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Exercise for Health for Early Postmenopausal Women

In Search of the Minimum Effective Dose among Continuous and Fractionated Walking Programs

■

ACADEMIC DISSERTATION

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the Faculty of Medicine of the University of Tampere,
for public discussion in the main auditorium of Building B,
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To all the strong women in my family tree
and especially to my daughters
Maria-Karoliina, Reetta-Johanna, Julia-Kristiina and Sofia-Charlotta

Contents

List of orginal communications

This thesis is based on the following original publications:

I. Asikainen T-M, Kukkonen-Harjula K, Miilunpalo S. Exercise for health for early postmenopausal women, a systematic review of randomized controlled trials. Sports Med 2004; 34: 753-778.

II. Asikainen T-M, Miilunpalo S, Oja P, Rinne M, Pasanen M, Uusi-Rasi K, Vuori I. Randomized, controlled walking trials in postmenopausal women: the minimum dose to improve aerobic fitness? Br J Sports Med 2002; 36: 189-194.

III. Asikainen T-M, Miilunpalo S, Kukkonen-Harjula K, Nenonen A, Pasanen M, Rinne M, Uusi-Rasi K, Oja P, Vuori I. Walking trials in postmenopausal women: effect of low doses of exercise and exercise fractionization on coronary risk factors. Scand J Med Sci Sports 2003; 13: 284-292.

IV. Asikainen T-M, Suni J, Pasanen M, Oja P, Rinne M, Miilunpalo S, Nygård C-H, Vuori I. Effect of brisk walking in one or two daily bouts and muscular training on walking performance and lower limb muscular strength and balance in early postmenopausal women. A randomized, controlled trial. In press in July 2006. Physical Therapy.

V. Asikainen T-M, Miilunpalo S, Oja P, Rinne M, Pasanen M, Vuori I. Walking trials in postmenopausal women: effect of one vs two daily bouts on aerobic fitness. Scand J Med Sci Sports 2002; 12: 99-105.

In the text the publications are referred with their Roman numbers.

In addition, some unpublished data are presented.

Abbreviations

ACSM	American College of Sports Medicine
ANCOVA	analysis of covariance
BMI	body mass index
BP	blood pressure
CENTRAL	The Cochrane Central Register of Controlled Trials
CHD	coronary heart disease
CI	confidence interval
CV	coefficient of variation
d	day
ECG	electrocardiogram
EBSCO	Elton B. Stephens Company for information services
EEE	exercise energy expenditure
F%	percentage of body fat, ratio of body fat to body weight
g	gram
HEPA	health-enhancing physical activity
HDL	high-density lipoprotein cholesterol
HR	heart rate
HR_{max}	maximal heart rate
$HR_{65\%}$	heart rate corresponding to 65% VO_2
$HR_{75\%}$	heart rate corresponding to 75% VO_2
HRF	health-related fitness
HRT	hormone (replacement) therapy
kcal	kilocalorie
kg	kilogram
km	kilometer
LDL	low-density lipoprotein cholesterol
LTPA	leisure-time physical activity
MEDLINE	US National Library's search service for biomedical information
mmHg	millimeter of mercury
min	Minute
OGTT	oral glucose tolerance test
OPA	occupational physical activity
PA	physical activity
RER	respiratory exchange ratio
RCT	randomized controlled trial
1RM	one repetition maximum

SPORT SEARCH	sports search engine by sportinglife.com.
SD	standard deviation
TC	total cholesterol
TG	Triglyceride
VO_2	aerobic power, oxygen uptake
VO_2R	maximum oxygen uptake reserve
VO_{2max}	maximal aerobic power, maximal oxygen uptake
wk	Week
WT	UKK Walk Test
UKK Institute	Urho Kaleva Kekkonen Institute for Health Promotion Research
US	United States

Abstract

The general aims of this study were to assess the effects of exercise on the health for early postmenopausal women by searching for the minimum effective dose in a systematic literature review and by conducting two randomized, controlled exercise trials.

Early postmenopausal women have not been a common study group for exercise training. It was not until the 1980s that any good quality, randomized controlled trials (RCT) were carried out on postmenopausal women. Three reports were published in the 1980s. In the first half of the 1990s seven research reports were published, and in the second half of the 1990s nine appeared. After 2000 until June 2004 seven RCT reports appeared in the literature. Thus the effects of exercise on health are only partly known for this age group of women. The RCTs on the effects of exercise on maximal aerobic power, body composition and muscular strength showed that early postmenopausal women are trainable. But very few or none of the studies used light intensity aerobic training, fractionated aerobic exercise or resistance training with simple equipment. Very few or none of the studies showed what would be the effective exercise dose to improve submaximal aerobic capacity, blood pressure, body composition, carbohydrate and lipid metabolism, flexibility, and postural control. Feasibility-related information was also very sparse in these RCTs. With these questions in mind, the design of the experimental part of this study was formulated.

The effects of six light-to-moderate intensity, continuous, and fractionated walking and resistance training programs on the health-related fitness of sedentary early postmenopausal woman were assessed in a two RCTs. The possible interactions of hormone-replacement therapy (HRT) on the results was also studied. In addition the feasibility and safety of these exercise programs were assessed for the sedentary participants. The participants were healthy, sedentary women, 2 - 10 years past the onset of menopause and between the ages of 48 and 63 years. An equal number of women with and without HRT were accepted. In the two studies of this research project, Study I and Study II, 134 and 121 participants, respectively, were randomized, HRT users and non-users separately, into exercise and control groups. The exercise intensity was planned to range from light-to-moderate (i.e. 45%, 55% or 65% of the maximal aerobic power (VO_{2max})). The weekly exercise volume was set at 1500 kcal or 1000 kcal. The exercise frequency was chosen to be 5 days a week, and the length of intervention was 15 or 24 weeks. Each day's training was continuous or fractionated (in Study I) into two equal sessions with at least a 5-hour interval. There was also a short resistance training program in Study I.

Among the six exercise regimens of this study, the minimum effective dose of exercise needed to improve most of the selected cardiorespiratory and morphological fitness components (maximal aerobic power (VO_{2max}) as measured by a maximal exercise test, submaximal capacity as measured by heart rate levels corresponding to 65% and 75% of the VO_{2max}, and the proportion of body fat estimated by skinfold measurement) was the smallest exercise dose. It included walking at an intensity of 45% VO_{2max} on 5 days a week, expending 1000 kcal (46 minutes) in weekly exercise for 24 weeks.

The minimum effective exercise dose to improve the metabolic components (blood glucose, diastolic blood pressure and body mass) and also the rest of the chosen cardiorespiratory and morphological fitness components of health-related fitness (HRF), was the largest exercise dose. It included walking at an intensity of 65% VO_{2max} continuously or fractionated into two exercise bouts on 5 days a week, expending 1500 kcal in weekly exercise in one (47 minutes) or two (2 x 24 minutes) exercise bouts per training day for 15 weeks. Approximately 15-20 minutes of moderate resistance training twice a week was combined with walking. This exercise regimen also improved walking performance and lower-extremity strength. The participants using and not using HRT had equal results for all of the chosen variables of HRF.

These exercise regimens were feasible for the participants. They adhered well to the program. The dropout rate was low. There was only a small risk of injury. Most of the participants did not consider the exercise program to be too strenuous. Approximately half of the participants in the continuous exercise groups had some mild, transient lower-extremity complaints, especially at the beginning of the exercise intervention. Those in the fractioned exercise groups had statistically significantly fewer lower-extremity complaints. Starting a regular exercise program seemed to provide the participants with more positive experiences than remaining sedentary in the control group did, regardless of the exercise dose.

The largest exercise regimen used in this study seems to be a feasible, practical minimum dose for health-enhancing physical activity for sedentary, early postmenopausal women to use to start improving most of the components of HRF. For more definite improvements, and also for improving other components of metabolic, musculoskeletal and motor fitness (lipids, muscle performance of the trunk and upper extremities, balance and flexibility), the exercise dose should be increased.

This study increased the knowledge on light intensity aerobic training for early postmenopausal women. It is the first study to show effects of fractionated aerobic exercise in this age group of women. It is also the first study to show any effect of exercise training on diastolic blood pressure and fasting blood sugar concentration in healthy, early postmenopausal women. It is also one of the few studies that used an exercise training program that can be performed home based; walking and resistance training with simple equipment. Feasibility-related information was also actively gathered. This is the first study to show that fractionated exercise causes fewer exercise-related lower limb problems that continuous.

There still remain unanswered questions concerning the effects of exercise on health-related fitness on early postmenopausal women. More RCTs are needed, especially on the effects of exercise on lipid levels, balance and flexibility. The interactions of HRT and exercise should be studied more in randomized, controlled settings.

Tiivistelmä

Vaihdevuosien aikana elimistön pienenevä estrogeenipitoisuus saattaa edesauttaa naisen verenkierto- ja hengityselimistön kunnon laskua, lihasvoiman heikkenemistä, luun haurastumista sekä painon nousua, erityisesti liikuntaa harrastamattomilla naisilla. Nämä kaikki nostavat riskiä sairastua yleisiin kansantauteihimme, kuten sepelvaltimotautiin, tyyppi 2 diabetekseen ja osteporoottisiin luunmurtumiin. Liikuntasuositukset perustuvat tietoon, jota on kerätty sekä väestötutkimuksista että liikuntaharjoittelututkimuksista. Näitä on tehty valtaosin miehille eikä niitä siksi sellaisenaan voida, asiaa tutkimatta, yleistää koskemaan vaihdevuosi-ikäisiä naisia. Suoritetun systemaattisen kirjallisuuskatsauksen perusteella tämän ikäryhmän naisia on tutkittu kovin vähän. Tämän tutkimuksen satunnaistetut, kontrolloidut liikuntainterventiot kohdistettiin juuri näihin vähiten tutkittuihin alueisiin terveyskunnosta.

Terveyskunnolla tarkoitetaan tässä niitä kunnon osa-alueita, joilla on terveysyhteyksiä: sydän- ja verenkiertoelimistön kuntoa, kehon rakennetta, tuki- ja liikuntaelimistön kuntoa, motorista kuntoa sekä aineenvaihdunnan "kuntoa". Terveysliikunnalla tarkoitetaan tässä sellaista liikuntaa joka tuo terveyshyötyjä, on liikkujalle sopivaa, eikä aiheuta hänelle haittavaikutuksia.

Tutkittavat olivat 48 - 63 vuotiaita naisia, joiden vaihdevuodet olivat olleet (kuukautiset loppuneet) 2 - 10 vuotta aiemmin. He olivat terveitä, tupakoimattomia, normaalipainoisia tai lievästi liikapainoisia, eivätkä harrastaneet säännöllistä ripeää liikuntaa kuin korkeintaan kerran viikossa. Mukaan valittiin yhtä paljon hormonihoitoa käyttäviä ja ilman sitä olevia naisia. Ensimmäiseen osatutkimukseen osallistui 134 naista ja toiseen 121.

Liikuntaharjoittelu suunniteltiin American College of Sports Medicine -järjestön liikuntasuosituksen mukaiseksi. Liikunnan tehoksi valittiin suosituksen alarajalla olevaa kevyttä kävelyä ja siitä asteittain nousevia tehoja ripeään asti, eli 45%, 55% tai 65% maksimaalisesta hapenkulutuksesta. Näitä vastaaviksi keskimääräisiksi liikuntaryhmien tavoitesykkeiksi saatiin maksimaalisen rasituskokeen perusteella 118, 124 ja 131 lyöntiä minuutissa. Liikunnan kesto laskettiin yksilöllisesti sen perusteella, että viikoittaiseksi energiankulutukseksi valittiin joko 1500 kcal (keskimääräinen kesto 47 minuuttia 65% teholla, 54 minuuttia 55% teholla ja 65 minuuttia 45% teholla liikuttaessa) tai 1000 kcal (38 minuuttia 55% teholla ja 46 minuuttia 45% teholla liikuttaessa). Harjoittelua tehtiin viidesti viikossa ja päivittäin liikuttiin yhdessä tai kahdessa erässä. Osa ryhmistä teki myös 15 - 20 min voimisteluohjelman kahdesti viikossa. Siinä oli 8 kohtuuteholla tehtyä dynaamista lihaskuntoharjoitetta suurimmille lihasryhmille, jotka toistettiin 10 kertaa. Ohjelmaan kuului myös liikehallintaa kehittämään

suunniteltuja harjoitteita sekä suurimmille lihasryhmälle venytykset. Harjoittelujakso kesti yhteensä 15 tai 24 viikkoa.

Mittaukset tehtiin ennen ja jälkeen harjoittelujakson. Maksimaalinen hapenkulutus ja submaksimaaliset sykevasteet 65% ja 75% tasolla maksimihapenkulutuksesta mitattiin suoran, maksimaalisen kävelymattotestin avulla. Lepoverenpaine mitattiin ennen testiä. Kehon koostumus arvioitiin mittaamalla pituus, paino ja neljä ihopoimua, joista laskettiin painoindeksi ja arvioitiin rasvaprosentti. Aineenvaihduntaa kuvaavina mittauksina käytettiin paastoverenglukoosia ja paastoinsuliinia. Lisäksi ensimmäisessä osatutkimuksessa mitattiin sokerirasituksen aikana 1 ja 2 tunnin glukoosin ja insuliinin pitoisuudet. Veren rasva-aineenvaihduntaa selvitettiin mittaamalla kokonaiskolesterolin, LDL-kolesterolin, HDL-kolesterolin ja triglyseridien paastoarvot. Lihaskuntotestit valittiin eri testistöistä niin, että ne olivat mahdollisimman sopivia koehenkilöille. Eurofit-testistöstä valittiin dynaaminen vatsalihastesti. UKK-terveyskuntotestistöstä valittiin askelkyykky alaraajojen voiman mittaamiseen ja staattinen selkälihastesti vartalon ojentajien lihaskestävyyden mittaamiseen. Invalidisäätiön toistotestiä käytettiin yläraajojen voiman mittaamiseen. Kudosten notkeutta arvioitiin UKK-terveyskuntotestistön vartalon sivutaivutustestillä. Tasapainoa mitattiin UKK-terveskuntotestistön yhden jalan seisontatestillä. UKK-kävelytestillä mitattiin kävelyaika 2 kilometrillä. Kävelyaika kuvastaa tässä sekä sydän- ja verenkiertoelimistön maksimaalista ja submaksimaalisesta suorituskykyä että kävelykykyä sinänsä myös tuki- ja liikuntaelimistön- ja motorisen kunnon kannalta.

Pienin annos, jolla saatiin 24 viikossa vaikutusta koehenkilöiden lähes kaikkiin sydän- ja verenkiertoelimistön kunnon ja kehon koostumuksen mittareihin (maksimaaliseen hapenkulutukseen, submaksimaalisiin sykearvoihin ja rasvaprosenttiin) oli tämän tutkimuksen pienin liikunta-annos. Kävelyn teho oli siinä 45% maksimihapenkulutuksesta. Liikunnan viikoittainen energiankulutus oli 1000 kcal. Tämä koostui keskimäärin 46 minuutin kävelyistä viitenä päivänä viikossa.

Pienin annos, jolla tässä tutkimuksessa saatiin vaikutusta edellisten lisäksi myös diastoliseen verenpaineeseen, kehon painoon ja veren glukoosiin oli suurin käytetty liikunta-annos. Siinä kävelyn teho oli 65% maksimaalisesta hapenkulutuksesta. Kävely tehtiin joko yhtäjaksoisesti tai kahteen päivittäiseen liikuntakertaa jaettuna niin, että se kulutti 1500 kcal viikossa. Tämä koostui 47 minuutin kävelyistä tai kahdesta 24 minuutin päivittäisestä kävelylenkistä viitenä päivänä viikossa. Lisäksi ohjelmaan kuului 15 - 20 min voimisteluohjelma kahdesti viikossa. Tämä ohjelma paransi 15 viikossa edellä lueteltujen kuntomuuttujien lisäksi myös kävelytestillä mitattua kävelyaikaa ja alaraajojen lihasvoimaa. Hormonikorvaushoitoa käyttävät koehenkilöt saivat samanlaisia tuloksia kuin sitä ilman olevat, eli liikunta oli kummallekin koehenkilöryhmälle yhtä tehokasta.

Käytetyt liikuntaharjoitteluohjelmat olivat sopivia ja toteuttamiskelpoisia tälle kohderyhmälle, joka sitoutui liikuntaohjelmaan hyvin. Tutkimuksesta pois jääneiden lukumäärä oli hyvin pieni. Myös vammojen määrä oli pieni. Useimmat pitivät liikunta sopivana myös rasitustasoltaan. Noin puolella koehenkilöistä oli lieviä, ohimeneviä alaraajavaivoja erityisesti ohjelman alkuvaiheessa. Alaraajavaivoja oli kahteen päivittäiseen jaksoon jaetun liikunnan ryhmässä merkittävästi vähemmän kuin yhtäjaksoisen liikunnan ryhmässä. Lisäksi se, että aloitti säännöllisen liikunnan, näytti lisäävän liikkujilla merkittävästi myönteisten tuntemusten määrää vertailuryhmään nähden. Myönteisten tuntemuksien määrä ei riippunut liikunta-annoksesta eikä siitä miten paljon kunto nousi.

Suurin käytetty liikunta-annos, ripeätehoista kävelyä noin 30 - 60 minuuttia viidesti viikossa yhdistettynä 15 - 20 minuutin kohtuutehoiseen voimisteluohjelmaan kahdesti viikossa, vaikuttaisi olevan liikuntaa aiemmin harrastamattomille, terveille vaihdevuosi-iän ohittaneille naisille suositeltava minimimäärä terveysliikuntaa, jolla aloittaa liikunta. Liikunnan voi halutessaan jakaa kahteen päivittäiseen jaksoon. Tällöin osalle liikuntaan tottumattomista ilmaantuvat, enimmäkseen totutteluvaiheen tuki- ja liikuntaelimistön kuormitustuntemukset vähenevät, mutta liikunnasta saadaan samat terveyshyödyt kuin yhtäjaksoisesti liikkumalla. Tällä liikunta-annoksella voidaan saavuttaa terveyskunnon kohenemista sen useimmilla osa-alueilla. Rasva-aineenvaihduntaa, vartalon ja yläraajojen lihasvoimaa ja liikehallintaa parantavien vaikutusten saavuttamiseksi liikuntaa pitää tästä lisätä.

Tämä tutkimus toi uutta tietoa liikunnan annos-vaste suhteista ja erityisesti matalatehoisen liikunnan terveysvaikutuksista vaihdevuosi-iän ohittaneille naisilla. Kyseessä oli ensimmäinen tämän kohderyhmän tutkimus, jossa saatiin tuloksia pätkiin jaetulla liikunnalla. Aiemmin ei ole myöskään tällaisella kohderyhmällä saatu liikuntaharjoittelulla vaikutuksia verenpaineeseen tai sokeriaineenvaihduntaan. Tämä oli yksi niitä harvoja tutkimuksia, jonka liikuntaohjelma on helposti sovellettavissa kotiharjoitteluun, ja johon riittävät yksinkertaiset välineet. Myös liikunnan soveltuvuudesta tälle ikäryhmälle tuotettiin uutta tietoa. Tämä oli ensimmäinen tutkimus, jossa todettiin pätkiin jaetun liikunnan aiheuttavan merkittävästi vähemmän tuki-ja liikuntaelimistön kuormitustuntemuksia liikuntaan tottumattomalle kuin yhtäjaksoisen liikunnan.

Vaihdevuosi-iän ohittaneiden naisten liikuntaharjoittelussa on kuitenkin vielä paljon tutkittavaa. Satunnaistettuja, kontrolloituja tutkimuksia tarvitaan erityisesti siitä, minkälaisella harjoittelulla voitaisiin parhaiten vaikuttaa rasva-aineenvaihduntaan, tasapainoon ja kudosten venyvyyteen. Myös hormonihoidon ja liikunnan mahdollisista yhteisvaikutuksista tarvitaan lisää tietoa.

Introduction

One might assume that, since the health effects of exercise are so widely accepted, they have been accepted for a long time - also for postmenopausal women. But this is not the case. Only 50 years ago, a book on the scientific basis of athlete training claimed that *"at puberty development of ability for strenuous exercise stops or even declines in girls while it continues to advance in boys"* (Morehaus and Rachs 1958). Some 40 years ago, it was understood that young girls and boys are equally trainable, but *"in females regular sport maintains maximal efficiency at a constant level from the age of sixteen to that of thirty years and then decreases"* and *"after the age of sixty, there is practically no observable effect"* (Hollmann 1964). It was not until 30 years ago that the first evidence was found that also postmenopausal women are trainable (Kilbom and Åstrand 1971, Adams and de Vries 1973, Drinkwater 1973, Drinkwater et al.1975). Today we know that postmenopausal women are not only trainable, but really need exercise for their health.

Menopause is defined as a natural age-related decrease and, finally, loss of ovarian estrogen production and secretion. Decreasing the estrogen level may start a rapid decline in aerobic fitness, muscle strength, and bone mineral density, in addition to weight gain, all of which increase the risk for many chronic diseases, for example, coronary heart disease (CHD), type 2 diabetes, and osteoporotic fractures - especially among sedentary women (Sowers and La Pietra 1995, Wilson 2003).

When a person approaches old age, low fitness and an increased number of chronic diseases is not only an individual problem leading to disability and lower quality of life, but also a problem of public health leading to a high cost for society (Colditz 1999, Garrett et al. 2004). Increased physical activity can partially reverse these events. Early postmenopause is an important phase in women's lives, if sedentary, in which to start to exercise (Taylor et al. 2003).

Exercise recommendations are based both on epidemiological evidence and on exercise trials, which have, for the most part, been conducted on men, and thus they may not be completely valid for postmenopausal women. In order to evaluate the relevance of these recommendations for early postmenopausal women, additional information should be obtained for this age group, especially from randomized, controlled trials (RCT's) that take gender into consideration.

Review of the literature

1. Definitions of physical activity and fitness

1.1. Basic terminology

The basic terminology of exercise physiology includes special terms, such as physical activity, leisure-time physical activity, occupational physical activity, health-enhancing physical activity, and exercise (Howley 2001). *Physical activity (PA)* is defined as any bodily movements produced by contractions of skeletal muscles that substantially increase energy expenditure. *Leisure-time physical activity (LTPA)* is described as any activity one participates in during free time, based on personal interest and needs. These activities include sport and formal exercise programs, as well as walking, hiking, gardening, dance, and the like that result in substantial energy expenditure, although the intensity and duration may vary considerably. *Occupational physical activity (OPA)* is defined as PA within the time-frame of 8-hour work day. *Health-enhancing physical activity (HEPA)* can be described as the kind of PA that will enhance health and not be harmful (Bouchard and Shephard 1994).

Exercise (or exercise training) is a subcategory of LPTA, in which planned, structured and repetitive bodily movements are performed to improve or maintain one or more components of fitness (Howley 2001). The most important main categories of exercise (training) are *aerobic exercise* (training) and *resistance exercise* (training) (Howley 2001, Bouchard and Shephard 1994, ACSM 1998a).

Aerobic exercise involves large muscle groups in dynamic activities that results, if effective, in improvements of function of especially the cardiovascular system and the skeletal muscles, leading to an increase in endurance performance (Howley 2001). Aerobic exercise can be of *high-impact* or *low-impact* type. A simple definition of high-impact exercise would be any activity in which one's feet leave the ground at the same time. Jumping rope, running, and jumping jacks are high-impact exercises. Whereas walking, cycling and swimming are examples of low-impact aerobic exercise.

The *exercise dose* in aerobic exercise training is usually described by the intensity, duration, and frequency of the training session, and in exercise trials also by the length of the exercise intervention (Howley 2001). *Intensity* is usually described as relative intensity, a percentage of the person's maximal aerobic power (VO_{2max}) or maximal heart rate (HR_{max}). *Duration* refers to the duration of a single exercise session. *Frequency* refers to the number of weekly exercise sessions. PA is behaviour that results in increased energy expenditure. The total volume of training accomplished, expressed as exercise energy expenditure (EEE), can also be used to describe exercise dose. *EEE* combines the factors of intensity, frequency, and duration of exercise but, on the other hand, loses some of the information, since different combinations of these factors may add up to equal EEE (Howley 2001, ACSM 1998a).

Resistance exercise is basicly designed to improve or maintain muscular strength, power, and endurance (Howley 2001). The exercise dose in resistance exercise training is usually described by the magnitude of resistance, the number of repetitions the resistance is moved in a single set of resistance exercise training, the number of sets done, and the length of the resistance training program. *Muscular strength* is a measure of a muscle's ability to generate force, *muscular powe*r is a measure of the rate at which force is generated, and *muscular endurance* is a measure of the ability of a muscle to make repeated contractions against constant resistance. Muscular strength is usually expressed as one-repetition maximum (1RM) for dynamic measurements (Howley 2001, ACSM 1998a).

Physical fitness is defined as a set of attributes (cardiorespiratory endurance, skeletal muscle strength, skeletal muscle power, flexibility, agility, balance, reaction time, and body composition) that people can have or achieve that relate to the ability to perform physical activity (Howley 2001). The term physical fitness is usually used in a performance-oriented context. *Health-related fitness* (*HRF*) is used to describe the components of physical fitness related to health (Bouchard and Shephard 1994).

1.2 Health-related fitness and health-enhancing physical activity

The health effects of PA can be analyzed and studied on the basis of the concept of health-related fitness. This concept was introduced in the 1990s (Bouchard and Shephard 1994). The components of HRF, as described in the original text, are cardiorespiratory, morphological, musculoskeletal, motor, and metabolic fitness (Table 1).

__Table 1.__ Components of health-related fitness (HRF,) modified from Bouchard and Shephard (1994)

Components	**Factors**
Cardiorespiratory fitness	Maximal aerobic power
	Submaximal cardiorespiratory capacity
	Blood pressure
Morphological fitness	Body composition
	Bone strength
Metabolic fitness	Carbohydrate metabolism
	Lipid metabolism
Musculoskeletal fitness	Muscular strength and endurance
	Flexibility
Motor fitness	Postural control

The factors of *cardiorespiratory fitness* are maximal aerobic power and submaximal cardiorespiratory capacity. Resting blood pressure (BP) can also be described as one of the factors, although it was not in the original list of factors. Good cardiovascular fitness prevents CHD and lowers all-cause mortality. *Morphological fitness* includes body composition and bone strength. Body composition is related to the incidence of CHD and type 2 diabetes, and bone strength is associated to osteoporosis and osteporotic fractures. *Musculoskeletal and motor fitness*, which includes muscle strength and endurance, flexibility, and postural control, is needed to preserve good functional capacity to ensure independent living during old age. These factors also prevent falls. Good musculoskeletal fitness has also been shown to be associated with low all-cause mortality (Rantanen 2003). Good *metabolic fitness*, as indicated by normal carbohydrate and lipid metabolism, reduces the risk of CHD and type 2 diabetes mellitus (Bouchard and Shephard 1994).

The concept of *health-enhancing physical activity* was adopted in a preparatory meeting supported by the European Commission and arranged by the Urho Kaleva Kekkonen Institute for Health Promotion Research (UKK Institute) for developing European strategies for HEPA (Vuori et al. 1996). HEPA can be described as the kind of PA that will enhance health and thus improve HRF. The essentials for HEPA are that physical activity should not only be effective, but also safe and feasible for the participant.

2. Dose-response issues concerning physical activity, fitness and health

2.1. General principles

The first basic principle of the dose-response relationship for PA and fitness is *overload* (Kesäniemi et al. 2001). Any physical activity will cause acute responses in cardiovascular and muscular systems, but only the dose of exercise that exceeds the habitual activity of an individual will cause training effects, if repeated. Thus an initially sedentary, low-fit person will undergo fitness improvement with a smaller exercise dose than a person who is initially more active and fit. When habitual PA increases, the dose of exercise that is needed to produce training effects increases. The training program must be *progressive* in order to increase fitness (Kesäniemi et al. 2001).

The greater the exercise dose (= intensity x frequency x duration), the greater the response (Kesäniemi et al. 2001). Intensity, frequency, and duration are, to some extent, *interchangeable* parameters of the exercise dose. It is possible to "trade duration for intensity" (i.e., choose a longer duration and lower intensity), and keep EEE constant. EEE is not, however, always a useful description of exercise dose, if exercise intensity is not taken into account. Equivolume exercise doses with different intensity have different effects on, for example VO_{2max}. An exercise dose with high exercise intensity and short duration will improve VO_{2max} more than an equivolume exercise dose with low exercise intensity and long exercise duration (Kesäniemi et al. 2001, Hardman 2001).

An important basic principle of the dose-response relationship for PA and fitness is the fact that all of the effects of PA are *site-specific*. Only those structures and bodily functions that are trained will develop responses. For example, strength training of the legs does not affect the arms, shoulders, or trunk muscles (Kesäniemi et al. 2001).

Acute effects of PA refer to any physiological and health-related changes that occur during and in hours of PA. For example the lowering of the resting blood pressure or improving insulin sensitivity and lipid metabolism after an exercise session are acute effects of PA. Chronic effects of PA occur over time due to the changes that PA has caused in the structure or function of various body systems. These are also called *training effects*. Muscular hypertrophy is an example of the training effect of PA. Thus exercise training will cause acute effects and also training effects if the exercise dose is adequate and the exercise sessions are repeated. Some of the effects of PA are combinations of both (Kesäniemi et al. 2001).

If a curve is drawn to illustrate the relationship between the exercise dose and training effects, the shape of the curve might be linear, as it is in the case of PA and all-cause mortality rates. In this case, an increase in PA will cause a corresponding decrease in all-cause mortality. The curve could also be such that small increases in PA from sedentary to active produces the largest benefits. At higher levels of activity, the extra benefit for health from training becomes small. This is assumed to be the case for most of the health effects of PA, for example, for resting blood pressure. The curve could also be such that only a considerable large dose of exercise produces the effect. For example, most of the harmful effects of exercise, overuse injuries, and cardiovascular accidents follow such a dose-response curve (Kesäniemi et al. 2001).

A basic principle of the dose-response relationship for PA and fitness is also the fact that there is great amount of individual *variability* in responses to a given amount of PA. This variability is due to hereditary factors (Bouchard and Rankinen 2001). An important dose-response principle is also the fact that all of the training effects of PA are *reversible* and will disappear with time if the exercise training is stopped (Kesäniemi et al. 2001).

2.2. Development of exercise recommendations

Interest in the performance-related effects of PA dates back to early civilizations, but the start of scientific study of the healthful effects of PA started in the 1920s (Montoye 1992). By 1978 the basic principles of the dose-response issues of PA, fitness, and health were gathered to form the first exercise recommendation of the American College of Sports Medicine (ACSM) (ACSM 1978). This recommendation focused on developing and maintaining cardiorespiratory fitness and body composition. Cardiorespiratory fitness, as assessed by VO_{2max} was considered the most important factor of fitness, since it had been found to be inversely related to all-cause mortality and cardiovascular diseases, especially to CHD. The recommended frequency of aerobic exercise training was 3-5 $d{\cdot}wk^{-1}$, the recommended intensity of training was 50-85% VO_{2max}, and the recommended duration of training was 15-60 minutes per session. The minimum recommended exercise intensity was moderate, but higher intensity was discovered to lead to greater improvements in the VO_{2max}. Thus the recommendation was often interpreted by health and exercise professionals as encouraging people to exercise as strenuously as possible and to participate in sport-like exercise modes, for example, jogging (ACSM 1978).

As the first ACSM exercise recommendation (ACSM 1978) focused on developing and maintaining cardiovascular fitness and body composition, the second ACSM exercise recommendation (ACSM 1990) focused on both of these and also included resistance training for muscular strength and endurance. The recommendation for aerobic exercise training was similar to the earlier one, the only difference being that the recommended duration had a sligthly longer minimum. The recomended duration was 20-60 minutes. The recommended frequency was 3 to 5 $d{\cdot}wk^{-1}$, but 3 $d{\cdot}wk^{-1}$ was considered optimal, since the added improvement qained by increasing the frequency to 5 $d{\cdot}wk^{-1}$ was small (ACSM 1990).

ACSM classified exercise by its intensity as very light (< 10%VO_{2max}), light (30-49% VO_{2max}), moderate (somewhat hard) (50-74% VO_{2max}), heavy (75%-84% VO_{2max}) and very heavy (> 85% VO_{2max}) (ACSM 1990). Light exercise was not considered effective for healthy adults, although for elderly and initially very low fit persons, it was assumed to have positive effects. The interest in moderate exercise, such as walking, was growing because of its feasibility and safety. Reports of sudden cardiac death during PA showed that high exercise intensity is related to this risk (Jokl and Melzer 1971, Vuori et al. 1982, Lavie et al.1992, Parkkari et al. 2004) and also to the risk of orthopedic injury (Pollock and Willmore 1990), especially among the elderly (Parkkari et al. 2004).

Strength training of moderate intensity, sufficient to develop and maintain fat-free weight, was recommended to be an integral part of an adult fitness program. One set of 8-12 repetitions of 8 to 10 exercises that condition the major muscle groups at least 2 $d \cdot wk^{-1}$ was considered the minimum. (ACSM 1990).

In 1993 ACSM focused solely on health-aspects in a recommendation for physical activity and public health (U.S. Centers for Disease Control and Prevention and American College of Sports Medicine 1993, Pate et al. 1995). The previous recommendations were primarily considered performance-related, and a more health-related approach was chosen for this recommendation. The epidemiological evidence for PA and health had been growing, and, in addition to CHD, PA was considered to be beneficial also with respect to many other diseases, for example, hypertension, type 2 diabetes, osteoporosis, colon cancer, anxiety, and depression. Experimental studies had also shown that exercise training influenced CHD risk factors such as blood lipid profile, resting blood pressure, glucose tolerance, and insulin sensitivity. Improvements in bone density, immune function and psychological function had also been recognized (Pate et al. 1995).

A few experimental studies (DeBusk et al.1990, Ebisu 1985) had shown that intermittent exercise was as effective as continuous exercise. Thus the *accumulation of exercise* was included as a principle in the recommendation. The purpose of this new recommendation was to lower the threshold to start exercise training by making the recommendation less demanding and simpler. It was also assumed that, even if the exercise dose would not be enough to improve VO_{2max}, it might have beneficial health effects. Thus it was recommended that *"every Amercian adult should accumulate 30 minutes or more of moderate-intensity physical activity over the course of most days of the week"*. Some of the health effects of exercise training were assumed to be at least partly acute effects of exercise, and thus it would be beneficial to exercise frequently. The dose-response relationship on health effects was not known, but it was a common view that the best effects on public health could be achieved as sedentary people become moderately active (Pate et al.1995).

Finally, the latest ACSM exercise recommendation for cardiorespiratory and muscular fitness, and flexibility was published in 1998 (ACSM 1998a). This recommendation combined the previous recommendations and also added flexibility training to the recommended exercise program. The aerobic exercise training recommendation was equal to the previous recommendation, with the exception of lowering the border of exercise intensity to 40/50% VO_{2max} reserve and allowing the fractionation of the exercise duration of 20-60 min to be 10-minute exercise bouts.

The minimum effective dose of exercise was discussed in this latest ACSM exercise recommendation (ACSM 1998a). The focus was on moderate exercise training, and even light exercise training was considered beneficial because the minimal threshold for improving fitness/health was considered variable at the lower end of the intensity scale. The initial level of fitness and also age had been found to greatly affect this minimal effective exercise dose. The minimal exercise dose was assumed to be usually less than the optimal exercise dose. For many fitness components, for example, for VO_{2max}, a mostly linear dose-response relationship could be demonstrated, in other words, the larger the exercise dose, the greater the effect. On the other hand, the smaller the exercise dose, the safer and more feasible the exercise training would be for a sedentary person. The risk for the adverse effects of exercise, complaints of overuse, injuries, and cardiovascular or other systematic accidents, increases as the exercise dose increases. The optimal dose would thus be large enough to ensure the positive effects on HRF, but also small enough to keep the risk low. It was understood that the two opposite needs had to be balanced (Haskell 1994, Pate 1995, Pate et al. 1995, ACSM 1998a).

The latest ACSM recommendation also discusses the total volume of exercise and the minimum volume of exercise. When exercise was performed above the minimum intensity threshold, the total volume of training accomplished, expressed as EEE, can also be used to describe exercise dose. For example, the exercise dose of 200-300 kcal per session was recommended for weight loss (for a 75-kg person) by ACSM (1998a). The Harvard study showed about a 40% reduction in age-related mortality among men at an EEE of 1500 $kcal \cdot wk^{-1}$(Paffenbarger 1986). Hambrecht (1993) concluded, in a RCT of coronary patients, mostly men, that 1400 $kcal \cdot wk^{-1}$ was the minimum dose of exercise to cause a measurable increase in VO_{2max}, and 2200 $kcal \cdot wk^{-1}$ was required to halt the progression of coronary lesions. A panel conclusion of a Consensus Symposium on Dose-Response Issues Concerning Physical Activity and Health (Ontario symposium) (Kesäniemi et al. 2001) concluded that there is a 30% reduction in mortality for sedentary persons at an EEE of 1000 $kcal \cdot wk^{-1}$. Even exercise doses as low as 500 $kcal \cdot wk^{-1}$ have been claimed to have some beneficial effect on all-cause mortality (Kohl 2001, Lee and Skerret 2001) and some consider this dose the minimum threshold for cardiovascular health benefits (Paffenbarger 1986).

The resistance training recommendation (ACSM1998a) was equal to the 1990 recommendation (ACSM 1990) with the exception that flexibility training for main muscle groups was added to the recommended exercise program. Any magnitude of overload in resistance training was considered beneficial, but heavier resistance loads were recognized to lead to greater training responses. For older persons, however, lower initial resistance loads and more repetitions were recommended to ensure the safety of the training. Resistance training was considered very important, especially when a person was approaching old age, for preserving adequate functional capacity for independent living (ACSM 1998b).

Other exercise recommendations for specific purposes have also been published lately; a recommendation for cardiovascular diseases (Mosca et al. 2004), hypertension (ACSM 2004), obesity (Klein et al. 2004, Jakicic et al 2001), osteoporosis (Cheung et al. 2004), and, after 65 years of age, a recommendation of exercise and PA for older adults in order to prevent the adverse effects of increasing age (ACSM 1998b). All of these aforementioned recommendations focus on various aspects of health and fitness and thus they come to somewhat different conclusions concerning the recommended exercise training program. The accumulation of everyday activities is recommended for general health. Moderate- to high-intensity aerobic training, combined with resistance exercises, is recommended for fitness and favorable body composition. Large volumes of exercise are recommended for weight control. High-impact training and strength training are recommended for osteoporosis, and moderate-intensity exercise is recommended for cardiac diseases and hypertension. Finally, with respect to old age, preserving muscle strength, balance, and coordination become the most important goals in training.

All of these recommendations are based both on epidemiological evidence and on exercise trials, which have, for the most part, been conducted on men, and thus they may not be completely valid for women and especially for postmenopausal women.

3. Gender aspects related to physical activity

3.1. Gender differences

Men and women differ anatomically and physiologically in many respects, starting with basic morphological differences. Women have, for example, smaller size, more body fat, and different fat distribution (Wilmore and Costill 1994). Women have fewer and smaller muscle fibers, and the absolute muscle strength of women is approximately 30% less than in men. Women have less dense bones. There are also differences in bone structure, joints and body posture and a more peripheral distribution of mass for women than men. These differences cause women to have a shorter stride length, a greater stride frequency for a given walking speed, and a greater mass-specific metabolic cost for walking. A wider pelvis, lower limb joint positions (increased femoral anteversion and greater genu valgum), and a possible hormonal-based laxity of ligaments and joints, together with lower muscle strength, predispose women to exercise-related injuries in lower limbs. For example, anterior cruciate ligament injuries of the knee are more common in women than in men (Belza and Warms 2004). On the other hand, when matched for muscle strength, women get tired more slowly and recover faster than men (Charkoudian and Joyner 2004).

The cardiorespiratory differences (Wilmore and Costill 1994) include, for example, a smaller heart size, a smaller blood volume, a lower stroke volume and cardiac output, fewer red blood cells, and less hemoglobin in women. Therefore, women have approximately a 15-30% lower oxygen carrying capacity and a lower VO_{2max}. Circuloregulatory differences have also been suggested. On the other hand, women are less susceptible to exercise-induced sudden death (Belza and Warms 2004). Ventilatory differences include a smaller lung size and thus a smaller capacity to oxygenate the blood during intense exercise in women. This smaller oxygenation capacity may limit performance and even cause exercise-induced arterial hypoxemia more often in women than in men. (Charkoudian and Joyner 2004, Hopkins and Harms 2004).

Many metabolic differences exist, for example, in hormone and lipid profiles at rest and during exercise (Wilmore and Costill 1994). Women use more fat and less carbohydrate to fuel exercise at the same relative intensity of exercise during long-duration exercise due to hormonal factors (Belza and Warms 2004).The hormonal differences may, in turn, influence the responses of the cardiorespiratory system to exercise and also thermoregulation during exercise. (Charkoudian and Joyner 2004, ACSM 1998a, Willmore and Costill 1994, Belza and Warms 2004)

In postmenopausal women stroke volume does not increase with exercise training, although increases in VO_{2max} have been found to be similar in men and women also among older aged persons. This phenomenon is believed to be due to estrogen deficiency, as estrogen is believed to have an effect on the walls of arteries (Charkoudian and Joyner 2004).

As there are many gender differences and also differences between pre- and postmenopausal women, all of which must be taken into account when a form of PA is chosen and the effects of exercise on fitness and health are evaluated. Thus it is necessary to study men and also pre- and postmenopausal women separately.

3.2. Menopause, hormone-replacement therapy and physical activity

Menopause is defined as a natural age-related decrease and, finally, loss of ovarian estrogen production and secretion, which occurs in Caucasian women at the average age of 50 years. Early postmenopause (i.e., from 50 to 65 years of age) is an important phase in a woman's life with many health risks, especially for physically inactive women. The decreasing estrogen level may start a rapid decline in aerobic fitness, muscle strength, and bone mineral density, in addition to weight gain, all of which increase the risk for many chronic diseases, for example, CHD, type 2 diabetes, and osteoporotic fractures (Sowers and La Pietra 1995, Wilson 2003). CHD is often considered to be more of a man's disease, but only when premenopausal women are compared with men. CHD is the leading cause of death among postmenopausal women in the western world (Goodman and Kirwan 2001).

Abdominal obesity, postmenopausal estrogen deficiency, and physical inactivity are associated with reduced insulin sensitivity, impaired glucose homeostasis, and lipid impairments, which lead to the entity "menopausal metabolic syndrome" (Spencer et al. 1997). In turn, the metabolic syndrome is associated with CHD, hypertension, and type 2 diabetes. Increased PA, weight loss, especially the loss of abdominal adipose tissue, and also hormone replacement therapy (HRT) can partially reverse this syndrome. Thus exercise training is very important in early postmenopause and will reduce the risks of menopause substantially.

HRT (i.e. estrogen alone or combined with progestin) has been widely used for the management of menopausal symptoms. It has also been recommended for the prevention of chronic conditions until recently, as harmful effects of HRT have been suspected to exceed the benefits (U.S.Preventive Services Task Force 2005). HRT increases muscle mass and strength (Copeland et al. 2004), increases bone density and reduces the risk for fracture (U.S.Preventive Services Task Force 2005), lowers resting blood pressure (Scuteri et al. 2001), improves the lipid profile (Binder et al. 2001), and prevents the increase of menopausal central adiposity (Tchernof et al. 2000). Some of the effects of HRT are controversial; for example, HRT was found to be associated with higher VO_{2max} by Redberg et al. (2001) in a longitudinal observational study, but Snabes (1996) found that HRT did not improve VO_{2max} in a randomized, double-blind, placebo-controlled, crossover trial. HRT increases the risk of breast cancer and venous tromboembolism. The evidence is insufficient to determine the overall effects of HRT on CHD and all-cause mortality in spite of the improvements in cardiovascular disease risk factors (U.S.Preventive Services Task Force 2005). HRT seems to have partly similar effects on HRF as PA.

