proportion of the elderly cannot be tested (28% in study 2) by the usual methods of exercise testing. Those subjects excluded from exercise testing were found to be at increased risk for death (study 2). Thus, clinical assessment prior to exercise testing was also found useful in risk assessment. The preventive measures should be directed first to those people excluded from the exercise test. On the other hand, more sophisticated methods are needed to assess physical capacity in elderly people. The selection of the method of functional or physical capacity should be individualized in elderly people. The physical capacity of those with poor health and impairment in the management in activities in daily living can be assessed by questionnaires, interview, by direct observation in daily living or by simple functional capacity tests (Spirduso, 1995). When diagnostic procedures are needed pharmacologic testing is a method of choice among the elderly people who cannot be tested by conventional methods of exercise testing.

7.4. Plasma C-ANP and N-ANP as markers of cardiac load during exercise tests (Study 1)

Plasma N-ANP concentration has been found to be an accurate measure of symptomless left-ventricular cardiac dysfunction (Lerman et al., 1993). Both the C-ANP and N-ANP increased by physical loading in study 3. This is well in line with earlier studies (Freund et al., 1988; Baker et al., 1991; Mandroukas et al., 1995). The percentage increase in C-ANP correlated with a few physiological variables e.g. cycling power in $W{\cdot}kg^{-1}$ body weight. A corresponding association with N-ANP was not found. It is suggested that C-ANP may be more sensitive to acute response than N-ANP which has 5-10 times longer half-life than C-ANP (Thibault et al., 1988). The differences in the C-ANP and N-ANP responses may be due to postsecretory mechanisms.

The basal N-ANP concentrations in study 1 were highest in those physically active elderly whose exercise test was prematurely terminated. Does a high basal N-ANP level predict a premature exercise termination? Variable reasons were, however, associated with high basal levels of N-ANP in this group. Also in the control women a corresponding association with high basal levels of N-ANP and prematurely terminated exercise test was not found. To clarify the reason for this need further studies with more precise evaluation of cardiac function.

7.5. Methodological considerations

A population-based approach was taken to study the beneficial or possible harmful effects of exercise on the health of elderly people. In studies 2, 3, 4 the basic study group comprised of a representative sample taken from a population register. In study 1 the sedentary control women were randomly taken from a population register of the rural municipality of Jyväskylä. Physically active women in study 1 were selected from a sample of 600 members of Finnish sport organisations on the basis of physical activity questionnaire. The most physically active were invited to further studies. The subjects of this study are thus representative of either the normal population or the subset of physically active persons. Such a method of subject recruitment forms a good basis for generalizing the results.

Our criteria for exclusion or from stopping the exercise test were based on the guidelines issued by American College of Sports Medicine (American College of Sports Medicine, ACSM, 1986). These guidelines have remained largely unchanged the past 14 years (American College of Sports Medicine, ACSM, 2000). The relative exclusion criteria and indications for stopping the test in the ACSM 2000 guidelines were all incorporated in the guidelines used in this research. Some differences, however, existed between our and the ACSM 2000 guidelines. Electrolyte abnormalities and chronic infectious disease (mononucleosis, hepatitis, AIDS) are listed in the contraindication list as relative contraindications but were absent in our list (ACSM, 2000). Subject refusal, left bundle branch block and anaemia (hemoglobin under 100 $g \cdot L^{-1}$) were listed in our list of contraindications but are missing in the ACSM 2000 guidelines. Furthermore, in the ACSM 2000 recent myocardial infarction (within 2 days) or other cardiac event is an absolute contraindication for the exercise test. In our list recent (under 3 months) or suspected myocardial infarction is an absolute contraindication (Table 10). Acute pulmonary embolus or pulmonary infarction is an absolute contraindication in the ACSM 2000 guidelines, but the time after which the exercise test can be performed is not defined. In our guidelines this was within 6 months of the incidence (Table 10). Technical difficulties, ST segment elevation (≥ 1mm in other leads than V1 and aVR) were listed as absolute indication for stopping the test but were missing in our list (Table 11). R on T premature ventricular beats and severe pain in musculoskeletal system were included in our list of indications for stopping the test but are missing in the ACSM 2000 guidelines.