After menopause the effects of aging also start to appear more clearly than before, especially in physically inactive women. Already early postmenopausal women should be prepared for the fact that, when approaching old age, after the age of 65 years, it is essential to preserve functional abilites for independent living to ensure a good quality of life (ASCM 1998b). As women have lower inital muscle strength of the lower limbs than men, muscular strength and also balance become the most important aspects of HRF. These characteristics ensure the ability to get up from chair and walk. Walking enables endurance training and ensures cardiovascular function and health (Guralnik et al. 2000). Thus exercise training is very important for early postmenopausal women also in order to preserve good functional capacity when approaching old age.

4. Systematic literature review of randomized, controlled exercise trials on the health-related fitness of early postmenopausal women

In order to determine, what would be an effective and feasible minimum exercise training program for HRF for early postmenopausal women, a systematic literature review of randomized, controlled exercise trials was carried out. This literature review included all other aspects of HRF, than bone strength. Bone strength was omitted because most of the RCTs with postmenopausal women have been aimed at studying bone strength, but very few have concerned other aspects of HRF. The bone studies started in the late 1980s through the 1990s, and, also recently, many good reviews have been published on the subject (Cheung et al. 2004, SBU 2003, Bajaj and Saag 2003, Wei et al. 2003, Follin and Hansen 2003).

4.1. Principles of searching scientific evidence

The principles of evidence-based medicine were used in the systematic literature review. The development of *evidence-based medicine* (Claridge 2005) started in the early 1990s, when the importance of scientific evidence in the development of guidelines was stressed by Eddy (1990).

According to the principles of evidence-based medicine, best evidence, *category A evidence,* is attained when many well-designed, RCTs exist on the chosen research problem. A substantial number of studies and a substantial number of participants are needed for this purpose. The *evidence category B* is reached when there is limited data from RCTs. RCTs can be small in size, the results can be inconsistent, or the participants can differ from the target population. The *evidence category C* comes from uncontrolled or non-randomized trials or from cross-sectional or prospective observational studies. The *evidence category D* comes from expert's opinions on a subject for which no scientific research has been carried out.

4.2. Literature search strategy

This systematic literature review searched for category A evidence on the effects of exercise on HRF among early postmenopausal women. A systematic search of the literature for well designed RCTs was conducted. Quality criteria were selected from Jadad et al. (1996), Schulz et al. (1995), Guyatt et al. (1993, 1994) and Oxman et al. (1993, 1994). All of the studies used in this literature review had to pass the following quality criteria: the trial had to be randomized and controlled, the results had to be presented in their original randomized groups, the number of participants had to be more than 25, and the proportion of dropouts had to be less than 35%. The final number of good-quality RCTs passing these criteria was 26 (Table 2). Out of the 26, only 10 were designed primarily to study HRF outcomes, other than bone strength. Others were designed primarily to reveal bone strength changes, but other HRF components were studied as secondary outcomes, and thus were included in this literature review.

The study was considered to be of very high quality if the following criteria were also fulfilled: over 100 participants, 20% or fewer dropouts, and at least one of the following additional criteria: supervision of all exercise sessions, monitoring with an exercise diary, reported statistical power calculations, reported method of randomization, and blinding of measuring personnel. It was considered impossible to blind the exercise supervisors or participants in exercise training. None of the studies fulfilled all of the very high-quality requirements. Only 10 studies fulfilled the main criteria and at least one of the additional criteria. The results of these 10 studies were considered the most valid when the information was gathered.

The participants had to be early postmenopausal, 50- to 65-year-old women. If the study also included men, the data on women had to be analyzed separately. If the study also included younger or older women, the study was accepted if the age was only a few years outside the limits but the mean age of the participants was in the range of 50 - 65 years. Healthy women and also women with diseases or risk factors such as dyslipidemia, hypertension, obesity, or osteoporosis were accepted. In addition HRT and other medications were allowed.

Exercise dose was assessed according to the duration, intensity, and frequency of the exercise session and the length of the exercise program. Some approximations were performed. If the intensity of the exercise prescription was given using HR_{max}, it was transformed to VO_{2max} using the formula $\%VO_{2max} = 1.28\%HR_{max} - 29.12$ (Oja 1973) so that comparisons could be made between studies. The length of the intervention was calculated in weeks if less than a year, on the assumption that all months had 4 weeks.

All exercise modes and doses were accepted. The minimum length of the intervention was chosen as 8 weeks. Shorter interventions were not expected to have an effect on HRF. Interventions that included dietary counseling, HRT, or other medications were accepted.

The outcome measures had to be based on components of HRF. The studies concentrating primarily on bone strength were included only if other components of HRF were studied as secondary outcomes. Among the outcome measures, the most frequently reported were chosen to enable comparison. The outcome measures had to have some relevance in clinical work. Cardiorespiratory fitness outcomes were assessed by direct measurements of VO_{2max} or indirect estimations made from maximal or submaximal exercise tests. Resting BP was also considered an outcome of cardiorespiratory fitness. The chosen morphological fitness outcome variables were weight and the ratio of body fat to body weight (F%). The musculoskeletal fitness measures were based on various muscle tests. Flexibility outcomes were based on tests of flexion, extension, or lateral flexion of the trunk or upper or lower limbs. The outcomes of motor fitness were based on different tasks requiring coordination. The metabolic fitness outcomes were total cholesterol (TC), low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), triglycerides (TG), glucose, and insulin concentrations.

The HRF outcomes of the interventions were observed as net changes (i.e. the changes of each intervention group minus the changes in the control groups). The changes were expressed as percentages when possible. If the net change could not be calculated or if it was important also to show the changes in the control groups, the changes of all of the groups were given separately.

The information on the feasibility of the exercise programs was based on attendance rates, and dropout rates, and the incidence of injuries was also searched for. If the attendace rates were not given, they were calculated from the number of prescribed exercise sessions and the mean number of completed exercise sessions, if available. The percentage of the women with injuries and with exercise-related medical problems were combined and recorded as injuries.

The main source for the search was The Cochrane Central Register of Controlled Trials (CENTRAL), using the key words "*women, exercise*" from 1974 to June 2004 (i.e., all years in the register), and 1479 references were found. Additional searches were performed using the United States (US) National Library of Medicine's search service for biomedical information (MEDLINE) with the key words "*postmenopause*, *exercise terms (exercise, exertion, physical fitness, sports, physical activity, exercise therapy*)" from 1999 to 2002, which resulted in 109 references, and with the words "*postmenopause, exercise terms, heart diseases, risk factors, hypertension, cholesterol, obesity*" from 1996 to 2004 which resulted in 184 references. A search using a sports search engine by sportinglife.com (SPORTSEARCH) with the word "*postmenopause*" from 1991 to 2004 resulted in 130 references. The Elton B. Stephens Company (EBSCO) information service was used to search for the words "*postmenopause, exercise*" from 1998 to 2004, with the result of 93 references. In addition, a hand search of the references in the original articles, reviews, and the table of contents from journals (*Sports Medicine, Maturitas, Scandinavian Journal of Medicine & Science in Sports*) was performed. From the headings, suitable abstracts were chosen for review and suitable full-length papers were checked.

Table 2. *List of reports[*] of good-quality randomized, controlled trials of early postmenopausal women (author, publication year) and their outcomes for health-related fitness (card, morph, met, musc, mot[†]) and quality-related information (sup, pow, rand, blind [‡]).*

Study	**N**	**Drop-outs**	**Mode**	**Length**	**Outcome**	**Sup**	**Pow**	**Rand**	**Blind**
Chow et al. 1987	58	17 %	Combined aerobic and resistance training	48 weeks	morph, card	+	+	+	+
Busby et al. 1988	50	12 %	Walking, jogging	12 weeks	met, card	+	-	-	-
Sinaki et al. 1989 Itoi and Sinaki 1994	68	4 %	Resistance exercise	96 weeks	morph, musc musc	+	-	-	+
Hopkins et al. 1990	65	18 %	Aerobic dance and stretching	12 weeks	Card, musc, mot, morph	+	-	-	-
King et al. 1991	160	18 %	Aerobic training	48 weeks	Card, met, morph	+	-	-	+
Hamdorf et al. 1992	80	18 %	Walking	26 weeks	Card, morph	+	-	-	-
Svendsen et al. 1993	121	2 %	Combined aerobic and resistance training	12 weeks	morph, cardio, met	+	+	-	+ partially
Lindheim et al. 1994	101	6 %	Walking, cycling	24 weeks	met, card, morph	+	-	-	-
Nelson et al. 1994 Morganti et al. 1995 Nelson et al. 1996	40	3 %	Resistance training	48 weeks	morph, mot, musc	+	-	-	-
Shinkai et al. 1994	32	-	Aerobic training	12 weeks	morph, card	+	-	-	-

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Study	N	Drop-outs	Mode	Length	Outcome	Sup	Pow	Rand	Blind
Bravo et al. 1996	142	13 %	Combined aerobic and resistance training	48 weeks	morph, musc, motor, card	+	+	+	+
Ready et al. 1996	79	33 %	Walking	24 weeks	Card, morph, met	+	-	-	-
Brooke-Wavell et al. 1997	84	7 %	Walking	48 weeks	morph, card	+	-	-	+
Heikkinen et al. 1997 Kyllönen et al. 1998	78	12 %	Combined aerobic and resistance training	96 weeks	morph, musc, met, mot	+	-	-	-
Bassey et al. 1998	147	16 %	High-impact training	48 weeks	morph, musc, motor	+	+	-	-
Heinonen et al. 1998	101	25 %	Combined aerobic and resistance training	72 weeks	morph, card, musc	+	+	+	+ partially
Mitchell et al. 1998	30	7 %	Combined aerobic and resistance training	12 weeks	morph, card, musc, mot	+	-	-	-
Stefanick et al. 1998	180	2 %	Walking, jogging	48 weeks	morph, card, met	+/-	-	-	-
Woolf-May et al. 1999	54	31 %	Walking	10 weeks	Met	+	-	-	+
Bemben et al. 2000	35	29 %	Resistance training	24 weeks	morph, musc	+	-	-	-
Sipilä et al. 2001	80	35 %	High-impact training	48 weeks	morph, musc	+	-	-	-
Courneya et al. 2003 Fairey et al. 2003	53	4 %	Cycling	15 weeks	Card, morph Met	+	-	-	-

Continued next page

Study	N	Drop-outs	Mode	Length	Outcome	Sup	Pow	Rand	Blind
Texeira et al. 2003 Cussler et al. 2003 Figueroa et al. 2003 Milliken et al. 2003	233	11 %	Resistance training and high-impact training	48 weeks	morph, musc	+	-	-	+
Irwin et al. 2003	173	3 %	Combined aerobic and resistance training	48 weeks	morph, card	+	-	-	+
Santa-Clara et al. 2003	60	-	Aerobic exercise	24 weeks	Card, morph	+	-	-	-
Uusi-Rasi et al. 2003	164	4 %	High-impact exercise and stretching	48 weeks	morph, musc, mot	+	+	-	+

** There are several articles on some of the studies.*
† Outcomes are listed in the order of importance in the study (i.e., primary outcomes are listed first), card = cardiorespiratory fitness outcomes, morph = morphological fitness outcomes, met = metabolic fitness outcomes, musc = musculoskeletal fitness outcomes, mot = motor fitness outcomes.
‡ Quality-related information: N = number of participants, drop outs = the percentage of dropouts, mode = exercise mode, length = length of the exercise program, sup = supervision of the exercise by the exercise leader reported or exercise diary kept and reported (+ = yes, - = information not reported), pow = power calculations reported, rand = the method of randomization reported, blind = blinding of the testing personnel reported.

4.3. Effects of exercise on cardiorespiratory fitness

4.3.1. Maximal aerobic power and submaximal cardiorespiratory capacity

VO_{2max} or other estimates of aerobic fitness were measured in 18 studies with 1733 participants (Bravo et al. 1996, Brooke-Wavel et al.1997, Busby et al. 1985, Chow et al.1987, Courneya et al. 2003, Fairey et al. 2003, Hamdorf et al. 1992, Heikkinen et al. 1997, Kyllönen et al. 1998, Heinonen et al. 1998, Hopkins et al.1990, Irwin et al. 2003, King et al.1991, Lindheim et al. 1994, Mitchell et al. 1998, Ready et al.1996, Shinkai et al. 1994, Stefanick et al. 1998, Svendsen et al. 1993, Santa-Clara et al. 2003*)*. In all but one of the studies, VO_{2max} improved. Walking was used as a mode of exercise in four of the studies, walking and/or other aerobic training in eight, and aerobic exercise combined with resistance training in six. One study used high-impact jumping combined with non-impact exercise. The exercise regimens varied as follows: the duration of aerobic exercise ranged from 15 to 60 minutes (mean 33 minutes), the range of the prescribed intensity was 48 - 84% of the VO_{2max} (mean 65% VO_{2max}), the exercise was performed on 2 to 5 days $\cdot wk^{-1}$ and the exercise interventions ranged from 10 weeks to 2 years. The net improvements in VO_{2max} ranged from 2.5 to 7 $ml \cdot min^{-1} \cdot kg^{-1}$ or from 4% to 32%. Indirect tests with estimations of VO_{2max} gave larger improvements than direct measurements did. The difference between the results may have been due to the greater inaccuracy of estimations when compared with direct measurements.

Aerobic fitness did not improve in a study with 12 weeks of 45 - 60 minutes of walking at an intensity of 50 - 60% VO_{2max} on 3 - 4 $d \cdot wk^{-1}$ (Shinkai et al.1994). The dropout and attendance rates were not given. Aerobic fitness was estimated by an indirect test. The training period did not reach the 15 weeks' duration considered to be necesary to produce a significant change in VO_{2max} (ACSM 1998a).

The training effects on VO_{2max} seem to be well-documented for moderate-to-heavy intensity exercise among early postmenopausal women. There were no studies on light intensity exercise. Submaximal aerobic capacity was not studied in any of the reports.

4.3.2. Blood pressure

The effect of PA on resting BP was studied in seven studies with altogether 781 participants (Hamdorf et al. 1992, King et al. 1991, Lindheim et al. 1994, Ready et al. 1996, Santa-Clara et al. 2003, Stefanick et al. 1998, Svendsen et al. 1993). The duration of the training session was 30 - 60 minutes, the intensity was 40% - 84% VO_{2max}, and the exercise was performed on 2 to 5 $d \cdot wk^{-1}$ for 12 weeks to 1 year. All of the exercise sessions were completely supervised or supervised in at least one of the weekly sessions. Heart rate (HR) monitors were used in two of the studies, and the HR palpation method was used in two.

The five studies with normotensive participants that used walking training alone or walking combined with other aerobic training did not show an effect on BP (Hamdorf et al. 1992, King et al. 1991, Lindheim et al. 1994, Ready et al. 1996, Stefanick et al. 1998).

Two studies with slightly hypertensive, overweight participants showed a reduction in BP and also in body mass index (BMI). In the study of Svendsen et al. (1993) the participants' initial BMI was 27-33 $kg \cdot m^{-2}$, the RR was < 190/100 mmHg and the intervention also included a reducing diet. Aerobic exercise of 30 - 55 minutes at 79% VO_{2max} on 3 $d \cdot wk^{-1}$ for 12 weeks combined with resistance training consisting of 1 set of 7 - 15 repetitions of 8 exercises performed on 3 d·wk^{-1} for 12 weeks decreased the systolic BP approximately by 10 mmHg and weight by approximately 10 kg. In a group of African-American women with an initial mean BMI of 29 kg·m^{-2} and a mean BP of 135/84 mmHg the study of Santa-Clara et al. (2003) showed a mean BMI and BP reduction to 23 kg·m^{-2} and 134/80 mmHg, respectively, while the control values remained unchanged. Walking, jogging, cycling, or rowing was performed for 45 - 60 minutes 3 - 4 d·wk^{-1} at an intensity of 60 - 80% VO_{2max} for 24 weeks. The exercise group with Caucasian women, with a lower initial mean BMI of 25 kg·m^{-2} and mean BP of 131/80 mmHg did not show any significant post-exercise changes in these parameters.

It is worth noting that none of the training studies on normotensive, normal weight women showed any effect on BP. Only two studies with slightly hypertensive, overweight participants showed positive results for moderate to heavy exercise training on BP, but weight loss might explain the reduction in BP in these cases. The literature review did not provide an answer to the question of what kind of PA influences normal BP in non-obese early postmenopausal women.

4.4. Effects of exercise on morphological fitness

4.4.1. Body composition

The effects of exercise on body composition was studied in 19 of the studies with altogether 1895 participants (Bassey et al. 1998, Bemben et al. 2000, Bravo et al. 1996, Brooke-Wavell et al. 1997, Cheng et al. 2002, Hamdorf et al. 1992, Irwin et al. 2003, King et al. 1991, Lindheim et al. 1994, Mitchell et al. 1998, Nelson et al. 1994, Nelson et al. 1996, Morganti et al. 1994, Ready et al. 1996, Shinkai et al. 1994, Sipilä et al. 2001, Suominen et al. 1999, Stefanick et al. 1998, Svendsen et al. 1993, Santa-Clara et al. 2003, Texeira et al. 2003, Figueroa et al. 2003, Cussler et al. 2003). Body composition was improved in seven of the studies (Brooke-Wavell et al. 1997, Irwin et al. 2003, Ready et al. 1996, Shinkai et al. 1994, Stefanick et al. 1998, Svendsen et al. 1993, Santa-Clara et al. 2003).

Only one of the studies had normal-weight participants (Ready et al. 1996). In the study of Ready et al. (1996) the participants walked 60 minutes at an intensity of 60% VO_{2max}, 3 - 5 d·wk^{-1} for 24 weeks and lost 0.1 kg. The controls gained weight.

In the studies with overweight participants, walking, other aerobic training, resistance training, or combinations of these exercise modes were used. The duration of aerobic exercise training was 20 - 60 minutes at an intensity of 50 - 80% VO_{2max}, and exercise was performed on 3 to 5 d·wk^{-1}. The three studies with overweight participants that used only exercise training without diet showed a weight loss of 0.1 - 2.0 kg in 12 -

52 weeks (Brooke-Wavel et al. 1997, Irwin et al. 2003, Santa-Clara et al. 2003). The best results were obtained by the three studies with overweight participants who used reducing diets in combination with their training (Shinkai et al. 1994, Stefanick et al. 1998, Svendsen et al. 1993). In these studies the mean weight loss was 2 - 10 kg in 12 weeks to 1 year.

On the basis of these studies, it can be concluded that exercise affects the body composition of normal-weight postmenopausal women only very slightly and, in obese women, the fat loss caused by exercise without a reducing diet is also small.

4.5. Effects of exercise on metabolic fitness

4.5.1. Carbohydrate metabolism

There were only two studies on the effects of exercise on blood glucose (Stefanick et al. 1993, Fairey et al. 2003) and one on insulin (Fairey et al. 2003). None of these studies showed training effects for glucose or insulin. The participants were overweight in both of the studies. Stefanick used diet combined with walking or cycling at an intensity of 70 - 75% VO_{2max} for 15 - 55 minutes for 1 year (1993). Fairey et al. (2003) used resistance training combined with aerobic exercise for 15 weeks. Both of these programs improved aerobic fitness, but only the longer study with a diet decreased weight, by 3.5 to 4 kg.

According to this literature review, there are no RCTs on early postmenopausal women that show the amount of exercise needed to influence glucose metabolism. Even those moderate-intensity exercise programs that were able to increase aerobic fitness did not show an effect on carbohydrate metabolism.

4.5.2. Lipid metabolism

Eight studies with altogether 1333 participants assessed the effects of exercise training on serum lipoproteins (Busby et al. 1995, King et al. 1991, Lindheim et al. 1994, Heikkinen et al. 1997, Ready et al.1996, Stefanic et al. 1998, Svendsen et al. 1993, Woolf-May et al. 1999).

In the studies (Busby et al. 1995, King et al. 1991, Ready et al. 1996, Woolf-May et al. 1999), normolipemic, non-obese participants walked 20 - 40 minutes in 1 - 3 daily exercise bouts at an intensity of 60 - 84% VO_{2max} on 3 - 5 $d{\cdot}wk^{-1}$ for 12 weeks to 1 year. No improvements in lipid levels could be found postexercise in spite of the fact that such exercise improved aerobic fitness in all three of the studies in which aerobic fitness was measured, and it also decreased weight slightly, by 0.6 kg, in one of the studies (Ready et al. 1996).

The four studies that combined a reducing diet (Stefanick et al. 1998, Svendsen et al. 1993) or HRT (Lindheim et al. 1994, Heikkinen et al. 1997) with exercise for slightly obese or dyslipemic participants showed a positive effect on the lipid profile for walking alone or combined with resistance training, 30 - 60 min, at an intensity of 60 - 70% VO_{2max} on 3 $d \cdot wk^{-1}$ for 12 weeks to 2 years. One of these studies found that the levels of triglycerides (TG), total cholesterol (TC), and low-density lipoprotein cholesterol (LDL) decreased and ratio of high-density lipoprotein cholesterol (HDL) to LDL increased by 20 - 30%, and weight was reduced by approximately 10 kg, equally in the diet-only and diet+exercise groups. This study did not have an exercise-only group (Svendsen et al. 1993). Another study combined a reducing diet and exercise for slightly dyslipemic women (Stefanick et al. 1998). LDL was reduced by approximately 10% in the diet + exercise group, but not in the diet-only or the exercise-only group; therefore exercise and diet seemed to have an additive effect on LDL. HDL was unchanged.

Two studies combined HRT with exercise and studied their effects on lipids. One of these studies showed that exercise alone decreased TC by 5%, TG by 2% and LDL by 10%, but HDL remained unchanged. In addition both HRT groups with or without exercise showed a decrease in TC, TG and LDL and also an approximately 10% increase in HDL by (Lindheim et al. 1994). The other study showed that HRT and HRT + exercise improved TC and HDL by approximately 10 -15%, but the effect of exercise alone on lipids was not reported (Heikkinen et al.1997). HDL did not improve in either of the groups. Neither of these studies reported weight changes.

In conclusion, none of the studies showed lipid changes in normal-weight, normolipemic women in this age group. For overweight or dyslipemic participants, moderate-to-heavy exercise training seems to improve the lipid profile. Adding HRT or diet improves lipids, and, in some of the studies, the effect was found to be additive, but the results are partly confusing.

4.6. Effects of exercise on musculoskeletal and motor fitness

4.6.1. Muscular strength and endurance

Altogether 12 studies with 1183 participants assessed muscular strength or endurance (Bassey et al. 1998, Bemben et al. 2000, Bravo et al. 1996, Heikkinen et al. 1997, Heinonen et al. 1998, Hopkins et al.1990, Mitchell et al. 1998, Nelson et al. 1994, Sinaki et al. 1989, Uusi-Rasi et al. 2003, Sipilä et al. 2001, Texeira et al. 2003). In all but two of the studies, muscular strength improved.

Five of the studies that showed positive effects on muscular strength used resistance training with weight machines alone or in combination with aerobic training (Texeira et al. 2003, Bemben et al. 2000, Bravo et al. 1996, Heikkinen et al. 1997, Nelson et al. 1994). Sinaki et al. (1989) used a single resistance back exercise. High-impact circuit training, aerobic dance, or jumping was used in two of the studies (Uusi-Rasi et al. 2003, Sipilä et al. 2001). Two of the studies used low-impact exercises or aerobic dance (Hopkins et al.1990, Mitchell et al. 1998).

The strength training programs consisted of 5 - 12 exercises that were repeated 8 times in 3 sets at an intensity of 40% to 80% of a 1RM on 2 - 3 days/d $\cdot wk^{-1}$ for 24 weeks to 1 year. The combined training included 60 minutes of aerobic training and resistance training on 3 - 4 $d\cdot wk^{-1}$ for 12 weeks to 2 years. A training program of 10 repetitions of a single resistance exercise, back extension, was used on 5 $d\cdot wk^{-1}$ for 2 years. The high-impact training programs consisted of 60-minute sessions performed on 3 $d\cdot wk^{-1}$ for 12 weeks. These training programs caused site-specific strength or endurance improvements of 9% to 76% in the trained muscles.

The studies that failed to show any effect on muscular strength used a 10-minute exercise program of 50 vertical jumps on 6 $d\cdot wk^{-1}$ for 52 weeks (Bassey et al. 1998) or circuit training with wrist and ankle weights and aerobic exercise 3 - 4 $d\cdot wk^{-1}$ for 72 weeks (Heinonen et al. 1998).

In most of the studies, HRT was not allowed or not reported. One of the studies stratified the participants by the use of HRT (Bravo et al. 1996). Three of the studies had separate HRT groups and compared the effects of HRT and exercise on muscular strength. Two of these studies showed that HRT had a favorable effect on muscular strength (Sipilä et al. 2001, Heikkinen et al. 1997), but in one of the studies this effect was not found (Texeira et al. 2003).

It seems well documented that early postmenopausal women are trainable using gym strength training equipment, and large improvements in muscular strength can be gained. Only one of the studies used simple equipment and a program that could also be performed at home, and the result was positive.

4.6.2. Flexibility

Altogether five studies with 416 participants assessed the effects of exercise training on flexibility (Bravo et al. 1996, Mitchell et al. 1998, Heikkinen et al.1997, Heinonen et al.1998). In three of the studies flexibility was improved by 5 - 25% (Bravo et al. 1996, Hopkins et al. 1990, Mitchell et al.1998). These studies used a training program of aerobic dancing or aerobic exercises combined with resistance training and stretching. The duration of the exercise session was approximately 60 minutes, and it was performed on 3 $d\cdot wk^{-1}$ for 12 weeks to 1 year. All of the exercise sessions were supervised.

In two of the studies, no training effect was found (Heikkinen et al.1997, Heinonen et al. 1998).The training program was a combination of aerobic and resistance training or strength training alone, both including stretching. The length of the program was 1.5 to 2 years. The exercise sessions were supervised once a week.

It seems that flexibility can be improved by exercise also among early, postmenopausal women. Possibly the correct stretching exercises need supervision because the best results were obtained in the fully supervised programs. But there were too few studies to draw any conclusion on what kind of exercise would be best, as all of the studies used different modes and doses of exercise.

4.6.3. Postural control

Balance or coordination was assessed in six of the studies with altogether 585 participants (Bassey et al. 1998, Bravo et al. 1996, Hopkins et al.1990, Mitchell et al.1998, Nelson et al.1994, Uusi-Rasi et al. 2003). Four of these exercise programs produced improvements in balance and coordination tests. These programs consisted of strength training with weight machines with 5 exercises at 80% of 1 RM with 8 repetitions and 3 sets on 2 $d{\cdot}wk^{-1}$ for 1 year (Nelson et al.1994) or 30 min of combined aerobic and resistance training on 3 $d{\cdot}wk^{-1}$ for 12 weeks (Mitchell et al.1998) or aerobic dance for 20 minutes performed 3 $d{\cdot}wk^{-1}$ for 12 weeks (Hopkins et al.1990) High-impact jumping in combination with low-impact exercises was also effective (Uusi-Rasi et al. 2003). Balance and coordination improved by 1 - 14%.

In two of the studies exercise did not affect balance. One year of combined aerobic exercise and resistance training on 3 $d{\cdot}wk^{-1}$ did not improve balance or coordination in spite of the fact that all of the exercise sessions were supervised (Bravo et al. 1996). In addition 50 jumps 6 $d{\cdot}wk^{-1}$ for 1 year did not improve balance (Bassey et al. 1998). Both exercise programs were supervised. The attendance was 91% in the jump program, but, in the combined exercise program, less than half of the exercisers adhered to the program.

Exercise training seems to improve the balance and coordination of early postmenopausal women, but no definite conclusions can be drawn, since it was reported in very few studies, all using different modes and doses of exercise.

4.7. Interactions between exercise and hormone replacement therapy

In most of the studies HRT was not allowed or not reported. Only five studies analyzed the interactions between HRT and exercise (Lindheim et al. 1994, Heikkinen et al. 1997, Sipilä et al. 2001, Texeira et al. 2003, Bassey et al. 1998). Lindheim et al. (1994) analyzed the effects of HRT and exercise on VO_{2max}, BP, and lipids. The participants were randomized into exercise, HRT, exercise + HRT, and control groups. The exercise program included walking and cycling 30 minutes at an intensity of 60% VO_{2max} 3 $d{\cdot}wk^{-1}$ for 24 weeks. Exercise with or without HRT improved VO_{2max} equally. The systolic BP decreased in all of the treatment groups. Exercise, HRT and HRT + exercise were related to a decrease in TC, TG and LDL, but only the HRT groups also showed an increase in HDL.

In this study HRT had a positive effect on BP, and it also had a clear effect on lipids. Exercise also improved the BP and lipid concentrations, but to a smaller extent. Exercise and HRT did not have an additive effect on any of the measurements.

Heikkinen et al. (1997) studied the effects of HRT and mixed resistance and aerobic training for approximately 50 minutes on 3 $d \cdot wk^{-1}$ for 2 years on lipids and muscular strength. The participants in the HRT and HRT + exercise groups showed a decrease in TC and an increase in HDL of approximately 10 - 15%, but an effect of exercise alone on lipids was not reported. There was no change in the LDL in either of the groups in this study. The HRT and HRT+ exercise had positive effects on muscular strength, and also exercise alone increased muscular strength. HRT was concluded to have an anabolic effect on muscles.

Sipilä et al. (2001) studied the effects of HRT and high-impact exercise sessions on 4 $d \cdot wk^{-1}$ for a year on body composition and muscular strength. There were no changes in body composition, but muscular strength improved in all of the treatment groups. Exercise and HRT seemed to have an additive effect on muscles, since the results were best on this group.

Texeira et al. (2003) studied the effects of HRT and a 60 to 75 min resistance training program that was performed on 3 $d \cdot wk^{-1}$ for 1 year on body composition and muscular strength. Body composition improved as the amount of lean soft tissue increased in both exercise groups, regardless of HRT, but only the HRT + exercise group also lost fat. The effect of exercise was superior to the effect of HRT on body composition, since the HRT-only groups did not show an increase in lean soft tissue even though HRT prevented the loss of lean soft tissue when the results of the HRT groups and the controls were compared. Muscular strength increased in both exercise groups, but this effect was not reported separately for the HRT users and non-users.

Bassey et al. (1998) studied the effects of HRT and a 24-week jumping program on body composition, muscular strength, and balance. The only significant effect was improvement of balance in the HRT + exercise group.

According to these studies HRT did not have an effect on aerobic power, but it decreased systolic BP, improved lipid profile, improved muscular strength and balance at least in some of the studies. Exercise and HRT did not have an additive effect on any of the variables in these studies except for muscular strength. No definite conclusions can be drawn because there were so few studies and the results are partly confusing.

4.8. Feasibility and the safety of the exercise modes used for early postmenopausal women

4.8.1. Walking

Most of the studies, 18 out of 25, used walking as the mode of exercise either alone or in combination with other aerobic or resistance training. In four of the studies walking was the only mode of exercise (Brooke-Wawell et al. 1997, Hamdorf et al. 1992, Ready et al. 1996, Woolf-May et al. 1999). In these studies the duration of the walking sessions ranged from 20 to 60 minutes, and the intensity of training was 40 - 75% VO_{2max}. The walking was performed on 2 - 5 $d{\cdot}wk^{-1}$ for 10 weeks to 1 year. Woolf-May et al. (1999) also had an exercise group that fractionated daily walking into 2 - 4 exercise bouts.

The mean dropout rate in these walking-only studies was 22%. The mean attendance was 81% in the two studies reporting it. Injuries were reported in three of the studies, and the mean injury rate was 5%. The walking was supervised fully in two of the studies and partly in two of the studies.

According to this literature review walking was the most feasible exercise mode. Walking programs had a high attendance and a small risk of injury.

4.8.2. Other aerobic exercise

Other forms of aerobic exercise, such as cycling, swimming, treadmill training, and aerobic dancing, either alone or combined with walking, were used in six studies with altogether 486 participants. The exercise was 20 - 60 minutes at an intensity of 48 - 84% VO_{2max}, and the training was performed on 3 - 4 $d{\cdot}wk^{-1}$ for 12 weeks to 1 year. Flexibility training was also included. The mean dropout rate was 14% in the four studies reporting dropouts. Attendance and injuries were reported in only one of the studies (King et al. 1991), the mean attendance was 77% in the home-based exercise group and 53% in the group-based exercise group. The injury rates were 23% in the high-intensity exercise group (64 - 84% of VO_{2max}) and 13% in the low-intensity exercise (48 - 64% of VO_{2max}) exercise group. All of the exercise was supervised in three of the studies, and in one of the studies (King et al. 1991) there was a supervised exercise group and a non-supervised home-based exercise group, controlled only through telephone contacts.

Other aerobic forms of exercise had a slightly higher injury rate than walking. Home-based exercise had better adherence than structured exercise classes, but no definite conclusions can be drawn, because injuries and adherence were reported in very few of these studies.

4.8.3. Resistance training

Strength training with weight machines was used in two studies (Bemben et al. 2000, Nelson et al. 1994) with altogether 75 participants. The exercise consisted of 5 to 12 exercises at an intensity of 40% or 80% of 1RM with 8 to16 repetitions in 3 sets on 3 $d \cdot wk^{-1}$ for 24 weeks or 1 year. The dropout rate was 16%. The mean attendance was 90%, and better in the training group with low-load and high-repetition exercise. This group also adapted faster to the training than did the group which trained with a higher load and used fewer repetitions (Bemben et al. 2000). The injury rate was 33% in the longer study. It was not reported in the shorter study. Weight training was supervised in both studies.

Three studies (Bassey et al. 1998, Sipilä et al. 2001, Uusi-Rasi et al. 2003) with 391 participants used high-impact training sessions on 3 to 4 $d \cdot wk^{-1}$ for 1 year. Attendance was 53-60%, with a dropout rate and injury rate of 18% and 7%, respectively.

One study used 10 to 50 repetitions of a single a back extensor exercise on 5 to 6 $d \cdot wk^{-1}$ for 2 years (Sinaki et al.1989). The attendance was not reported. The injury rate was 3%.

Resistance training with weight machines had the highest injury rates, even when supervised. Attendance and adaptation to training was better if the loads of resistance training were low.

4.8.4. Combined aerobic and resistance training

Combined aerobic and resistance training was used in eight studies with altogether 936 participants (Bravo et al.1996, Chow et al.1997, Heikkinen et al. 1997, Heinonen et al. 1998, Irwin et al. 2003, Mitchell et al. 1998, Svendsen et al.1993, Texeira et al. 2003). Aerobic modes such as walking, jogging, cycling, dancing, and stair walking were combined with resistance training with wrist and ankle weights and elastic bands or training with weight machines. Flexibility training was also included. The aerobic sessions lasted 30 - 70 minutes at an intensity of 42 - 75% VO_{2max} , and the resistance training had a low-to-high intensity of 10% to 70 - 80% of 1RM for 12 weeks to 2 years.

The mean dropout rate was 11%. The mean attendance rate was 73%, and it was better in the exercise groups that had more endurance training versus those with resistance training. The mean injury rate was 2%. All of the exercise was supervised in these studies, at least in the beginning of the study or on 2 - 3 $d \cdot wk^{-1}$.

4.9. Unanswered questions in the systematic literature review

The literature review showed that there are many unanswered questions concerning the effects of exercise training on the health of early postmenopausal women. Very few or none of the studies used light-intensity aerobic training, fractionated aerobic exercise, or resistance training with simple equipment. In addition very few or none of the studies determined the effective exercise dose for improving submaximal aerobic capacity, BP, body composition, carbohydrate and lipid metabolism, flexibility and postural control in healthy early postmenopausal women. Feasibility related information was also very sparse in this literature review. On the basis of these questions, the aims of the experimental part of this study were formulated.

Aims of the study

The *general aims* of this study were to assess the effects of exercise on the health of early postmenopausal women by searching for the minimum effective dose in a systematic literature review and by conducting a series of randomized, controlled exercise trials.

The *specific aims* of the study with respect to sedentary, early postmenopausal women were the following:

1. To study the effects of six exercise regimens of light-to-moderate intensity on cardiorespiratory, morphological and metabolic fitness and to determine the minimum effective dose.

2. To study the effects of walking at a moderate intensity and a moderate resistance training program on musculoskeletal and motor fitness.

3. To compare the effects of fractionated and continuous walking.

4. To study the interactions between exercise and hormone replacement therapy on health-related fitness.

5. To study the feasibility and safety of the studied exercise regimens.

The *practical aim* of the study was to define a minimum health-enhancing physical activity program that can be recommended for sedentary, early postmenopausal women as a starting-dose of exercise.

Participants and methods

1. Study design

The study design included a systematic literature review of RCTs of the effects of exercise on the HRF of early postmenopausal women (Publication I).

The experimental part of the study consisted of two interventions, Study I and Study II. Study I was an RCT with three parallel groups, moderate dose exercise in either one continuous or two daily walking sessions combined with resistance training in groups (E1, E2) and a non-exercise control group (C1) (Publications II, III, IV). The exercise in Study I started in September 1995 and continued for 15 weeks.

Study II was an RCT with five parallel groups, four low-dose exercise groups (E3-6) and a non-exercise control group (C2) (Publication I, II). The exercise in Study II started in November 1996 and continued for 24 weeks. The study plan was approved by the independent Research Ethics Committee of the Urho Kaleva Kekkonen Institute for Health Promotion Research (UKK institute), Tampere, Finland.

2. Participants in Study I and Study II

The participants were recruited through announcements in the local newspapers. In Study I, 700 women responded, out of which the suitable women were interviewed and given a medical examination accompanied by a submaximal exercise test. Finally, 134 women fulfilled all of the eligibility criteria and were accepted. In Study II, 413 women responded, and 121 were selected.

The eligibility criteria for both studies were female, 2 - 10 years past the onset of menopause, 48 - 63 years of age, no chronic diseases or regular medication except possible HRT, non-smoker, BMI < 32 $kg\cdot m^{-2}$, systolic BP < 160 mmHg, and diastolic BP < 100 mmHg, and not engaged in strenuous work or regular brisk leisure-time exercise more than once a week. An equal number of women with and without HRT were recruited. All of the participants gave their written informed consent.

A women was considered postmenopausal if it had been at least 2 years since her last menstruation or, after a hysterectomy, it had been 2 years since she had

had a period of hot flashes and related symptoms. Two years of HRT use was also considered postmenopausal.

In Study I, the HRT users and non-users were randomized, 15 at a time with the use of a computer, into the three groups, each including an approximately equal number of HRT users and HRT non-users. The procedure placed 46, 43 and 45 women into groups E1, E2 and C1, respectively. In Study II, the HRT users and non-users were also randomized separately according to computer-generated random numbers into one of four walking groups or into a control group. So that the statistical power of Study II would be improved as practically as possible, more women were allocated to the control group than into the intervention groups. After randomization, there were 21, 21, 18, 21, and 40 subjects in groups E3, E4, E5, E6, and C2, respectively. In both studies both the participants and the testing personnel were informed of the group results of the randomization only after the baseline exercise test. The baseline measurements of the study participants in the exercise and control groups are shown in Table 3.

***Table 3**. Baseline characteristics of the participants in Study I and Study II, means (standard deviations).*[*].

	Study I			Study II				
	C1	E1	E2	E3	E4	E5	E6	C2
	N = 45	N = 46	N = 43	N = 21	N= 21	N = 18	N= 21	N = 40
Characteristics								
Age, years	57 (4.2)	58 (4.4)	58 (4.2)	57 (3.8)	55 (3.7)	54 (3.5)	55 (4.2)	56 (3.8)
Years from menopause	6 (2.0)	6 (2.2)	6 (1.8)	6 (1.6)	6 (2.4)	5 (2.6)	5 (2.4)	6 (2.4)
Weight, kg	67.0 (8.5)	67.6 (8.2)	67.9 (8.5)	67.9 (10.4)	68.7 (9.5)	67.5 (10.9)	66.1 (8.5)	70.8 (9.3)
BMI, $kg \cdot m^{-2}$	26 (2.8)	26 (2.7)	26 (2.8)	26 (3.2)	26 (3.1)	26 (3.7)	25 (3.3)	27 (3.1)
$VO_{2\,max}$, $ml \cdot min^{-1} \cdot kg^{-1}$	27.7 (3.5)	29.0 (3.8)	28.4 (3.6)	30.3 (5.0)	30.8 (4.2)	29.4 (4.1)	30.2 (4.1)	29.3 (3.6)
PA, score	2.5 (0.7)	2.6 (0.5)	2.6 (0.5)	2.4 (0.7)	2.2 (0.5)	2.2 (0.7)	1.9 (0.6)	2.4 (0.6)

[*] C1 = control group in Study I, C2 = control group in Study II, E1 and E2 = exercise groups in Study I, E3 - E6 = exercise groups in Study II, BMI = body mass index, VO_{2max} = maximal aerobic power, PA score according to questionnaire = physical activity score (1 = no regular PA weekly, 2 = some light PA every week, 3 = once a week brisk PA, 4 = twice a week brisk PA, 5 = three times a week or more brisk PA)

3. Exercise programs in Study I and Study II

The exercise programs were planned according to the principles of the ACSM[1] (1990, 1998a) recommendations. The intensity of the exercise was planned to be light to moderate; 45% VO_{2max}, 55% VO_{2max} or 65% VO_{2max}. The lowest intensity was approximately the minimum intensity of the recommendation and the highest intensity was moderate. The weekly exercise volume was set at 1500 kcal or 1000 kcal, which should be at the lowest border of effective exercise to influence cardiovascular risk according to ACSM (1998a), Hambrecht (1993) and the Ontario symposium (Kesäniemi 2001). The frequency of exercise was chosen to be five $d \cdot wk^{-1}$, which is more frequent than the minimum requirement of the recommendation, in order to keep the exercise duration feasible. The daily training was continuous in groups E1, E3, E4, E5, and E6 and two equally long sessions with at least a 5-hour interval in group E2 in order to test the fractionization of exercise. Walking was considered the most common and most feasible form of sustainable dynamic aerobic exercise for sedentary women and was chosen as the mode of exercise (Morris and Hardman 1997). The minimum recommended length for an intervention, 15 weeks, was chosen in Study I (ACSM 1998a). A longer length, 24 weeks, was chosen for Study II, because the smaller exercise doses were suspected to be slower to produce effects on the chosen variables.

The individual target heart rate, corresponding to 45% VO_{2max}, 55% VO_{2max} or 65% VO_{2max}, was determined for each participant in the first maximal exercise

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[1]ACSM 1998:

Cardiorespiratory fitness and body composition:

1. Frequency of training: 3-5 $d \cdot wk^{-1}$.

2. Intensity of training: 55/65% of maximum heart rate or 40/50-85% of maximum oxygen uptake reserve (VO_2R) or HR_{max} reserve (HRR). HRR and VO_2R are calculated from the difference between resting and maximum heart rate and resting and maximum VO_2, respectively. To estimate training intensity, a percentage of this value is added to the resting heart rate and/or resting VO_2 and is expressed as a percentage of HRR or VO_2R.

3. Duration of training: 20-60 min of continuous or intermittent (minimum 10 min bouts accumulated through the day) aerobic activity.

Muscular strength and endurance, body composition, and flexibility:

1. Resistance training: One set of 8-10 exercises that condition major muscle groups 2-3 $d \cdot wk^{-1}$, 8-12 repetitions of each exercise and for older persons over 50-60 years 10-15 repetitons may be more appropriate.

2. Flexibility training: These exercises should stretch the major muscle groups and be performed a minimum of 2-3 $d \cdot wk^{-1}$. Stretching should include appropriate static and/or dynamic techniques.

test. The duration of daily exercise corresponding to 300 kcal or 200 kcal was also calculated individually in the first maximal exercise test using the Weir formula[2], which estimates energy expenditure (kcal · min^{-1}) from measured oxygen consumption (L · min^{-1}) and carbon dioxide production (L · min^{-1}) (de Weir 1949) (Table 4).

Table 4. *The exercise program prescribed for the exercise groups in Study I and Study II (standard deviation)*[*]

	Study I		Study II			
	E1	E2	E3	E4	E5	E6
Intensity of walking, % VO_{2max}	65	65	55	45	55	45
Mean target heart rate of the walking, beats · min^{-1}	132 (10.7)	130 (11.2)	124 (8.4)	118 (9.1)	124 (7.7)	118 (9.3)
Exercise energy expenditure per exercise session, kcal	300	300	300	300	200	200
Mean target exercise duration, min	47 (5.4)	2 x 24 (3.2)	54 (5.6)	65 (7.8)	38 (3.9)	46 (6.2)
Frequency of training, sessions per week	5	2 x 5	5	5	5	5

[*] *E1-E2 = exercise groups in Study I, E3-E6 = exercise groups in Study II, BMI = body mass index, VO_{2max} = maximal aerobic power*

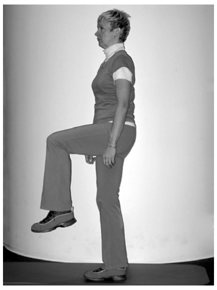
A short resistance training program was also used in groups E1 and E2 in Study I. It was planned according the minimum requirement of the ACSM recommendation (1990, 1998a), and was planned to be performed with as little equipment as possible (Figure 1).The resistance training program consisted of one set of eight moderate-intensity, dynamic exercises with 10 repetitions for each for the main muscle groups twice a week. Body weight or 2-5 kg dumbbells were used as resistance. Some of the exercises were also planned to have an effect on motor fitness, and also flexibility exercises were conducted. The program consisted of two exercises in a standing position for the leg muscles, balance and coordination (knees-up, back touch), one for hip and knee extensor muscles (squat), one for muscles of the upper arms using 2- or 5- kg dumbbells (dumbbell military press), two for back extensor muscles in the prone position,

[2] Weir 1949:
Exercise energy expenditure (kcal·min^{-1}) = (3.941 x VO_2 (L·min^{-1}))+ (1.106 x VCO_2 (L·min^{-1}))

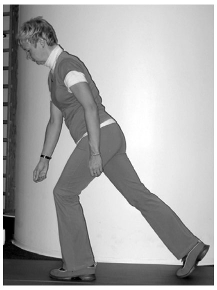
two for the abdominal region (sit-ups straight and diagonally), followed by five subsequent stretching exercises. The duration of the muscular training bout was approximately 15 to 20 minutes.

Figure 1. *Resistance training program used in Study I*

Warm-up and to improve standing balance and body coordination



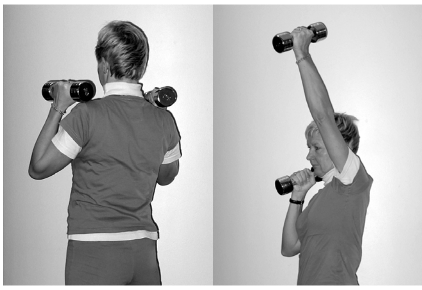
Exercise 1



Exercise 2

1) Knees-up in standing position with alternating legs	20 rep. (2 x 10+10 rep.)
2) Back touch in standing position with alternating legs	20 rep. (2 x 10+10 rep.)

Warm-up and enhancement of endurance of the trunk, legs and upper limb muscles



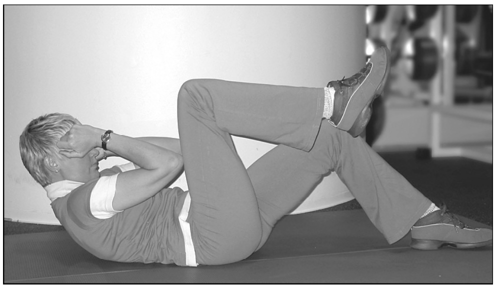
Exercise 3

Excersice 4

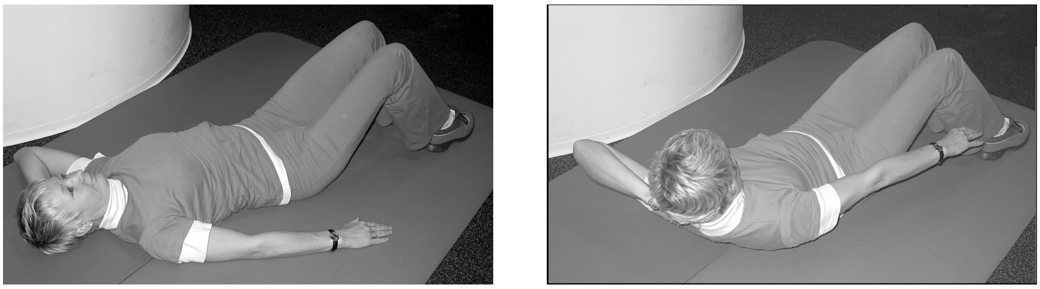
Excersise 5

Excersise 6

3) Dumbbell military press with alternating arms	20 rep. (2 x 10+10 rep.) with 2 to 5 kg weight
4) Squat exercise on two legs	10 rep.
5) Back extensor exercise on prone: Lifting opposite upper and lower limbs	10 rep. with 5 seconds hold
6) Upper body extensor exercise on prone	10 rep. with 5 seconds hold



Excercise 7



Excercise 8

7) Curl-ups on supine with alternating legs — 10 rep.

8) Curl-ups and side bending on supine — 20 rep. (2 x 10+10 rep.) for both sides

Recovery after aerobic exercise to increase the flexibility and to prevent musculoskeletal complaints





Excercise 9 Excercise 10 Excercise 11 Excercise 12 Excercise 13

9) Stretching exercise for hamstrings	30 seconds for each leg
10) Stretching exercise for pectoralis major	30 seconds for both sides
11) Stretching exercise for calf muscles	30 seconds for both legs
12) Stretching exercise for thoracic region	30 seconds
13) Stretching exercise (lateral bending) for neck muscles	30 seconds stretch for both side

rep.= repetitions

Two of the weekly walking sessions were supervised by an exercise leader on an indoor track. These sessions included the resistance training program as a warm-up for walking in Study I. The other weekly walking sessions, three for Group E1, E3, E4, and E5 and eight for Group E2 were unsupervised and took place outdoors. A few minutes of light flexibility exercises of the participants' own choice were recommended before and after every session as a warm-up and cool-off and for injury prevention.

HR monitors (Polar Edge, Polar Electro, Kempele, Finland) were used as a means of controlling the HR in the two weekly supervised sessions and every third week in all weekly sessions. The participants were also advised to estimate the length of their walking route periodically, in order to keep the same relative pace in all weekly sessions. The duration of the exercise session with a prescribed target HR was registered in an exercise diary. In addition the participants wore pedometers (step counters) (Fitty 3, Kasper & Richter, Utrecht, Germany) for 3 days, from Friday to Sunday, in the middle of the intervention period.

4. Measurements and outcome indicators in Study I and Study II

4.1. Cardiorespiratory fitness

4.1.1. Maximal aerobic power and submaximal cardiorespiratory capacity

All of the measurements were conducted before and after the training intervention. The participants were asked to eat only a light meal approximately 4 hours prior to the exercise test, but coffee and cola drinks were not allowed. Heavy physical exercise was not allowed on the day before the exercise test. A progressive, maximal exercise test on a treadmill (Telineyhtymä Oy, Kotka, Finland) was used to measure the VO_{2max}. The submaximal response to the exercise was monitored by HR measurements at absolute exercise levels corresponding individually to 65% VO_{2max} and 75% VO_{2max} in the baseline exercise test. The treadmill test protocol (Oja 1973) consisted of a warm-up for 5 minutes at 5 $km \cdot h^{-1}$ on a 5% incline of the treadmill. The workload was increased in 3-minute intervals, from very light to maximal load. The speed was increased by 0.5 $km \cdot h^{-1}$ during the third, sixth, and ninth stages, and the elevation of the treadmill was increased by 2.5% at each stage, except the third. The electrocardiogram (ECG) was monitored (Case 12, Marquette Electronics Inc., Milwaukee, WI, USA) continuously. The participants reported their perceived exertion on the Borg scale (Borg 1970) during each exercise stage. The room temperature was normal, but cooled, when necessary during the exercise test. For habituation, and as a health check, a submaximal exercise test with a similar test protocol was performed a few days before the first maximal exercise test.

Oxygen uptake (VO_2) was measured breath-to-breath using a metabolic cart (Metabolic Measurement Cart 2900Z, Sensor Medics Corp., Anaheim, CA, USA). The analyzer was calibrated before each test. The VO_{2max} was obtained from 1-min collected values (Howley et al.1995). The criteria for maximum were the following: best possible effort as judged by the test supervisor, perceived exertion 19 - 20 on the Borg scale, HR over 85% of the age-predicted maximum, no significant rise (>2 $ml \cdot min^{-1} \cdot kg^{-1}$) in VO_{2max} between the consecutive minute-to-minute gas analyses, and respiratory exchange ratio (RER) over 1.05. All of the participants had to fulfill the first criterion. The test was repeated within a week if a participant failed to give her best possible effort or if less than three of the other four criteria were not fulfilled.

The VO_{2max} and submaximal capacity were also estimated from the results of the UKK Walk Test (WT). (See Section 4.4. Musculoskeletal and motor fitness).

4.1.2. Blood pressure

Blood pressure measurement took place between 8 am to 4 pm in a quiet room, and coffee and cola drinks were not allowed prior to the measurement. The resting BP was measured twice with a random zero sphygmomanometer (Hawksley & Son Ltd., Sussex, United Kingdom) from the right arm as the participant sat after 5 minutes of rest. An appropriate-sized cuff was used, and the BP instrument was positioned on a flat surface at the approximate level of the heart. For all of the readings, Korotkoff phases 1 and 5 established the levels of systolic and diastolic pressures, respectively. The BP was measured to an accuracy of 2 mmHg. The lowest of the two measurements with a 2-min interval was used in all of the BP measurements in Study I. In Study II the mean of the two measurements was used in all of the BP measurements.

4.2. Morphological fitness

4.2.1. Body composition

Body composition was estimated using body mass, height and skinfold thickness measurements. BMI was calculated, and the F% was estimated. Body mass (kg) and height (m) were measured in light clothing without shoes. Height was obtained to an accuracy of 0.005 m, and body mass was measured to the nearest

0.1 kg. The BMI was calculated as body mass (kg) divided by the square of the height (m). Skinfold thickness was measured at four sites, mid-triceps, biceps, subscapularis and suprailiac muscles, using a Harpenden skinfold caliper (British Indicators, Ltd, Luton, Beds., United Kingdom). Body density was estimated from the sum of the skinfolds according to a linear regression equation with age- and sex-specific coefficients according to Durnin and Womersley (1974) and converted to the F% using an adaptation of Siri's formula[3] (Siri 1961) for elderly women[4] (Deurenberg et al. 1989). The standard error of this body fat assessment system, when skinfold measurements are properly taken, is 3 - 4%.

4.3. Metabolic fitness

4.3.1. Conduction of the laboratory measurements

All of the measurements were conducted before and after the training period. The exercise training was allowed to start only after the first measurement. At the end of intervention the last exercise bout had to have been completed approximately 48 hours before the sampling. Venous blood samples were obtained at 7 to 9 am after a 12-hour overnight fast, after a 15-minute rest while the participant was supine.

4.3.2. Carbohydrate metabolism

Blood fasting glucose and plasma fasting insulin levels were measured to determine carbohydrate metabolism. In Study I the area under curve determinations of insulin in an oral glucose tolerance test (OGTT), and 1-hour and 2- hour insulin values were also used. OGTT was carried out with a glucose dose of 75 g. Fasting blood samples were taken for baseline glucose and insulin determinations before the oral glucose administration. Blood was also sampled at 30, 60 and 120 min during OGTT for glucose and insulin measurements. In Study II, the fasting blood samples were taken twice with a 1- week interval. The mean of the two measurements was used.

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[3]Siri 1956:

Fat (%) = 495 / body density - 450.

1 / body density = adipose tissue specific weight / 0.9 + (1-fatfree tissue-specific weight) / 1.1

[4] Deurenberg 1989:

Fat (%) = (1.2 x Body mass index) + (0.23 x age) – (10.8 x sex) – 5.4

Sex: 1 for males, 0 for females.

All of the analyses, except those for glucose, were carried out using frozen (-70° to -20°C) samples, and all of the samples from each participant were analyzed within a single batch to minimize analytical variations. Blood glucose was assessed by the glucose dehydrogenase method (Epos 5060, Eppendorf, Germany). Plasma insulin determinations were done by radioimmunoassay (Phadeseph Insulin RIA, Pharmacia, Sweden).

The analytic variations (i.e., inter-assay coefficient of variation (CV)), calculated from human serum-based quality control materials (Labquality, Helsinki, Finland and also others), were 0.8 - 3.4% for glucose (at the level of 2.22 mmol/l, 7.5 mmol/l and 10.13 mmol/l in Study I and also 25.5 in Study II) and 2.1- 5.0% (at the level of 13.5 mU/l, 42.4 mU/l and 107.5 mU/l) for insulin.

4.3.3. Lipid metabolism

Serum concentrations of TC, TG, HDL, and LDL were used as the lipid and lipoprotein metabolism indicators. Fasting blood samples were taken for the serum lipoprotein determinations. Fasting blood samples were taken for serum lipids before the oral glucose administration for OGTT. In Study II, the fasting blood samples were taken twice with a 1-week interval. The mean of the two measurements was used.

In both studies all of the analyses were carried out using frozen (-70° to -20°C) samples, and all of the samples from each participant were analyzed within a single batch to minimize analytical variations. The TC and TG concentrations were measured using routine enzymatic methods (Mira Plus, Roche, Switzerland, CHOD-PAP, Boehringer Mannheim, Germany and TRIG UNIMATE 5, 15x30ml, Roche, Art.07 3679 1, Switzerland). HDL was determined by dextran sulfate precipitation. LDL was calculated by the equation of Friedewald et al. (1972)[5].

The analytic variations (inter-assay CV), calculated from human serum-based quality control materials (Labquality, Helsinki, Finland and also others), were 0.8 - 1.1% for TC and 1.9 - 1.1% for HDL at the concentration level of 1.4 - 1.6 $mmol \cdot L^{-1}$, and 4.2 - 4.6% at the very low HDL- level of 0.50 $mmol \cdot L^{-1}$, and 1.1 - 3.8% for TG.

[5] Friedewald 1972:

Low-density lipoprotein cholesterol = total cholesterol – high-density lipoprotein cholesterol – triglyceride / 2.2

(used only when serum triglyceride < 4 mmol/l)

4.4. Musculoskeletal and motor fitness

In Study I musculoskeletal and motor components of HRF were measured with field-based fitness tests (Suni 2000, Suni et al.1998a, Suni et al.1998b, Malmberg et al. 2002, Suni et al. 1996, Rinne et al. 2001). The reliability (Suni et al.1996, Rinne et al. 2001, Oja et al. 1991a), safety, and feasibility (Suni et al. 1998a, Suni et al. 1998b) and the health-related validity of these field-based fitness tests have been established in a series of studies (Suni et al. 1998a, Malmberg et al. 2002). All of the tests followed a standard sequence. Balance was measured first, followed by flexibility, strength and the WT.

Musculoskeletal fitness tests measuring muscular strength and endurance were, in the order of the measuring sequence, the sit-up test from the Eurofit test battery to test dynamic trunk flexor muscles (Oja and Tuxworth 1995), the one-leg squat from the UKK health-related fitness test battery for lower extremity strength (Suni et al. 1996, Malmberg et al. 2002), the static trunk extensor endurance test from the UKK health-related fitness test battery (Suni 2000), and the dynamic test for the upper extremities from the test battery of the Invalid Foundation (Alaranta 1990). Flexibility was measured by the trunk side bending test from the UKK health-related fitness test battery (Suni 2000).

Motor fitness was measured by one-leg standing for static postural control from the UKK health-related fitness test battery (Suni 2000, Suni et al. 1996, Rinne et al. 2001). Walking performance was measured by the WT for walking time and predicted VO_{2max} (Oja et al. 1991a, Laukkanen et al.1992). WT reflects both submaximal aerobic capacity (Oja et al. 1991a) and musculoskeletal functioning in walking (Suni et al.1998b).

4.5. Feasibility and safety of the exercise programs

Injury prevention included instructions on proper walking technique and choosing good walking shoes and the gradual onset of exercise, as well as providing the possibility to progress gradually to the full exercise program. The participants were recommended to contact the consulting physician (T-MA) with any health problems at the onset of the problem.

The feasibility and safety of this exercise regimen during the intervention was assessed in several ways. Every exerciser used an exercise diary, into which the following information was recorded after every exercise session: date, time at the onset and at the end of exercise, the exercise duration with target HR from the HR monitor reading. The time spent in habitual PA (i.e., other walking than exercise training, and possible cycling, calisthenics and the like) was recorded. The exercise diary was checked by the exercise leaders every 3 weeks. Adherence to the exercise program was measured from the exercise diaries by calculating a percentage of completed exercise versus prescribed exercise for the duration of the exercise session, the frequency of the weekly sessions, the number of supervised sessions per week, and the length of the exercise program.

The pedometric measurement was taken only in the exercise groups, and it included all PA of the day, also walking training.The total amount of weekly walking was estimated from a 3-day pedometer recording.

All of the participants completed a questionnaire at the beginning and at the end of the intervention with 26 questions followed by an interview to make sure that all of the questions were understood correctly. Four of the questions were on PA, one on OPA, 8 on health and medication, 8 on menopause and HRT, 5 on recent changes concerning health, habitual PA, diet, maintaining weight, and cigarette smoking. All of the participants were asked to keep their normal diet, daily PA habits, and the use of HRT constant. The adherence to the habitual PA routine was checked with a questionnaire.

In an interview after the intervention the feasibility and safety of the exercise was also assessed using an additional questionnaire with a question of the subjective intensity of the exercise and two questions on exercise-related pain and injuries. The safety of the exercise regimen was assessed by recording the injuries that involved physician consultations.

In Study II personal experiences concerning the body, mood and well-being during the preceding 3-4 weeks were requested by means of a 28-item list of short statements in a questionnaire filled out at the end of the intervention and also by a personal interview. The items were based on earlier spontaneous reports of the participants. Two summarizing indices, one for the intensity and the other for the scope of the experiences, were built from the responses to the 19 positive and 9 negative items.

In Study II current daily dietary intake was estimated on the basis of complete 3-day (including one weekend day) food diaries at the beginning and end of the study. The participants were given oral and written instructions for estimating their food intake with household measures. The food composition data were calculated with MicroNutrica software (Social Insurance Institution, Helsinki, Finland).

5. Statistical analyses in Study I and Study II

5.1. Power calculations

The calculations for adequate sample size were based on the assumption of about a 10% (3 $ml \cdot min^{-1} \cdot kg^{-1}$) (SD 4) increase from the baseline VO_{2max} in the exercise group when compared with the change in the control group (type 1 error alpha 0.05). The power of the test was selected as 0.90. The calculations yielded a minimum of 39 participants for each study group. The actual number of participants in each group was 43 - 46 at the onset of the study in Study I. In Study II the number of participants was 18 - 21 for the exercise groups and 40 for the control group at the onset of the study. It was calculated that, if necessary for the sake of statistical significance, E3 and E5, as well as E4 and E6, could also be combined to form adequate groups for determining the effect of the exercise intensity on the results. E3 and E4, as well as E5 and E6, could also be combined to determine the effect of the energy expenditure of the exercise. According to the *intention-to-treat principle* all of the participants were asked to participate in the follow-up measurements, in spite of possible dropout from the exercise program or a change in HRT use.

5.2. Analysis of covariance

The results are given as the means and standard deviations (SD). An analysis of covariance (ANCOVA) with the baseline measurements as the covariates was used to analyze the training effects. The P-values were calculated in tests for any differences between the groups. The training effects were determined as the net differences (i.e, the differences between the changes in each walking group and the control group). We calculated the 95% confidence intervals (CI) for the net change. A two-way ANCOVA with the exercise groups and the HRT groups as factors was used to analyze the interaction of these factors with the outcome measures.

5.3. Subgroup analyses

The subgroup analysis of the HRT users and non-users was carried out to determine the eventual effects of HRT on the results. The exercise groups were combined when BP was analyzed in Study I to show an effect of exercise in a comparison with the controls. In Study II a subgroup analysis according to intensity and exercise energy expenditure was carried out in order to evaluate the effect of intensity and exercise energy expenditure on the variables.

5.4. Additional analyses

The outcomes of the one-leg standing balance and one-leg squat tests showed a skewed distribution and were analyzed using the proportion of the participants that achieved maximum results in tests before and after the intervention. The binary logistic regression analysis was used as the statistical method and the odds ratios and their 95% CI were calculated between the exercise and control groups at the end of the intervention and adjusted for the differences in the baseline distributions.

Results

1. Overview of the results of the systematic literature review of randomized, controlled exercise trials on the health-related fitness of early postmenopausal women

VO_{2max} or other estimates of aerobic fitness were measured in 18 studies. In most of the exercise regimens, in which the duration ranged from 15 to 60 min (mean 33 min), the range of the prescribed intensity was 48 - 84% of VO_{2max} (mean 65% of VO_{2max}), the exercise was performed on 2 to 5 days per week from 10 weeks to 2 years, improved VO_{2max} by 2.5 to 7 $ml \cdot min^{-1} \cdot kg^{-1}$ (4% to 32%). Thus the training effects on VO_{2max} were well documented for moderate-to-heavy intensity exercise, but there were no studies on light intensity exercise, and submaximal aerobic capacity was not studied in any of the reports.

The effect of PA on resting BP was studied in seven studies. None of the training studies on normotensive, normal weight women showed any effect on BP. Two studies with slightly hypertensive, overweight participants showed a reduction in blood pressure by 1-10 mmHg, but as the BMI was also decreased, weight loss might explain this reduction in BP. The literature review did not provide an answer to the question of what kind of PA influences normal BP in non-obese early postmenopausal women.

The effects of exercise on body composition were studied in 19 of the studies. There was only one study with normal-weight participants that showed a slight reduction of 0.1 kg in weight with 60 min of walking at an intensity of 60% VO_{2max}, 3 - 5 $d \cdot wk^{-1}$ for 24 weeks. Three studies with overweight participants showed a loss of 0.1 - 2 kg, and three studies who used reducing diets in combination with their training program showed a 2 - 10 kg weight loss. On the basis of these studies, it can be concluded that exercise affects the body composition of normal-weight postmenopausal women only very slightly, and for obese women, the fat loss caused by exercise without a diet change is small.

There were only two studies on the effects of exercise on blood glucose and one on insulin, and neither of these studies showed training effects. According to this literature review, there are no RCTs with early postmenopausal women that show the amount of exercise needed to influence glucose metabolism.

Eight studies assessed the effects of exercise training on lipids, but no improvements could be found postexercise. For overweight or dyslipemic participants, moderate-to-heavy exercise training seems to improve the lipid profile. Adding HRT or diet improves lipids, and in some studies the effect was found to be additive, but the results are partly confusing. In conclusion, no studies showed lipid changes in normal-weight, normolipemic women in this age group.

Altogether 12 studies assessed muscular strength or endurance, and in all but two muscular strength improved 9% to 76%. The strength training programs consisted of 5 - 12 exercises that were repeated 8 times in 3 sets at an intensity of 40% to 80% of a 1-repetition maximum (1RM) on 2 - 3 days/d·wk^{-1} for 24 weeks to 1 year. Combined aerobic and resistance training, high-impact training and repeating a single resistance exercise also improved muscular strength. It seems well documented that early postmenopausal women are trainable using gym strength training equipment, and large improvements of muscle strength can be gained. Only one of the studies used simple equipment and a program that could also be performed at home, and the results were also positive.

Five studies assessed the effects of exercise training on flexibility, and, in three of the studies, flexibility was improved by 5% - 25%. The training program consisted of aerobic dancing or aerobic exercises combined with resistance training and stretching. It seems that flexibility can be improved by exercise also in early postmenopausal women. But there were too few studies to draw any conclusion on what kind of exercise would be best, as all of the studies used different modes and doses of exercise.

Balance or coordination was assessed in six of the studies, and four of these exercise programs produced 1 - 14% improvements with gym strength training, combined aerobic and resistance training or aerobic dance or high-impact jumping in combination with low-impact exercises. Exercise training seems to improve the balance and coordination of early postmenopausal women, but no definite conclusions can be drawn, since it was reported in very few studies, all using different modes and doses of exercise.

Only five studies analyzed the interactions between HRT and exercise. According to these studies HRT did not have an effect on aerobic power, but it decreased systolic BP, improved the lipid profile, and improved muscle strength and balance at least in some of the studies. Exercise and HRT did not have an additive effect on any of the variables in these studies, except for muscular strength. No definite conclusions can be drawn because there were so few studies and the results are partly confusing.

Walking seemed to be the most feasible mode of exercise for this age group of women, as judged by the low injury rates (5%) and high attendance rates (81%). Only one of the studies fractionated walking into 2-4 exercise bouts. Other forms of aerobic exercise, such as cycling, swimming, treadmill training, and aerobic dancing, either alone or combined with walking, were also feasible. They were used in six studies with altogether 486 participants. The exercise was 20 - 60 min at an intensity of 48 - 84% VO_{2max}, and the training was performed on 3 - 4 d·wk^{-1} for 12 weeks to 1 year. Flexibility training was also included. The mean dropout rate was 14% in the four studies reporting dropouts. Attendance and injuries were reported in only one of the studies (King et al. 1991), the mean attendance was 77% in the home-based exercise group and 53% in the group-based exercise group. The injury rates were 23% in the high-intensity (64 - 84% of VO_{2max}) exercise group and 13% in the low-intensity (48 - 64% of VO_{2max}) exercise group. All of the exercise was supervised in three of the studies, and in one of the studies (King et al. 1991) there was a supervised exercise group and a nonsupervised home-based exercise group, controlled only through telephone contacts.

Other aerobic forms of exercise had a slightly higher injury rate (13-23%) and lower attendance rate (53-77%) than walking, but no definite conclusions can be drawn, because injuries and adherence were reported in very few of these studies. Resistance training with weight machines had the highest injury rates (33%), even when supervised. The attendance and adaptation to training was better if the loads of the resistance training were low (90%). (Publication I).

2. Results of Study I and Study II

2.1. *Effects of the exercise programs on cardiorespiratory fitness*

2.1.1. *Maximal aerobic power and submaximal cardiorespiratory capacity*

The mean net increase in VO_{2max} was approximately 9%, 2.5 $ml \cdot min \cdot kg^{-1}$ (95% CI 1.5 to 3.5) ($p < 0.001$) in Study I for exercise groups E1 (65% VO_{2max}, 300 kcal) and E2 (65% VO_{2max}, 150 kcal + 150 kcal), equal in one session and two session exercise groups. In Study II there was also an approximately 9% mean net improvement from the baseline values: 2.9 $ml \cdot min \cdot kg^{-1}$ (95% CI 1.5 to 4.2), 2.6 $ml \cdot min \cdot kg^{-1}$ (95% CI 1.3 to 4.3), 2.4 $ml \cdot min \cdot kg^{-1}$ (95% CI 0.9 to 3.8) and 2.2 $ml \cdot min \cdot kg^{-1}$ (95% CI 0.8 to 3.5) for exercise groups E3 (55% VO_{2max}, 300 kcal), E4 (45% VO_{2max}, 300 kcal), E5 (55% VO_{2max}, 200 kcal), and E6 (45% VO_{2max}, 200 kcal), respectively ($p < 0.001$). In Study I the changes in submaximal HR were not statistically significant, but, in Study II, in all of the exercise groups, there was a mean decrease of 4 to 8 beats per minute in the submaximal HR at both measured submaximal exercise levels, $HR_{75\%}$ and $HR_{65\%}$ ($p = 0.001$). (Publications II and V).

2.1.2. *Blood pressure*

As analyzed in the original groups, there was no significant change in mean BP in any of the groups in Study I. In E1 (65% VO_{2max}, 300 kcal) the mean net change in diastolic BP was -2.6 mmHg (-5.5 to 0.4) (95% CI) and, in E2 (65% VO_{2max}, 150 kcal + 150 kcal), it was -3.3 mmHg (-6.3 to -0.4) (95% CI) mmHg (p= 0.071). When exercise groups E1 and E2 were combined in Study I (65% VO_{2max}, 300 kcal in one or two sessions) and exercise groups E3, E4, E5, and E6 were combined in Study II (45-55% VO_{2max}, 200-300 kcal) and a comparison was made with the controls, there was a statistically significant reduction in the mean diastolic BP of 3.0 mmHg (-5.5 to -0.4) (95% CI) (p = 0.025) in Study I. There were no significant changes in BP in Study II, in which the exercise doses were smaller. In Study II an additional analysis that grouped the participants into two exercise groups according to exercise intensity or exercise energy expenditure did not show any statistically significant changes either. (Publication III).

2.2. Effects of the exercise programs on morphological fitness

2.2.1. Body composition

The mean body mass decreased by approximately 1 kg (1.7%), and the BMI was reduced by approximately 0.5 units in Study I in both exercise groups, E1 (65% VO_{2max},300 kcal) and E2 (65% VO_{2max},150 kcal + 150 kcal) (p = 0.001) when compared with the controls. In Study II, in which the exercise doses were smaller, there were no significant changes in body mass or BMI. The mean F% decreased approximately 2 percentage units in both exercise groups, E1 (65% VO_{2max}, 300 kcal) and E2 (65% VO_{2max}, 150 kcal +150 kcal) in Study I (p < 0.001). In Study II, the mean F% decreased approximately 1percentage unit in exercise groups E3 (55% VO_{2max}, 300 kcal), E4 (55%, 200kcal), and E6 (45%, 200kcal) (p = 0.007). The result in group E5 was not statistically significant.

In Study II, additional analyses, such as grouping the participants into two exercise groups according to exercise intensity or exercise energy expenditure, did not show significant changes. (Publication II and IV).

2.3. Effects of the exercise programs on metabolic fitness

2.3.1. Carbohydrate metabolism

The mean fasting blood glucose declined by 0.21 $mmol \cdot L^{-1}$ (-0.33 to -0.09) (95% CI) in group E1 (65% VO_{2max}, 300 kcal) and 0.13 $mmol \cdot L^{-1}$ (-0.25 to -0.01) (95% CI) in group E2 (65% VO_{2max},150 kcal + 150 kcal) when compared with that of the controls in Study I (p = 0.003). The mean 2-hour glucose in the OGTT also declined by 0.48 mmol·L^{-1} (-0.89 to -0.08) (95% CI) in group E1 (65% VO_{2max}, 300 kcal) and by 0.43 mmol·L^{-1} (CI -0.83 to -0.029) (95% CI) in group E2 (65% VO_{2max},150 kcal +150 kcal) in Study I ($p = 0.039$). No statistically significant changes occurred in the fasting plasma insulin, 2-hour insulin concentration in the OGGT, or the insulin area under the curve of the OGGT values in Study I. In Study II, in which the exercise doses were smaller, there were no significant changes in any of the measured carbohydrate metabolism variables. In Study II, even the additional analyses that grouped the participants into two exercise groups according to exercise intensity or exercise energy expenditure did not show changes either. (Publication II).

2.3.2. Lipid metabolism

The exercise in Study I and Study II did not cause statistically significant changes in any of the measured lipid metabolism variables, TC, TG, HDL or LDL when the results were compared with those of the controls. Combining the exercise groups in Studies I or II did not give any change either. In Study II, in the additional analyses, grouping the participants into two exercise groups according to exercise intensity or exercise energy expenditure did not show any change induced by training.

2.4. Effects of the exercise programs on musculoskeletal and motor fitness

In Study I musculoskeletal and motor fitness tests were performed. In the musculoskeletal fitness tests only the one-leg squat test for lower extremity strength improved statistically significantly when the results of the exercise groups were compared with those of the controls. The improvement was equal in group E1 (65% VO_{2max}, 300 kcal) and group E2 (65% VO_{2max}, 150 kcal + 150 kcal) (Table 5). The exercise training did not improve trunk flexion in the sit-up test, trunk extension in the static test, or upper limbs in the dynamic test (Table 5). Flexibility in the trunk side-bending test did not improve either (Table 5).

The motor fitness balance test, one leg standing, did not show significant changes, but the proportions of participants in the exercise groups who achieved a maximum result in the balance test was greater after the intervention than before it. In groups E1 (65% VO_{2max}, 300 kcal) and E2 (65% VO_{2max}, 150 kcal + 150 kcal) 24 and 23 participants, respectively, achieved maximum results at the beginning, and 33 and 28 at the end of the intervention. In control group the respective numbers were 20 and 23. (Table 6).

In the WT walking performance improved. The mean walking time improved by approximately 1 min and the estimated VO_{2max} by approximately 10%, equally in both of the exercise groups when compared with the results of the controls. (Table 5).

Table 5. *Mean values and standard deviations (SD) before and after the intervention and the net change (95% CI) between the exercise and control groups in Study I*[*†]

	N[‡]	Before	After	Net change (95%CI)	P-value[†]
UKK Walk Test, walking time, min					
E1	45	17.5 (1.1)	15.6 (1.0)	-1.2 (-1.6, -0.9)	
E2	43	17.4 (1.2)	15.5 (1.0)	-1.3 (-1.6, -0.9)	
C1	44	17.6 (1.3)	16.9 (1.2)		<0.001
VO_{2max}, ml·min·kg^{-1}, estimated by the UKK Walk Test					
E1	44	30.0 (3.5)	34.7(3.2)	3.3 (2.3, 4.2)	
E2	43	30.3 (4.1)	34.8(3.6)	3.2 (2.2, 4.2)	
C1	43	29.9 (3.8)	31.3(3.6)		<0.001
Dynamic test for the upper extremities, the sum of the right and left hand, number of lifts (maximum 100)					
E1	46	37.2 (14.4)	43.8 (16.3)	2.7 (-2.4, 7.7)	
E2	41	40.3 (15.5)	46.6 (17.4)	2.9 (-2.3, 8.1)	
C 1	41	36.0 (16.6)	40.1 (18.9)		0.465
Static trunk extensor endurance test, time of holding the correct position, s (maximum 240 s)					
E1	44	60.3 (35.9)	69.3 (47.1)	13.0 (1.2, 24.9)	
E2	42	67.1 (44.0)	68.5 (40.1)	7.2 (-4.7, 19.2)	
C1	43	65.9 (34.7)	60.4 (29.7)		0.097
Trunk side bending, cm					
E1	46	17.9 (2.9)	18.5 (2.8)	0.3 (-0.4, 1.1)	
E2	43	16.7 (3.0)	17.3 (3.2)	0.1 (-0.6, 0.8)	
C1	44	17.4 (2.7)	17.8 (2.6)		0.653

[*] *VO_{2max} = maximal aerobic power, E1 = one-session exercise group, E2 = two-session exercise group, C = control group.*
[†] *Analysis of covariance.*
[‡] *Dropouts excluded.*

Table 6. *Proportion of participants who achieved a maximum result in tests before and after the intervention and the odds ratios (95% confidence intervals) between the exercise and control groups at the end of the intervention, adjusted for differences in the baseline distributions in Study I*[*†]

	N[‡]	**Before**	**After**	**Odds ratio (95%CI)**	**P-value**[†]
One-leg standing, s (maximum 60 sec)					
E1	46	52%	72%	2.6 (0.9 to 6.9)	
E2	43	58%	63%	1.2 (0.5 to 3.4)	
C1	44	46%	52%	1.0[§]	0.175
Sit-up test for trunk flexors, the number of sit-ups (maximum 15 repetitions)					
E1	46	65%	80%	5.5 (1.1 to 26.1)	
E2	43	58%	67%	2.1 (0.4 to 10.4)	
C1	43	54%	58%	1.0[§]	0.095
One-leg squat, sum of scores of right and left feet, points (maximum 12 points)					
E1	46	24%	52%	4.1 (1.5 to 11.6)	
E2	43	16%	51%	4.6 (1.6 to 13.2)	
C1	43	23%	26%	1.0[§]	0.008

[*] *E1 = one-session exercise group, E2 = two-session exercise group, C1 = control group.*

[†] *Binary logistic regression analysis.*

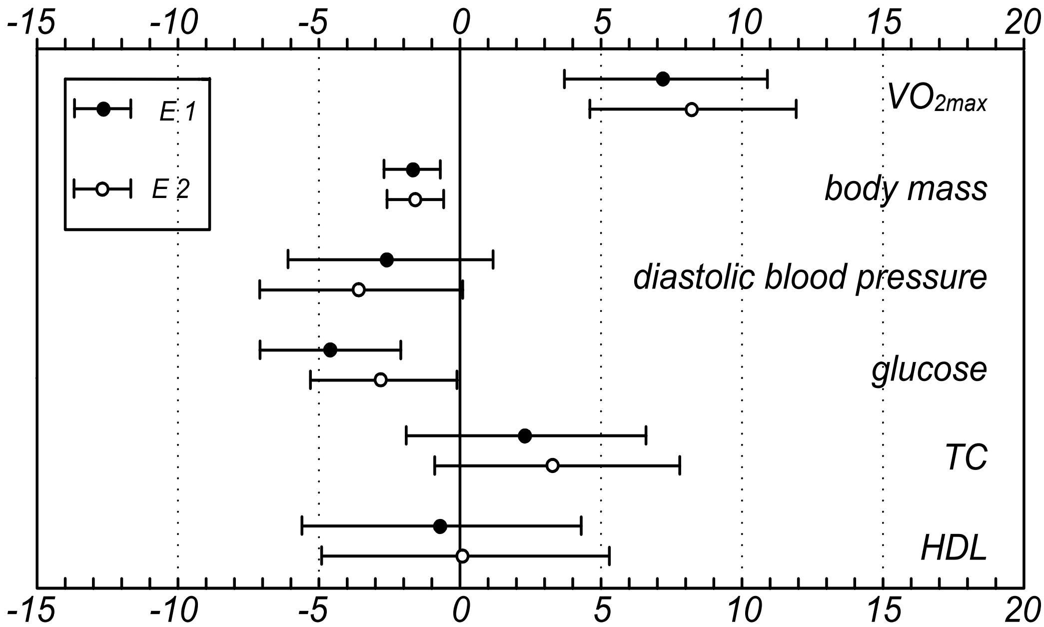
[‡] *Drop-outs are excluded.*

[§] *Reference category.*

2.5. Effects of the fractionated exercise

Fractionated exercise was prescribed for exercise group E2 in Study I. The effects of the fractionated exercise (Group E2) were equal to that of continuous exercise (Group E1) for all of the measured cardiorespiratory, morphological, metabolic and musculoskeletal fitness parameters, VO_{2max}, $HR_{75\%}$ and $HR_{65\%}$, BP, body composition, carbohydrate and lipid metabolism variables, the one-leg squat test for the lower extremity, the sit-up test for the trunk flexors, the static test for the trunk extensors, the dynamic test for the upper limbs, the trunk side-bending test for flexibility, and the one-leg standing balance test. The WT results, walking time and estimated VO_{2max} of fractionated exercise group were also equal to corresponding values of the continuous exercise (Figure 2). This result indicated that the exercise regimen (65%VO_{2max}, 47 min) could be divided into two daily bouts (65%VO_{2max}, 2 x 24 min) without compromising the results.

Figure 2. *Effect of continuous and fractionated walking on selected variables*. Percentage of the net difference (95% CI) during training in the exercise groups† versus the control group in Study I‡.*



* *Selected variables: VO_{2max} = maximal aerobic power, TC = total cholesterol concentration, HDL = high-density lipoprotein concentration*
† *Exercise groups: E1 = continuous exercise (47 min) E2 = fractionated exercise (2 x 24 min)*
‡ *Analysis of covariance with the baseline measurements as covariates*

2.6. Interactions between the exercise and hormone replacement therapy

In both studies the subgroup analysis of the HRT users and non-users showed equal results in all of the measurements, for VO_{2max}, $HR_{75\%}$ and $HR_{65\%}$, BP, body composition, carbohydrate and lipid metabolism variables, the one-leg squat test for the lower extremities, the sit-up test for the trunk flexors, the static test for the trunk extensors, the dynamic test for the upper limbs, the trunk side-bending test for flexibility and the one-leg standing balance test. The WT results, walking time and estimated VO_{2max} were also equal for the HRT users and non-users. This finding indicates that exercise was equally beneficial for hormone users and non-users.

2.7. Feasibility and safety of the exercise programs

The adherence to the exercise program in terms of the duration of completed exercise sessions at the prescribed target HR, frequency of sessions and length of exercise program was 84% -104%, similar in all of the exercise groups of both studies according to the exercise diary recordings. The participation in the supervised exercise sessions was 89% - 95% in Study I and 63% - 65% in Study II. The amount of habitual physical activity, other than the exercise training, was 24 - 28 min in Study I and 11 - 16 min in Study II according to the exercise diaries. (Table 7)

An additional few weeks were allowed with a slightly reduced walking time or intensity for the habituation for participants with exercise-related health problems at the onset of the exercise, for 6 participants in group E1, 7 in group E2, 6 in group E3, 1 in group E4, 1 in group E5, and 3 in group E6. During the last weeks of the intervention 5 participants in group E1, 6 in group E2, 1 in group E3, 1 in group E4, and 1 in group E5 were allowed to use extra 1-kg wrist weights, stair walking or occasional steps of jogging to reach their target HR. The walking program was stopped for one day before the exercise test.

In Study I, in which the exercise dose was highest, most of the participants considered their exercise program feasible in terms of perceived exertion (not too light and not too strenuous) according to the questionnaire. The continuous and fractionated exercise groups showed equal results (Table 8). In addition, according to the questionnaire, most of the participants in the exercise groups did not have any exercise-related lower-limb problems. Two daily walking sessions (fractionated exercise, group E2) caused fewer lower-limb complaints than the continuous exercise did (group E1) ($p = 0.021$ for the difference of proportions) (Table 8).

In Study I and Study II 23% and 27% of the participants, respectively, consulted the physician. Of the total of 73 consultations in Study I, 49 concerned exercise-related problems, as did 50 of the 60 consultations in Study II. Most of the exercise-related consultations concerned the lower limbs at the beginning of the study; also low-back problems occurred. Approximately half of the consultations resulted in temporary changes in the exercise program, but exercise absence was very low because most of the problems were minor and transient. Absence from exercise was due to health problems, family reasons, work duties, or travel. Less than 1% of the absence was due to musculoskeletal problems, and the difference between the exercise groups was not statistically significant.

Of the 134 participants only 4 (3%) had major exercise-related health problems in Study I. Three of the 88 exercising participants interrupted the exercise program, two because of lower-limb problems (persistent plantaris fascitis or newly detected knee arthrosis) and one because of psychosocial reasons. One case of mild, recurrent arrhythmia (paroxysmal ventricular extrasystoles) was detected in an exercise group member after the intervention. A cardiologist suspected that the problems had been caused by overtraining, since no other reason for the arrhythmia was found. One participant in the control group fell on an icy walking trail and suffered a radius fracture.

In Study II also 4 (3%) out of the 121 participants had major problems. Of the 81 exercising participants, 3 interrupted their exercise program. The reasons were psychosocial for 3 of the participants. Two participants in the exercise group had recurrent, mild arrhythmias (paroxysmal ventricular and supraventricular extrasystoles), but continued to exercise after a short rest of a couple of days. One control group member had a distorsion of the knee and one a fracture of the tibia. Most of these women participated, however, in end measurements and were included in the results according to the intention-to-treat principle.

In Study I, 4 out of 134 women did not participate in the 15-week measurements of VO_{2max} because of health problems (one control recovering from a gallbladder operation, one control with newly detected diabetes, one exerciser with an acute lumbar problem, and one exerciser whose test was interrupted because of frequent ventricular extrasystoles). In addition, because of technical difficulties, there was one missing value from the submaximal HR measurement at 75% of VO_{2max} and four at 65% of VO_{2max}.