In study 1 some technical difficulties were encountered in measuring oxygen uptake directly in all of the subjects. The mouthpiece felt uncomfortable to some of the subjects, so we had to use an air-cushioned mask, which had to be positioned very carefully to avoid leakage of air from the mask. In spite of these precautions, it was impossible to measure the direct oxygen uptake in seven of the physically active women and nine of the control women.

The dose and duration of the strength and endurance exercise training used in this study (study 3) was sufficient for the improvement of cardiovascular fitness and muscular strength on the basis of the earlier studies (Charette et al., 1991; Shephard 1997b; McCartney et al., 1995; Taaffe 1996). The large variation in responses and the small number of subjects may limit the statistical power of these exercise effects. Furthermore, the subject's initial exercise capacity and physical activity level can modify the gain in exercise capacity. In the present study no significant correlation was in fact found between relative increase in aerobic capacity and initial exercise capacity or physical activity level. The effects of strength and endurance training on cardiovascular fitness may be influenced by differences in the level of loading of the initial and later exercise tests. The peak RER values were, however, comparable during the initial and later cycle ergometer tests. The RER values suggest that many of the exercise tests were submaximal and prematurely terminated because of abnormal cardiovascular responses. It is probable that low effort tolerance and decreased health hinder elderly women from being prescribed a sufficient exercise dose.

7.6. Strengths and weaknesses of the research

One of the main strengths of the present research is that a population-based approach was taken. Effort tolerance and cardiovascular responses to acute exercise were studied in relation to the whole-population study in the selected age-group. Few population-based studies have been performed to confirm the safety, substantial and consistent beneficial effects of physical exercise on cardiovascular functions and fitness. Earlier studies have been performed among selected populations with few or no health problems. Ageing, diseases, medications and physical activity level evidently modify the acute and prolonged effects of exercise on cardiovascular functions. There are, however, a number of factors which may complicate the interpretation of the results in population level studies. The heterogeneity of the population group means wide variation in the response, leading to loss of statistical significance. The drop-out rate in the training study raises doubts about the feasibility of the physical exercise among elderly populations even though the over-all effects of the present exercise were beneficial.

The mortality analysis in study 2 suffers from several methodological limitations. First, the low number of study subjects did not allow us to utilise other kinds of information, such as socio-economic factors, severity of disease, dietary factors, and alcohol consumption as cofounders influencing mortality. In addition, non-medical reasons for excluding subjects from the exercise test or for terminating the test render the interpretation of the data difficult. The subjects were representative only of a one-year birth cohort living in a small geographical area. Studying more people across a broader age range and over a larger geographical area would have allowed us to generalise the findings among elderly people with more certainty.

In the exercise intervention study we used a control group with randomisation. This is essential if the true effects of exercise are to be established in an elderly population in which decline in physical performance with ageing may occur in a relatively short period of time. The randomisation of the subjects was successful, because the groups did not differ significantly from each other at the baseline in relation to the variables used. Furthermore, no major changes in overall physical activity level were found in the control group. The controls simply continued to function at their habitual physical activity level and did not increase it.

Common standard exclusion criteria (ACSM) for physical exercise were used in this research. Efforts were made to ensure thorough medical supervision and careful monitoring of the subjects during the exercise test and training program. The adverse effects of exercise were detected by direct immediate monitoring, by ambulatory 24-hour monitoring, repeated clinical examinations, and also by checking the patient registers in the local hospital. By this way any immediate or prolonged adverse effect could be detected. Every exercise dose was also individually tailored according to commonly used guidelines. It is difficult to see improvement could in relation to the exclusion criteria and safety monitoring. However, our studies were performed a few years ago and the guidelines and methods used today are not exactly the same (see methodological considerations above). Different cohorts of elderly people may be different in health, medication, and levels of physical activity and thus show different responses to physical exercise.

A further weakness in this research concerns the relatively narrow age range (76 to 78 years) in the exercise intervention study. The responses to exercise training may differ between subjects under 70 years and those 80 years or older. The effects of physical training may also differ between the sexes. The effects of exercise training were studied only among elderly women.