In Study II 5 of the 121 women did not participate in the end measurements for the following reasons: two exercisers had psychosocial problems, two controls had lower-limb injuries, and one control had been recently diagnosed as having a chronic disease as mentioned earlier.

According to the questionnaire, no other changes in exercise, than the changes corresponding to the intervention program, were reported in the exercise groups. No changes in exercise were reported by the participants of the control groups. Six participants changed their HRT status in Study I. In group E1, two women started and one stopped the HRT. In group E2 one woman started and two stopped the HRT. All six women were included in their original groups in the analyses to meet the intention-to-treat principle. In Study II the HRT remained unchanged.

There were no changes in diet reported in the questionnaire in Study I or Study II. In Study II food diaries were used. Four participants did not return their food diaries, and seven diaries were disqualified because of recording inaccuracies. The mean daily energy intake of the participants in the exercise groups, as calculated from the food diary, was 7.5 (SD1.5) MJ in the beginning and 7.5 (SD 1.4) MJ at the end of the intervention. The respective values of the controls were 7.6 (SD 1.3) MJ and 7.3 (SD 1.4) MJ. No significant quantitative or qualitative changes occurred in the diet of the participants during the intervention.

The subjective experiences of the exercising women with respect to their bodies and well-being were gathered in Study II. In both summarizing indices, one for intensity and one for scope of the experiences, the only significant differences were found between exercise groups E3 - E6 and control group C2. The exercise groups had significantly more positive experiences (unpublished data). (Table 9.)

Table 7. *Training compliance[*] and habitual physical activity[†].*

	Study I		Study II			
	E1[‡]	E2	E3	E4	E5	E6
Duration of session, %	103%	104%	95%	90%	98%	98%
Walking sessions, sessions · wk^{-1}	89%	95%	89%	85%	84%	84%
Supervised sessions, sessions · wk^{-1}	89%	95%	67%	67%	69%	63%
Habitual physical activity, min · d^{-1}	24	28	16	15	11	11
Total walking, km · d^{-1}	9.2	10.4	8.7	8.3	7.0	7.1
Length of intervention, %	96%	99%	97%	98%	99%	99%

[*]*Compliance with the program is expressed as the percentage of completed exercise sessions versus prescribed exercise.*
[†]*Habitual physical activity included walking, cycling, calisthenics and the like, but did not include walking training. All of the variables were calculated from the exercise diary recordings, except total walking, which was estimated from a pedometric measurement. The pedometric measurement was taken only in the exercise groups, and it included all of the physical activity of the day, including the walking training, for 3 days.*
[‡]*E1 = one-session exercise group in Study I, E2 = two-session exercise group in Study I, C1 = control group in Study II. E3-E6 = exercise groups in Study II and C2 = control group in Study II.*

Table 8. *The subjective feasibility of the exercise program in Study I in the continuous (E1) and fractionated exercise (E2) groups according to two questions from the questionnaire.*

	E1	E2
How was the exercise program in general after you became used to it ?		
Very strenuous for me.	7% (3 participants)	None
Somewhat strenuous for me.	22% (10 participants)	26% (11 participants)
Not light but not strenuous for me.	65% (30 participants)	67% (29 participants)
Somewhat light for me.	7% (3 participants)	5% (2 participants)
Light for me.	None	2% (1 participant)
Did you have severe exercise-related lower-limb problems: pain, profound swelling, disturbing muscle tension, overstrain symptoms or overuse injuries during the exercise program?		
Not at all.	41% (19 participants)	65% (28 participants)
Only at the onset of the intervention.	30% (14 participants)	19% (8 participants)
Only during the middle or at the end of intervention.	34% (11 participants)	12% (5 participants)
All the time.	4% (2 participants)	5% (2 participants)

***Table 9**. A list of statements of positive experiences from the questionnaire of Study II. These statements were based on spontaneously reported experiences by participants in the exercise groups.*

- Feeling good.
- I feel refreshed.
- Exercise relaxes me.
- More energetic.
- Feeling active.
- It is easier to restrict overeating .
- Easier to sleep.
- Less pain.
- Less easily irritated.
- Fever gastric or bowel problems.
- Time for myself through exercise.
- Refreshing experiences in natural and new surroundings.
- I have better control of my body.
- It is pleasent to exercise.
- I have a better understanding of my body. I can feel my muscles working.
- My muscular strength has increased.

Discussion

The general aims of this study were to assess the effects of exercise on the health of early postmenopausal women by searching for the minimum effective dose in a systematic literature review and by conducting a series of randomized, controlled exercise trials.

1. Discussion of the systematic literature review of randomized, controlled exercise trials on the health-related fitness of early postmenopausal women

The first problem in conducting the literature search on the was the finding that early postmenopausal women have not been a common object of study with respect to exercise training. It was not until the 1980s that any good quality RCTs on postmenopausal women were carried out. Three reports were published in the 1980s. In the first half of the 1990s, at the time when this study was planned, seven study reports were published, and in the second half of the 1990s nine appeared. After 2000 until June 2004, seven RCT reports were found in the literature. Most of the studies, that we found, were on Cochrane. The study search was very large and this assured that most of the studies were found. The literature search was limited by the fact that only English literature was searched. This was done because of practical reasons. In this literature review enough studies were found only on some of the HRF components to be able to draw conclusions with respect to early postmenopausal women.

Studies were relatively short, which might be due to the tradition of exercise science that considers aerobic fitness the most central aspect of fitness, and 12 weeks or even a shorter period is sufficient to improve it. The bone studies were longer. Also practical reasons make long studies more difficult. An intervention, that is many years long, requires much work to ensure adherence. Prolonging the interventions might show a different picture of the effects of exercise on health.

Exercise prescription was reported well on most of the studies and also how the adherence to it was controlled. HR monitors were not available in the oldest studies. Pulse palpation method was used and it is not as accurate as HR monitor. Some studies used intensity prescription "brisk pace" or "a comfortable pace", that are not very accurate. A few studies had no intensity prescription at all. Changing HR_{max} to VO_{2max} also caused some inaccuracy since this formula was originally formed for men.

Some information was missing in the studies. Very few reported how the randomizing was performed, if there were power calculations, and if performing measurements were blinded. Some of the studies did not report dropouts, attendance or injuries. These are important information in order to understand how feasible and safe exercise programs were.

In The Evidence-Based Symposium on Dose-Response Issues Concerning Physical Activity and Health (Ontario symposium), an expert judgment (evidence category D), concluded that the minimum recommended intensity of exercise for the aerobic fitness and health of adults is 40-60% of VO_{2max} (Shephard 2001).

The present literature review showed that aerobic exercise improves the VO_{2max} of early postmenopausal women in a dose-response manner in moderate-to-high intensity exercise, but there were no studies using intensities of 50% VO_{2max} or below. The minimum dose for improving aerobic capacity in this age group is not known. Improving the submaximal capacity is relevant for sedentary people, since most daily tasks do not demand maximal effort and are more easily performed with good submaximal endurance. However, submaximal capacity was not reported in any of these studies.

In the Ontario symposium, strong evidence (category A) was found (from RCTs, mostly on men) that approximately 50% of the maximal exercise tolerance is effective in reducing BP and that training at a high-intensity level does not appear to provide additional benefit. Dynamic aerobic exercise should be performed 3 - 5 $d \cdot wk^{-1}$ for 30 to 60 min. The symposium also emphasized that it is hard to differentiate between the acute and chronic effects of PA (Kesäniemi et al. 2001).

Not enough data were available in the present literature search with which to draw any conclusions on the effects of exercise on BP in early postmenopausal women since none of the training studies on normotensive, normal weight women showed any effect on BP. Only two studies with slightly hypertensive, overweight participants showed positive results of exercise training on BP and BMI, and one of the two studies also used a reducing diet. It is not possible to determine whether the decreasing BP in these studies was due to exercise or weight loss. Thus it is not known whether exercise influences normal BP or what the sufficient exercise dose should be to lower elevated BP in this age group.

The Ontario symposium also found strong evidence (category A) of a linear dose-response relationship (from RCT's, mostly on men) between the volume of PA and the amount of weight loss in studies with less than 16 weeks' duration. Trials lasting more than 24 weeks did not show the effect. The Consensus Panel noted, however, that there is evidence for other health benefits as a result of modest weight loss in association with PA. (Kesäniemi et al. 2001).

Astrup (1999) conducted a systematic review of postmenopausal women to assess body fat and PA. The review showed that, in cross-sectional observational studies, postmenopausal women with high levels of PA had lower levels of body fat and less abdominal fat. Longitudinal studies showed that physically active women were less likely to gain body fat and abdominal fat after menopause than sedentary women were. However, there were very few RCTs comparing exercise with no intervention, and diet with diet + exercise, and the results did not allow a firm conclusion to be drawn as to whether PA could prevent or limit the gain of total fat and abdominal fat after menopause or whether it might be effective as part of an obesity treatment program.

There was only one study in the present literature search that showed a small weight change after 6 months of moderate exercise training without dieting among normal weight early postmenopausal women. For obese postmenopausal women exercise caused a fat loss of 1 - 2 kg, but combining exercise with diet was more effective. In the studies that did not improve body composition, the exercise modes were similar to those used by effective studies, but either the duration or the intensity or the frequency of exercise was smaller. Thus the exercise volume was inadequate to cause a loss of fat. This result indicates that exercise energy expenditure seems to be more relevant than exercise intensity, although exercise only without diet changes does not seem to be very effective in weight reduction among early postmenopausal women.

The Ontario symposium stated that, according to RCTs, mostly on men, there is substantial evidence that moderate-to-hard exercise has a favorable influence on blood lipid levels (category B). On the other hand, exercise volume seems to be even more important than exercise intensity (category B and C evidence). Most of the studies showed HDL improvements with moderate-to-hard intensity activities for at least 30 minutes, on 3 $d{\cdot}wk^{-1}$, with EEE of 1500 kcal for men and 1200 kcal for women. Baseline lipid levels seem to strongly influence the lipid response to PA. (Kesäniemi 2001).

In their review of exercise and lipids among women, Krummel et al. (1993) stated that, in cross-sectional studies, there was a positive association between exercise and HDL among both pre- and postmenopausal women. Women on HRT who reported exercising also had a higher HDL level than sedentary women on HRT. The results from longitudinal training studies were reported to be inconsistent, but, in approximately half of the intervention studies, an increase in HDL was shown, the magnitude of the response being approximately 10%, but the responsiveness of the pre- versus postmenopausal women to exercise intervention was reported to be unknown.

Kelley et al. (2004) presented a meta-analysis of RCTs on aerobic exercise and lipids and lipoproteins among adult women and found that reductions of approximately 2%, 3%, and 5% were observed for TC, LDL, and TG, respectively, whereas an increase of 3% was observed for HDL. This review did not pay special attention to postmenopausal women.

Too few studies were available in the present literature search with which to draw conclusions about the effects of exercise on metabolic fitness in early postmenopausal women. There are no RCTs to show the amount of exercise needed to influence glucose metabolism. Neither are there RCTs showing lipid changes in normal weight, normolipemic women in this age group. For overweight or dyslipemic participants, exercise training seems to improve the lipid profile. Adding HRT or diet with or without exercise improves lipid concentration, and, in some studies, the effect was found to be additive, but the results were partly confusing.

It seems to be well documented, according to the present systematic literature review, that early posmenopausal women are trainable using gym strength-training equipment, and large improvements of muscle strength can be gained. Only one of the studies used simple equipment and a program that could also be performed at home. Exercise programs that could be performed at home should be given more attention since adherence seems to be better in home-based programs.

Most of the studies in the present review stated that the exercise program consisted of 5 - 10 min warm-up and cool-off periods with stretching, but the effects on flexibility were seldom studied. Stretching is recommended by the ACSM (1998a) for every exercise session. More studies are needed to show the effective ways of performing stretching for early postmenopausal women.

The effect of exercise training on the balance and coordination of early postmenopausal women was reported in very few studies, all using different modes and doses of exercise. More studies are needed to help determine the dose-response relationship between exercise and balance and coordination.

In their review of HRT and exercise on cardiovascular disease risk factors for postmenopausal women Haddock et al. (2000) found that, generally, estrogen replacement decreases TC and increases HDL and TG concentration. The addition of progestogen to estrogen may negate some of the beneficial effects of estrogen, most notably the increase in HDL. However, progestogen has also been reported to offset the increase in TG seen with unopposed estrogen replacement. Regular aerobic exercise increases HDL and decreases TG, but, according to the review, most of the research supporting the effects of exercise on risk factors of CVD has been done on men, and, even when research has included women, very few studies have focused on postmenopausal women. However, the research done on postmenopausal women points to a significantly improved risk factor profile for CVD with regular cardiorespiratory exercise.

In the present literature review only five of the studies focused on the effects of exercise and HRT. According to one, HRT did not have an effect on aerobic power, but it decreased systolic BP. Two of the studies showed that HRT and exercise improve lipid profiles almost equally, the only difference being that, in one study, only HRT had an effect on LDL when compared with the effects of exercise, whereas in the other study only HRT had an effect on HDL when compared with the effect of exercise. Exercise and HRT did not have an additive effect on any of the variables in these studies.Two of the studies reported an additive effect on muscular strength, and one of the studies reported a positive effect of HRT on balance. More studies must be carried out on the possible effect of HRT on the response to exercise training before any conclusions can be drawn, because so far the results have been partly confusing.

Copeland et al. (2004) reviewed studies on aging, PA and hormones and reported that the studies generally showed that increasing age blunts the acute hormonal response to exercise, although this finding may be explained by a lower exercise intensity among older women. PA may have an effect on hormone action as a result of changes in protein carriers and receptors, and future research needs to clarify the effect of age and exercise on these other components of the endocrine system. The authors concluded that the value and safety of hormone supplements must be examined, especially when used in combination with an exercise program.

Walking seems to be the most feasible and safest exercise mode for this age group in terms of low dropout rate, high attendance, and low injury rate, although these variables were not reported in some of the studies.

Exercise in several daily bouts has been suggested in exercise recommendations (Pate et al.1995, ACSM 1998a), but so far only one good-quality RCT has been carried out in this age group using fractionated exercise, and the study also included men. Only the result of no effect on lipids was reported separately for the two genders (Woolf-May et al.1999). The feasibility of fractionated exercise in comparison with continuous exercise was not reported.

The injury rate for mixed aerobic training was slightly greater in the only study in which it was reported than in walking-only studies, especially when the intensity was high. Definite conclusions on injury rate cannot be drawn because most of the aerobic training studies did not report it. More studies are needed on versatile forms of aerobic exercise in this age group. Combined aerobic and resistance training required supervision in most of the exercise sessions. The injury rate was low. The dropout rate for this kind of training combination was approximately equal to that of walking and aerobic exercise studies, but the attendance was smaller than in aerobic exercise or walking only groups.

Weight training with machines required instruction and supervision, and even when supervised, it was associated with a higher injury rate than any other type of training in this literature review.

High-impact training had lower attendance and a higher injury rate than walking, which suggests limited feasibility for this form of exercise.

Exercise prescription was well reported in most of the studies, as was the control of adherence to exercise prescription. HR monitors were not available in the oldest studies, and the pulse palpation method was used, which is not as accurate as the HR monitor. Some studies used even less accurate intensity prescription, "brisk pace" or "a comfortable pace". A few studies in this review did not have an intensity prescription at all. HR_{max} was transformed to correspond to VO_{2max} in order to be able to make comparisons, and this transformation could also have caused some inaccuracy since this formula was originally formed for men (Oja 1973). It was used, however, because there are no corresponding transformation formulas for women. Many of the studies did not report the attendance, dropout or injury rates. Such information would be important for the assessment of the feasiblity and safety of exercise programs.

ASCM recommends 30 min of exercise on most days, and assumes it could have some metabolic health effects even though it was suspected not to increase cardiorespiratory fitness (Pate et al. 1995). Oguma (2004) presented a review and meta-analysis of PA and CVD risks among women and concluded that PA was associated with a reduced risk of CVD among women in a dose-response fashion. Inactive women would benefit by increasing their PA, walking 1 hour per week or possibly even less was beneficial, and more benefit was gained from additional PA. This review did not draw any conclusions for postmenopausal women. In their tutorial review for perimenopausal and postmenopausal woman Miszko and Cress (2000) recommended aerobic exercise on 3 to 7 $d \cdot wk^{-1}$ for 15 to 60 min at 65% to 70% of HR reserve and also strengthening exercises 2 to 3 $d \cdot wk^{-1}$ at 40% to 80% 1RM with appropriately selected exercises in order to improve the quality of life and attenuate some of the physiological changes associated with aging.

According to the present literature review, the metabolic health effects seem to be harder to acchieve by PA than improvements in cardiorespiratory fitness, contrary to earlier beliefs. For early postmenopausal women, these recommended minimum exercise regimens of ACSM (1995) and Oguma (2004) may improve aerobic fitness, but probably not lipid levels or glucose metabolism - not at least in short-term training. Whereas using the tutorial recommendation of Miszko and Cress (2000), in which the exercise dose is larger, the possiblity of getting an effect on HRF is better, and exercise doses like this should be studied in RCTs with early postmenopausal women.

2. Discussion of Study I and Study II

The specific aims of the Study I and Study II were to assess the effects of six exercise regimens of light-to-moderate intensity on the cardiorespiratory, morphological, metabolic, muscular and motor fitness of sedentary, early postmenopausal women in RCT settings and to determine the minimum effective dose. The interactions between exercise and HRT on health-related fitness were also studied, as well as the feasibility and safety of the studied exercise regimens.

2.1. Baseline characteristics

The randomization succeeded in producing equal groups of participants in both studies (Table 3). The mean age of the participants varied from 54 to 58 years depending on the group, the mean years from menopause renged from 5 to 6 years, the mean weight from 66 to 70 kg, and the mean VO_{2max} from 28 to 30 $ml \cdot min^{-1} \cdot kg^{-1}$ in the groups. The mean PA activity score (2.2 - 2.6) of the groups showed that the participants performed some light PA every week, but participated less than once a week in brisk PA. The mean cardiorespiratory fitness VO_{2max} of the groups was 28-30 $ml \cdot min^{-1} \cdot kg^{-1}$,which corresponds to "3 = average fitness" on the Finnish fitness scales of the Paavo Nurmi Centre, Turku, Finland (Viljanen et al.1990).

2.2. Cardiorespiratory fitness

2.2.1 Effect of intensity and exercise energy expenditure on maximal aerobic power

Cardiorespiratory fitness, maximal aerobic power, as measured by VO_{2max} and with the WT, and also submaximal capacity, as measured from the $HR_{75\%}$ and $HR_{65\%}$, improved in all or most of the exercise groups. The net increase in VO_{2max} was small, but significant and consistent in all of the groups.

There were, however, some trends that can be speculated to show a dose-response trend. The effect of exercise intensity was compared combining the results of the two studies. In the exercise groups in which the exercise energy expenditure was 300 kcal but the exercise intensity varied, the improvement in VO_{2max} was 7.2% in Study I with the intensity of 65% VO_{2max} (group E1). In Study II the VO_{2max} improvement seemed to be slightly higher, but actually there was no difference between the results of both Studies. In Study II the improvement was 9.5% with an exercise intensity of 55% VO_{2max} (group E3) and 8.1% with an intensity of 45% VO_{2max} (group E4). There seems to have been a trend towards a dose-response relationship between the exercise intensity and the magnitude of VO_{2max} improvement in Study II. Combining the groups according to intensity in Study II also showed the dose-response relationship trend of less response with less intense exercise. The improvement was 9.4% for the groups with an exercise intensity of 55% VO_{2max} in the combined group (E3 + E5) and 8.7% when those with an intensity of 45% VO_{2max} (E4 + E6) were combined.

The effect of exercise energy expenditure showed a similar dose-response trend. For the groups with an exercise energy expenditure of 300 kcal combined (E3 + E4), the VO_{2max} improved by 10 %, and those with an exercise energy expenditure of 200 kcal (E5 + E6) showed an 8% improvement in VO_{2max} when combined.

No other low-intensity studies have been carried out with early postmenopausal women that have used exercise groups with a 50% VO_{2max} exercise intensity or below. With regard to the magnitude of the VO_{2max} improvement, our findings are consistent with those of randomized, controlled low-intensity walking studies of slightly younger women. Oja et al. (1991b) used walking training with the intensity of 50% VO_{2max}, and the VO_{2max} improvement was 8%. Duncan et al. (1991) used walking training of approximately 46% VO_{2max} and showed an improvement of 4% in VO_{2max}, as measured by a maximal exercise test.

The exercise regimen used in Study II seemed to be approaching, but possibly not reaching, the minimum dose, since even the lowest dose of walking improved the VO_{2max}. The minimum dose of exercise needed to improve the aerobic fitness of early postmenopausal women equals or is less than the lowest exercise dose used in this study (45% VO_{2max}, 200 kcal). For practical purposes this can be considered the minimum dose. But if the dose-response trend of this study is extrapolated, probably the actual minimum dose to improve VO_{2max} could be around 40% VO_{2max} but this is pure speculation and it remains to be proved in the future, as more low-intensity RCT's are published on early postmenopausal women.

2.2.2 Health-related significance of the improvements in maximal aerobic power

According to epidemiological studies, the most benefit for public health will come as sedentary people become active (Pate et al. 1995). The improvement in VO_{2max} in this study was enough to increase most of the participants' level of fitness close to or exceeding the VO_{2max} value of 31.5 $ml \cdot min^{-1} \cdot kg^{-1}$ and, therefore, to move the participants into a low-risk category for all-cause mortality on the basis of the study of Blair et al. (1989). They followed 3120 women for 8 years and found that the VO_{2max} value of 31.5 $ml \cdot min^{-1} \cdot kg^{-1}$ represented the level of fitness at which the risk level for all-cause mortality clearly decreased in this age group of early postmenopausal women. A more recent epidemiological study by Farrel et al. (2002) suggested an even lower value, a VO_{2max} of 28.0 $ml \cdot min^{-1} \cdot kg^{-1}$, for 40- to 49-year-old women to be classified as moderately fit and have decreased mortality when compared with women with a lower VO_{2max}. Thus the exercise dose, used in the present study, might, after all, have some long-term clinical significance for early postmenopausal sedentary women, if exercise is continued.

2.2.3 Blood pressure

There was no statistically significant effect on the mean resting BP in the exercise groups of this study. Combining the exercise groups showed a 3-mmHg reduction in the mean diastolic BP in Study I, but not in Study II. This difference could have been due to the greater exercise dose in Study I.

So far no other exercise-training studies have been carried out on normotensive, normal-weight early postmenopausal women that have shown an effect on BP. Even in this study the result coud be seen only after the exercise groups were combined. Thus the result is only preliminary, and the exact exercise dose needed to influence the normotensive level of BP in this age group is not known.

The ACSM position on exercise and hypertension recommends that hypertensive adults participate in endurance types of PA, supplemented by resistance exercise, on most, and preferably all, days of the week (ACSM 2004). The intensity of exercise should be moderate, 40% to <60% of the VO_{2max}. The recommendation states that, inside these limits, there is no influence of exercise intensity or that a lower intensity might be associated with a larger reduction in BP (ACSM 2004).

A recent meta-analysis of 54 RCTs of 2419 adults, mostly men, concluded that systolic and diastolic BP can be lowered by approximately 4 mmHg and 2 mmHg, respectively, in normotensive persons and by approximately by 5 mmHg and 4 mmHg in hypertensive adults, respectively, with aerobic dynamic physical training (Whelton et al. 2002). Kelley and Sharpe Kelley (1999) suggested, on the basis of a meta-analysis of 21 randomized and non-randomized, controlled studies on women, that the training effect would be smaller for women, approximately 2 mmHg for systolic BP and 1 mmHg for diastolic BP. The studies included in these meta-analyses used training regimens of 2 to 5 $d \cdot wk^{-1}$, 15-60 minutes per session, with an intensity of 40% to 80% of the VO_{2max}. The optimal exercise intensity remained unclear.

The exercise doses of the present study were at the lowest border when compared with the exercise doses of the aforementioned meta-analyses. According to the Finnish national evidence-based recommendation that is based on WHO recommendation (Whitworth 2003) defines normal BP as < 130/85 mmHg. Most of the participants in Study I were normotensive according to the initial BP measurement. Approximately one-third of the participants had elevated blood pressure (130/85 mmHg - 160/100 mmHg) initially. The number of participants with an elevated diastolic BP decreased during the training in Study I, from 40 to 34 participants at the end of the intervention.

The Hawksley random-zero sphygmomanometer that we used is considered a good method for blinding the measurements, but it has been shown to give slightly smaller readings than an ordinary mercury manometer. The mean difference is less than 1 mmHg (Kronmal 1993). As we used the same method in all of the measurements, there should not be any effect on the results. The measurements were recorded using an accuracy of 2 mmHg. Thus the mean 3 mmHg reduction that was calculated only after the exercise groups were combined should be interpreted with caution. A mean decrease of 3 mmHg in diastolic pressure, however, means that approximately half of the participants had even larger reductions, and this finding may have some clinical relevancy for these participants.

The practical minimum dose to be recommended for inducing a minimal decrease in diastolic BP in the mostly normotensive study group of sedentary postmenopausal women of this study is probably close to the exercise dose of Study I (65% VO_{2max}, 1500 $kcal \cdot wk^{-1}$). A larger exercise dose is probably needed to get a clearer effect, one that would also influence systolic BP.

2.3. Morphological fitness

Body mass decreased by approximately 1 kg (1.7%) in Study I, in which the exercise dose was largest. As 1 kg fat equals 7000 kcal and the calculated exercise energy expenditure for Study I with 15 weeks of intervention was 15 x 1 500 kcal = 22 500 kcal and that for Study II with 24 weeks of intervention was 24 x 1000 to1500 kcal = 24 0000 to 36 000 kcal, it was theoretically not possible to lose more than 3 to 5 kg with exercise alone. There was a very small F% decrease in almost all of the exercise groups, approximately 2 percentage-units in Study I and 1 percentage-unit in Study II. All of these changes were small but consistent and statistically significant, but, as the standard error of the measurement system used for F% was 3-4%, these results on F% must be interpreted with caution.

Only one RCT has thus far been carried out with normal-weight early postmenopausal study participants (Ready et al. 1996). It showed a slight decrease in body mass. In this study the participants walked 60 minutes at an intensity of 60% VO_{2max}, 3 - 5 $d{\cdot}wk^{-1}$ for 24 weeks and lost 0.1kg of body mass, and the percentage of body fat decreased 1.1-1.3%-units. The controls gained weight. The findings of other randomized, controlled walking studies on normal-weight, slightly younger women have shown similar results. Kukkonen-Harjula et al. (1998) found a 1.5% reduction in weight in their 15-week walking study. Murphy and Hardman (1998) found a slight reduction in four skinfold thicknesses in both exercise groups in their 10-week walking study with fractionated exercise, but a significant 2.6% reduction in body mass only for the walkers with fractionated exercise.

Exercise intensity should not be as important a factor of exercise dose as the total amount of energy expended in exercise when the aim is to improve body composition with exercise. In Study II expending 1500 kcal walking at the intensity of 55% or 45% VO_{2max} did not decrease body weight, and there were only minimal decreases in F %. However, Study I, with a greater intensity but equal energy expenditure, did show small improvements in body mass, BMI and F%. Study I also included 10 -15 min of resistance training twice a week in addition to the 1500 kcal of weekly walking, but the exercise energy expenditure of such a short and moderate resistance training program could only partly explain the better results in Study I. Very high-intensity exercise causes a postexercise increase in metabolic rate, and this increase may contribute to a larger daily total energy expenditure, but this was probably not the case in Study I since 65% VO_{2max} is moderate not high intensity. Thus the explanation for a possible effect of intensity remains unsettled. The exercise dose of expending 1500 $kcal{\cdot}wk^{-1}$ for 15 weeks by walking at an intensity of 65% VO_{2max} and short, moderate resistance training twice a week seems, however, to be very close to the practical minimum dose of exercise to be recommended for effects on body composition in early postmenopausal women.

2.4. Metabolic fitness

2.4.1. Glucose metabolism

There was a statistically significant, small reduction in the fasting and 2-hour glucose concentrations in Study I, but not in Study II, in which the exercise intensity and exercise energy expenditure were smaller. The fasting blood glucose concentration in group E2 and the 2-hour glucose concentration in groups E1 and E2 decreased only when compared with the results of the controls; the absolute values decreased in group E1 but slightly increased in group E2. The absolute values of the control group increased.

Thus far, no RCTs have reported what would be the effective dose of exercise for sedentary, early postmenopausal women with respect to carbohydrate metabolism. Manson et al. (1991) found a relationship between regular vigorous exercise and the subsequent incidence of type 2 diabetes in a prospective cohort of 87253 healthy US women aged 34-59 years in 8 years of follow-up. In the Nurses Health Study, Hu et al. (1999) found that walking reduced the risk, but vigorous exercise reduced it even more.

The practical minimum dose of exercise to be recommended for a small effect on glucose in normoglycemic, sedentary postmenopausal women is probably very close to the largest exercise dose of this study (65% VO_{2max}, 1500 $kcal \cdot wk^{-1}$) combined with a moderate, short resistance training program twice a week. For a stronger effect, more exercise is needed.

2.4.2. Lipid metabolism

There were no statistically significant changes in the chosen lipid metabolism variables in any of the exercise groups in this study. There was much variability to be found in the responses of the participants in this study in spite of the good compliance and careful blood sampling. For this age group, no RCTs have shown lipid changes in normal weight, normolipemic women.

According to a meta-analysis of 28 RCTs, mostly on men using endurance training, the response between individuals varied greatly for the same training stimulus (Leon and Sanchez, 2001). They showed that aerobic exercise increased HDL by 4% to 5%. Most of the studies had an exercise frequency of 3 to 5 $d \cdot wk^{-1}$ and 30 minutes or more of exercise per session at moderate to strenuous intensity. There is limited evidence that higher exercise intensity will give a larger HDL response than moderate or light intensity. The threshold to influence lipids during weekly training seems to be an exercise energy expenditure of 1200 - 1500 kcal, and the minimum length of the training should be 12 weeks (Leon and Sanchez 2001).

A more recent finding in the 6-month study of 111 overweight men and women of Krauss et al. (2002) suggests that energy expenditure is crucial and more important than exercise intensity alone, and the most marked effects are observed at an energy expenditure of 2000 kcal with strenuous intensity.

The length of the training period may also be very important, especially for postmenopausal women. In one RCT 1 year of moderate training among postmenopausal women was not enough, but the 2-year uncontrolled extension of the study showed statistically significant lipid improvements (King et al. 1995).

According to Leon and Sanchez (2001) baseline lipid levels strongly predict response, in that the lower the baseline HDL, the higher the response to exercise. Premenopausally, women have higher HDL levels due to their hormonal status, but postmenopausally the levels decrease. HRT decreases TC and increases HDL and TG levels (Haddock et al. 2000), and thus HRT must be taken into account in exercise trials.

The baseline lipid concentrations of the participants of this study were mostly in the normal range (e.g. 95% of the participants had a baseline level of over 1.00 $mmol \cdot l^{-1}$ for HDL). The study design of this study called for an equal number of participants with or without HRT in each group.

The doses of exercise in the present study were at the lower border of the suggested minimum requirements for lipid improvements. The minimum dose of exercise for healthy, sedentary, normolipemic postmenopausal women with or without HRT seems to be more than the largest exercise dose of this study.

2.5. Musculoskeletal and motor fitness

The musculoskeletal function, balance and coordination tests were chosen mostly from the UKK health-related fitness test battery, but some of the tests were from Eurofit and the Invalid Foundation test battery. The selected tests were evaluated as the best tests for this group of sedentary early postmenopausal women.

Walking performance improved in Study I as walking time decreased in the WT. Walking performance measured by the WT is associated with both submaximal aerobic capacity (Oja et al.1991a) and musculoskeletal functioning (Suni et al.1998a). At the population level, maintaining a good ability to walk is perhaps one of the key issues in the prevention of mobility-related disability. Earlier population studies among middle-aged (Suni 1998a) and older populations (Guralnik et al. 2000, Malmberg et al. 2002) have shown a strong association between different performance tests using walking and mobility-related function. In older populations a slow walking speed has also been associated with an increased risk of falls among elderly long-term institutionalized patients (Luukinen et al. 1995).

Lower-limb strength improved equally in both exercise groups in Study I. In practice the participants in the training groups were able to perform the squat test with a 30% extra load of body weight, which was, on average, one level higher than at baseline (20%). It is worth noting that the participants in this study accomplished this result without specific resistance training equipment by engaging in simple, closed-kinetic-chain, muscular exercises and walking. Heavy resistance training with special equipment can result in much larger, two to threefold, increases in strength (Nelson et al. 1994, Fiatarone 1994). However, it also requires close supervision and participant travel to exercise facilities, which may become barriers to training.

The performance of the trunk flexors, trunk extensors and upper extremities was not improved by the exercise program of Study I. There should have probably been more repetitions or sets, or the training should have been more frequent in order to elicit improvements in muscular strength in a simple low-resistance program using only body weight and 5-kg dumbbells. The stretching program should also have been more effective. This program could, however, easily be developed to be more effective. Home-based programs may be more feasible in the long term (King et al. 1991), and thus simple programs may be more preferable than gym programs for many women.

Balance was not improved by this exercise program. However, there was a positive trend towards improvement in group E1. The number of participants who reached a full score result increased during the intervention. The fact that over 50% of the participants reached the maximum score in the baseline balance testing may have decreased the possibility to detect the real training effect. A more challenging test of balance would have been more appropriate for the relatively fit participants of this study. The three upright exercises used in this muscular training program (knees-up, back touch, squat) were aimed at improving balance and coordination of the hip, knee, and ankle musculature (Flanagan et al. 2003). Heitkamp et al. (2001) reported significant improvements in both balance and lower-limb strength after a similar type of closed-kinetic-chain balance exercises with younger participants. They measured balance with a more-difficult one-leg standing test on a narrow edge. The balance test that was chosen for this study was not suitable for the participants. It is possible that the use of a more-challenging balance test in this study might have shown an improvement in balance, but this is merely speculation.

2.6. Fractionated exercise

The improvements in VO_{2max}, $HR_{75\%}$ and $HR_{65\%}$, BP, body composition, carbohydrate metabolism variables, the one-leg squat test for lower-extremity strength, and also the WT improvements, walking time and estimated VO_{2max} with fractionated exercise were equal to those produced by continuous exercise in Study I. Lipid concentration, the sit-up test for trunk flexors, the static test for trunk extensors, dynamic test for upper limbs, the trunk side-bending test for flexibility, and the one-leg standing balance test did not show any significant changes in either of the exercise groups in Study I. Thus the effects of fractionated exercise seemed to be equal to those of continuous exercise for all of the selected variables in this study.

Thus far, only one study has been carried out on the effects of fractionated exercise on postmenopausal women. Woolf-May et al. (1999) conducted a study of 56 adults including 19 men and 37 women between 40 and 66 years of age walking 20 - 40 minutes in one, two or three bouts and reported equal responses by all of the exercise groups in a standardized step test and blood lactate measurements indicating aerobic fitness. The results of the men and women were analyzed separately only regarding lipid response; the result was non significant.

Staffileno et al. (2001) studied the effects of intermittent, moderate exercise with an intensity of 50 - 60% VO_{2max}, 3 bouts of 10 minutes a day, 5 $d \cdot wk^{-1}$ for 8 weeks on18 hypertensive, postmenopausal women and found that systolic BP was reduced by 8 mmHg and diastolic BP by 5 mmHg in the exercise group versus the controls. Staffileno et al. (2001) did not have a continuous exercise group.

There are some RCTs which studied other age groups or men. Jakicic et al. (1995) compared the effects of 20- to 40-min brisk walking done in one continuous session or multiple 10-min bouts in a 20-week trial on 56 obese 35- to 46-year-old women. The multiple-bout group had better adherence and exercised more than the continuous exercise group. The VO_{2max} increases were 6% in the multiple-bout group and 5% in the continuous exercise group. Murphy and Hardman (1998) studied 47 women, aged 38 to 51 years, doing 10 weeks of brisk walking at an intensity of 70 - 80% of the HR_{max}, 5 $d \cdot wk^{-1}$, in one 30-min session versus three 10-min sessions, and found improvement of approximately 8% in the VO_{2max} of both groups. Ebisu (1985) studied the effects of jogging the same distance in one, two, or three daily sessions at 80% of the HR_{max} for 10 weeks on 53 male students and found VO_{2max} responses of 6.9%, 9.8% and 8.3%, respectively. There are also other studies on exercise accumulation showing primarily that accumulated exercise is as effective as continuous exercise, but these studies lack randomization or are uncontrolled or do not compare effects of short bouts to a long bout of equivolume exercise (DeBusk et al. 1990, Snyder et al. 1997, Woolf-May et al. 1998, Jakicic et al. 1999, Donnelly et al. 2000, Boreham et al. 2000).

The decrease in diastolic BP in Study I seemed to be similar in the one-session, -2.6 (95%CI -5.5 to 0.4) mmHg, and two-session, -3.3 (95%CI -6.3 to -0.4) mmHg ($p = 0.071$) exercise groups, even the change was not statistically significant in the original exercise groups. The result could be interpreted as statistically significant only after the exercise groups were combined, -3.0 (-5.5 to -0.4) mmHg ($p = 0.025$). No other RCTs have compared the effects of fractionated exercise with continuous exercise on the BP of women of this age group.

There are few studies on younger, obese, or hypertensive women on the effects of fractionated exercise on BP. In the study of Jakicic et al. (1995) the multiple-bout group had better adherence and exercised more than the continuous exercise group. There was a mean decrease of 2.6 mmHg and 5.6

mmHg in systolic and diastolic BP, respectively, in the multiple-bout exercise group, and the corresponding decreases for the continuous exercise were 3.9 mmHg and 4.1 mmHg, while the data for the control groups were not shown. In the study of Murphy and Hardman (1998) no statistically significant changes in BP were found.

The exercise dose of Study I had a small effect on the fasting blood glucose level and the 2-hour glucose concentration in OGGT in a comparison with the controls, and the effect was equal in the continuous and fractionated exercise groups. So far there has not been any other RCT on the effects of fractionated exercise on carbohydrate metabolism.

The exercise dose of the present study was not enough to induce statistically significant changes in the lipid values. However, when the effects are looked at graphically, one can assume that the effect of fractionated and continuous exercise on lipids may be similar (Figure 2.) No RCTs have shown any effects of fractionated exercise on lipids in early postmenopausal women.

In the study of Woolf-May et al. (1999) on adults, LDL decreased in the long (-0.29 $mmol \cdot l^{-1}$) and intermediate (-0.41 $mmol \cdot l^{-1}$) bout groups, but not in the short bout group. However there were no HDL changes in any of the exercise groups. But when the participants were divided into subgroups, it was found, that the lipid changes were not significant in the subgroup of postmenopausal women. In the study of Ebisu (1985) with young men, there was a significant approximately 4% increase in HDL cholesterol only in the three-session exercise group. The 10 weeks of exercise in this study may have been too short to reveal the full, long-term effect on lipid levels.

The effects of fractionated exercise were similar on all of the studied components of HRF in this study. This is the first study with early postmenopausal women to compare the effects of fractionated and continuous exercise and find that fractionated exercise is as effective as continuous exercise. In order for definite conclusions to be drawn, additional studies must be carried out, especially regarding the effects of fractionated exercise on BP and metabolic fitness.

2.7. Interactions between exercise and hormone replacement therapy

All of the participants in this study were postmenopausal according to the questionnaire and interview. An equal number of women using and not using HRT were selected and randomized separately into exercise and control groups. The HRT included many different kinds of commercial estrogen-progesterone products that the participants had already been using for at least 6 to 12 months. The study did not start with a specific HRT and compare the results of the HRT-only to exercise-only and control groups, although such a study design would have been a more accurate way to determine the effects of HRT and exercise on HRF components. This study merely compared the results of women using HRT and those not using HRT in comparison with controls. Thus the results should be considered preliminary and must be verified by more specific studies.The subgroup analyses showed similar results for all of the HRF components among the women using or not using HRT. HRT or lack of it did not interfere with the effects of training.

In the study of Lindheim et al. (1994), HRT did not affect maximal aerobic power. In addition 24 weeks of walking and cycling improved aerobic power equally with or without HRT. These results are similar to those of the present study. HRT alone did not improve aerobic fitness in the study of Lindheim et al. (1994).

Lindheim et al. (1994) also found that HRT and exercise had positive effects on BP, but the effects were not additive. Therefore no difference could be found between the results of exercise on blood pressure among the exercising women using or not using HRT, which is similar to the finding of Study I study.

Also according to Lindheim et al. (1994), HRT and exercise had positive, but different effects on lipids concentrations in that they both decreased TC, TG and LDL, but only the HRT also increased HDL. Exercise and HRT did not have an additive effect on these variables. In their study of 2 years of mixed resistance and aerobic training with HRT and HRT + exercise groups Heikkinen et al. (1997) found decreased TC and increased HDL in both intervention groups, but the effect of exercise alone on lipids was not reported by Heikkinen et al. (1997). LDL cholesterol was not improved in either of the groups in this study. The exercise in the present study had no effect on any of the lipid levels either in the participants using HRT or not using it; therefore the study could not verify any of the slightly controversial findings of Lindheim et al.(1994) and Heikkinen et al. (1997).

Texeira et al. (2003) found that 1 year of resistance training improved body composition by increasing lean soft tissue by approximately 1 kg in both exercise groups, regardless of HRT, but only the HRT + exercise group also lost fat by approximately 1 percentage-unit. This study differs from the finding of the present study, in which the magnitude of fat decrease was equal to taht of the study by Texeira et al, but no differences were found between the improvements among the HRT users and non-users. Texeira et al. (2003) concluded, however, that the effect of exercise was more important than the effect of HRT on body composition, since the HRT-only groups did not show any improvement in lean soft tissue, but it was shown to prevent a decrease in lean soft tissue when the findings for the group were compared to controls. The study of Texeira et al. (2003) lasted longer, the resistance training program was more intensive, and the means of analyzing the lean and fat tissue was more accurate (dual energy x-ray absorptiometry) than the method (skinfold measurement) used in the present study. These differences could explain the discrepancy between the results of the two studies. The findings of the present study cannot rule out the possibility that HRT may affect body fat. More studies are needed before definite answers will be available.

Muscle strength improved in the exercise groups in the study of Texeira (2003), but this effect was not reported separately for HRT users and non-users.

Sipilä et al. (2001) studied the effects of high-impact exercise sessions for 1 year and HRT on body composition and muscular strength. There were no changes in body composition, but muscular strength improved in all of the treatment groups. Exercise and HRT seemed to have an additive effect on muscles, since the results were best in this group. Heikkinen et al. (1997) studied the effects of mixed resistance and aerobic training for about 2 years and HRT on muscular strength. The HRT and HRT+ exercise and exercise-only groups all had positive effects on muscular strength. HRT was concluded to have an anabolic effect on muscles. No anabolic effect was found in Study I of the present study, and improvements in muscular strength were equal among the HRT users and non-users. In addition it must be taken into account that Study I lasted only 15 weeks versus 1 year in the study of Sipilä (2001) and 2 years in the study of Heikkinen et al. (1997). A longer period may have increased the possible small differences in the results of the HRT users and non-users. Thus the possibility of an anabolic effect of HRT cannot be ruled out with the results of the present study.

Bassey et al. (1998) studied the effects of a 24-week jumping program and HRT on body composition, muscle strength and balance. There were no significant effects on body composition and muscle strength. Only the HRT+ exercise group, not exercise alone, improved balance. In the present study no statistically significant improvements in balance could be found. No definite conclusion on the effect of HRT on balance can be drawn from any of these results.

On the basis of the results, it can be concluded that HRT or the lack of it does not seem to interfere with the effect of exercise on aerobic power. The effect of HRT and exercise on other aspects of HRF, especially BP, body composition, lipids, and muscular strength needs additional study before definite conclusions can be drawn.

2.8. Feasibility and safety of the exercise programs

A dose-response relationship has been found that shows that, especially for elderly people low- to- moderate intensity exercise is safer than high-intensity exercise (ACSM 1998b). This relationship emphasizes the need to find the lowest effective dose of exercise for HRF for early postmenopausal women. Exercise recommendations estimate that it is 40 - 50% of the maximum oxygen uptake reserve (ACSM 1998a). If the estimate of 45% VO_{2max} is used as the minimum recommended intensity, the present study shows that this intensity with an exercise volume of 1000 -1500 $kcal \cdot wk^{-1}$ was able improve some components of the cardiorespiratory and morphological fitness of sedentary, early postmenopausal women. However, if BP and blood glucose should be affected, the intensity has to be at least 65% VO_{2max}, and the exercise volume should be 1500 kcal. If lipid levels are to be improved, the exercise dose must be even higher.

A large individual variation was found in this study when the components of exercise dose, target HR and target duration were calculated for the participants of the study. For example, in the exercise groups with a target exercise energy expenditure of 300 kcal per session, the mean target HR rates and the durations for the participants in the exercise groups with different exercise intensities were 131 beat·min^{-1} and 47 min for 65% VO_{2max} (= moderate (somewhat hard) intensity), 124 beat·min^{-1} and 54 min for 55% VO_{2max} (moderate intensity) and 118 beat·min^{-1} and 65 minutes for 45% VO_{2max} (light intensity). The range of these target measures was very large in the exercise groups: 103 -158 beat·min^{-1} and 36-61 min for moderate (somewhat hard) intensity, 107 - 141 beat·min^{-1} and 41 - 63 min for moderate intensity and 99 - 136 beat·min^{-1} and 53 - 82 min for light-intensity exercise. This large variability was primarily due to the variability in maximal HR, and also to the variability of the VO_{2max} and body weight at the onset of the intervention. The range of the VO_{2max} was 22.4 to 42.9 ml·min·kg^{-1} and that of the weight was 42.9 to 93.0 kg. In a normal population these values vary even more, because the participants of this study were chosen from sedentary women with a BMI of < 32 kg·m^{-2}. The range of the HR_{max} for the participants of this study was 141 to 202 beat·min^{-1}. The usual estimation for the HR_{max} is HR_{max} = 220 - years of age, which gives an estimation of 157 to 172 beat·min^{-1} for the HR_{max} of the 48- to 63- year-old participants. The variation is usually considered to be + - 20 beat·min^{-1}, but +- 30 beat·min^{-1} was found to be the case in this study. The practical process of describing somewhat hard, moderate, light or any exercise for an early postmenopausal woman at a certain intensity level using age-related formulas of HR_{max} is bound to cause a large degree of inaccuracy and should be used only with great caution. When an accurate target HR is needed, a maximal exercise test should be performed.

The sufficient duration of exercise for a given target energy expenditure at a given intensity level also varied a great deal, the lighter women having to walk longer and the heavier women expending the same amount of energy in a shorter time. The women with a high initial VO_{2max} also walked faster at a given relative intensity level and expended a given amount of energy in a shorter time than the less fit women did.

If exercise is to be prescribed according to a target HR that corresponds to a certain percentage level of the VO_{2max}, this target HR will not remain correct when VO_{2max} improves as training continues. As cardiac function becomes more effective, HR decreases and it is more difficult to reach the target HR. A few participants experienced such a phenomenon in the 15-week intervention of Study I. In such cases the target HR should be redefined with a new maximal exercise test because it no longer represents the same percentage intensity as in the beginning of the exercise, but is instead higher. In the present study this was not considered necessary, 15 weeks being a relatively short time, but in exercise counseling this possibility may be important to take into consideration. The practical process of using any submaximal exercise test that extrapolates the result to HR_{max} is also inaccurate because it often uses age-related formulas.

The dropout rates were very small in this study, and adherence to the exercise program was very good and relatively similar in all of the exercise groups. The number of completed supervised exercise sessions was somewhat smaller in Study II than in Study I. This difference was due to the fact, that during Study II, the walking track of the UKK Institute had more reservations for other studies than during Study I, and some of the participants found it difficult to find enough suitable training hours weekly to fit their own timetables. The information from the questionnaire revealed that most of the participants considered the exercise regimen feasible and not too strenuous.

Altogether the intervention period produced more positive emotional experiences among the exercisers in all of the exercise groups than among the controls in Study II. It seems that the change from being sedentary to a physically more active status is more important than the dose of the exercise used. Even the smallest exercise dose of our study seemed to be associated with positive experiences. The value of these findings is, however, limited since these questions were asked only at the end of the intervention. These questions were not included in the original study plan, but were added to the end questionnaire during the final stage of Study II in order to record the numerous spontaneous positive experiences that the participants reported to various members of the research team. This information was considered of practical importance to exercise counselors. All of these results, however, confirmed that the exercise program was feasible for the participants.

The Ontario symposium found category C evidence from RCTs, mostly on men, indicating that aerobic exercise training for 6-12 weeks in mild-to-moderate depression and anxiety is consistently associated with an improvement of symptoms (category B). Neither the intensity of the exercise nor the level of fitness was clearly associated with the magnitude of the response (Kesäniemi 2001). This result is similar to the findings of Study II.

Exercise-related lower-limb complaints were few. This seems to be the first study to show that fractionated exercise can lead to even fewer exercise-related lower-extremity complaints than continuous exercise. This finding can be easily explained by the fact that two exercise sessions give muscles of the lower extremities a possibility to rest between sessions, whereas continuous exercise does not. This is a finding that can be of great practical importance.

There were only a few major injuries, and most of the injuries were mild. Three of the 89 exercising participants in Study I and 3 of the 81 exercising participants in Study II interrupted the exercise because of major health problems. Some of the major injuries occurred in the control group members. Approximately half of the exercising women had transient exercise-related lower-limb problems in the beginning or at the end of the exercise program, but only four persons experienced such problems throughout the intervention period.These figures are comparable with the 14 injuries among 202 women, aged 55-64 years, who commuted to work by walking for a year in the study of Parkkari et al. (2004), who followed a cohort of 3657 persons from the 15- to 74-year-old Finnish population. Approximately 25% of these walking injuries were severe enough to stop the walking for at least 1 day, and most of the injuries were mild and transient. The authors reported that many mild disturbances might have been unrecorded since the information was gathered in an interview every 4 months. In Study I and II of the present study the participants were encouraged to contact the physician at the onset of any exercise-related problems in order to treat injuries as early as possible, and therefore the number of mild complaints was probably higher than those made with the use of the interview method, and also greater than the number that would be expected from contacts with the health care system in normal life. Possibly most of the walking-related health problems were detected, because it was made very easy for the participants to contact the consulting physician.

These findings indicate that walking combined with a short, simple muscle training program is a feasible form of exercise for sedentary postmenopausal women, and there is a very small risk of health problems. Especially walking in two exercise bouts is recommended. Any adverse effects should be prevented by guiding the participant to avoid overstrain. Therefore, there should be a gradual increase in the weekly training program and proper recovery between exercise sessions. If exercise-related symptoms appear, early contact with the exercise or health professional is recommended.

2.9. Methodology, strengths and weaknesses of the study

In the search for a valid content for HEPA for early postmenpausal women, the concept of a minimum exercise dose was used. The term "minimum exercise" has been used in this study to describe the smallest amount of exercise that has favorable effects on the components of HRF. It can be considered practically as the minimum exercise dose that can be recommended for a group of sedentary, early postmenopausal women in order to attain a positive health effect. Some individuals may actually be affected by an even smaller exercise dose, and some need more exercise for health effects because of large interindividual differences in the response to exercise. It is also a practical minimum dose in the sense that it represents the minimum dose that can be potentially detected with usual measurement techniques and verified statistically. Actually it is possible that there is no absolute minimum dose, but instead there is a continuum of smaller effects from smaller exercise doses, and the exact threshold cut point for a no-effect exercise dose cannot be defined. Different HRF factors also have different minimum doses, and thus a practical minimum dose has to be a compromise that at least produces some important HRF effects. (Haskell 1994, Pate1995, Pate et al. 1995, ACSM 1998a)

Theoretically the question of a minimum dose is also challenging. Traditional statistical methods test the difference between groups with a zero hypothesis of "no difference". Sometimes even a small difference can be statistically significant, if the number of participants is large. In this study, the number of participants was not very large, and the minimum dose was extrapolated from the results of a series of study groups. Therefore the method was not perfect. But even with a rather small number of participants and wide margins in the criteria for choosing the participants some of the results were statistically significant. The results are also clinically significant as they can be used as a practical minimum dose for exercise counseling for healthy, sedentary postmenopausal women.

When the minimum exercise dose with respect to coronary risk factors is being studied using exercise groups with small exercise doses, small changes are to be expected. Some of the changes are statistically significant and some fall below the border of statistical significance. Some variables only show a trend towards change, but they are interpreted as no change according to the dichotomous nature of statistical science.

The interpretation of the results of this study raises several questions. What are the smallest changes that can be detected with the measurements that were used? Are the changes caused by the regression towards the mean of variables with high interindividual variation? Have the biological day-to-day and seasonal variations been taken into account?

These problems were confronted in many ways. The smallest possible change that can be detected with the equipment that was used was estimated. The number of participants sufficient for adequate statistical comparisons was also estimated. A control group was used to minimize systemic errors, for example, possible seasonal fluctuations. An analysis of covariance was used so that the results would be unaffected by possible minor baseline differences and the regression towards the mean. The randomized groups were comparable. The exercise dose was carefully controlled with personal supervision, HR monitors, exercise diaries, food diaries, and pedometers. The program was closely followed by the participants, and dropouts were few. The measurements were done in strictly controlled, similar conditions, and the exercise group members and controls in were tested in mixed order. The laboratory staff was experienced and trained in taking measurements.

To some of these questions, there are no definite answers. Therefore no exact values for the minimum effective dose can be given on the basis of this study. But for practical purposes the approximations of a minimum dose that were used in this study may be very useful.

The strengths of the study were a simple design that enabled comparisons of different exercise doses, a sufficient number of participants to draw conclusions, successful randomization, good adherence to exercise, and careful and reliable measurements. The aim of the study was not only scientific, but also practical implications were considered, as the exercise that was studied was planned to be easy to perform in every day living and also home-based.

If the design were to be improved further, the number of participants could have been larger and the intervention could have been longer to ensure that all potential effects, especially those on lipids, were detected. All of the exercise sessions could have been supervised. The injuries of the controls could have been recorded as actively as those of the exercise groups. The balance test should have been more demanding. The resistance training program should have been more effective for the trunk and upper-limb muscles.

This study increased the knowledge on light intensity aerobic training among early, postmenopausal women. It is the first study to show that fractionated aerobic exercise in this age group of women is as effective as continuous exercise. It is also the first study to show any effect of exercise training on diastolic BP and blood glucose concentration in early postmenopausal women. It is also one of the few studies that has used an exercise training program that can be performed at home with walking and resistance training with simple equipment. In addition, feasibility-related information was gathered actively. This is the first study to show that fractionated exercise causes fewer exercise-related lower limb problems than continuous exercise.

There still remain unanswered questions concerning the effects of exercise on health-related fitness among early postmenopausal women. Some of the exercise-induced improvements in this study were very small. More randomized controlled studies are needed, especially on the effects of exercise on lipid levels. The interactions between HRT and exercise should also be studied more.

Summary and conclusions

According to the *general* aim of the study, the systematic literature review showed that for early postmenopausal women:

The effects of exercise on health are only partly known. The RCTs on the effects of exercise on maximal aerobic power, body composition and muscular strength showed that early postmenopausal women are trainable. But very few or none of the studies used light intensity aerobic training, fractionated aerobic exercise and resistance training with simple equipment. Very few or none of the studies showed what would be the effective exercise dose to improve submaximal aerobic capacity, blood pressure, body composition, carbohydrate and lipid metabolism, flexibility, and postural control. Thus the minimum effective dose could not be estimated. Feasibility-related information was also very sparse. Therefore there was a clear need for specific RCTs on these items. (Publication I)

According to the *specific* aims of the study, the experimental part of the study showed that for sedentary, healthy, early postmenopausal women:

1. The minimum effective dose of exercise to improve maximal aerobic power, submaximal cardiorespiratory capacity and to reduce body fat is equal to or is less than walking at an intensity of 45% of the VO_{2max} 5 $d \cdot wk^{-1}$ expending 1000 kcal (46 minutes) in weekly exercise in 24 weeks. (Publication II)

   Walking at an intensity of 65% VO_{2max} on 5 $d \cdot wk^{-1}$, expending 1500 kcal (47 minutes) in weekly exercise in one or two exercise bouts a day combined with approximately 10 -15 minutes of moderate resistance training twice a week is the minimum dose of exercise to improve glucose metabolism and diastolic blood pressure in 15 weeks. (Publication III)

   The minimum dose of exercise to have an effect on lipid metabolism in 15 weeks is more than the highest exercise dose of this study. (Publication III)

2. Walking at an intensity of 65% VO_{2max} on 5 $d \cdot wk^{-1}$, expending 1500 kcal (47 minutes) in weekly exercise in one or two exercise bouts a day combined with approximately 10 - 15 minutes of moderate resistance training twice a week improves walking performance and lower-

extremity strength, but it is not enough to improve the muscular strength of the trunk and upper limbs and postural control. (Publication IV)

3. The effects of fractionated and continuous exercise were equal for all of the chosen variables of HRF. (Publication V)

4. Hormone replacement therapy users and non-users had equal results for all of the chosen variables of HRF. (Publication, II, III, IV and V)

5. All of the exercise regimens were feasible, very few injuries occurred, and the participants adhered well to the program. Starting a regular exercise program gave the participants positive experiences, and most of the participants considered that the exercise was not too strenuous. Half of those in the continuous exercise groups had some mild, transient lower-extremity complaints, especially at the beginning of the exercise intervention. Those in the fractioned exercise groups had significantly fewer lower-extremity complaints. (Publication, II, III, IV and V)

According to the *practical* aim of this study, the following conclusion can be drawn:

The highest exercise regimen of this study, approximately 30 to 60 minutes of moderate walking five days a week, combined with a 15 - 20 minutes resistance training program twice a week, seems to be a feasible, practical minimum dose of health-enhancing physical activity for sedentary, early postmenopausal women to use to start to improve most components of health related fitness. In order to attain more definite improvements and also to affect other components of metabolic, musculoskeletal, and motor fitness (lipids, muscle performance of the trunk, and upper extremities, balance or flexibility), the exercise dose should be increased.

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Exercise for Health for Early Postmenopausal Women

A Systematic Review of Randomised Controlled Trials

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Contents

Abstract

Women who pass menopause face many changes that may lead to loss of health-related fitness (HRF), especially if sedentary. Many exercise recommendations are also relevant for early postmenopausal women; however, these may not meet their specific needs because the recommendations are based mainly on studies on men. We conducted a systematic review for randomised, controlled exercise trials on postmenopausal women (aged 50 to 65 years) on components of HRF. HRF consists of morphological fitness (body composition and bone strength), musculoskeletal fitness (muscle strength and endurance, flexibility), motor fitness (postural control), cardiorespiratory fitness (maximal aerobic power, blood pressure) and metabolic fitness (lipid and carbohydrate metabolism). The outcome variables chosen were: bodyweight; proportion of body fat of total bodyweight (F%); bone mineral density (BMD); bone mineral content (BMC); various tests on muscle performance, flexibility, balance and coordination; maximal oxygen consumption ($\dot{V}O_{2max}$); resting blood pressure (BP); total cholesterol (TC); high-density lipoprotein-cholesterol; low-density lipoprotein-cholesterol; triglycerides; blood glucose and insulin.

The feasibility of the exercise programme was assessed from drop-out, attendance and injury rates. Twenty-eight randomised controlled trials with 2646 participants were assessed. In total, 18 studies reported on the effects of exercise on bodyweight and F%, 16 on BMD or BMC, 11 on muscular strength or endurance, five on flexibility, six on balance or coordination, 18 on $\dot{V}O_{2max}$, seven on BP, nine on lipids and two studies on glucose an one on insulin. Based on these studies, early postmenopausal women could benefit from 30 minutes of daily moderate walking in one to three bouts combined with a resistance training programme twice a week. For a sedentary person, walking is feasible and can be incorporated into everyday life. A feasible way to start resistance training is to perform eight to ten repetitions of eight to ten exercises for major muscle groups starting with 40% of one repetition maximum. Resistance training initially requires professional instruction, but can thereafter be performed at home with little or no equipment as an alternative for a gym with weight machines. Warm-up and cool-down with stretching should be a part of every exercise session. The training described above is likely to preserve normal bodyweight, or combined with a weight-reducing diet, preserve BMD and increase muscle strength. Based on limited evidence, such exercise might also improve flexibility, balance and coordination, decrease hypertension and improve dyslipidaemia.

1. Background

When a woman who has recently passed menopause asks a health professional for advice on how to improve her health with exercise, how should we answer? In US and European female populations, menopause occurs at the average age of 50 years. It may start a rapid phase of losing aerobic fitness, muscle strength and bone mineral density (BMD) as well as gaining weight, which increase the risk for many chronic diseases such as coronary heart disease (CHD), type 2 diabetes mellitus and osteoporotic fractures, especially in sedentary individuals.[1]

Many exercise recommendations are also relevant for postmenopausal women such as those for public health,[2] cardiorespiratory and muscular fitness and flexibility,[3] cardiovascular diseases,[4,5] obesity,[6] osteoporosis,[7] hypertension[8] and exercise for older adults (for those aged over 65 years).[9] These recommendations focus on various aspects of health and fitness and reach somewhat different conclusions. Everyday physical activities (e.g. walking short distances, commuting to work, walk-

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ing up stairs, housework, gardening) are recommended for general health, moderate- to high-intensity aerobic training combined with resistance exercises are recommended for fitness, large volumes of exercise for weight control, high-impact training and strength training for osteoporosis, and moderate intensity exercise for cardiac diseases. When approaching old age, preserving muscle strength, balance and coordination become the most important goals in training. So what exercise should we recommend for an early postmenopausal woman? Do the above-mentioned recommendations consider her special needs? The above recommendations are based on epidemiological evidence and exercise trials that were mostly conducted on men. Only some 40 years ago, exercise researchers claimed "after the age of 60, there is practically no observable effect"[10] and almost 10 years passed before the first study showed that postmenopausal women could benefit from exercise.[11]

There are many physiological differences in women compared with men. For example, starting with morphology, women have smaller size, more body fat, different fat distribution, less dense bones and differences in bone structure, joints and body posture that predispose to exercise-related injuries in lower limbs. Women have approximately 30% less muscle strength and are usually more flexible than men. Women have approximately 20% lower maximal aerobic power and lower oxygen carrying capacity of blood due to smaller haemoglobin concentration and there are also sex differences in haemodynamics during exercise. There are also many metabolic differences between women and men, for example, hormonal differences in rest and in response to exercise, and also differences in blood lipids.[12,13] All this must be considered in an exercise training programme. For example, slow jogging might be feasible for middle-aged, sedentary men, but for some sedentary postmenopausal women it could be too strenuous. All of the above differences make it very important to study both men and women.

To answer the questions raised earlier in this section, we conducted a systematic review on randomised, controlled exercise trials that focused on early postmenopausal women. We chose outcomes according to the concept of health-related fitness (HRF), the components of which are related to health and can be influenced by physical activity.[14] HRF includes morphological, musculoskeletal, motor, cardiorespiratory and metabolic components (table I). Morphological fitness includes body composition and bone strength, which are important in preventing CHD, type 2 diabetes, osteoporosis and osteporotic fractures. Musculoskeletal and motor fitness, which includes muscle strength and endurance, flexibility and postural control, are needed to preserve good functional capacity to ensure prolonged independent living at old age and also to prevent falls. Good cardiorespiratory fitness prevents CHD and reduces all-cause mortality. Good metabolic fitness, i.e. normal carbohydrate and lipid metabolism reduces the risk for CHD and type 2 diabetes.[14]

2. Objectives

The objective of this review is to evaluate data on exercise training studies with special reference to improving health in early postmenopausal women. Randomised controlled trials (RCTs) were chosen because they provide the most valid evidence of effectiveness.[15] This information is needed by health professionals in order to give advice to pa-

Table I. Components of health-related fitness (HRF) and chosen outcome measures of randomised controlled trials according to HRF

Fitness component	Outcome measures
Morphological	
Body composition	Weight, body fat
Bone strength	Bone mineral density
Musculoskeletal	
Muscle strength and endurance	Various muscle tests
Flexibility	Various flexibility tests
Motor	
Postural control	Balance and coordination tests
Cardiorespiratory	
Maximal aerobic power	Maximal oxygen consumption
Submaximal cardiorespiratory capacity	Blood pressure
Metabolic	
Carbohydrate metabolism	Glucose, insulin
Lipid metabolism	Total cholesterol, high-density lipoprotein, low-density lipoprotein, triglycerides

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tients. For the information to be clinically applicable, we were also interested in the safety and feasibility of training regimens. Another objective of this review is to identify areas for future research.

3. Criteria for Studies

3.1 Types of Studies

We chose RCTs with more than 25 participants and less than 35% of drop outs. Also, the overall quality of the study had to be sufficient (see section 5.3). All three authors agreed on the criteria.

3.2 Participants

The study participants were postmenopausal women aged 50–65 years. If the study also included younger or older women then it was accepted providing that the age was only few years off the limits, but the mean age of the participants was in the range of 50–65 years. If the study also included men, the women had to be analysed separately. Study subjects had been selected either on a voluntary basis or from a population-based sample. Participants were sedentary at onset or had some leisure physical activity that was kept constant during the study. Healthy women were accepted as well as subjects with diseases or risk factors such as dyslipidaemia, hypertension, obesity or osteoporosis. Also, hormone-replacement therapy (HRT) and other medications were allowed.

3.3 Types of Intervention

All exercise modes and prescriptions were accepted. Interventions that included dietary counselling were also accepted. The minimum length of the intervention was chosen to be 8 weeks.[9] Shorter training was not expected to have an effect on HRF.

3.4 Outcome Measures

Outcome measures defined by us were based on components of HRF. Among these, we chose the most frequently reported outcome measures in these studies to enable comparison. The outcome measures also had to have some relevance in clinical work. The chosen morphological fitness outcome variables were bodyweight, the proportion of body fat to total weight (F%) and BMD or bone mineral content (BMC). Musculoskeletal fitness measures were based on various muscle tests. Flexibility outcomes were based on tests of flexion, extension or lateral flexion of the trunk or of upper or lower limbs. Outcomes of motor fitness were based on different tasks requiring coordination. Cardiorespiratory fitness outcomes were assessed by direct measurements of maximal oxygen consumption ($\dot{V}O_{2max}$) or indirect estimations of it in maximal or submaximal tests. Resting blood pressure (BP) was also an outcome measure of cardiorespiratory fitness. Metabolic fitness outcomes were levels of: total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-C), low-density lipoprotein-cholesterol (LDL-C), triglycerides (TG), glucose and insulin. Some clinically useful measurements were omitted because they were measured and reported in only few studies, for example, body mass index (BMI) and waist circumference, and heart rate (HR) in submaximal exercise.

We also focused on information on the feasibility of exercise programmes based on attendance and drop-out rates, and incidence of injuries. In addition to the statistical significance, the clinical relevance of these outcomes was also addressed.

4. Search Strategy

We conducted a systematic search of the literature. The main source was the Cochrane Central Register of Controlled Trials (CENTRAL), using the keywords 'women' and 'exercise' from 1974 to November 2002, (i.e. all years in the register) and 1467 references were found. Additional searches were performed in Medline with the keywords 'postmenopause' plus all exercise terms ('exercise', 'exertion', 'physical fitness', 'sports', 'physical activity', 'exercise therapy') from 1999 to November 2002, which resulted in 109 references, and with the keywords 'postmenopause' and all exercise terms plus 'heart diseases' plus 'risk factors', 'hypertension', 'cholesterol', 'obesity' from 1966 to November 2002 resulting in 60 references. A search in Sport Discus using the keyword 'postmenopause' from 1991 to 2000 resulted in 68 references. Ebsco was searched using the keywords 'postmenopause' and 'exercise' from 1998 to 2002 with the result of 50 references. In addition, we hand-searched refer-

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ences from original articles, reviews and contents pages during the past 5 years from journals (*Sports Medicine*, *Maturitas*, *Scandinavian Journal of Medicine & Science in Sports*), searched our own files and consulted colleagues. From the titles of the references, we chose suitable abstracts for reading and from these abstracts we chose suitable full-length papers to be assessed. The total number of RCTs that met our basic criteria was 41.

The search strategy was planned together by the authors. The basic search was planned by the first and second authors. Abstracts and articles were checked and selected by the first author. Selected articles were assessed and discussed by all authors. Data extraction was completed by the first author.

5. Description of Studies

5.1 Accepted Studies

Out of the 41 RCTs that were found, we excluded 13[16-28] because they did not meet our quality criteria (see section 5.3). Twenty-eight good quality studies that met our criteria are included in this review and are presented in table I.

The total number of participants was 2632. There were 26 studies concerning morphological fitness with 2528 participants,[29-57] 11 studies on musculoskeletal fitness[31-33,40-42,47,48,57-61] with 950 participants, six studies on motor fitness with 588 participants,[31,33,42,47,48,57] 18 studies on cardiorespiratory fitness[29,30,33-35,38,40-43,45-47,50,51,55,56,62] with 1488 participants and ten studies on metabolic fitness[40,45,46,50,55,56,62-64] with 1078 participants.

5.2 Exercise Prescription

In 19 studies,[29,30,33-35,38-41,43,45-47,50,51,55,56,62,64] walking was the most frequently chosen mode of exercise training. Walking was used as the only mode of training or as an alternative to other aerobic activities or combined with resistance training. Resistance training with no equipment or with sandbags or training in a gym with weight machines was used in 15 studies.[31-33,35-37,40,41,43,44,47-49,52-54,56-61]

Assessment of the exercise prescription was based on the duration, intensity and frequency of each exercise session, and the length of the exercise programme. The exercise prescription for aerobic training was described in detail in 25 studies. According to the purpose of this review, there was inadequate information concerning the exercise prescription in three studies.[34,42,55] To monitor the intensity of aerobic exercise, HR monitors were used in nine studies,[29,30,34,41,42,46,51,63] HR palpation in six studies[33,35,38,39,45,50] and in five studies[40,47,55,56,58,62] that used aerobic training there was no information of monitoring the intensity. In ten studies,[31-33,35-37,41,47-49,52-54,56,57,59,60] the exercise prescription for resistance training was described in detail and the description of the exercise was inadequate in five studies.[40,43,44,53,54,58,61]

All exercise sessions were supervised in 12 studies[31-33,35-38,42,46,48,49,51,56,57,59,64] and some of the sessions in 12 studies.[29,30,34,39-41,43-45,47,50,53-55,58,61-63] In one study, all sessions were home based.[52,60] In another study there were both home-based and supervised exercise groups.[45] Other means of monitoring the exercise prescription were exercise diaries in 16 studies,[29,30,32,34,36,37,40,41,43-47,50,52-54,57,58,60-64] telephone contacts in four studies[43,45,55,64] and newsletters in five studies.[29,30,43,55,63,64] All studies reported at least some means of how exercise sessions were controlled.

Special attention was given to adherence to the prescribed programme. The attendance rate and the amount of injuries were also recorded. Information on attendance was reported in 18 studies[29-33,35-38,41,43-45,47-50,53,54,56,57,59,61,63] and in 14 studies.[29-31,34,35,38,39,41,43-45,47,50,52,57,60,63] information of injuries was reported.

5.3 Methodological Quality

Quality criteria were modified from Jadad et al.,[65] Schulz et al.,[66] Guyatt et al.[67,68] and Oxman et al.[69,70] All studies included in the present review had to pass following quality criteria: (i) the trial had to be randomised and controlled; (ii) the results had to be analysed in their original randomised groups; and (iii) the number of study participants had to be more than 25 and the proportion of drop outs <35%. The study was considered high quality if there were over 100 participants and ≤20% drop outs, and at least one of the following additional criteria was fulfilled: supervision of all exercise sessions or monitoring with an exercise diary; statistical power calculations reported; the method of randomisation

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reported; and blinding of measuring personnel performed. We considered it impossible to blind the exercise supervisors or subjects in exercise training. The high-quality studies were considered more valid when gathering the information for the conclusion of this review than the low-quality studies. None of the studies fulfilled all high-quality requirements. Nine studies fulfilled the main criteria and at least one of the additional criteria.[29-31,33,43,45,46,56,57,63]

6. Methods of Review

6.1 Data Extraction

Information on exercise design, study participants, exercise prescription, HRF outcomes, HRF results, monitoring of exercise, attendance rates and injuries reported from the accepted studies are presented in table I. Some approximations in data extraction were performed to enable comparisons. In some studies only a range for the participants age was given instead of the mean age and vice versa. Then the mean age of the participants was estimated from the mean ages of participants in randomised groups, if available. If the mean BMI values were not given for all participants, as in most cases, they were calculated from the means of the randomised groups. If the intensity of the exercise prescription was given using maximal heart rate (HR_{max}). HR_{max} was transformed to $\dot{V}O_{2max}$ using the formula:[71]

$$\%\dot{V}O_{2max} = 1.28\%\ HR_{max} - 29.12$$

The length of intervention was recorded in weeks, assuming that all months have 4 weeks. Results of the interventions on HRF outcomes are given as net changes, i.e. the changes of the intervention group minus the changes in the control group. Percentage changes were used where possible. If the net change could not be calculated, or if it was important to also show the change in the control group, the changes of all groups were given separately. If attendance rates were not given, they were calculated from the number of prescribed exercise sessions and the mean number of completed exercise sessions, if available. The number of subjects with injuries and with exercise-related medical problems were recorded combined as injuries.

6.1.1 Analysis of the Studies

A meta-analysis of the studies was not done because for some outcomes there were not enough studies. Also, the studies were too heterogeneic for this purpose. The purpose of this review was to systematically gather and describe the data from good quality RCTs, in order to increase knowledge on the training effects on HRF. The conclusions of this review are based on synthesis of these data.

7. Results

7.1 Feasibility and Effects of Different Modes of Exercise

7.1.1 Walking

Most of the studies used walking as the primary mode of exercise. In nine studies[29,30,34,38,39,50,55,62,64] with 817 participants, walking or walk-jogging was the only mode of exercise. The duration of walking sessions ranged from 30 to 60 minutes and the walking was done in one to three daily sessions at an intensity of 40–75% of $\dot{V}O_{2max}$ on 2–5 days/week for 10 weeks to 1 year. The mean drop-out rate in these studies was 13%. The mean attendance was 84% in the four studies reporting attendance.[29,30,38,50] Injuries were reported in six studies[29,30,34,38,39,50] and the mean injury rate was 3%. All walking was supervised in two studies, partly supervised in six studies and mostly unsupervised in one. Walking training decreased weight and body fat in most of the studies, and improved $\dot{V}O_{2max}$ in all seven studies[29,30,34,38,50,55,62] where it was measured and resulted in favourable changes in BMD in both studies[34,39] where it was measured. Walking did not influence BP in three studies,[30,38,45] but improved diastolic pressure in one of the studies[29] where it was measured. Walking had no effect on lipids in most of the studies where it was measured. Only one study with a weight-reducing diet and walking resulted in favourable effects on lipids in dyslipidaemic subjects.[55] Walking improved glucose levels in the only study where it was measured.[29] Six components of HRF: body composition, BMD, $\dot{V}O_{2max}$, BP, lipids and glucose were measured in these walking studies. Walking caused improvements in five of these components, did not require supervising for more than some of the ses-

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sions and seemed to be feasible considering the low drop-out rate, high attendance and low injury rate.

7.1.2 Combined Aerobic Exercise

Walking, in conjunction with other aerobic exercise forms such as cycling, swimming and aerobic dancing, was used in four studies[42,45,46,51] with 312 participants. The range of duration of exercise was 30–60 minutes, intensity 50–84% of $\dot{V}O_{2max}$ and training was performed on 3–4 days/week for 12 weeks to 1 year. Flexibility training was also a part of the exercise programme in these studies. The mean drop-out rate was 12% in the three studies reporting drop outs.[42,45,46] Attendance and injury rates were reported in only one of these studies;[45] the mean attendance was 77% in home-based exercise and 53% in group-based exercise. The incidence of injuries was 23% from high-intensity exercise and 13% from low-intensity exercise. All exercise was supervised in three studies[42,46,51] and in the fourth study[45] there was a supervised exercise group and non-supervised home-based exercise group, controlled only by telephone contacts.

Aerobic exercise training improved $\dot{V}O_{2max}$[45,46] and BP,[46] resulted in favourable changes in lipids,[46] and decreased weight and body fat.[51] Aerobic dancing also improved muscle strength and endurance, flexibility and balance.[42] Aerobic training seemed to be effective in seven components of HRF that were assessed. This exercise did not necessarily need supervision. The incidence of injuries was reported in only one study[45] and it was slightly higher than in the walking-only studies, especially if the exercise intensity was high. However, we cannot draw definite conclusions on the incidence of injuries because most aerobic training studies did not report injuries. Aerobic exercise in these studies was more beneficial than walking and it seemed to improve more components of HRF compared with only walking.

7.1.3 Combined Aerobic and Resistance Training

Combined aerobic and resistance training was measured in nine studies.[33,35,40,41,43,44,47,53,54,56,58,61] Aerobic exercise modes such as walking, jogging, cycling, dancing and stair-walking were combined with resistance training using wrist weights, ankle weights, elastic bands or weight machines. Flexibility training was also included in all of these studies. Aerobic sessions were performed for 30–70 minutes at 42–75% of $\dot{V}O_{2max}$. Resistance training was of low to high intensity, i.e. 10% to 70–80% of one repetition maximum (1RM).

In most studies, exercise either improved BMD or prevented the age-related decrease of BMD observed in controls;[33,35,40,41,44] musculoskeletal fitness was also improved.[33,40,47,61] Motor fitness was improved in one[47] of the two studies, where it was assessed and $\dot{V}O_{2max}$ improved in all of the six studies where it was assessed.[33,35,42,43,47,56] Training decreased weight or body fat in some of the studies where participants were overweight or where there was also a weight-reducing diet.[43,56] The mean drop-out rate was 15% and the mean attendance was 67%, being higher in the exercise groups with more endurance training versus resistance training. The mean injury rate was 6%. All exercise was supervised in four studies;[33,35,40,56,58] other studies[41,43,44,47,53,54,61] had supervised exercise on 1–3 days/week.

Combined aerobic and resistance training had many favourable effects on all four HRF components that were studied. The drop-out rate was higher and the attendance lower than in the aerobic exercise-only groups. The injury incidence rate was slightly higher than in low-intensity aerobic exercise. Combined aerobic and resistance training included supervision in most of the exercise sessions.

7.1.4 Resistance Training

Strength training with weight machines was used in two studies[32,48,49,59] with 75 participants. It consisted of 5–12 exercises at 40% or 80% of 1RM with 8–16 repetitions in three sets on 3 days/week for 24 weeks or 1 year. Muscle strength improved in both training programmes, but only the longer training showed BMD improvements compared with controls.[48] Body fat decreased and motor balance improved in the 1-year training programme.[48,49] The mean drop-out rate was 16% and mean attendance was 90%, being higher in the low-load/high-repetition training group, which also responded faster to the training than the high-load/low-repetition group. The injury rate was 33% in the 1-year training programme.[48,49,59] Weight training was supervised in both studies.

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Three studies[31,53,54,57,61] with 391 participants used high-impact training sessions on 3–4 days/week for a year. BMD and BMC, muscle strength, muscle performance, balance, agility and cardiorespiratory fitness improved. The mean attendance rate was 68% and the mean injury rate was 8%.

Two studies measured one single exercise, jumping[31] or a back extensor exercise[52,60] for 1 or 2 years, with 10–50 repetitions on 5–6 days/week. The back extensor training programme increased back strength,[52,60] but BMD did not improve in either of the studies. Attendance was 91% in the jumping study[31] and the injury rate ranged from 2% to 3%.

Strength training with weight machines was effective on the three components of HRF that were assessed. Low-load/high-repetition was more feasible than high-load/low-repetition and almost as effective in improving muscle strength. Weight training with machines required instruction and supervising, and even when supervised it was associated with a higher injury rate than any other study in this review. High-impact training was effective on bone and muscle strengthening and also had favourable effects on balance and motor control; however, lower attendance and higher injury rates reveal that high-impact training is not very feasible. Performing a single exercise caused site-specific improvements in muscle strength and was very safe and feasible; however, in order to affect several muscle groups, BMD and also motor fitness, a more versatile training programme is needed.

7.2 Effects of Exercise on Morphological Fitness

7.2.1 Body Composition

Weight and body fat were studied in 18 studies with 1804 participants.[29-34,38,42,43,45-51,53-56] Body composition was improved in nine studies.[29,30,34,48-51,55,56] Walking, other aerobic training, resistance training, strength training with weight machines or combinations of these were used. Most studies showed a small loss of weight and body fat. The best results were accomplished in the three studies with overweight participants who also used weight-reducing diets in combination with training.[51,55,56] The mean weight loss ranged from 2 to 10kg in 12 weeks to 1 year. High-quality studies that decreased fat or weight without diet used walking[29,30,34,55] or walking combined with other aerobic training,[51] or a combination of aerobic training and strength training.[56] Two studies with fewer participants used strength training[48,49] or walking.[50] The most effective exercise prescription for losing body fat was 30–60 minutes of walking or other aerobic training at 45–75% of $\dot{V}O_{2max}$ on 3–5 days/week for 15 weeks to 1 year, or strength training with weight machines, five exercises with 80% of 1RM with eight repetitions and three sets twice a week for 1 year.

In the training studies where participants were not overweight, adipose tissue was not lost as often as with overweight participants. The exercise regimen that did not influence body composition differed from the effective studies in that the frequency of exercise was lower and thus the volume (energy expenditure) of the exercise must also have been lower. Exercise seems to affect body fat most effectively in obese individuals, where it is mostly needed. The effect seems to be optimal when combining exercise with a weight-reducing diet.

7.2.2 Bone Strength

BMD or BMC was studied in 16 studies with 1373 participants.[31-37,39-41,44,48,52-54,56,57] A total of 12 studies showed improvements in BMD or BMC in exercise groups compared with controls.[31,33-37,39-41,44,48,49,53,54,57-59,61] Ten of the studies did not include patients who were taking HRT,[32,35,39,40,44,48,49,52-54,56-61] others[31,36,37,41] included them and two studies stratified the groups by use of HRT.[33,36,37] The high-quality studies with the most participants and positive outcomes used aerobic training combined with resistance training,[33,35-37,40,41,44] high-impact circuit training and aerobic dance,[53,54,61] high-impact training combined with alendronic acid (alendronate)[57] or walking training.[34] The studies with fewer participants used strength training,[48,49,59] circuit training and walking.[39] Strength training programmes comprising five to nine exercises at 80% of 1RM to maximal repetitions with 8–16 repetitions in two to three sets on 3–5 days/week for 1–2 years. One of the walking studies compared high- and moderate-intensity walking and found that only walking at the intensity of over 70% of $\dot{V}O_{2max}$ influenced BMD.[39] The

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other walking study used self-selected brisk pace, corresponding to 54–69% of $\dot{V}O_{2max}$ and found it effective.[34] Walking programmes were on 3–5 days/week and lasted for 6 months to 1 year. The improvements in BMD were site-specific and mostly in the magnitude of 0–2% in the exercise groups, while BMD in the controls decreased approximately 1% yearly. The use of HRT[36,37,40,51,54,58,63] and also alendronic acid[57] had a favourable effect on BMD.

BMD was not affected in three studies using 12 weeks of combined aerobic and resistance training,[56] 24 weeks of strength training[32] or repeating a single muscle exercise, jumping[31] or back extensor exercise[52,60] for 1–2 years. These studies had an equal or slightly smaller exercise prescription than those studies that showed an effect on BMD.

7.3 Musculoskeletal Fitness

7.3.1 Effects of Exercise on Muscular Strength and Endurance

A total of 11 studies[31-33,40-42,47,48,57-61] with 950 participants assessed muscular strength or endurance. In most studies, muscular strength improved. Strength training with weight machines,[32,48,49,59] combined resistance training with aerobic training,[33,40,47,53,54,58,61] a single resistance exercise,[52,60] and high-impact circuit training with aerobic dance[53,54,61] or low-impact aerobic exercises[42,47] were used. Strength-training programmes consisted of 5–12 exercises that were repeated eight times in three sets at the intensity of 80% 1RM on 2–3 days/week for 24 weeks to 1 year. Combined training included 60 minutes of aerobic training and resistance training on 3–4 days/week for 12 weeks to 2 years. A single resistance exercise, back extension, with ten repetitions on 5 days/week for 2 years was also studied. High-impact training programmes consisted of 60-minute sessions performed on 3 days/week for 12 weeks. These training programmes showed an increase in site-specific strength or endurance ranging from 20% to 76%.

Two studies did not improve muscle strength, one study with aerobic and resistance training for 72 weeks[41] and another study with high-impact jumps for 1 year.[31]

Two of the studies showed that HRT had a favourable effect on muscle strength;[53,54,61] however, this effect was not found in one study.[40,58] Most studies did not include subjects who were using HRT,[32,48,49,52,59,60] or did not analyse the results separately according to HRT use,[31,41] or HRT status was not reported.[47]

7.3.2 Flexibility

Five studies[33,41,42,47,58] with 416 participants studied flexibility. In three studies,[33,42,47] flexibility was improved by 5–25% and in two studies there was no effect.[40,41,58] Aerobic dancing with stretching[42] or aerobic training combined with resistance training and stretching[33,47] increased flexibility. The duration of exercise sessions was approximately 60 minutes and it was performed on 3 days/week for 12 weeks to 1 year. All exercise sessions were supervised.

The two studies that did not improve flexibility used a combination of aerobic and resistance training for 1.5 years[41] or strength training including stretching for 2 years.[40,58] Drop-out rate and attendance in these studies was quite similar to the studies with flexibility improvements. The only difference was that the exercise sessions were supervised only once a week.

7.4 Effects of Exercise on Motor Fitness

7.4.1 Balance and Coordination

Balance and coordination were assessed in six studies[31,33,42,47-49,57,59] with 588 participants. Five of these studies[31,42,47-49,57,59] gave positive results. The effective programmes consisted of strength training with weight machines, five exercises at 80% of 1RM with eight repetitions and three sets on 2 days/week for 1 year,[48,49,59] or 30 minutes of combined aerobic and resistance training on 3 days/week for 12 weeks[47] or 50 jumps on 6 days/week for 1 year.[31] High-impact jumping combined with low-impact exercises were also effective.[57] The drop-out rate in the studies ranged from 3% to 18%. Balance and coordination improved from 11% to 20%.

In a 12-week study of supervised aerobic dancing[42] balance improved, but not coordination. In a 1-year study of combined aerobic exercise and resistance training on 3 days/week,[33] where all exercise sessions were supervised, coordination did not improve. Drop-out rate was slightly higher in these

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studies ranging from 13% to 16% and attendance was not reported.