7.7. Practical implications and suggestions for further research

Physically active elderly women had a markedly higher cardiovascular fitness and effort tolerance in the cycle ergometer test than their physically less active controls. This finding supports the argument that prolonged physical training together with better trainability results in improved cardiovascular performance and effort tolerance. The percentage increase in plasma C-ANP had a significant association with watts per kg body weight in the cycle ergometer tests among both the physically active and control women. C-ANP may be a useful measure of cardiac load in the context of exercise tests in elderly people.

High cycling power in the ergometer test was found to be strongly and independently associated with decreased mortality in both elderly men and women. The non-exercise test subjects were at an increased risk for death. The subjects with premature exercise test termination did not have excessive mortality compared to those with non-terminated tests. Exercise testing thus provides information on the risk for death that is incremental to clinical data and traditional risk factors in elderly people.

The 18-week endurance and strength training programmes resulted in a small and individually variable increase in cardiovascular fitness (peak oxygen uptake). It is noticeable that both endurance and strength training resulted in a significant increase in cycling power (watts per kg body weight) compared to the change in the control group. Strength training was directed at increasing the strength of the lower extremities, which is one of the important factors that determinants of performance in the cycle ergometer test. Strength training also resulted in a significant decrease in body fat compared to the corresponding change in the control group. Although the beneficial effects of strength and endurance training were quite small, both training methods are considered useful mean of resisting the deleterious effects of ageing on body composition and physical performance.

A considerable number of the exercise tests were terminated for cardiac arrhythmia and deep ST segment depressions. Although most of the cardiac disturbances were benign in nature, medical supervision and cardiovascular monitoring is recommended among people older than 65 years during maximal exercise tests. The ambulatory ECG recordings showed that the progressive exercise tests did not have a long-lasting increasing effect on cardiac disturbances among these elderly subjects. In some of the subjects, however, cardiac disturbances tended to occur within a period of 2 hours before and after the exercise test. Exercise-tested elderly persons should therefore remain under supervision during the immediate and late recovery period.

No serious complications were found in these studies in relation to the progressive cycle ergometer tests. Elderly subjects relatively seldom reach their peak aerobic capacity in exercise tests, which may be one factor protecting them against serious complications during such tests. During the strength and endurance training programmes all of the cardio- or cerebrovascular problems occurred unexpectedly in subjects who initially did not manifest that particular health problem. Are elderly people more prone to health problems with repeated physical loading than we have thought so far? How can such events be prevented and what are the optimal dose-response relationships in elderly people with low cardiovascular fitness and health problems? What factors influence individual responses to physical exercise in relation to physical performance and health? These are important questions that remain to be addressed in future studies.

8. CONCLUSIONS

1. Forty-eight percent of the exercise tests among physically active women and 14% in the less active control women continued to the objective maximum. In the maximal exercise tests mean peak oxygen uptake was 26.2 and 18.7 $ml \cdot kg^{-1} \cdot min^{-1}$ among the physically active women and control women, respectively. A markedly higher effort tolerance and aerobic capacity was found among the physically active compared to less active control women.

2. High physical capacity in the cycle ergometer test was independently associated with decreased mortality among elderly people. Exercise testing provides prognostic information that is incremental to clinical data and traditional risk factors for death.

3. The 18-week strength training resulted in a 9.4% increase in peak oxygen uptake while the endurance training improved peak oxygen uptake by 6.8%. A statistically significant increase in cycling power in watts per kg body weight was found in the strength training group compared to changes in the control group. A corresponding increase was also found in the endurance training group. Both endurance and strength training increased performance in the cycle ergometer test. The effect of the 18-week endurance and strength training programmes on peak oxygen uptake could, however, considered small in comparison to levels found in earlier studies.

4. Twenty-three percent of the cycle ergometric testing in the elderly men was stopped because of cardiac arrhythmia or ST segment depressions. In the elderly women the corresponding proportion was 7%. A considerable number of exercise tests in elderly people, especially among elderly men, are prematurely terminated because of cardiac disturbances. Cardiovascular monitoring is recommended in relation to exercise testing in elderly people for safety reasons.

5. Five cases of cardio- or cerebrovascular health problems emerged in the exercise training groups. These health problems were not directly related to physical exertion. Nevertheless, the adverse effects of repeated physical exercise cannot be ruled out.

6. The overall dose-response relationships of physical exercise need further clarification among elderly people in population-based, randomised controlled trials.

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