7.5 Effects of Exercise on Cardiorespiratory Fitness

7.5.1 Maximal Aerobic Power

$\dot{V}O_{2max}$ was measured in 18 studies[29,30,33-35,38,40-43,45-47,50,51,55,56,62] with 1488 participants. In all but one study[51] $\dot{V}O_{2max}$ was improved. Walking was used as the only mode of exercise in five studies,[29,30,34,38,50] walking and/or other aerobic training in six studies[42,45,46,51,55,62] and aerobic exercise combined with resistance training/strength training in seven studies.[33,35,40,41,43,47,56-58] Exercise training consisted of 30–65 minutes of aerobic training with the intensity of 45–84% of $\dot{V}O_{2max}$ on 2–5 days/week for 12 weeks to 2 years. The mean of the prescribed exercise intensities in these studies was 68% of $\dot{V}O_{2max}$. The improvements in $\dot{V}O_{2max}$ ranged from 2.5 to 7 mL/kg/min or 4% to 32%. As expected, indirect tests with estimations of $\dot{V}O_{2max}$ gave larger improvements than direct measurements.

Aerobic fitness did not improve in a 12-week study of overweight subjects with 45–60 minutes of walking at 50–60% of $\dot{V}O_{2max}$ on 3–4 days/week[51] combined with a weight-reducing diet. Drop-out and attendance rates were not reported. The aerobic fitness was estimated by an indirect test.

7.5.2 Blood Pressure

Resting BP was measured in seven studies[38,45,46,50,55,56,63] with 976 participants. In a study[63] with normotensive subjects, 15 weeks of walking 5 days/week for 30–60 minutes in one or two exercise bouts at 65% of $\dot{V}O_{2max}$ decreased diastolic pressure by 3mm Hg; however, walking at 55% or 45% of $\dot{V}O_{2max}$ did not have any effect on BP. The mean attendance was 89–95% and the drop-out rate was 3%. HR monitors were used and exercise was supervised on 2 days/week. Four studies with normotensive participants with walking training alone[38,50] or walking with other aerobic training[45,46] did not cause improvements in BP. Training duration ranged from 30 to 60 minutes, the intensity was 40–84% of $\dot{V}O_{2max}$ and the exercise was performed on 2–5 days/week for 12 weeks to 1 year. The mean attendance was 73% and drop-out rate 19%. The exercise sessions were supervised for at least one session/week. HR monitors were used in two studies[46,63] and HR palpation method in two studies.[38,50]

One study with hypertensive and overweight participants showed positive results.[56] The participants' BMI was 27–33 kg/m^2 and BP <190/100mm Hg, and the intervention also included a weight-reducing diet. Aerobic exercise of 30–55 minutes at 79% of $\dot{V}O_{2max}$ on 3 days/week for 12 weeks combined with resistance training consisting of one set of 7–15 repetitions of eight exercises on 3 days/week for 12 weeks decreased systolic pressure by approximately 10mm Hg. The weight loss was 10kg. The mean attendance was 97% and the drop-out rate was 2%. All exercise sessions were supervised. However, in a study with mildly overweight (mean BMI 26 kg/m^2) participants, who were also hypertensive (BP <190/100mm Hg), diet, walking and jogging of 16 km/week for 1 year did not improve BP.[55] Weight loss was 2.5–3kg. The intensity of exercise was not prescribed.

Training seemed to give a larger effect on the BP of hypertensive and obese subjects compared with normotensive subjects especially when weight loss had occurred. The effect of weight loss on BP was not discussed separately in these studies.

7.6 Effects of Exercise on Metabolic Fitness

7.6.1 Blood Lipids

Nine studies[40,45,46,50,55,56,58,62-64] with 1024 participants assessed blood lipids. Four studies that combined a weight-reducing diet or HRT with exercise in overweight or dyslipidaemic participants found a positive effect on blood lipids.[40,46,55,56,58] The exercise programme consisted of 12 weeks to 2 years of aerobic training, walking, jogging or cycling[46,55] for 30–60 minutes, at 60–70% of $\dot{V}O_{2max}$ on 3 days/week, or aerobic training combined with resistance training.[40,56,58] One study combined a weight-reducing diet and exercise for overweight women and TC, LDL-C and TG decreased and HDL-C increased, all of the changes being 20–30% from the diet-only and diet plus exercise groups.[56] This study did not have an exercise-only group. Another study combined a weight-reducing diet and exercise for dyslipidaemic women.[55] TC and LDL-

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C decreased in the diet plus exercise group, but not in the diet-only or the exercise-only group, so exercise and diet seemed to have an additive effect on lipids. The third study combined HRT with training and found that exercise alone, HRT alone and exercise plus HRT decreased TC and LDL-C, but only the HRT and HRT plus exercise groups improved HDL-C.[46] The fourth study showed that HRT and HRT plus exercise improved TC and HDL-C, but the effect of exercise alone on lipids was not reported.[40,58] HDL-C was not improved by either of the groups.

In the five studies where no improvements in lipids could be found[45,50,62-64] the participants were normolipidaemic and mean BMI varied from 24 to 27 kg/m^2. The training was quite similar to the studies where effects could be found: walking 20–40 minutes in one to three daily exercise bouts at 60–84% of $\dot{V}O_{2max}$ on 3–5 days/week for 12 weeks to 1 year. Such exercise improved aerobic fitness in three of the studies[45,50,62] and weight in one of the studies.[50] The results are partly confusing, but it seems that in overweight or dyslipidaemic participants, who need the improvements most, exercise training more often improves the lipid profile compared with healthy subjects. For early postmenopausal women, there are no RCTs showing lipid profile improvements in normal weight, normolipidaemic subjects.

7.6.2 Blood Glucose and Insulin

There were only two studies on blood glucose[55,63] and one on insulin levels.[63] Only one study showed that exercise was effective in improving blood glucose levels[63] and the only study on insulin showed no effect from exercise.[63] Walking at 65% of $\dot{V}O_{2max}$ for 30–60 minutes in one or two exercise bouts for 5 days/week for 15 weeks improved blood glucose levels.[63] A similar walking study with a lower exercise intensity of 45–55% of $\dot{V}O_{2max}$ did not affect blood glucose levels.[63] These two programmes used HR monitors. The study with the exercise prescription of brisk walking or jogging for 16km weekly for 1 year did not influence blood glucose levels.[55] All of these training prescriptions improved aerobic fitness but only the one with controlled brisk intensity improved blood glucose levels.[63]

8. Discussion

Early postmenopausal women have not been a common study group for exercise training. Of the good quality RCTs of this review, only three were published in the 1970s and 1980s, 17 were published in the 1990s and eight since the year 2000. Many more studies were found with participants who were mostly male or younger women. Most of the 28 studies that we found were located in Cochrane databases. The study search was comprehensive and we are confident that most studies were found. The limitation of our study was the fact that for practical reasons we only searched for English-language literature.

Training programmes were relatively short in duration, which might be due to the tradition of exercise science that considers aerobic fitness the most central aspect of fitness, and that 12 weeks or an even shorter period is sufficient for improvement.[3] The bone studies were longer, because it is known that it takes a year or more to get observable changes in BMD. Also, practical reasons make long-lasting studies more difficult. Such an intervention requires much work to ensure adherence. King et al.[72] noticed the rising drop-out rates in her non-controlled extension for a second year of her 1-year RCT and commented that a reduction in stuff support might have been one of the reasons for decreasing adherence. However, her study was very important because it showed that lipid profiles did not change during the first year, but seemed to improve after 2 years. Too short interventions could be a reason why, for example, lipids did not improve more frequently in the studies of this review. If we want to promote life-long exercise, we should not study only the effects of few months of training. Prolonging the interventions might give a different picture of the effects of exercise on health.

Exercise prescription and it's control was well reported for most of the studies. HR monitors were not available in the oldest studies and the pulse palpation method was used instead. Some studies used intensity prescription such as 'brisk pace' or 'a comfortable pace', that are not very accurate. Few studies had no intensity prescription at all. Changing HR_{max} to $\dot{V}O_{2max}$ for the purposes of this review might also have caused some inaccuracy since this

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formula used by us was originally developed for men.[71]

Some information was missing in our studies. Few reported in detail how the randomising was performed, if there were power calculations, and if the staff performing the measurements were blinded. Some of the studies did not report drop-out, attendance or injury rates. This would be important information to understand how feasible and safe exercise programme was.

We found a good number of studies on aerobic power, but reporting submaximal endurance was often missing. Aerobic exercise will improve aerobic maximal power in a dose-response manner and some improvements can be seen even with relatively low intensities of exercise and also when the exercise is fractionated in shorter, 10-minute daily bouts. Improving submaximal capacity is relevant for sedentary people, because most of the daily tasks do not require maximal effort, but are more easily performed with good submaximal endurance. There are not enough data on the effects of exercise on hypertension in early postmenopausal women. More studies are needed, since elevated BP is a very common problem.

BMI and waist circumference should be used more often in studies in order to be able to compare the study subjects of different size. It can be concluded from these training studies, that exercise energy expenditure is more relevant than intensity in weight control. One kilogram of fat equals 7000 kcal and requires a lot of exercise to lose it, if exercise is the only means of losing fat. Exercise alone should not be recommended to a patient as the way to lose weight. These exercise studies show that, for an overweight person, combining exercise with diet is the best way to lose weight. The goal should be to change eating and exercise habits permanently. Physical activity might also help in weight maintenance after weight reduction.[73]

Training studies on muscle strength showed that women at postmenopausal age are trainable and large improvements in muscle strength can be expected in sedentary subjects. Muscle strength is very important for postmenopausal women not only for helping to preserve independent living at old age, but poor muscle strength is also a powerful risk factor for total mortality.[74]

Most training studies mentioned that the exercise programme consisted of warm-up and cool-down periods with stretching; however, their effects on flexibility were seldom studied. Stretching is recommend by the American College of Sports Medicine (ACSM) [1998] for every exercise. Stretching might relieve pain deriving from a tight musculoskeletal system and prevent injuries. In younger participants, the value of strengthening has been questioned.[75] More studies are needed on flexibility in early postmenopausal women. In addition, motor fitness components, balance and coordination have seldom been studied. These are important factors in reducing the risk for falls in the elderly and also helping independent living at old age. Strength of lower limbs and balance are essential for an elderly person and even more important than aerobic fitness.[76]

There are few training studies on metabolic fitness in this age group. Women are at risk of developing a menopausal metabolic syndrome, especially if sedentary, and exercise is recommended to prevent this.[1] The ASCM recommends 30 minutes of exercise on most days for all ages and assumes that it improves health and could also have some metabolic health effects.[2] It seems that in early postmenopausal women, such exercise might improve aerobic fitness but not lipid profiles or glucose levels, not at least in short-term training. More studies and especially longer studies with good adherence are needed to solve this important problem.

Walking was the most common mode of exercise and also the most feasible exercise. Walking can be performed home-based and without supervision. Accumulation of walking in short 5- to 10-minute bouts means that exercise can be better incorporated into daily routines. The effects of accumulated exercise are similar compared with continuous exercise in improving aerobic exercise and body composition[29] and there is some evidence that this would also be true for BP and glucose levels;[63] however, more studies are needed to confirm these findings. Fractionated exercise might also be effective for other components of HRF, probably on musculoskeletal fitness and motor fitness but there are no studies on the subject. Performing some muscular exercises in the morning and some in the evening could be feasible for many subjects who are busy during the day.

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Other modes of exercise should also be studied. We have training studies with many aerobic forms of exercise, for example, resistance training with elastic bands and wrist weights, strength and circuit training in a gym and home calisthenics; but what about nordic walking (fast walking with ski-poles), tennis, golf, yoga etc.? Some women might enjoy exercising in a gym environment, but there are also people who prefer home-based activities[45,72] and home-based equipment. One of these studies used sandbags and backpacks as weights for exercise[52,60] and this was a very good alternative. Also, 1kg of plastic rice-bags elicits a similar effect as 1kg of hand weights on muscles, and a cleaning equipment stick could be used as a stretching pole. This might be feasible physical activity for a woman who finds the very idea of exercise distant.

This systematic review has gathered data from good quality RCTs. There is enough information to understand the training effects on morphological fitness, musculoskeletal fitness and maximal aerobic power and on this basis to prescribe exercise in clinical practice in early postmenopause. However, there are too few studies to draw conclusions on the training effects on BP, lipids, glucose levels, flexibility, balance and coordination.

9. Conclusions

9.1 Implications for Practice

A health professional should inform her/his sedentary patient in early postmenopause, who is worried of her decreasing fitness, diminishing muscle strength, increasing weight, weakening bones and rising BP, that she can improve her HRF with a simple exercise programme. This programme should consist of at least 30 minutes of daily moderate walking in one to three bouts in addition to resistance exercises twice a week.

For a sedentary person, walking is a feasible way to start exercise by incorporating it into everyday life. A feasible way to start resistance training is to perform eight to ten repetitions of eight to ten exercises for major muscle groups starting with 40% 1RM. Resistance training requires professional instructions at the beginning but later can also be performed at home with little or no equipment as an alternative to attending a gym.

Warm-up and cool-down with stretching should be a part of every exercise session. Such exercise training is likely to increase cardiorespiratory capacity, preserve normal weight, or combined with a weight-reducing diet decrease overweight, preserve BMD and increase muscle strength. This exercise might also improve flexibility, decrease hypertension and improve disorders of lipid and carbohydrate metabolism.

9.2 Implications for Research

More randomised, controlled training studies of various regimens are recommended on the effects of exercise on lipids, glucose, BP, balance and coordination and also on submaximal aerobic capacity in early postmenopausal women.

There is a need for longer, e.g. 2–5 year-long studies. Also, more studies on fractionated exercise on various components of HRF are needed. Studies should have enough participants and try to improve adherence with individual counselling techniques and understanding the social environments of the participants. Power calculations and methods of randomisation should be reported and the results analysed in randomised groups independent of the compliance, using the intention-to-treat principle. Exercise prescription should be discussed in detail and controlled.

More studies on home-based exercise and using simple exercise equipment are needed. Different modes of exercise should also be studied including lifestyle activity.

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Appendix

See table AI.

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Table AI. Randomised controlled trials of early postmenopausal women with health-related fitness (HRF) outcome measures

Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m^{2}[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
Asikainen et al.[29,63]	2 EX: EX1, EX2 and CTL, stratified by HRT	134 (57y)	4 (3%)	Healthy, postmeno, sedent, BMI <32 (mean 26)	Walking 15 wks	300 kcal, 30–60 min, 65% $\dot{V}O_{2max}$, in one (EX1) or two (EX2) daily sessions, 5 d/wk	Cardio, morph, metab	$\dot{V}O_{2max}$, BP, weight, F% (SF), TC, LDL-C, HDL-C, TG, glu, ins	$\dot{V}O_{2max}$ +2.5 ml/kg/min (EX1, EX2), in combined EX diastolic BP −3mm Hg, glu −0.21 mmol/L (E1), −0.13 mmol/L (E2), ins NS, weight −1.2kg (EX1), −1.1kg (EX2), F% −2.1% (EX1), −1.7% (EX2), lipids NS	HRM, ex diary, newsletters, meetings, SV 2/wk, att 89–95%, inj 2%	Power +, rand +, semi-blinded meas.
Asikainen et al.[30,63]	4 EX: EX1–4 and CTL, stratified by HRT	121 (55y)	5 (4%)	Healthy, postmeno, sedent, BMI <32 (mean 26)	Walking 24 wks	300 kcal, 54 min, 55% $\dot{V}O_{2max}$ (EX1) 300 kcal, 65 min, 45% $\dot{V}O_{2max}$ (EX2) 200 kcal, 38 min, 55% $\dot{V}O_{2max}$ (EX3) 200 kcal, 46 min, 45% $\dot{V}O_{2max}$ (EX4), 5 d/wk	Cardio, morph, metab	$\dot{V}O_{2max}$, BP, weight, F% (SF), TC, LDL-C, HDL-C, TG, glu, ins	$\dot{V}O_{2max}$ +2.9 mL/kg/min (EX1), +2.6 mL/kg/min (EX2), +2.4 mL/kg/min (EX3), +2.2 mL/kg/min (EX4), BP NS, weight NS F% −1.2% (EX1), −1.1% (EX2), −0.6% (EX3), −1.0% (EX4), lipids NS, glu NS, ins NS	HRM, ex diary, newsletters, meetings, SV 2/wk, att 84–89%, inj 2%	Power +, rand +, semi-blinded meas.
Bassey et al.[31]	EX, CTL	147 (54y)	23 (16%)	Healthy, postmeno, sedent	High-impact training 1y	10 min, 50 jumps/d, 6 d/wk	Morph, musc, motor	BMD (DEXA) lumbar, femur, weight	BMD NS, weight NS, strength NS, balance NS	EX SV, att 91%, inj 2%	Power +, rand NR, blind NR, Ca-suppl

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Table AI. Contd

Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m2[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
				BMI 20–31 (mean 25), normal BMD, HRT allowed				Leg extensor power, calf strength, dynamic balance	Subgroup analysis of subjects with HRT balance +20%		
Bemben et al.[32]	2 EX: high load, high rep and CTL, stratified by BMD	35 (51y)	10 (29%)	Healthy, sedent, normal BMD, BMI 25, no HRT	Strength training (Cybex) 24 wks	12 ex, 80% 1RM with 8 rep (high load) or 40% 1RM with 16 rep, 3 sets, 3 d/wk	Morph, musc	BMD (DEXA) lumbar, femur, total body, weight, F% (DEXA), muscle strength	BMD NS, weight NS, F% NS, muscle strength +20 to +40% (both EX)	EX SV, ex diary, att 87% (high load) and 93% (high rep), inj NR, subjects adapted faster high rep programme	Power NR, rand NR, blind NR, Ca-suppl
Bravo et al.[33]	EX, CTL stratified by age and etionate and HRT	142 (60y)	18 (13%)	Healthy, postmeno, sedent, low BMD, etionate and HRT allowed, BMI 24	Walking, aerobic dancing, resistance ex (wrist weights, elastic tubes), flex and coordination ex 1y	10 min warm-up and flex ex; 25 min, aerobic training, 54–69% $\dot{V}O_{2max}$; 15 min ex for upper limbs and trunk, 12–15 maximal rep; 5 min ex for flex and coordination, 3 d/wk	Morph, musc, motor, cardio	BMD (DEXA) lumbar, femur, weight, strength, flex, coordination, half-mile walk time	Lumbar BMD unchanged in EX, −1% in CTL, femoral BMD NS, weight NS, flex +5% (unchanged in EX, but ↓ in CTL), strength +15%, coordination NS, half-mile walk time −9%	EX SV, HRP, 17 subjects in EX did not adhere to the programme, att of the 40 adherers 70%, inj NR	Power +, rand +, blinded meas., some subjects >65y
Brooke-Wavell et al.[34]	EX, CTL	84 (64y)	6 (7%)	Healthy, postmeno, sedent	Walking 1y	20 min, self-selected brisk pace	Morph, cardio	BMD (DEXA) lumbar, femur, calcaneus	BMD in calcaneus in EX +0.2 (CTL −2)	EX mostly unSV, ex diary	Power NR, rand NR, blinded meas.

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Table AI. Contd

Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m^2[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
				No HRT, BMI 26		54–69% $\dot{V}O_{2max}$, 5 d/wk		Weight, $\dot{V}O_{2max}$ (indirect)	BMD lumbar and femur NS, weight in EX −0.1kg, −0.1 (CTL + 0.9g) $\dot{V}O_{2max}$ +2 mL/kg/min in EX, +3 mL/kg/min in CTL who swam, −1.5 mL/kg/min in CTL who did not swim	Occasionally HRM, att NR, inj 2%	9 of 40 controls swam 68 min/wk, many subjects >65y
Busby et al.[62]	EX, disc., EX + disc., CTL	50 (52y)	6 (12%)	Healthy, sedent, BMI 24	Walking-jogging 12 wks	30 min, 60–73% $\dot{V}O_{2max}$, 3 d/wk	Metab, cardio	TC, TG, HDL-C, $\dot{V}O_{2max}$	Lipids NS, $\dot{V}O_{2max}$ approx. +2 mL/kg/min, +4% in EX, +6% in disc. group	EX SV 1/wk, ex diary, att NR, inj NR	Power NR, rand NR, blind NR, some subjects <50y
Chow et al.[35]	A, A+S, CTL	58 (56y)	10 (17%)	Healthy, postmeno, no HRT, BMI NR, normocalcaemic	Walking, jogging dancing, resistance ex (wrist and ankle weights) 1y	30 min, 73% $\dot{V}O_{2max}$ (A, A+S); 10–15 min of limb and trunk ex, 10RM, 10 rep (A+S), 3 d/wk	Morph, cardio	Bone mass (NAA), $\dot{V}O_{2max}$ (indirect)	Bone mass +4% to +7% in A+E (CTL unchanged), $\dot{V}O_{2max}$ approx. +7 mL/kg/min, +22% in A and +10 mL/kg/min, +32% in A+S	EX SV, HRP, att 70%, inj 6% in A and 19% in A+S	Power +, rand +, blinded meas., PA of CTL NR
Milliken et al.,[36] Cussler et al.[37]	EX, EX+HRT, HRT, CTL	94 (55y)	10 (11%)	Healthy, postmeno, sedent	Weight bearing activities (wrist weights)	60–70 min including weight-bearing activities as warm-up	Morph	BMD (DEXA), lumbar, femur, total body	BMD ↓ at all sites in CTL	EX SV, ex diary, att 72%, inj NR	Power NR, rand NR, blind NR
				HRT allowed, BMI 26 (20–33)	Strength training (weight machines, free weights) 1y	Weightlifting, strength training, 8 ex, 70–80% 1RM, 6–8 rep, 2 sets, 3 d/wk			EX+HRT resulted in more favourable changes than either alone (except in femur largest changes in HRT)		Ca-suppl. 2 non-compliers excluded

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Table AI. Contd

Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m²[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
Hamdorf et al.[38]	EX, CTL	80 (64y)	14 (18%)	Sedent, postmeno, BMI NR	Walking 26 wks	45 min, 40–60% $\dot{V}O_{2max}$, 2 d/wk	Cardio, morph	HR_{max} (submaximal ex test), BP, F% (SF thickness)	HR −7% at submaximal ex test, BP NS, F% NS	EX SV, HRP, att 91%, inj 5%	Power NR, rand NR, blind NR, many drop-outs Almost half of the subjects >65y
Hatori et al.[39]	High intensity EX, low intensity EX, CTL	35 (57y)	2 (6%)	Healthy, postmeno, no HRT, BMI 24	Walking 28 wks	30 min, HR > AT (≈60–70% $\dot{V}O_{2max}$) or < AT, 3 d/wk	Morph	BMD (DEXA), lumbar	BMD +2.1% in high intensity, −1% in low intensity, −1.7% CTL	ex group probably SV, HRP, ECG after training sessions, att NR, inj 0	Power NR, rand NR, blind NR, some subjects >65y
Heikkinen et al.,[40] Kyllönen et al.[58]	EX, estrogen 1, estrogen 1+EX, estrogen 2, estrogen 2+EX, CTL	78 (53y)	9 (12%)	Healthy, postmeno, no previous HRT, BMI 26 (18–34)	Strength training (gym), walking, jogging, swimming etc. 2y	40–60 min, 10 min stretching at the beginning and at the end of each session, 3 d/wk	Morph, musc, metab, cardio	BMD (DEXA) lumbar, femoral neck, trochanter, muscle strength, lumbar flex, TC, HDL-C, LDL-C, TG, AT	HRT groups improved BMD in all sites, ex groups improved in femoral neck, in CTL BMD ↓ No synergistic effect of ex and HRT on BMD, HRT and ex groups ↑ muscle strength, flex ↓ in all groups, HRT ↓ TC and LDL-C, AT NS	EX SV 1/wk, ex diary, att NR, inj NR	Power NR, rand NR, blind NR, intensity NR, many ex modes

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Table AI. Contd

Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m[2b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
Heinonen et al.[41]	2 EX: CA, E, CTL	101 (53y)	25 (25%)	Healthy, perimeno, sedent, BMI 26 (<33), HRT allowed	Resistance training (wrist and ankle weights) [CA]; walking, cycling, stair-climbing (E) 72 wks	8 ex, 42% $\dot{V}O_{2max}$, 16 rep, 3 sets, 16 rep (CA); 30 min	Morph, cardio, musc	BMD (DEXA) femur, lumbar, radius, calcaneus	BMD in femoral neck unchanged (E), in other groups −1%	EX SV at least 1/wk, HRM, ex diary	Power +, rand +, semi-blinded meas., perimeno women
						72% $\dot{V}O_{2max}$ (E)		$\dot{V}O_{2max}$, muscle strength, lumbar flex		att 66% (CA), 80% (E), inj 2% (E)	
						10 min warm-up and 10 min cool-down with balance and flex ex in both groups, 3–4 d/wk			$\dot{V}O_{2max}$ +6% in E compared with CTL, muscle strength NS, lumbar flex ↓ in all groups		
Hopkins et al.[42]	EX, CTL	65 (65y)	12 (18%)	Healthy, sedent, BMI NR	Aerobic dance and stretching 12 wks	15 min warm-up, 20 min low-impact, target 100–20, 15 min cool-down, 3 d/wk	Cardio, musc, motor, morph	Half-mile walk test, strength/ endurance, flex, balance, motor control, F% (SF)	Aerobic fitness +17%, strength/ E +62%, flex +9%, balance +12%, motor control NS, F% did not change	EX SV, occasional HRM, att NR, inj NR	Power NR, rand NR, blind NR, many subjects >65y
Irwin et al.[43]	EX, CTL	173 (61y)	5 (3%)	Healthy, postmeno, sedent, BMI 31 (>25), no HRT	Walking, cycling, strength training 1y	45 min, 75% $\dot{V}O_{2max}$, 3 d/wk	Morph, cardio	Weight, F% (DEXA), $\dot{V}O_{2max}$	Weight −1.4 kg, F % −1.0, $\dot{V}O_{2max}$ +11%	EX 3mo 2/ wk SV, then 1/wk, HRM, ex diary, phone calls, newsletters, meetings, att 83%, no injuries	Power NR, rand NR, blinded meas., in baseline not sedent, CTL stretching 1/wk and 6% ↑ PA

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Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m2[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
Kerr et al.[44]	2 EX: S, F, CTL	126 (60y)	37 (29%)	Healthy, postmeno, sedent No HRT, BMI NR	Resistance ex, cycling 2y	9 ex, 8 rep, 1 set for F, 3 sets Progressive for S, F also cycling, 3 d/wk	Morph	BMD (DEXA, QDR 200 equipment) Hip, lumbar, forearm, total body	BMD hip +1.2% (S), lumbar NS, forearm NS	7d ex diary, EX SV 3/wk att 74% (S), 77% (F), inj 2% (F), most drop-outs from S group	Power NR, rand NR, blind NR, Ca-suppl
King et al.[45]	3 EX: HIG, HIH, LIH, CTL	160 (57y)	28 (18%)	Healthy, postmeno, sedent, no HRT, BMI 27	Walking, jogging, cycling, treadmills 1y	40 min, 64–4% $\dot{V}O_{2max}$, 5 d/wk (HIG, HIH); 48–64% $\dot{V}O_{2max}$, 3 d/wk (LIH)	Cardio, metab, morph	$\dot{V}O_{2max}$, BP, TC, TG, HDL-C, F% (hydrostatic weighing)	$\dot{V}O_{2max}$ +1.5 to +2.3 mL/kg/min, approx. 5% in all EX, BP NS, TC NS, TG NS, HDL-C NS, F% NS	EX SV (HIG), phone contacts (HIH, LIH), ex diary, HRP, HRMs for some subjects, att in home-EX 77% Group EX 53%, injuries in high-intensity 23%, in low intensity 13%	Power NR, rand NR, blinded meas., lipids improved in non-controlled extension of the study to total of 2y[19]
Lindheim et al.[46]	EX, HRT, EX+HRT, CTL	101 (NR)	6 (6%)	Healthy, postmeno, sedent	Walking, cycling 24 wks	30 min, 60%	Metab, cardio, morph	TC, HDL-C, TG, body mass, $\dot{V}O_{2max}$, BP	TC −11% (EX), −10% (HRT), −7% (EX+HRT)	EX SV, HRM, att NR, inj NR	Power NR, rand NR, blind NR

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Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m2[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
				No previous HRT, BMI NR		$\dot{V}O_{2max}$, 3 d/wk			LDL-C −7% (EX), −11% (HRT), −6% (EX+HRT); HDL-C NS (EX), +10% (HRT), +12% (HRT+EX); TG −6% (EX) Other groups NS, $\dot{V}O_{2max}$ +4% to + 6% (EX, EX+HRT), systolic BP −1 to −3% (EX, HRT, EX+HRT)		
Mitchell et al.[47]	EX, CTL	30 (NR)	2 (7%)	Osteoporotic, HRT NR, BMI NR	Low-impact aerobic ex, resistance ex, stretching, also home ex, walking or other 12 wks	5 min warm up, 20 min weight-bearing activities, resistance ex at own pace, 48–60% $\dot{V}O_{2max}$, 10 min cool-down, 2 d/wk 20 min brisk walking 1 d/wk	Morph, cardio, musc motor	Weight, F% (SF), $\dot{V}O_{2max}$ (indirect), quadriceps strength, flex, balance	Weight NS, F% NS, $\dot{V}O_{2max}$ approx. 6 mL/kg/min, +25%, strength +17% to +30%, flex +27%, balance +11%	EX SV 2 d/wk, ex diary, att 87%, inj NR	Power NR, rand NR, blind NR control of intensity NR
Nelson et al.,[48,49] Morganti et al.[59]	EX, CTL	40 (60y)	1 (3%)	Healthy, postmeno, sedent, no HRT,	Strength training	5 ex, 80% 1RM, 8 rep, 3 sets, 2 d/wk	Morph, musc, motor	BMD (DEXA) lumbar, femur, total body, BMI	BMD lumbar + 0.9% in EX, −2.5% in CTL, femoral + 1% in EX	EX SV, att 88%	Power NR, rand NR, blind NR Ca-suppl if needed

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Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m2[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
				<130% ideal weight, BMI 23	(pneumatic resistance machines) 1y			F% (SF, hydrod etc.), muscle strength, dynamic balance/ coordination	−1.8% in CTL, weight NS, in hydrostatic weighing fat-free mass, +1.3kg in EX, +0.9kg in CTL	Occasional ECG and BP monitoring	
									Fat mass −0.9kg in EX, +0.4kg in CTL, muscle strength +35% to +76% in EX, −9% to +19% in CTL, balance +14% in EX, −8.5% in CTL	No ECG problems, minor BP elevations (<20mm Hg), injuries 33%	
Ready et al.[50]	2 EX: 3 d/wk, 5 d/wk, CTL	79 (61y)	26 (33%)	Postmeno, no HRT, healthy, sedent, BMI <34, TC <8.0 mmol/L, TG <4.2 mmol/L	Walking 24 wks	60 min 60% $\dot{V}O_{2max}$, 3 or 5 d/wk	Cardio, morph metab	$\dot{V}O_{2max}$, BP, weight, F% (SF), TC, TG, HDL-C	$\dot{V}O_{2max}$ +12% (3 d/wk), +14% (5 d/wk), weight −0.6kg (3D), F % −4.2% (3D), −4.0% (5D), BP NS, TC NS, TG NS, HDL-C NS	HRP, ex diary, EX SV 1–2 d/wk, att 63–80%, adherence better in 3 d/wk, inj 8%, more in 5 d/wk	Power NR, rand NR, blind NR
Shinkai et al.[51]	EX+diet, CTL	32 (54y)	NR	Healthy, sedent, BMI 27	Cycling, walking, jogging, swimming 12 wks	45–60 min, 50–60% $\dot{V}O_{2max}$, 3–4 d/wk	Morph, cardio	Weight, F% (hydrostatic weighing)	Weight −6%, F% −10%, $\dot{V}O_{2max}$ NS	HRM, EX SV, att NR, inj NR	Power NR, rand NR, blind NR

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Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m[2b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
								$\dot{V}O_{2max}$ (indirect)			Some subjects premeno, energy intake of 1.05–1.14 MJ/d, drop-outs NR
Sinaki et al.,[52,60]	EX, CTL	68 (56y)	3 (4%)	Healthy, postmeno, no HRT, BMI NR	Resistance ex for back (sandbag) 2y	Progressive back extensor strengthening ex on the floor, 30% RM, 10 rep, 5 d/wk	Morph, musc	BMD of lumbar spine (dual photon absorptiometry, strength of back extensors	BMD NS, back muscle strength +27kg (72%) in EX and +14kg in CTL	EX home-based, ex diary, att NR, inj 3%	Power NR, rand NR, blinded meas., baseline PA NR, CTL might have exercised also
Sipila et al.,[53,54,61]	EX, HRT, EX+HRT, CTL	80 (NR)	28 (35%)	Healthy, postmeno, no previous HRT	Circuit training and aerobic dance 1y	High-impact physical ex, 4 d/wk	Morph, musc	BMD (QCT) calcaneal, weight, F% (bioimpedance), muscle strength and performance	BMD ↑ in all treatment groups, weight NS, F% NS, muscle strength and performance ↑ in all treatment groups	EX SV 2 d/wk, att approx. 60% (EX+HRT), 50% (EX), ex diary, inj NR	Power NR, rand NR, blind NR, many drop-outs
									Best results in EX+HRT, knee extensions +8.3%, vertical jump +17.2%		
Stefanic et al.[55]	EX, diet, EX+diet, CTL	180 (57y)	3 (2%)	Healthy, postmeno, dyslipidaemic, no medication	Walking, jogging 1y	Brisk jog-walk 16 km/wk, starting with 60 min, 3 d/wk	Morph, cardio, metab	Weight, $\dot{V}O_{2max}$, BP, TC, HDL-C	Weight −2.5 to −3kg in both DIET groups	EX SV at onset, group lectures	Power NR, rand NR, blind NR

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Table AI. Contd

Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m^2[b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
				HRT allowed, BP <160/95mm Hg, glu <7.77 mmol/L, BMI 26 (<32)				TG, LDL-C, plasma glucose	$\dot{V}O_{2max}$ +2.5 to +4.5 mL/kg/min in both EX, BP NS, TC and LDL-C ↓ in DIET+EX, HDL-C NS, TG NS, glu NS	Meetings, mail, phone contacts, att NR, inj NR	Intensity NR, dietary fat intake ↓ 8%
Svendsen et al.[56]	Diet, diet+EX, CTL	121 (54y)	3 (2%)	Healthy, postmeno, BMI 27–33, no HRT, BP <190/100mm Hg	Cycling, stair walking, treadmill running, strength training (weight machines) 12 wks	30–55 min, 70% $\dot{V}O_{2max}$; 8–10 ex 7–15 rep, 1 set, 3 d/wk	Morph, cardio, metab	Weight, F% (SF), BMD (DEXA) lumbar, $\dot{V}O_{2max}$, BP, TC, TG, HDL-C, LDL-C	Weight approx. −10kg in DIET, DIET+EX groups, EX+DIET lost more fat than DIET, lumbar BMD NS $\dot{V}O_{2max}$ approx. +6 mL/kg/min in EX+DIET, systolic BP approx. −10mm Hg in DIET, EX+DIET groups, TC, TG, LDL ↓ and HDL ↑ by 20–30%	EX SV, weekly meetings with physician or nutritionist, att 97% (DIET+EX), inj NR	Power +, rand NR, semi-blind meas., usual leisure ex allowed, 1000 kcal/day diet
Uusi-Rasi et al.[57]	AA+EX, AA, placebo+EX, CTL	164 (53y)	7 (4%)	Healthy, sedent, no HRT, BMI 27	High-impact jumping, non-impact ex, stretching 1y	15 min warm-up, 20 min multidirectional jumping, 15 min stretching and non-impact ex, 10 min cool-down, 3 d/wk	Morph, musc, motor	BMC (DEXA), lumbar, femur, distal tibia, leg extensor strength	BMC AA groups lumbar +3.5%, femur +1.3%, EX lumbar and femur NS	EX SV, ex diary, pedometers for daily PA, att 53%, inj 12%	Power +, rand NR, blinded meas., Ca-suppl, vitamin D suppl

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Table AI. Contd

Study	Groups	n (mean age)	No. of drop-outs[a]	Health, PA level, HRT, BMI, kg/m[2b]	Mode of ex and duration of study	Training prescription (duration, intensity, frequency)[c]	Subgroups of HRF as study outcomes	Main outcomes based on HRF	Main results according to HRF[d]	Control of training, att, injuries[e]	Comments
								Leg dynamic power, agility/ postural balance test, indirect test for aerobic fitness (UKK walk test)	EX distal tibia +3.6%, EX leg dynamic power +8.5%, EX postural balance +1.4%, UKK walk test +3.1		
Woolf-May et al.[64]	3 EX: LW, IW, SW, CTL	54 (NR)	17 (31%)	Healthy, sedent, BP <160/95mm Hg	Walking 10 wks	20–40 min (LW), 10–15 min in 2–3 bouts (IW), 5–10 min in 3–4 bouts (SW), 70–75% $\dot{V}O_{2max}$, 1000 kcal/wk	Metab	TC, LDL-C, HDL-C	TC NR, LDL-C NR, HDL-C NR	EX SV 1 d/wk, ex diary, newsletters, phone calls, HRMs for some of the subjects, HRP, att NR, inj NR	Power NR, rand NR, blind meas.

a Number of drop-outs and proportion of the total number randomised.

b BMI of participants, range and mean.

c Prescribed exercise, if reported; formula $\%\dot{V}O_{2max} = 1.28\% \ HR_{max} - 29.12$ was used; warm-up, cool-down and flexibility exercises mentioned only if flexibility was an outcome measure.

d Net changes (the change in the EX minus the change in the CTL) or the change in both EX and CTL.

e Attendance as a proportion (%) of exercise sessions participated as monitored by exercise diaries or by the supervisors. Injuries are measured as a percentage of the total number of exercise-related health problems of all participants.

A = aerobic; **AA** = alendronic acid; **approx.** = approximately; **AT** = anaerobic threshold; **att** = attendance in training sessions; **blind** = blinding of measurements, subjects and staff; **BMC** = bone mineral content; **BMD** = bone mineral density; **BMI** = body mass index (kg/m^2); **BP** = blood pressure; **CA** = callisthenics group; **cardio** = cardiorespiratory fitness; **Ca-suppl** = calcium supplementation; **CTL** = control group; **DEXA** = dual energy x-ray absorptiometry; **disc.** = discussion; **E** = endurance group; **ex** = exercise; **EX** = exercise group; **F** = fitness; **flex** = flexibility; **F%** = proportion of body fat from bodyweight (%); **glu** = glucose; **HDL-C** = high-density lipoprotein-cholesterol; **HIG** = high-intensity group-based; **HIH** = high-intensity home-based; **HR** = heart rate; **HRM** = heart rate monitor; **HR$_{max}$** = maximum heart rate; **HRP** = heart rate palpation; **HRT** = hormone replacement therapy; **hydrod** = hydrodensitometry; **inj** = injuries and exercise-related health problems; **ins** = insulin; **IW** = intermediate walkers; **LDL-C** = low-density lipoprotein-cholesterol; **LIH** = low-intensity home-based; **LW** = long walkers; **meas.** = measurements; **metab** = metabolic fitness; **morph** = morphological fitness; **motor** = motor fitness; **musc** = musculoskeletal fitness; **NAA** = neutron activation analysis; **NR** = not reported; **NS** = nonsignificant statistical change; **PA** = physical activity; **perimeno** = perimenopausal; **postmeno** = postmenopausal; **power +** = statistical power calculations performed to show that the number of participants is adequate; **QCT** = quantitative computed tomography; **rand +** = randomisation method valid and described in detail; **rep** = number of repetitions of exercise in strength training; **RM** = maximal repetitions in strength training; **S** = strengthening; **sedent** = sedentary; **SF** = skinfolds; **SV** = supervised; **SW** = short walkers; **TC** = total cholesterol; **TG** = triglycerides; **$\dot{V}O_{2max}$** = maximal oxygen consumption; ↓ indicates decrease; ↑ indicates increase.

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ORIGINAL ARTICLE

Randomised, controlled walking trials in postmenopausal women: the minimum dose to improve aerobic fitness?

T-M Asikainen, S Miilunpalo, P Oja, M Rinne, M Pasanen, K Uusi-Rasi, I Vuori

Br J Sports Med 2002;**36**:189–194

Background: The American College of Sports Medicine recommends 20–60 minutes of aerobic exercise three to five days a week at an intensity of 40/50–85% of maximal aerobic power (VO_2MAX) reserve, expending a total of 700–2000 kcal (2.93–8.36 MJ) a week to improve aerobic power and body composition.
Objective: To ascertain the minimum effective dose of exercise.
Methods: Voluntary, healthy, non-obese, sedentary, postmenopausal women (n = 121), 48–63 years of age, were randomised to four low dose walking groups or a control group; 116 subjects completed the study. The exercise groups walked five days a week for 24 weeks with the following intensity (% of VO_2MAX) and energy expenditure (kcal/week): group W1, 55%/1500 kcal; group W2, 45%/1500 kcal; group W3, 55%/1000 kcal; group W4, 45%/1000 kcal. VO_2MAX was measured in a direct maximal treadmill test. Submaximal aerobic fitness was estimated as heart rates at submaximal work levels corresponding to 65% and 75% of the baseline VO_2MAX. The body mass index (BMI) was calculated and percentage of body fat (F%) estimated from skinfolds.
Results: The net change (the differences between changes in each exercise group and the control group) in VO_2MAX was 2.9 ml/min/kg (95% confidence interval (CI) 1.5 to 4.2) in group W1, 2.6 ml/min/kg (95% CI 1.3 to 4.0) in group W2, 2.4 ml/min/kg (95% CI 0.9 to 3.8) in group W3, and 2.2 ml/min/kg (95% CI 0.8 to 3.5) in group W4. The heart rates in standard submaximal work decreased 4 to 8 beats/min in all the groups. There was no change in BMI, but the F% decreased by about 1% unit in all the groups.
Conclusions: Walking (for 24 weeks) at moderate intensity 45% to 55% of VO_2MAX, with a total weekly energy expenditure of 1000–1500 kcal, improves VO_2MAX and body composition of previously sedentary, non-obese, postmenopausal women. This dose of exercise apparently approaches the minimum effective dose.

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The American College of Sports Medicine (ACSM) states that, to gain positive effects on aerobic fitness and body composition, an adult should exercise three to five days a week at an intensity of 40/50–80% of maximum oxygen uptake (VO_2MAX) reserve for 20–60 minutes continuously or accumulate the exercise in several daily bouts of at least 10 minutes duration, so that a total of 700–2000 kcal (2.93–8.36 MJ) are expended weekly.[1] (VO_2MAX reserve is calculated from the difference between resting and maximum VO_2 values. To estimate training intensity a percentage of this value is added to the resting VO_2 and is expressed as a percentage of VO_2MAX reserve.) Current exercise recommendations are more moderate, and more frequent, but light exercise with intensity below 40% VO_2MAX is not considered effective.[1] Some researchers[2–4] claim that sufficient experimental evidence is lacking to settle the matter because the minimum effective dose varies depending on the initial fitness level, the duration of the exercise session, the length of the exercise programme, and the individual characteristics of the participant. Very few studies have considered exercise programmes at intensities that border on light and moderate,[5–7] and the evidence on the benefits of such exercise is sparse and confusing.[8]

We conducted a randomised, controlled trial to compare the effects of four low dose exercise programmes on the cardiorespiratory fitness and body composition of postmenopausal women. We chose postmenopausal women, because regular exercise may be of specific importance in this group. Mortality from coronary heart disease rises after the menopause.[9] Also this group is rarely included in exercise studies and thus the need for more studies in postmenopausal women is obvious.[1] According to our hypothesis, the exercise groups would show dose-response improvement, and the minimum dose of effective exercise could be found.

METHODS

Design

The study was a randomised, controlled walking trial with walking groups W1, W2, W3, and W4 and control group C. The outcome measures were the changes in VO_2MAX, submaximal cardiorespiratory fitness, and body composition. The study design was approved by the research ethics committee of the UKK Institute for Health Promotion Research. All the subjects gave their written informed consent.

Subjects

The subjects were recruited through an announcement in the local newspaper. Altogether 413 responded, and 121 were selected. Figure 1 shows the recruitment process.

The eligibility criteria were (*a*) female, (*b*) 2–10 years past the onset of menopause at the start of the study, (*c*) 48–63 years of age, (*d*) no chronic diseases, (*e*) no regular medication, (*f*) non-smoker, (*g*) body mass index (BMI) <32 kg/m, (*h*) resting blood pressure <160/100 mm Hg measured in sitting position, (*i*) not engaged in strenuous work or in regular brisk leisure time exercise more than once a week or in light exercise more than three times a week, and (*j*) willing to continue previous diet and physical activity habits in addition to

Abbreviations: VO_2MAX, Maximal aerobic power; BMI, body mass index; HRT, hormone replacement therapy; F%, percentage of body fat

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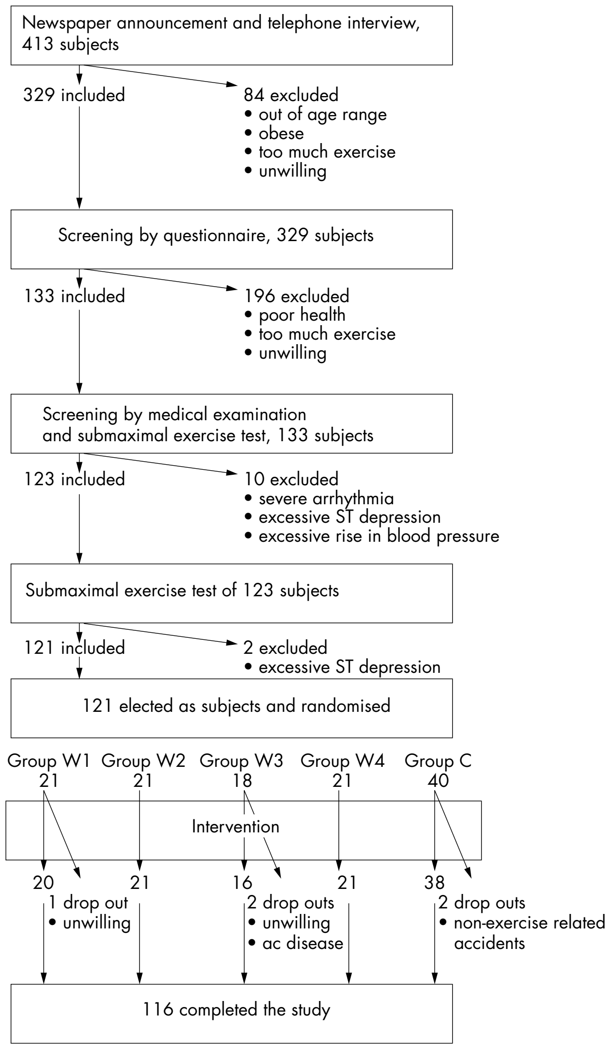

Figure 1 Recruitment and selection of subjects.

the exercise requirements of the study group. Only participants willing to agree to the results of randomisation were accepted in the study.

Randomisation

The 121 subjects were randomly assigned to one of four walking groups or to a control group using computer generated random numbers, and the subjects, as well as the testing personnel, were informed about the group results after the baseline exercise test. To improve the statistical power of the study design in the most economical way, we allocated more people to the control group than to the intervention groups. Users of hormone replacement therapy (HRT) and non-users were randomised separately into the groups so that the number of HRT users and non-users would be approximately equal in each group. There were 21, 21, 18, 21, and 40 subjects in groups W1, W2, W3, W4, and C respectively. Figure 1 shows the randomisation. Table 1 shows the baseline characteristics of the subjects.

Exercise intervention

The exercise programme was planned according to the principles of the exercise recommendation of ACSM.[1] The training intensities were selected from the low range of the recommendation, 55% (groups W1 and W3) or 45% (groups W2 and W4) of the VO_2MAX. The weekly energy expenditure of the exercise was set at 1500 kcal (groups W1 and W2) or 1000 kcal (groups W3 and W4), which were also from the lower end of the recommendation. The subjects in the exercise groups exercised five days a week. A high weekly frequency was chosen to reflect recent recommendations.[1] Twenty four weeks was chosen for the intervention so that the recommended minimum of 15–20 weeks would be exceeded and most of the possible effect would be attained.[1] Walking was considered the commonest and most feasible form of sustainable dynamic aerobic exercise for sedentary subjects[10] and was chosen as the mode of exercise.

The individual target heart rate for the exercise, corresponding to the chosen intensity, was determined for each subject in the baseline exercise test. The target heart rate varied between the subjects, mainly because of the individual differences in maximal heart rate. A heart rate monitor (Polar Edge; Polar Electro, Kempele, Finland) was used to control heart rate during walking. For each subject, the Weir formula,[11] which estimates energy expenditure (kcal/min) from measured oxygen consumption (litres/min), was used to calculate the duration of the daily walking session that would correspond to the chosen weekly energy expenditure. The exercise duration varied between the subjects mainly because of the differences in VO_2MAX, which is related to initial fitness and body mass. Table 2 presents the characteristics of the walking programmes of the exercise groups.

All the participants were asked to maintain their previous diet and daily exercise habits and also refrain from changing their current use or non-use of HRT. The training was to be added to the baseline daily physical activity. Two weekly walking sessions were supervised by an exercise leader on an indoor track. The other three sessions were performed according to the participants' preferences on sidewalks, streets, or forest trails or in parks. As a warm up and for injury prevention, the subjects performed a few minutes of light dynamic exercises at the beginning of each session. Standard flexibility exercises were performed as a cool down after the sessions. Once a month the control group attended a meeting with lectures on different exercise and health topics and a few

Table 1 Baseline characteristics of the subjects

	Group W1	Group W2	Group W3	Group W4	Group C
Number	21	21	18	21	40
Age (years)	57 (3.8)	55 (3.7)	54 (3.5)	55 (4.2)	56 (3.8)
Years since menopause	6 (1.6)	6 (2.4)	5 (2.6)	5 (2.4)	6 (2.4)
Weight (kg)	67.9 (10.4)	68.7 (9.5)	67.5 (10.9)	66.1 (8.5)	70.8 (9.3)
Body mass index (kg/m)	26 (3.2)	26 (3.1)	26 (3.7)	25 (3.3)	27 (3.1)
Fat%	36 (5.5)	37 (4.6)	36 (5.9)	36 (4.8)	38 (3.1)
VO_2MAX (ml/kg/min)	30.3 (5.0)	30.8 (4.2)	29.4 (4.1)	30.2 (4.1)	29.3 (3.6)
PA score	2.4 (0.7)	2.2 (0.5)	2.2 (0.7)	1.9 (0.6)	2.4 (0.6)

Values are mean (SD).
Fat%, percentage of body fat; VO_2MAX, maximal aerobic power; PA score, physical activity score (1–5): 1 = no regular PA, 2 = some light PA every week, 3 = once a week brisk PA, 4 = twice a week brisk PA, 5 = three times a week or more brisk PA.

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Table 2 Prescribed exercise programme in groups

	Group W1	Group W2	Group W3	Group W4	Group C
Intensity of walking (% VO_2MAX)	55	45	55	45	–
Target heart rate of the walking (beats/min)	124 (8.4)	118 (9.1)	124 (7.7)	118 (9.3)	–
Energy expenditure per exercise session (kcal)	300	300	200	200	–
Target exercise duration (min)	54 (5.6)	65 (7.8)	38 (3.9)	46 (6.2)	–
Sessions/week	5	5	5	5	–
Supervised sessions/week	2	2	2	2	–
Length of intervention (weeks)	24	24	24	24	24

Where applicable, values are mean (SD).
VO_2MAX, Maximal aerobic power.

minutes of light flexibility exercises. After the intervention, the control group was given detailed instructions on how to start to exercise according the ACSM exercise recommendation.[1] A heart rate monitor was used for the first week of the exercise programme. All the participants were invited to the UKK 2 km walk test after one year of exercise and were instructed to come to the public, yearly walk test events of the UKK institute thereafter.

Measurements

All measurements were performed twice, once before and once after the intervention. A submaximal exercise test was performed before the actual baseline maximal test as a part of the subject screening and also for habituation. A direct, progressive, maximal exercise test on a treadmill (Telineyhtymä Oy, Kotka, Finland) was used to measure VO_2MAX. Submaximal responses to the exercise were monitored by heart rate measurements at absolute exercise levels corresponding individually to 65% and 75% of the VO_2MAX of the baseline exercise test. The treadmill test protocol[12] consisted of a warm up for five minutes at a speed of 5 km/h on a 5% incline, after which the workload was increased at three minute intervals, from very light to maximal load. The speed was increased by 0.5 km/h during the third, sixth, and ninth stages, and the elevation of the treadmill was increased by 2.5% at each stage, except the third. The electrocardiogram was monitored (Case 12; Marquette Electronics Inc, Milwaukee, Wisconsin, USA) continuously by a doctor. The participants reported their perceived exertion on the Borg scale[13] during each exercise stage.

VO_2 was measured using a metabolic cart (Metabolic Measurement Cart 2900Z; Sensor Medics Corp, Anaheim, California, USA). The device was calibrated before each exercise test. VO_2MAX was calculated from one minute collected values.[14] The criteria for reaching VO_2MAX were the following: (*a*) best possible effort of the subject as judged by the test supervisor; (*b*) perceived exertion rated at 19–20; (*c*) heart rate >85% of the age predicted maximum; (*d*) no significant rise (<2 ml/min/kg) in VO_2 between the consecutive minute to minute gas analyses; (*e*) respiratory quotient over 1.05. All the subjects had to fulfil the first criterion. The test was repeated within a week if the subject failed to give her best possible effort or if less than three of the other four criteria were not fulfilled.

Body mass (kg) and height (m) were measured in light clothing without shoes. Height was measured to an accuracy of 0.5 cm and body mass to the nearest 0.1 kg. BMI was calculated as body mass (kg) divided by the square of the height (m). Skinfold thicknesses were measured at four sites (the mid-triceps, biceps, subscapularis, and suprailiac muscles) using a Harpenden skinfold caliper (British Indicators Ltd, Luton, Beds, UK). Total body density was estimated from the sum of the skinfolds according to a linear regression equation with age and sex specific coefficients as described by Durnin and Womersley[15] and converted to the percentage of body fat (F%) using an adaptation of Siri's formula[16] for elderly women.[17]

The physical activity of all the subjects—that is, the prescribed exercise and other habitual exercise—was recorded daily in exercise diaries. The participants also wore pedometers (Fitty 3; Kasper & Richter, Utreht, Germany) for three days (Friday to Sunday) in the middle of the intervention period. The diet and exercise habits and the HRT use of all the subjects were checked with a questionnaire at baseline and again at the end of the intervention period. Current dietary intake was also estimated on the basis of three-day (including one weekend day) food diaries at the beginning and end of the study. The subjects were given oral and written instructions on recording their food intake with household measures. The food composition data were calculated with MicroNutrica software (Social Insurance Institution, Helsinki, Finland).

Sample size and statistical analysis

The calculations for adequate sample size were based on the assumption of about 10% (mean (SD) 3 (4) ml/min/kg) change from the baseline VO_2MAX in the exercise group when compared with the change in the control group (type 1 error α 0.05). The power of the test was selected as 0.90. The calculations yielded a minimum of 39 subjects for each study group. The actual number of subjects in each group was 18 to 21 at the onset of the study. It was calculated that, if necessary for the sake of statistical significance, groups W1 and W3 and groups W2 and W4 could be combined to form adequate groups for determining the effect of intensity on the results. Groups W1 and W2 and groups W3 and W4 could be combined to determine the effect of energy expenditure. The intention to treat principle was used, and all the subjects were asked to participate in the end measurements, in spite of possible drop out from the exercise programme or change in HRT.

The results are given as mean (SD). An analysis of covariance with the baseline measurements as the covariates was used to analyse the training effects. p values were calculated for differences between the study groups. Training effects were determined as net differences—that is, the differences between the changes in each walking group and the control group) with 95% confidence intervals (CI). A two way analysis of covariance with the exercise groups and the HRT groups as factors was also used to analyse their interaction with the outcome measures.

RESULTS

Compliance

Three of the 81 exercising subjects interrupted the exercise programme. The reasons were psychosocial for two subjects and unwillingness for one. One of these subjects participated, however, in the end measurements and was included in the results in order to fulfil the intention to treat principle.

Five of the 121 subjects did not participate in the end measurements for the following reasons: one was not willing to continue; one had psychosocial problems; two controls had lower limb injuries; one had a recently diagnosed chronic disease. Figure 1 shows the number of subjects completing the study in each group.

Compliance with the exercise programme and the amount of habitual physical activity was similar in all the groups. All

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Table 3 Training compliance and habitual physical activity

	Group W1	Group W2	Group W3	Group W4	Group C
Duration of session	95%	90%	98%	98%	–
Walking sessions/week	89%	85%	84%	84%	–
Supervised sessions/week	67%	67%	69%	63%	–
Habitual physical activity (min/day)	16	15	11	11	23
Total walking (km/day)	8.7	8.3	7.0	7.1	–
Length of intervention	97%	98%	99%	99%	121%

Compliance with programme is expressed as a percentage of the completed exercise versus prescribed exercise.
Habitual pysical activity includes walking, cycling, calisthenics, etc but does not include walking training. All variables are calculated from exercise diary recordings, except total walking, which is a pedometric measurement. Pedometric measurements were recorded only in exercise groups and include all physical activity of the day, also walking training.

the subjects worked up gradually to their full exercise programme in the first two weeks. An additional few weeks were allowed with a slightly reduced walking time or intensity for six subjects in group W1, one subject in group W2, one subject in group W3, and three subjects in group W4 . The use of extra 1 kg weights, stair walking, or occasional jogging were allowed for one subject in groups W1, W2, and W3 in the last third of the intervention, in order for them to reach the target heart rate. No other changes in exercise, other than those corresponding to the intervention, were reported in the questionnaire at the end of the intervention. Table 3 presents the details of the subjects' compliance with the exercise programme and also their habitual physical activity.

According to the responses to the questionnaire at the end of the intervention, HRT use remained unchanged. No dietary changes were reported. The mean (SD) daily energy intake of the subjects in the exercise groups, as calculated from the food diary, was 7.5 (1.5) MJ at the beginning and 7.5 (1.4) MJ at the end of the intervention. The respective values for the controls were 7.6 (1.3) MJ and 7.3 (1.4) MJ. No significant quantitative or qualitative changes occurred in the diet of the subjects during the intervention.

Changes in cardiorespiratory fitness

V_{O_2}MAX improved in all the exercise groups. Table 4 shows the mean values before and after the intervention, and the net

Table 4 Main variables before and after the intervention and the net change (95% confidence interval) between the exercise and control groups

	N	Before	After	Net change (95% CI)	p Value
V_{O_2}MAX (ml/kg/min)					
Group W1	20	30.3 (5.1)	31.3 (5.0)	2.9 (1.5 to 4.2)	
Group W2	21	30.8 (4.2)	31.4 (4.4)	2.6 (1.3 to 4.0)	
Group W3	16	29.9 (4.1)	30.4 (4.9)	2.4 (0.9 to 3.8)	
Group W4	21	30.2 (2.8)	30.5 (3.6)	2.2 (0.8 to 3.5)	
Group C	38	29.2 (3.7)	27.5 (3.4)		<0.001
HR at 75% V_{O_2}MAX (beats/min)					
Group W1	20	145 (10)	141 (12)	–7 (–11.1 to –3.1)	
Group W2	21	147 (10)	146 (10)	–4 (–8.3 to –0.5)	
Group W3	16	145 (8)	140 (8)	–8 (–12.5 to –3.9)	
Group W4	21	148 (12)	146 (12)	–5 (–8.6 to –0.7)	
Group C	38	146 (11)	149 (12)		0.001
HR at 65% of V_{O_2}MAX (beats/min)					
Group W1	20	135 (10)	132 (12)	–7 (–10.4 to –2.7)	
Group W2	21	137 (10)	137 (10)	–4 (–7.8 to –0.2)	
Group W3	16	134 (7)	131 (7)	–8 (–11.9 to –3.6)	
Group W4	21	138 (12)	137 (12)	–4 (–8.2 to –0.6)	
Group C	38	136 (11)	140 (11)		0.001
Body mass (kg)					
Group W1	20	67.8 (10.7)	67.0 (10.4)	–0.8 (–1.9 to 0.2)	
Group W2	21	68.7 (9.5)	68.4 (10.0)	–0.4 (–1.4 to 0.7)	
Group W3	16	66.5 (11.1)	66.0 (11.1)	–0.5 (–1.6 to 0.7)	
Group W4	21	66.1 (8.5)	66.2 (9.1)	0.1 (–1.0 to 1.1)	
Group C	38	71.0 (9.3)	71.1 (9.8)		0.528
BMI (kg/m^2)					
Group W1	20	25.7 (3.2)	25.4 (3.1)	–0.2 (–0.7 to 0.1)	
Group W2	21	26.0 (3.1)	25.9 (3.3)	–0.1 (–0.5 to 0.3)	
Group W3	16	25.6 (3.8)	25.4 (3.8)	–0.2 (–0.6 to 0.3)	
Group W4	21	25.4 (3.3)	25.4 (3.5)	0.0 (–0.4 to 0.4)	
Group C	38	26.8 (3.1)	26.8 (3.3)		0.670
Fat%					
Group W1	20	36.2 (5.5)	35.1 (5.5)	–1.2 (–1.9 to –0.4)	
Group W2	21	37.2 (4.6)	36.2 (4.8)	–1.1 (–1.8 to –0.4)	
Group W3	16	35.6 (6.0)	35.1 (6.0)	–0.6 (–1.4 to 0.2)	
Group W4	21	36.0 (4.8)	35.1 (5.3)	–1.0 (–1.7 to –0.2)	
Group C	37	38.3 (3.1)	38.4 (3.3)		0.007

Values are mean (SD). Analysis of covariance is used. Drop outs are excluded.
V_{O_2}MAX, Maximal aerobic power; HR at the 75% or 65% or 55% of V_{O_2}MAX, heart rate at the absolute workload of exercise test corresponding to 75% or 65% of the V_{O_2}MAX of the initial test; BMI, body mass index; Fat%, percentage of body fat.

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Table 5 Some randomised, controlled dose-response studies of VO_{2MAX} and body mass of women

Study	Age group (years)	Length of training (weeks)	Intensity of exercise (% of VO_{2MAX})	Net change in VO_{2MAX} approximately (%)	Net change in body mass approximately (%)
Santiago *et al*[18]	20–40	20			
Jogging			78	31	No change
Walking			62	21	No change
Duncan *et al*[6]	20–40	24			
Walking			83	16	No change
Walking			60	9	No change
Walking			46	4	No change
Ready *et al*[19]	56–67	23			
Walking 5 times/week			60	14	No change
Walking 3 times/week			60	12	No change
Kukkonen-Harjula *et al*[20]	30–55	15			
Walking			65–75	6.8	−1.3
Murphy *et al*[21]	38–50	10			
Walking			63–76	8	−1.3
Jakicic *et al*[22]	35–46	20			
Walking and diet			60	5.6	−7.1
Oja *et al*[5]	20–65	10			
Walking			50	4.5	No change

The formula $\%VO_{2MAX} = 1.28\%HR-29.12$ was used, where HR is heart rate.[11]
The subjects were normal weight in all studies except that of Jakicic *et al*, in which they were obese.
VO_{2MAX}, Maximal aerobic power.

changes. The mean net increase in VO_{2MAX} was 2.2 to 2.9 ml/min/kg (almost 10%) in the exercise groups. In comparison with the controls, the exercise groups showed a 4 to 8 beat/min decrease in the submaximal heart rates at both the measured submaximal exercise levels.

Changes in body composition

Table 4 gives the net changes in body mass, BMI, and F%. Body mass and BMI did not show significant changes, but fat decreased slightly in most of the exercise groups in comparison with the controls. In additional analyses, such as grouping the subjects into two exercise groups according to exercise intensity or exercise energy expenditure, the results were similar. Nor did HRT have any effect on the results.

DISCUSSION

The purpose of our study was to determine the minimum effective dose of exercise for maximal aerobic power and body composition. The net improvement in VO_{2MAX} in our study was modest, 9.5%, 8.7%, 8.1%, and 7.3% in groups W1 to W4 respectively, partly because the control group developed in a pathogenic way, but the change was statistically significant. We have no explanation for the pathogenic development of the control group other than the fact that being sedentary decreases fitness. With regard to the magnitude of the VO_{2MAX} improvement, our findings are consistent with other randomised, controlled walking studies of women[5 6 18–22] (table 5). There seems to be a dose-response relation between exercise intensity and the magnitude of VO_{2MAX} improvement. Our results show a similar trend, although the differences between the results of the groups were small. Our exercise regimen seemed to approach, but not reach, the minimum dose, as even the lowest dose of walking improved maximal aerobic power in our study. A recent, uncontrolled study of 18 premenopausal women showed similar improvements in high exercise intensity and low exercise intensity while energy expenditure was kept constant.[7] Total energy expenditure probably plays an important part in exercise response.

The changes in body mass were not statistically significant, but there was slight improvement in body fat. It is possible that the length of our intervention was too short to detect all the possible change in body composition. Our study apparently approached, but did not reach, the minimum dose of exercise to influence body composition. Our results are in agreement with those of earlier studies of women,[5 6 18–22] with no clear dose-response relation between exercise intensity and changes in body mass or fat. Combining exercise with diet change seems to improve the results.[22] Table 5 summarises the basic elements of these studies. Total energy expenditure during exercise is probably an important factor, but it was not estimated in most of the studies.

In our study, very few injuries occurred as a result of the training. Consultation with a doctor (T-MA) was strongly recommended at the onset of any health problems. A total of 34 subjects consulted the doctor, and 25 subjects complained of exercise related, mostly mild, lower limb or back problems, yet absence from the exercise programme because of injury was low. There was no difference in the injury rate between the exercise groups. Two subjects had transient, mild cardiac problems. The number of injuries was similar to those of the study of Kukkonen-Harjula *et al*,[20] although the latter study also reported some serious injuries. Duncan *et al*[6] reported no injuries, but their subjects were younger women. Our findings support the observation that walking is a feasible form of exercise for sedentary postmenopausal women and has only a relatively small risk of health problems.

Our study had several strengths. The number of subjects was sufficient for adequate statistical comparisons. The randomised groups were comparable. The exercise dose was carefully controlled with supervision, heart rate monitoring, and exercise diaries. The energy intake was controlled with a food diary. The programme was closely followed by participants and the drop out rate was small. To improve the design further all the exercise sessions could be supervised.

Take home message

Sedentary postmenopausal women may benefit from a relatively small dose of exercise. When performed regularly and on most days of the week, aerobic fitness and body composition are improved.

Conclusion

We conclude that 24 weeks of walking at moderate intensity—45–55% of the VO_{2MAX} with a total weekly energy

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expenditure of 1000–1500 kcal—improves VO_{2MAX} and body composition in previously sedentary, non-obese or slightly overweight postmenopausal women. The dose of exercise used in this design apparently approaches the minimum effective dose, but even this low dose of regular aerobic training leads to significant training effects.

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Walking trials in postmenopausal women: effect of one vs two daily bouts on aerobic fitness

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We compared the effects of one vs two daily bouts of walking on aerobic fitness and body composition in postmenopausal women. One hundred and thirty-four subjects were randomized into exercise groups or a control group and 130 completed the study. The subjects walked 5 d/week for 15 weeks at 65% of their maximal aerobic power expending 300 kcal (1255 kJ) in exercise in one (Group S1) or two daily sessions (Group S2). VO_{2max} was measured in a direct maximal treadmill test. Body mass index (BMI) was calculated and the percentage of body fat (fat%) estimated using skinfold measurements. The net change in the VO_{2max} was 2.5 mL min/kg (95% CI 1.5, 3.5) (8.7%) in Group S1 and 2.5 mL min/kg (95% CI 1.5, 3.5) (8.8%) in Group S2. The net change in body mass was −1.2 kg (95% CI −1.9, −0.5) in Group S1 and −1.1 kg (95% CI −1.8, −0.4) in Group S2. The net fat% change was −2.1% (95% CI −2.7, −1.4) in Group S1 and −1.7% (95% CI −2.3, −1.0) in Group S2. Exercise improved the maximal aerobic power and body composition equally when walking was performed in one or two daily bouts.

The latest exercise recommendation of the American College of Sports Medicine (ACSM) (1998) states that adults should exercise 3–5 d/week at 40/50–80% of their maximum oxygen uptake reserve continuously for 20–60 min or accumulate the same amount of exercise in several daily bouts, for a minimum of 10 min, and expend 700–2000 kcal (2929–8368 kJ) weekly to gain positive effects on aerobic fitness and body composition (ACSM, 1998). The trend of exercise guidelines has been towards more frequent and more moderate exercise and also towards daily accumulation of exercise.

The theory of exercise accumulation is based mainly on epidemiological evidence. Only four randomized, controlled intervention studies (Ebisu, 1985; Jakicic et al., 1995; Murphy & Hardman, 1998; Woolf-May et al., 1999) with a total of 212 subjects support it. Some researchers regard the accumulation aspect of the latest ACSM exercise recommendations to be still speculative, because of sparse data (Barinaga, 1997; Hardman, 1999). More randomized, controlled dose–response studies with a sufficient amount of subjects in all age groups are clearly needed. There are no published studies on the accumulation hypothesis in postmenopausal women.

We conducted a randomized, controlled trial to compare the effects of equivolume brisk walking, once or twice a day, on aerobic fitness and body composition on 134 post-menopausal women. According to our hypothesis, both exercise groups should show similar and significant improvements in relation to a control group.

Material and methods

Design

The study was a randomized, controlled trial with three parallel groups: one (S1), two (S2) and no (C) daily walking sessions. The outcome measures were changes in maximal aerobic power, submaximal cardiorespiratory fitness and body composition. The study plan was approved by the Research Ethics Committee of the UKK Institute for Health Promotion Research. All the subjects gave their written informed consent.

Participants

The participants were recruited through an announcement in the local newspaper. A total of 700 subjects responded and 134 subjects fulfilled all the eligibility criteria and were accepted (Fig. 1).

The eligibility criteria were that the subjects were (1) female, and that at the time of the onset of the study should be (2) 2–10 years past the onset of menopause, (3) 48–63 years of age (4), no chronic diseases, (5) no regular medication, (6) non-smokers, (7) body mass index (BMI) < 32 kg/m, (8) resting blood pressure < 160/100 mmHg measured after 5 min bedrest, (9) not engaged in physically strenuous work or regular brisk leisure-time exercise more than once a week and (10) willing to continue previous diet and physical activity habits in addition to the exercise requirements of the study group. An equal number of women on hormone replacement therapy (HRT) and women without HRT were accepted.

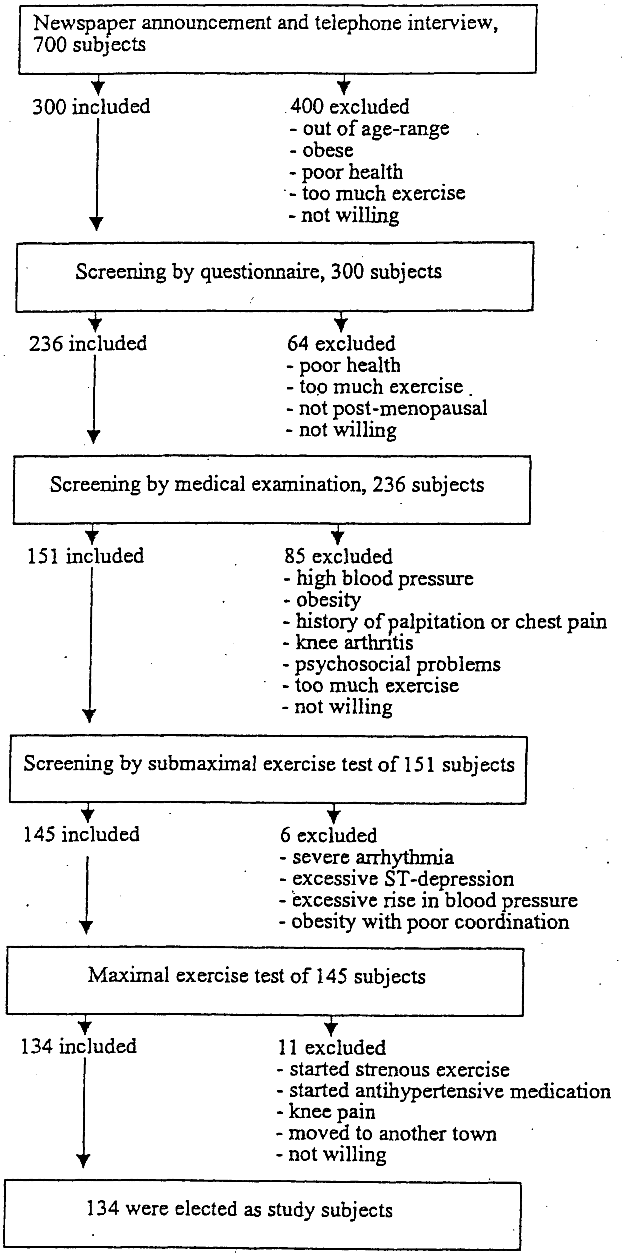

Fig. 1. Recruitment process.

Randomization

The HRT users and non-users were randomized separately in blocks of 15 subjects into the three groups, each including an approximately equal number of HRT users and non-users. The procedure yielded 46, 43 and 45 subjects in Groups S1, S2 and C, respectively (Fig. 2). The baseline characteristics of the subjects are shown in Table 1. The age range was 47–64 years, weight range 50–93 kg and BMI range 19–32.

Exercise intervention

The exercise program was planned according to the principles of the ACSM (1998) recommendation. The frequency of exercise was 5 d/week, the intensity 65% of the VO_{2max} and the weekly exercise volume 1500 kcal (6276 kJ). Daily training was

Table 1. Baseline characteristics of the subjects, means and standard deviations (SD)

	C	S1	S2
N	45	46	43
Age, years	56.5 (4.2)	57.8 (4.4)	57.6 (4.2)
Years from menopause	5.8 (2.0)	6.0 (2.2)	6.0 (1.8)
Weight, kg	67.0 (8.5)	67.6 (8.2)	67.9 (8.5)
BMI, kg/m	25.7 (2.8)	25.8 (2.7)	25.9 (2.8)
F percentage	37.2 (4.5)	36.9 (4.4)	37.1 (4.9)
VO_2 max, ml/kg	27.7 (3.5)	29.0 (3.8)	28.4 (3.6)
PA score (1)	2.5 (0.7)	2.6 (0.5)	2.6 (0.5)

(1) PA score = physical activity score (1–5).
1 = no regular PA weekly; 2 = some light PA every week; 3 = once a week brisk PA; 4 = twice a week brisk PA; 5 = three times a week or more brisk PA.

continuous in Group S1 and divided into two equally long sessions with at least a 5-h interval in Group S2. Brisk walking was considered the most common and feasible form of sustainable dynamic aerobic exercise for sedentary subjects (Morris & Hardman, 1997) and was chosen as the mode of exercise. The minimum (15 weeks) recommended length for an intervention was chosen.

The individual target heart rate, corresponding to 65% of the VO_{2max}, was determined for each subject in the first maximal exercise test. The mean target heart rate was 132 (SD 10.7) beat/min in Group S1 and 130 (SD 11.2) beat/min in Group S2. The duration of daily exercise corresponding to 300 kcal (1256 kJ) was also calculated individually in the first maximal exercise test using the Weir formula, which estimates energy expenditure (kcal/min) from measured oxygen consumption (L/min) (Weir, 1949). The mean target duration was 46.6 (SD 5.4) min for Group S1 and 2×24.0 (SD 3.2) min for Group S2.

Two weekly walking sessions were supervised by an exercise leader on a 100-m indoor track. The other sessions, three for Group S1 and eight for Group S2, were unsupervised and took place according to the participants' preferences, on sidewalks, streets or forest trails or in parks. A heart rate monitor (Polar Edge, Polar Electro, Kempele, Finland) was used to control the walking pace in the 2-weekly supervised sessions and every third week in all weekly sessions. The participants, including those without the heart rate monitor, were also advised to record periodically the length of their walking route, in order to maintain the same relative pace in all weekly sessions.

The subjects in the exercise groups recorded their programmed exercise and also other habitual exercise in exercise diaries. They also wore step counters (Fitty 3, Kasper & Richter, Uttreuth, Germany) for 3 d, from Friday through Sunday, in the middle of the intervention period.

The supervised exercise sessions of both exercise groups included a light dynamic muscle workout for the main muscle groups (10 exercises in one set with 10 repetitions using 5-kg dumbbells or body mass as resistance) and flexibility exercises according to the ACSM (1998) guidelines as a warm-up and also for injury prevention. The flexibility exercises were repeated as a cool-down after walking. A few minutes of similar exercises were also recommended for use before and after the unsupervised exercise sessions.

Once a month the control group attended a meeting with lectures on health topics and a few minutes of light flexibility exercises. All the participants were asked to keep their previous diet, daily exercise habits and use of HRT constant. This was checked with a questionnaire followed by an interview at the beginning and at the end of the intervention.

Measurements

All the measurements were conducted before and after the training. A progressive, maximal exercise test on a treadmill

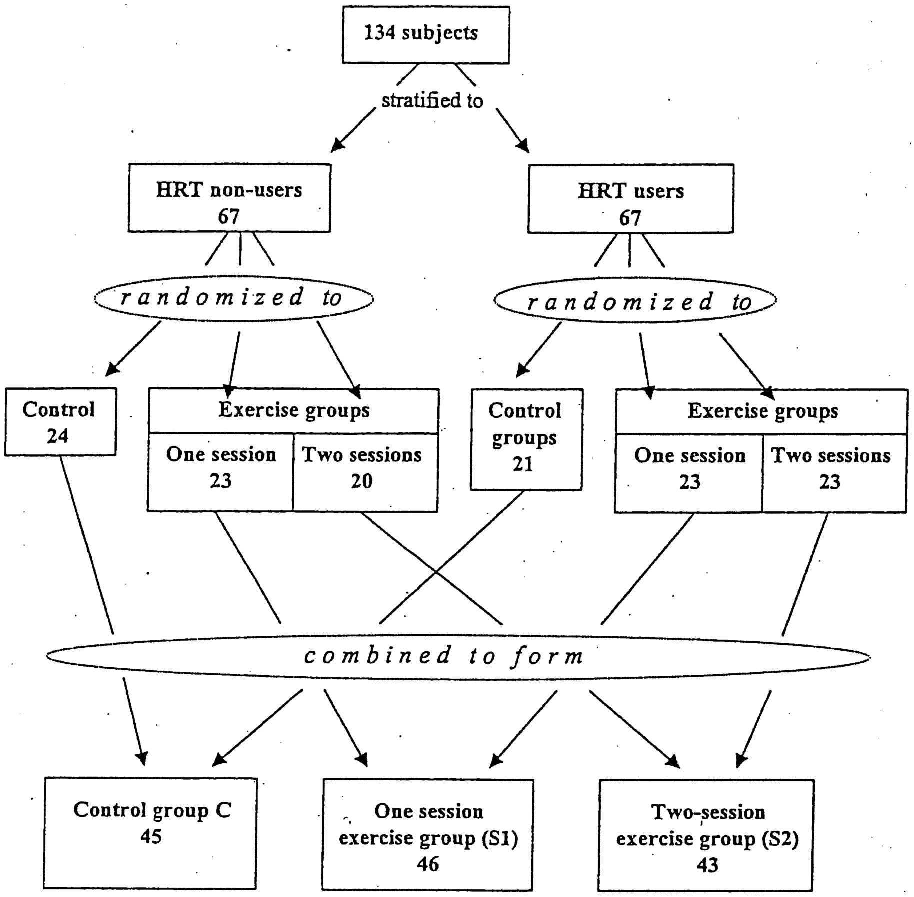

Fig. 2. Randomization process.

(Telineyhtymä Oy, Kotka, Finland) was used to measure the VO_{2max}. The submaximal response to exercise was monitored by heart rate measurements at absolute exercise levels corresponding individually to 65% and 75% of the VO_{2max} in the baseline exercise test. The treadmill test protocol (Oja, 1973) consisted of a warm-up for 5 min at 5 km/h on a 5% incline. The workload was increased in 3-min intervals, from very light to maximal load. The speed was increased by 0.5 km/h during the third, sixth and ninth stages, and the elevation of the treadmill was increased by 2.5% at each stage except the third. The electrocardiogram (ECG) was monitored (Case 12, Marquette Electronics Inc., Milwaukee, WI, USA) continuously. The participants reported their perceived exertion on the Borg scale (Borg, 1970) during each exercise stage. For habituation a separate submaximal test was performed few days before the first maximal exercise test.

VO_2 was measured breath-to-breath using a metabolic cart (Metabolic Measurement Cart 2900Z, Sensor Medics Corp., Anaheim, CA, USA). The analyzer was calibrated before each test. The maximum VO_2 was obtained from 1-min collected values (Howley et al., 1995). The criteria for maximum were the following: (1) best possible effort as judged by the test supervisor, (2) perceived exertion 19–20, (3) heart rate over 85% of the age-predicted maximum, (4) no significant rise (< 2 mL min/kg) in VO_{2max} between the consecutive minute-to-minute gas analyses and (5) respiratory quotient over 1.05. All the participants had to fulfill the first criterion. The test was repeated within a week if the subject failed to give her best possible effort or if less than three of the other four criteria were not fulfilled.

Body mass (kg) and height (m) were measured in light clothing without shoes. Height was obtained to an accuracy of 0.005 m, and body mass was measured to the nearest 0.1 kg. The BMI was calculated as body mass (kg) divided by the square of the height (m). Skinfold thicknesses were measured at four sites: the mid-triceps, biceps, subscapularis and suprailiac muscles, using a Harpenden skinfold caliper (British Indicators Ltd, Luton, UK). Body density was estimated from the sum of the skinfolds according to a linear regression equation with age- and sex-specific coefficients according to Durnin (1974) and converted to the percentage of body fat using an adaptation of Siri's formula (Siri, 1961) for elderly women (Deurenberg, 1989).

Previous diet, daily exercise habits and use of HRT constant were checked with a questionnaire followed by an interview at the beginning and at the end of the intervention.

Physical activity was enquired using a PA score (1–5), described as follows: 1 = no regular PA weekly, 2 = some light PA every week, 3 = once a week brisk PA, 4 = twice a week brisk PA, 5 = three times a week or more brisk PA. Questions concerning exercise-related pain and injuries were asked at the end of intervention.

Sample size and statistical analyses

The calculations for adequate sample size were based on the assumption of about a 10% (3 mL min/kg (SD 4)) increase from the baseline VO_{2max} in the exercise group when compared with the change in the control group (type 1 error alpha 0.05). The power of the test was selected as 0.90. The calculations yielded a minimum of 39 participants for each study group. The actual number of subjects in each group was 43–46 at the onset of the study. The intention-to-treat principle was used, and all the subjects were asked to participate in the 15-week measurements, in spite of possible dropout from the exercise program or change in HRT use.

Results are given as means and standard deviations (SD). An analysis of covariance (ANCOVA) with baseline measurements as the covariates was used to analyze the training effects. *P*-values were calculated in testing for any differences between the groups. Training effects were determined as the net differences (i.e. the differences between the changes in each walking group and the control group). We calculated the 95% confidence intervals (CI) for the net change. A two-way analysis of covariance with the exercise groups and the HRT groups as factors was also used to analyze the interaction of these factors with the outcome measures.

Results

Compliance

Four subjects out of 134 did not participate in the 15-week measurements because of health problems: one subject was recovering from a gallbladder operation, one had an acute lumbar problem and one had newly detected diabetes. One exercise test was interrupted because of cardiac problems. In addition, because of technical difficulties, there was one missing value from the submaximal heart rate measurement at 75% of VO_{2max} and four at 65% of VO_{2max}.

Three of the 88 exercising subjects interrupted the exercise program: two because of lower limb problems, plantar fascitis and newly detected knee arthritis and one because of family reasons. All of them participated, however, in both exercise tests and were included in the results according to the intention-to-treat principle.

The mean values calculated from the exercise diaries showed that Group S1 attended 89% of the prescribed 75 sessions and Group S2 95% of the 150 prescribed sessions. Group S1 attended 88% and Group S2 92% of the 30 supervised exercise sessions. Absence from exercise was due to health problems, family reasons, work duties or travel. Less than 1% of the absence was due to musculoskeletal problems and the difference between the exercise groups was not statistically significant. The mean total duration of walking at the target heart rate per session was 47.9 (SD 14.2) min for Group S1 and 25.0 (SD 3.2) min for Group S2. The mean total daily duration of habitual physical activity, other than prescribed exercise, was 23.9 (SD 18.3) min for Group S1 and 27.8 (SD 18.8) min for Group S2. The mean total daily amount of walking, including both the prescribed exercise and habitual physical activity, estimated from the pedometer recordings, was 9.2 (SD 3.1) km for Group S1 and 10.4 (SD 3.0) km for Group S2.

All participants were given the possibility to work up gradually to their full exercise program during the first 2 weeks. An additional 2 weeks was allowed for six subjects in Group S1 and seven subjects in Group S2. During the last weeks of intervention five subjects in Group S1 and six subjects in Group 2 were allowed to use extra 1-kg weights, stair-walking or occasional jogging steps to reach their target

Table 2. Mean values and standard deviation (SD) before and after the intervention, and the net change (95% CI) between exercise and control groups* †

	N‡	Before	After	Net change (95% CI)	*P*-value†
VO_{2max}, ml/kg min					
S1	44	28.8 (3.7)	32.4 (4.1)	2.5 (1.5, 3.5)	
S2	43	28.4 (3.7)	32.0 (3.8)	2.5 (1.5, 3.5)	
C	43	27.7 (3.5)	28.9 (3.7		<0.001
HR at 75%VO_{2max}, bpm					
S1	44	141 (11)	140 (12)	−1.9 (−5.0, 1.1)	
S2	43	141 (11)	137 (12)	−3.7 (−6.8, −0.7)	
C	42	139 (13)	138 (15)		0.059
HR at 65%VO_{2max}, bpm					
S1	42	130 (12)	128 (13)	−1.4 (−4.7, 1.8)	
S2	42	129 (12)	126 (13)	−2.5 (−5.7, 0.7)	
C	41	128 (14)	128 (15)		0.310
Weight, kg					
S1	44	67.6 (8.4)	66.4 (7.8)	−1.2 (−1.8, −0.5)	
S2	44	67.8 (8.4)	66.6 (8.2)	−1.1 (−1.8, −0.4)	
C	43	66.7 (8.3)	66.7 (8.2)		0.001
BMI, kg/m²					
S1	44	25.8 (2.7)	25.3 (2.5)	−0.5 (−0.7, −0.2)	
S2	44	25.9 (2.8)	25.5 (2.7)	−0.4 (−0.7, −0.2)	
C	43	25.6 (2.8)	25.6 (2.8		0.001
Fat%					
S1	45	36.8 (4.4)	34.3 (3.8)	−2.1 (−2.7, −1.4)	
S2	44	37.2 (4.9)	35.1 (4.6)	−1.7 (−2.3, −1.0)	
C	42	36.9 (4.2)	36.5 (3.7)		<0.001

VO_{2max} indicates maximal aerobic power; S1, one-session exercise group; S2, two-session exercise group: C, control group; HR, heart rate; BMI, body mass index; fat%, percentage of body fat.
†Analysis of covariance.
‡Dropouts are excluded.

heart rate. The mean length of the intervention was 14.4 (SD 2.9) weeks for Group S1 and 14.8 (SD 2.5) weeks for Group S2. The walking program was stopped 1 d before the exercise test.

There were no changes in diet reported in the questionnaire. Changes in exercise, corresponding to the intervention program, were reported in Groups S1 and S2. No changes in exercise were reported in the participants of the control group. Six participants changed their HRT status. In Group S1 two subjects started and one subject stopped the HRT. In Group S2 one subject started and two subjects stopped the HRT. All six subjects were included in their original group in the analyses to meet the intention-to-treat principle.

Changes in aerobic fitness and body composition

Aerobic fitness and body composition improved equally in both exercise groups compared to controls. The net increase in VO_{2max} was approximately 8%. The changes in submaximal heart rate were not statistically significant. Body mass decreased approximately 1 kg in both exercise groups and the corresponding BMI change was approximately 0.5 units. The fat% decrease was approximately 2% units in both groups (Table 2).

Discussion

The purpose of our study was to test the accumulation hypothesis among post-menopausal women, a group not investigated previously in accumulation studies.

The VO_{2max} improvement in our study was similar in both exercise groups, and agreed with the findings of other randomized, controlled accumulation studies. Ebisu (1985) studied the effects of jogging the same distance in one, two or three daily sessions at the 80% of the maximal heart rate (HR_{max}) for 10 weeks on 53 male students and found VO_{2max} responses of 6.9%, 9.8% and 8.3%, respectively. Jakicic et al. (1995) compared the effects of 20–40-min brisk walking performed in one continuous session or multiple 10-min bouts in a 20-week trial on 56 obese 35–46-year-old-women. The multiple-bout group had better adherence and exercised more than the continuous exercise group. The VO_{2max} increases were 5.6% in the multiple-bout group and 5.0% in the continuous exercise group. Murphy and Hardman (1998) studied 47 women, aged 38–51 years, performing 10 weeks of brisk walking at an intensity of 70–80% of the HR_{max}, 5 d/week, in one 30-min session vs three 10-min sessions, and found approximately 8% improvement in the VO_{2max} in both groups. Woolf-May et al. (1999) conducted a study of 56 adults walking 20–40 min in one, two or three bouts and reported similar responses in all exercise groups in a standardized step test and lactate measurements indicating aerobic fitness.

Table 3. Some randomized, controlled dose–response studies on VO_{2max} in women

Study	Intensity of exercise, % of the VO_{2max}*	Net change of VO_{2max} approximately
Santiago et al. (1987)		
20–40-year-old women		
jogging	78	31%
walking	62	21%
20 weeks		
Duncan et al. (1991)		
20–40-year-old women		
walking	83	16%
	60	9%
	46	4%
24 weeks		
Ready et al. (1996)		
56–67-year-old women		
walking	60	14%
5 or 3 times/ week		12%
24 weeks		
Kukkonen-Harjula et al. 1997		
30–55-year-old women		
walking	65–75	6.8%
15 weeks		
Murphy et al. 1998		
38–50-year-old women		
walking	63–76	8%
10 weeks		
Asikainen et al. (this study)		
43–63-year-old women		
walking	65	8%
15 weeks		
Jacicic et al. 1995		
35–46-year-old obese women		
walking and diet	60	5.6%
20 weeks		
Oja et al. (1991)		
20–65-year-old women		
walking	50	4.5%
10 weeks		

*The formula percentage VO_{2max} = 1.28% HR-29.12 was used.

There are also six other studies on exercise accumulation showing mainly similar results, but these studies lack randomization, or are uncontrolled, or do not compare effects of short bouts to long bouts of equivolume exercise (DeBusk et al., 1990; Snyder et al., 1997, Woolf-May et al., 1998; Jakicic et al., 1999; Boreham et al., 2000; Donnelly et al., 2000).

Regular brisk walking also had beneficial effects on the body composition of our participants. Body mass reduction was similar (1.7%) in both groups. The reduction in the percentage of body fat was also similar in both groups (about 2%-units). All these changes were small but consistent and statistically significant. Since our participants were not markedly obese and they reported no dietary changes, only slight reductions in body weight could be expected during our 15-week intervention period, for which the total exercise energy expenditure was about 22 500 kcal (94 125 kJ). The findings of other randomized, controlled walking studies on normal-weight women have shown similar results: for example Kukkonen-Harjula et al. (1998) found a 1.5% reduction and Murphy and Hardman (1998) a slight reduction in four skinfold thicknesses in both exercise groups, but a significant 2.6% reduction of body mass only in short bout walkers. Ready et al. (1996) reported no significant changes in body mass, but the percentage of body fat decreased 1.1–1.3%-units.

The participants were recommended to contact the consulting physician (T-MA) in the event of any health problems. Of the total 73 consultations, 49 concerned exercise-related problems. In the questionnaire at the end of intervention 35% of the participants reported some exercise-related pain in the lower limbs, and for 17% the walking program was disturbed temporarily by pain, mainly at the beginning of the intervention. Exercise absence was very low, however, because most of the problems were minor. Four participants of 88 (5%) met major exercise-related health problems: one persistent plantaris fascitis, one deterioration of low back symptoms, one radius fracture on the icy walking trial and one mild, recurrent arrhythmia. Thus, our findings indicate that walking is a feasible form of exercise for sedentary post-menopausal women but there is a small risk of health problems. In exercise counseling these adverse effects should be prevented by guiding the participant to avoid overstrain. This means a gradual increase in the weekly training program and proper rest between exercise sessions. If exercise-related symptoms appear, early contact with the exercise counselor or a doctor is recommended.

Our study had several strengths. We had more subjects that any other accumulation study and the number of subjects was sufficient for adequate statistical comparisons. The randomized groups were comparable. The exercise dose was controlled carefully with supervision, heart rate monitors, exercise diaries and pedometers. The program was followed closely by participants and the dropout rate was small. Aerobic capacity was measured in a direct, maximal exercise test. To improve the design further, all the exercise sessions could be controlled and the intervention could be longer to ensure the detection of all potential effect.

Perspectives

Our study supports the current physical activity recommendation (ACSM, 1998). Regular brisk walking can produce training effects in post-menopausal women if the total amount of exercise is sufficient. Exercise can be divided into two daily bouts without compromising the training effects. This finding is useful for physicians as well as other professionals in exercise counseling for sedentary, post-menopausal women. The barriers to starting and maintaining a regular, time-consuming exercise program are great for elderly women who have not been accustomed to exercise training (Shephard, 1993). Physical activity that is integrated into everyday life, for example daily commuting or shopping, may be easier to begin and will be more likely to be continued regularly (Andersen et al., 1999; Dunn et al., 1999). Our results encourage the use of everyday possibilities for multiple walking bouts.

Key words: body fatness; dose–response; exercise; randomized controlled trial.

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Effect of brisk walking in one or two daily bouts and moderate resistance training on lower extremity muscular strength, balance and walking performance in early postmenopausal women. A randomized, controlled trial.

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Abstract

Background and purpose - To study the effects and feasibility of walking in one or two exercise bouts and resistance training on lower extremity muscular strength, balance and walking performance.

Subjects – 134 early postmenopausal women.

Methods - A 15–week, randomized, controlled trial with continuous and fractionated exercise groups.The outcomes were lower extremity muscular strength, balance and walking time of 2 km. Feasibility was assessed by questionnaires, interviews and training logs.

Results – 128 women completed the study. Compliance was 92 %. Both continuous and fractionated exercise groups improved equally lower extremity muscular strength and walking time but not balance. Almost 70 % of the subjects considered the program feasible. Two daily walking sessions caused fewer lower extremity complaints than continuous.

Discussion and conclusion - Brisk walking combined with moderate resistance training is feasible and effective. Fractionating the walking in to two daily sessions is more feasible than continuous walking.

Background and purpose

On average menopause occurs among the US and European women at the age of 50 years. Menopause is defined as a natural, age-related decrease and, finally loss of ovarion estrogen production and secretion. The decreasing estrogen level, and also other related hormonal changes, affects, especially inactive women, in many unwanted ways. In addition to weight gain, menopause may induce a phase of rapid decreases in bone mineral density, aerobic fitness, muscle strength and balance[1]. This might lead to inability to stay mobile and live independent life when approaching old age. Physical activity might help to pass menopausal transition with much less dramatic changes and help to preserve good functional capacity[2].

There are reports that show the complexity of interaction between physical activity, health, fitness and hormones[3]. It is not clear, what is the exact dose-response relationship of exercise and fitness in early postmenopause, after menopausal changes in hormonal balance. Decreasing level of anabolic hormones may be associated for example with musculoskeletal athrophy, but on the other hand physical activity itself might have an effect on hormone action as a result of changes in protein carries and reseptors. The response to exercise might differ between women with natural postmenopausal hormone levels and women taking the hormone replacement therapy (HRT).

The latest exercise recommendation of American College of Sports Medicine (ACSM) states that adults should exercise 3 - 5 $d \cdot wk^{-1}$ at 40/50%-80% of their maximum oxygen uptake reserve (VO_2R) for 20 - 60 minutes continuously or accumulate the same amount of exercise in several daily bouts, minimum 10 minutes, which means expending approximately 700 - 2000 kcal weekly to gain positive effects on aerobic fitness and body composition[4]. VO_2R is calculated from the difference between resting and maximum VO_2 and the percentage of this value is added to the resting VO_2 and expressed as a percentage of VO_2R. Resistance training should include one set of 8 - 10 exercises that condition major muscle groups 2 - 3 $d \cdot wk^{-1}$, 8 - 12 repetitions of each exercise and for older persons over 50-60 years 10-15 repetitons may be more appropriate. Stretching should include appropriate static and dynamic techniques.
For older adults ACSM recommends exercise that preserves or improves muscle mass, lower extremity muscular strength, balance and the ability to walk[2].

Aerobic exercise in defined as planned, sturctured physical activity that involves large muscle groups in dynamic activites that results, if effective, in improvements of function of especially cardiovascular system and the skeletal muscles, leading to increase in cardiovascular fitness (endurance performance). The exercise dose in aerobic exercise training is usually described by the intensity, duration, and frequency of the training session, and in exercise trials also by the length of the exercise program. Intensity is usually described as a relative intensity, a percentage of the subject's maximal aerobic power ($\%VO_{2max}$) or maximal heart rate (HR_{max}). Duration refers to the duration of a single exercise session. Frequency refers to the number of weekly exercise sessions. The total volume of training accomplished, expressed as exercise energy expenditure (EEE) can also be used to describe exercise dose[5,4].

Resistance exercise is basicly designed to improve muscular strength, power and endurance. The exercise dose in resistance exercise training is usually described by the magnitude of resistance, the number of repetitions the resistance is moved in a single set of exercise, the number of sets done, and the length of resistance training program. Muscular strength is a measure of muscle's ability to generate force, muscular power is a measure of rate at which force is generated and muscular endurance is a measure of ability of a muscle to make repeated contractions against a constant resistance. Muscular strength is usually expressed as one-repetition maximum (1RM) for dynamic measurements[5,4].

The basic principle of dose-response is overload. Any physical activity will cause acute responses in cardiovascular and muscular systems, but only the dose of exercise that exceeds the habitual activity of an individual will cause a training effect, if repeated. Thus initially sedentary, low-fit individuals will get fitness improvements with a smaller exercise dose than initially more fit individuals. The greater the exercise dose (= intensity + frequency + duration), the greater the response (training effect) is. This can be seen most clearly on the maximal aerobic power response to aerobic exercise. Intensity, frequency and duration are, to some extent, changeable parameters of exercise dose. For example the high intensity can be changed to a lower intensity, if the frequency and duration of exercise training are enlarged in order to keep the exercise dose as efective on maximal aerobic power. All of the training effects of exercise are reversible and will disappear by time, if the exercise training is stopped[5,4].

ACSM classified exercise by it's intensity as very light (< 10%VO_{2max}), light (30-49% VO_{2max}), moderate (somewhat hard) (50-74% VO_{2max}), heavy (75%-84% VO_{2max}) and very heavy (> 85% VO_{2max}) (ACSM 1990). Light exercise is not considered effective for healthy adults, although in elderly and initially very low fit, however, it is assumed to have positive effects. The interest in moderate exercise, such as walking, has been growing because of feasibility and safety aspects[4]. Reports of sudden cardiac death during exercise show that high exercise intensity is related to this risk[6,7] and also to the risk of orthopaedic injury especially in elderly[7]. The frequency of 3 $d \cdot wk^{-1}$ is considered optimal, since increasing the frequency to 5 $d \cdot wk^{-1}$ the added improvement in fitness is small.

When exercise is performed above the minimum intensity treshold, the total volume of training accomplished, expressed as exercise energy expenditure (EEE) could also be used to describe exercise dose. The exercise dose of 200-300 kcal per session is recommended for weight loss (for a 75-kg person) by ACSM[4]. The Harward study showed about 40% reduction in age-related mortality among men at an EEE of 1500 $kcal \cdot wk^{-1}$ [8]. Kesäniemi et al.[9] found a 30% reduction in mortality for sedentary subjects at an EEE of 1000 $kcal \cdot wk^{-1}$. Even exercise doses as low as 500 kcal·wk^{-1} have been claimed to have some beneficial effect on all-cause mortality[10,11].

These recommendations are based both on epidemiological evidence and on exercise trials which are mostly conducted on men, and thus they may not be completely valid for women. Also the effects of exercise might be different in women of different ages. There is a need of randomized, controlled trials on the effects of exercise on early postmenopausal women that take natural hormonal status of postmenopause and also possible hormone-replacement therapy in consideration.

A recent systematic review on dose-response relationships between exercise and fitness of RCTs of 50-65-year-old women states that early postmenopausal women are very seldom studied in exercise trials[12]. Writers identified only 11 studies on muscular strength and 6 studies on balance and/or coordination and only one of the studies used exercise that was fractionated in several daily bouts. Most studies on muscular strength used weight machines or high impact circuit training.There were no studies on the effect of walking and simple resistance training program without equipment on muscle strength. The studies that focused on balance and coordination also mostly used resistance training in gym or high impact jumping. Only one of the studies reported using walking or other low impact aerobic training combined with resistance exercises. The only study that reported using fractionated exercise included also men and the only result that was raported separately for both genders was that there was no effect on lipids[13]. The feasibility of fractionated exercise compared to continuous was not reported. So it seems, that as common mode of exercise walking is, and as much as it is recommended as effective exercise[14], it has been studied mostly on men and other age groups[12].

For this purpose we conducted a randomized controlled trial on early postmenopausal women, which included moderate intensity walking in one or two exercise bouts and moderate intensity resistance training with simple equipment. The hypothesis was that there would be improvements in lower extremity muscular strength, balance and the ability to walk. In addition, the feasibility of fractionated walking training was evaluated with reference to continuous walking training. The results of exercise training of women on HRT and not using it were compared.

Participants

An announcement in a local newspaper produced 700 answers, out of which 300 participated in a questionnaire screening, 236 participated in a medical examination, 151 participated in submaximal exercise test and 145 participated in maximal exercise test and finally 134 participants were included in the intervention. All of these participants fulfilled the eligibility criteria. The eligibility criteria were: 1) female, 2) 2-10 years past the onset of menopause, 3)

48-63 years of age, 4) no chronic diseases, 5) no regular medication except possible HRT, 6) non-smoker, 7) body mass index < 32 kg/m^2, 8) resting blood pressure < 160/100 mmHg, 9) not engaged in strenuous work or regular brisk leisure-time exercise more than once a week, 10) willing to continue previous diet and physical activity habits in addition to the exercise requirements of the study group and 11) willing to accept the result of randomization. An equal number of women on HRT and women without HRT were accepted. The process is previously described in detail[6].

Methods

The study was a randomized, controlled trial with two exercise groups. The participants in Group E1 used continuous exercise, the training was performed in one daily exercise bout. The exercise training in Group E2 was fractionated into two daily bouts and a control Group C kept their daily physical activity habits unchanged. We have previously reported that both of these training regimens improved maximal aerobic power, measures of submaximal fitness, resting blood pressure, body mass, the proportion of body fat[15] and also blood lipids, glucose- and insulin-levels[16].The main outcome measures in this report are lower extremity muscular strength, balance and walking performance. The study design was approved by the Research Ethics Committee of the Urho Kaleva Kekkonen Institute for Health Promotion Research. All the subjects gave their written informed consent.

Randomization

The HRT users and non-users were randomized separately in blocks of 15 subjects into the three groups, each including an approximately equal number of HRT users and non-users. The procedure yielded 46, 43 and 45 subjects in Group E1, E2 and C, respectively. The baseline characteristics of the subjects are presented in Table 1.

Table 1.

Baseline characteristics of the subjects. Means (standard deviation) or proportions of subjects.

	E1	E2	C
N	46	43	45
Age, Years	57.8 (4.4)	57.6 (4.2)	56.5 (4.2)
Years from menopause	6.0 (2.2)	6.0 (1.8)	5.8 (2.0)
Weight, kg	67.6 (8.2)	67.9 (8.5)	67.0 (8.5)
BMI*), kg·m^{-2}	25.8 (2.7)	25.9 (2.8)	25.7 (2.8)
Walking time‡) min	17.5 (1.1)	17.4 (1.2)	17.6 (1.3)
One-leg squat¶)	9.6 (2.1)	9.2 (2.1)	8.8 (2.4)
One-leg stand			
0 – 29 sec	23 %	28 %	28 %
30 – 59 sec 32 %	20 %	14 %	
60 sec	46 %	52 %	58 %
Physical activity habits			
no regular weekly	0 %	2 %	9 %
some light every week	35 %	37 %	34 %
once a week brisk	65 %	61 %	57 %

*) BMI = body mass index
‡) in UKK Walk Test
¶) sum of scores of right and left feet, scoring range 0-12 points

Exercise Intervention

The exercise program was planned according to the principles of the ACSM recommendation[4]. The minimum recommended length for an exercise training intervention, 15 weeks, was chosen. Walking was chosen as the mode of aerobic exercise. It was considered the most common, feasible and safest form of sustainable dynamic aerobic exercise also for our study subjects[14]. The intensity 65% of the maximal aerobic power (VO_{2max}) was chosed, as this intensity is considered moderate by ACSM[4]. Total EEE of walking training was chosen to be 300 kcal, which yields a weekly exercise volume of 1500 kcal. This was chosen to be more than the minimum weekly EEE, in order to keep the exercise dose adequate for producing training effects even when the chosen intensity was moderate. The lower the intensity, the longer duration the participant has to walk in order to expend a given amount of energy. The frequency of walking training, five $d \cdot wk^{-1}$, was also chosen to be more than the minimum requirement. The frequency had to be high, also, because the intensity was moderate and weekly EEE considerabely high, in order to keep the duration feasible.

Daily walking was continuous in Group E1 and fractionated into two equal sessions with at least a five-hour interval in Group E2. The individual target heart rate in walking, corresponding to 65% of the VO_{2max}, was determined for each subject in a maximal graded exercise test. The mean target heart rate was 132 (SD 10.7) $beats \cdot min^{-1}$ in Group E1 and 130 (SD 11.2) $beats \cdot min^{-1}$ in Group E2. The duration of daily walking training corresponding to 300 kcal was calculated individually using the Weir formula, which estimates energy expenditure from measured oxygen consumption and carbondioxide production[17]. The mean target duration was calculated to be 46.6 (SD 5.4) minutes for Group E1 and two times 24.0 (SD 3.2) minutes for Group E2.

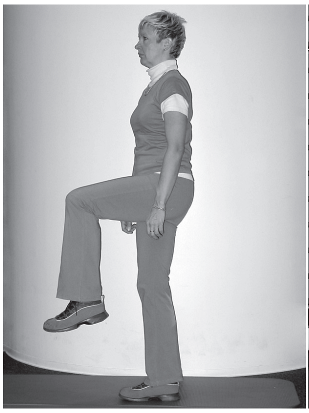
The resistance training program consisted of one set of 8 moderate, dynamic exercises with 10 repetitions in each for the main muscle groups twice a week according to the minimum requirements byt ACSM[4]. Body weight or 2-5 kg dumbbells were used as resistance. The program consisted of two exercises in standing position to improve the strength of leg muscles, balance and coordination, one exercise for the strength of hip and knee extensor muscles, one for the upper arms using dumbbells, two for back extensor muscles on prone position, two for the muscle strength of abdominal region followed by five subsequent stretching exercises. The main emphasis of the resistance training program was, however, on mobility related aspects; improving lower limb strength, balance and it also served as a warm-up for the main muscle groups. This was consedered important in order to prevent injuries. The duration of this resistance training bout was approximately 15 to 20 minutes. Rationale for the resistance training program and the order and dosage of each exercise are described in Table 2.

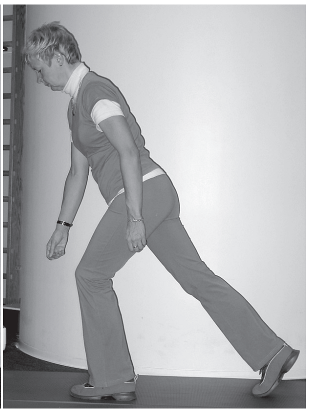
Table 2. Rationale for the resistance training program and the order and dosage of each exercise

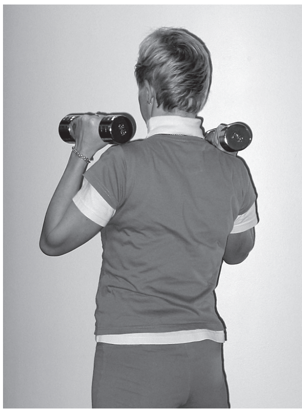
Exercises and their rationale	Dosage
Warm-up and to improve standing balance and body coordination	
1) Knees-up in standing position with alternating legs	20 rep. (2 x 10+10 rep.)
2) Back touch in standing position with alternating legs	20 rep. (2 x 10+10 rep.)
Warm-up and enhancement of endurance of the trunk, legs and upper limb muscles	
3) Dumbbell military press with alternating arms	20 rep. (2 x 10+10 rep.) with 2 to 5 kg weight
4) Squat exercise on two legs	10 rep.
5) Back extensor exercise on prone: Lifting opposite upper and lower limbs	10 rep. with 5 seconds hold
6) Upper body extensor exercise on prone	10 rep. with 5 seconds hold
7) Curl-ups on supine with alternating legs	10 rep.
8) Curl-ups and side bending on supine	20 rep. (2 x 10+10 rep.) for both sides
Recovery after aerobic exercise to increase the flexibility and to prevent musculoskeletal complaints	
9) Stretching exercise for hamstrings	30 seconds for each leg
10) Stretching exercise for pectoralis major	30 seconds for both sides
11) Stretching exercise for calf muscles	30 seconds for both legs
12) Stretching exercise for thoracic region	30 seconds
13) Stretching exercise (lateral bending) for neck muscles	30 seconds stretch for both sides

rep.= repetitions

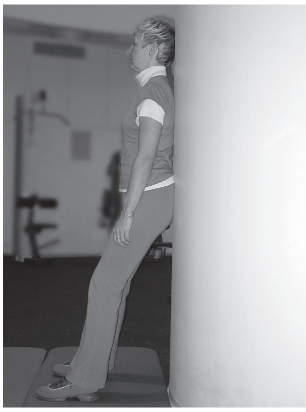
Figure 1 The description of the resistance training program.

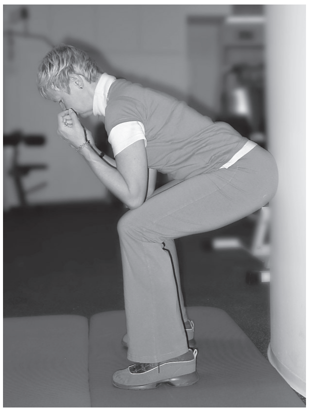

Exercise 1


Exercise 2


Exercise 3a

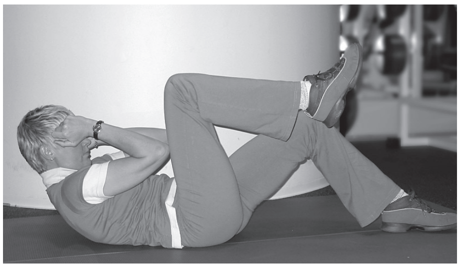

Exercise 3b


Exercise 4a


Exercise 4b

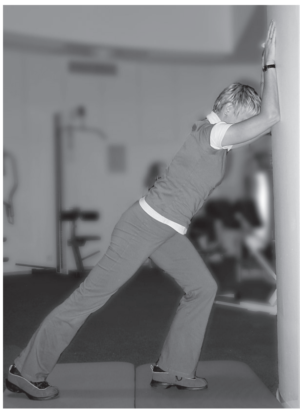

Exercise 5


Exercise 6


Exercise 7

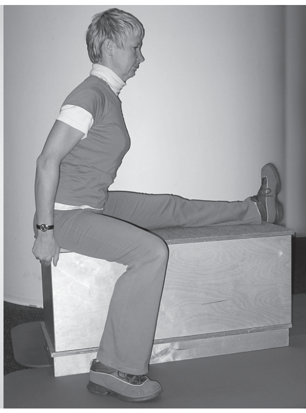

Exercise 8a

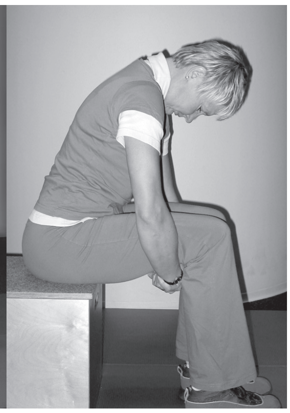

Exercise 8b


Exercise 9


Exercise 10


Exercise 11


Exercise 12


Exercise 13

The two weekly walking sessions that included the muscular exercise program were supervised by an exercise leader on an indoor track. The other weekly walking sessions, three for Group E1 and eight for Group E2 were unsupervised and took place outdoors. A few minutes of light flexibility exercises of own choice were recommended prior and after every session as a warm-up and cool-down and for injury prevention.

Heart rate monitors (Polar Edge*) were used as means of controlling the target heart rate in the two weekly supervised sessions and every third week in all weekly sessions. The participants were also advised to periodically estimate the length of their walking route, in order to keep the same relative pace in all weekly sessions. Every exerciser used an exercise diary, into which the following information was gathered after every exercise session: date, time at the onset and at the end of exercise, the exercise duration with target heart rate from heart rate monitor reading. Also the time spend in habitual physical activity, including other walking than exercise training, and possible cycling, calisthenics and the likes was recorded. Exercise diary was checked by the exercise leaders every 3 weeks. In addition the participants wore electronic pedometers (step counters) (Fitty-3†) for three days, from Friday through Sunday, in the middle of the intervention period.

Once a month the control group attended a meeting with lectures on health topics and performed a few minutes of light flexibility exercises. All of the participants were asked to keep constant their previous diet, daily physical activity habits and use of HRT, and these were checked with a questionnaire followed by an interview at the beginning and at the end of the intervention. Physical activity was asked using a score (1-5), described as follows: 1 = no regular physical activity weekly, 2 = some light physical activity every week, 3 = once a week brisk physical activity , 4 = twice a week brisk physical activity , 5 = three times a week or more brisk physical activity . Questions concerning exercise related pain and injuries were asked at the end of intervention.

Feasibility

Injury prevention included instructions of proper walking technique and advice in purchasing suitable walking shoes, and also giving the possibility to gradually progress to full exercise program. An additional 2 weeks was allowed for 6 subjects in Group E1 and 7 subjects in Group E2. During the last weeks of intervention 5 subjects in Group E1 and 6 subjects in Group E2 were allowed to use extra 1kg wrist weights, stair walking or occasional steps of jogging to reach their target heart rate.

The feasibility and safety of this exercise regimen during the intervention was assessed in several ways. Adherence to the exercise program was measured from exercise diaries by calculating a percentage of completed exercise versus prescribed exercise for duration of exercise session, frequency of sessions per week, supervised sessions per week

* Polar Edge, Polar Electro Oy, Professorintie 5, 90440 Kempele, Finland
† Fitty-3, Kasper & Richter, P.O. Box 10, D-8525 Uttenreuth, Germany

and length of exercise program. Total amount of weekly walking was estimated from a 3-day pedometer recording. Pedometric measurement was measured only in exercise groups and it included all physical activity of the day, also walking training.

Feasibility and safety of the exercise was also assessed from a questionnaire completed with interview after the intervention concerning subjective intensity of exercise, exercise related pain and injuries.

Safety of the exercise regimen was assessed by recording the injuries from the data from physician's consultations. The participants were recommended to contact the consulting physician (T-MA) in any health problems at the onset of the problem.

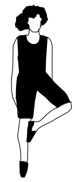
Measurements

Lower extremity muscular strength, balance and ability to walk was measured using tests from the UKK Health-related Fitness Test Battery for Middle-Aged Adults (UKK HRF test battery)[18.19]: one-leg squat for lower extremity muscular strength, one-leg standing for balance and the UKK 2 km Walk Test (WT) walking time was used as a measure of ability to walk. The reliability, safety and feasibility and health-related validity of these field-based fitness tests has been established in a series of studies[20-25]. Based on our experiences from the population study in which the UKK HRF test battery was developed, we considered the selected tests suitable for the present study subjects who were of same age range and a high functioning sample of population[18].

All tests followed a standard sequence. Balance was measured first followed by strength and the WT was perfomermed on another day. The testing personnel, 2 physiotherapists were educated using a standard education program with a test manual developed for UKK HRF test battery to ensure quality and safety of the measurements. Consulting physician (T-MA) gave written safety instructions, and was consulted in all cases of suspected health risk were. In the case of emergency during fitness testing, a physician, nurses, and equipment for cardiopulmonary resuscitation were available. A description of the test methods is given in Figure 2.

Figure 2. Description of the mobility related HRF-tests[17]

MOTOR FITNESS: ONE-LEG STANDING
Purpose: To assess static postural control while the area of support is reduced.
Method: The subject wears sport shoes. She places one foot at knee level along the inner side of the supporting leg and rotates the thigh outwards. The subject is advised to stand as still as possible.
Outcome: Duration of the balance task up to 1 minute as measured with a stopwatch in seconds.



MUSCULOSKELETAL FITNESS: ONE-LEG SQUAT
Purpose: To assess muscle strength of the lower extremity extensor muscles.
Method: The subject takes a short step forward on the mat, first with the right leg, squats down until lightly touching the mat with the left knee, rises immediately and steps backward to the starting position; she then repeats the squat with the left leg.
Outcome: The load limit for a successful squat task measured as the maximum weight relative to the subject's body weight (BW) up to 140%. The test starts with BW (i.e., no added weight) and 10% increments of BW are added at 4 successive steps of 10%, 20%, 30% and 40% using a weight belt system.

AEROBIC FITNESS
UKK WALK TEST
Purpose: To predict maximal oxygen uptake (VO_{2max}) on the basis of test time, heart rate at the end, body mass index, age and sex.
Method: The subject walks as fast as possible with a constant speed on a flat surface using a normal walking style.
Outcome: Predicted VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) and walking time (min).

Sample Size and Statistical Analyses

As described in the former publication[15] the main outcome was directly measured maximal aerobic power. The calculations for adequate sample size were based on the assumption of about a 10% (3 $ml{\cdot}min^{-1}{\cdot}kg^{-1}$ (SD 4)) increase from the baseline VO_{2max} in the exercise group when compared with the change in the control group (type 1 error alpha 0.05). The power of the test was selected as 0.90. The calculations yielded a minimum of 39 subjects for each study group. The actual number of subjects in each group was 43-46 at the onset of the study. The intention-to-treat principle was used, and all the subjects were asked to participate in the 15-week measurements at the end of the intervention, in spite of possible drop out from the exercise program. On the basis of the widths of the calculated confidence intervals of the group differences of VO_{2max}, the sample sizes can be considered adequate for finding meaningful group differences of also other outcomes.

The results are given as means and standard deviations (SD) or proportions of study subjects. Analysis of covariance (ANCOVA) with the baseline measurements as the covariates was used to analyze training effects on walking performance. P-values were calculated in testing for any differences between the groups. Training effects were determined as net differences (i.e. differences between the changes in both exercise groups and the control group) and their 95% confidence intervals (CI) for the net change.

The outcomes of one-leg standing balance and one-leg squat test showed a skewed distribution as considerably many study subjects achieved maximum results allready at the beginning of the study. Thus the results were analyzed using the proportion of the subjects that achieved maximum results in tests before and after the intervention. The binary logistic regression analysis was used as the statistical method and the odds ratios and their 95% CI were calculated between exercise and control groups at the end of intervention adjusted for differences in baseline distributions.

The subgroup analysis of the HRT users and nonusers was carried out to determine the possible effects of HRT on the results.

Results

Compliance

Three of the 88 exercising subjects interrupted the exercise program. However, all three participated in the 15-week post-intervention measurements and were included in the analysis according to the intention-to-treat principle. Six of 134 subjects did not participate in all of the 15-week measurements due to acute transient medical conditions.

Subjects in both exercise groups followed the exercise prescription closely. Most subjects reached their target heart rate after 2 weeks' training and all after 4 weeks from the beginning. Both groups exceeded the mean prescribed target duration by one minute per session. The attendance in exercise sessions ranged from 88 % to 95 %. The habitual PA of the subjects was equal in both exercise groups according to exercise diary, questionnaire answers and step-counter recording. These are reported in detail earlier[6].

Feasibility

The mean values calculated from the exercise diaries showed that Group E1 attended 89% of the prescribed 75 sessions and Group E2 95% of the 150 prescribed sessions. Group E1 attended 88% and Group E2 92% of the 30 supervised exercise sessions. Absence from exercise was due to health problems, family reasons, work duties or travel. Less than 1% of the absence was due to musculoskeletal problems and the difference between the exercise groups was not statistically significant. The information from exercise diaries showed that the mean total duration of walking at the target heart rate per session was 47.9 (SD 14.2) minutes for Group E1 and 25.0 (SD 3.2) minutes for Group E2. The mean total daily duration of habitual physical activity, other than prescribed exercise, was 23.9 (SD 18.3) minutes for Group E1 and 27.8 (SD 18.8) minutes for Group E2.

The mean total daily amount of walking estimated from the pedometer recordings, was 9.2 (SD 3.1) km for Group E1 and 10.4 (SD 3.0) km for Group E2. The mean length of the intervention was 14.4 (SD 2.9) weeks for Group S1 and 14.8 (SD 2.5) weeks for Group S2. The walking program was stopped one day before the exercise test.

According to the questionnaire and the interview completed at the end of the intervention regarding walking training most of the subjects considered their exercise program feasible (not too light and not too strenuous). In Group E1 7 % (3 subjects) considered exercise very strenuous, 22 % (10 subjects) somewhat strenuous, 65 % (30 subjects) not light but not strenuous, 7 % (3 subjects) somewhat light and none very light. In Group E2 the corresponding figures were zero as very strenuous, 26 % (11 subjects) as somewhat strenuous, 67 % (29 subjects) as not light but not strenuous, 5 % (2 subjects) as somewhat light and 2 % (1) as very light.

Only changes in exercise, corresponding to the intervention program, was reported in questionnaire in Groups E1 and E2. No changes in exercise were reported in the participants of the control group. Six participants changed their HRT status. In Group E1 two subjects started and one subject stopped the HRT. In Group E2 one subject started and two subjects stopped the HRT. All six subjects were included in their original group in the analyses to meet the intention-to-treat principle. There were no changes in diet reported in the questionnaire.

Also according to the questionnaire and interview most of the subjects in the exercise groups did not have any exercise-related lower limb problems; stiffnes, pain or injuries. Two daily walking sessions (fractionated exercise) caused fewer lower limb problems compared to one continuous exercise: no exercise-related lower limb problems 65 % (28 subjects) vs. 41

% (19 subjects) (p = 0.021 for the difference of proportions); problems at the onset of program 19 % (8 subjects) vs. 30 % (14 subjects); problems during the middle or at the end of exercise program 12 % (5 subjects) vs. 34 % (11 subjects); and exercise-related lower limb problems all the time during the exercise program 5 % (2 subjects) vs. 4 % (2 subjects), respectively.

The descriptive data of physicians consultations shows that out of the total 73 consultations, 49 concerned exercise-related problems. Most of the problems were minor. Of the 134 participants only 4 (3%) incurred major exercise related health problems. Three of the 88 exercising participants interrupted the exercise program, two because of lower-limb problems (persistent plantaris fascitis or newly detected knee artrosis) and one because of psychosocial reasons. One case of mild, recurrent arrhythmia (paroxysmal ventricular extrasystoles) was detected in an exercise group member after the intervention, and a specialist in cardiology suspected that the problems had been caused by overtraining, since no other reason for the arrhythmia was found. One participant in the control group fell on an icy walking trail and suffered a radius fracture.

Lower extremity muscular strength

At baseline 21 % of the study subjects scored the maximum of 12 points (able to squat down with 40 % additional load of their body weight, see Figure 2) in the one-leg squat test. The proportion of subjects reaching maximum points increased statistically significantly in both exercise groups when compared to the control group (OR's 4.1 and 4.6 in Groups E1 and E2 respectively) (Table 3). The mean sum score of both legs in one-leg squat test was 9.6 (SD 2.1) in Group E1 at the onset and 10.4 (2.2) at the end of intervention. The corresponding values were 9.2 (2.1) and 10.3 (2.2) in Group E2 and 8.8 (2.4) and 8.8 (2.6) in the control group.

Balance

At baseline over 50 % of the study subjects scored the maximum of 60 seconds in the one-leg standing balance test. The proportion of subjects reaching this maximum after the intervention increased in all study groups (Table 3) but the differences of the between-group changes were not statistically significant. In Group E1 24 participants out of 46 and in Group E2 23 out of 43 participants acchieved maximum results at the beginning and 33 and 28 at the end of the intervention, respectively. In control group change in the number of the participants with maximum result was from 20 to 23 out of 44 participants**.** However, the group mean value of balance time of those subjects who did not reach the maximum value at baseline, increased in both exercise groups after the intervention, in subgroup of E1 (n = 22) by 13.9 s (SD 23.9) and in subgroup of E2 (n = 18) by 12.4 s (SD 18.4). In the subgroup of controls (n = 24) the mean value decreased by 0.3 s (SD 26.5).

Table 3.

One-leg squat and one-leg stand, proportions (%) of subjects who achieved the maximum result in tests before and after the intervention, and the odds ratios (95% confidence intervals) between exercise and control groups at the end of the intervention adjusted for differences in baseline distributions*, †)

	N‡)	Before	After	Odds ratio (95%CI)	P-value*)
One-leg squat**)					
E1	46	24 %	52 %	4.1 (1.5 to 11.6)	
E2	43	16 %	51 %	4.6 (1.6 to 13.2)	
C	43	23 %	26 %	1.0¶)	0.008
One-leg stand‖)					
E1	46	52 %	72 %	2.6 (0.9 to 6.9)	
E2	43	58 %	63 %	1.2 (0.5 to 3.4)	
C	44	46 %	52 %	1.0¶)	0.175

*) binary logistic regression analysis
†) E1 = one-session exercise group, E2 = two-session exercise group, C = control group.
‡) number of subjects, drop-outs excluded
‖) scoring range 0-60 sec
¶) reference category
**) sum of scores of right and left feet, scoring 0-12 points

Walking performance

The walking time in WT improved statistically significantly and equally in both exercise groups when compared to the control group (Table 4). The net improvement in walking time was 3.3 % (95 % CI: 2.3 % to 4.2 %) in Group E1 and 3.4 % (2.4 % to 4.3 %) in Group E2.

Table 4.
Walking time in UKK Walk Test. Mean values (standard deviation) before and after the intervention, and the net change, (95% confidence interval) between exercise and control groups †)

	N‡)	Before	After	Net change (95%CI)	P-value†)
Walking time, min					
E1	45	17.5 (1.1)	15.6 (1.0)	-1.2 (-1.6 to -0.9)	
E2	43	17.4 (1.2)	15.5 (1.0)	-1.3 (-1.6 to -0.9)	
C	44	17.6 (1.3)	16.9 (1.2)		<0.001

†) analysis of covariance
E1 = one-session exercise group, E2 = two-session exercise group, C = control group.
‡) number of subjects, drop-outs are excluded

Interactions of exercise and hormone replacement therapy

In both studies the subgroup analysis of the HRT users and nonusers showed equal results in all of the measurements, the one-leg squat test for the lower extremities, the one-leg standing balance test and walking time in WT results.This indicates that exercise was equally beneficial for hormone users and non-users.

Discussion and Conclusion

The main purpose of the present work was to report the effects of two exercise programs including moderate-intensity walking in one or two exercise bouts and moderate-intensity resistance training on lower extremity muscular strength, balance and walking performance in sedentary, early postmenopausal women. In addition, the feasibility of the training program was evaluated. The present results show that lower extremity muscular strength and walking speed improved equally in the two exercise groups when compared to the control group. However, the effect of training on balance was not statistically significant. The exercise was equally beneficial for HRT users and non-users.

Lower limb strength improved equally in both exercise groups in our study. In practice the subjects in the training groups were able to perform the squat test with 30 % extra load of body weight, which was on average one level higher than at baseline (20 %). It is worth noticing that the subjects in our study accomplished this result without specific resistance training equipment engaging simple closed-kinetic chain muscular exercises and walking. Heavy resistance training with special equipment can result in much larger, two to threefold increases in strength[26-28]. However, it also requires close supervision and participant travel to exercise facilities, which may become barriers to training. High-impact aerobic circuit training combined to aerobic dance has also been reported to improve muscular strength[29] as well low impact aerobic dance combined with other low impact aerobic exercise[30,31]. This is the first study to show that walking combined to a simple resistance exercise program, that could easily be performed also home-based, will improve lower extremity muscle strength in sedentary, early posmenopausal women.

At population level, maintaining a good ability to walk is perhaps one of the key issues in the prevention of mobility-related disability. Earlier population studies among middle-aged[20] and older populations[21,31] have shown a strong association between different performance tests using walking and mobility-related function. Slow walking speed has also been associated with increased risk of falls[32,33]. In the present study walk performance as measured by walking time of 2 km distance improved statistically significantly and equally in both exercise groups. Walking time measured by the UKK WT reflects both submaximal aerobic capacity and musculoskeletal functioning[19].

Balance was not improved by our exercise program. However, there was a positive trend towards improvement in E1. The fact that over 50 % of the subjects reached the maximum score in the baseline balance testing might have decreased the possibility to detect the real training effect. A more challenging test of balance would have been more appropriate for the subjects of our study. Three upright exercises in our muscular training program (knees-up, back touch, squat) were aimed at improving balance and coordination of hip, knee and ankle musculature[34]. Heitkamp et al.[35] reported significant improvements in both balance and lower limb strength after similar type of closed-kinetic-chain balance exercises in younger subjects. They measured balance with a more difficult one-leg standing test on a narrow edge. Improvement in postural stability in early postmenopausal women have been reported with programs of low-impact aerobic dancing and walking combined with resistance training, with strength training alone[28], with aerobic dance[20, 31] and with high impact jumping[36,37].

When approcahing old age muscular strength, balance and ability to walk preserve adequate functional capacity for the requirements of everyday living and also to prevent falls[38, 41]. Mobility limitations appear earlier in aging women than in men[42], thus muscular strength, balance and ability to walk are very important aspects of fitness already for early postmenopausal women.

The prescribed exercise combination proved to be a feasible training method with only a relatively small risk of injury and other health problems among the sedentary study subjects. The amount and severity of the injuries in our program (3%), was similar to those in the other walking studies of early postmenopausal women[12]. In training studies combining walking with resistance exercise the injury rate varied from none to 13 %.

Our results further indicate that walking training can be divided into two daily bouts without compromising the training effects also in early postmenopausal women, which is a age group that has been on a RCT using fractionated exercise only once before this study[13] . Not only fractionated exercise improved walking performance similarly to continuous exercise, but it also caused fewer lower limb problems and was not considered more strenuous than the continuous exercise. As far as we know, this is the first report suggesting that fractionated exercise causes fewer exercise related lower limb complaints in sedentary subjects. The finding could be explained by the fact that fractioned exercise allows the lower limb muscles to rest between the exercise sessions compared to continuous exercise. Fractionated physical activity may also be better integrated into everyday life when compared to one longer continuous session and thus may improve the possibilities to start regular exercise when compared to physical activity prescription requiring special arrangements[38-40].

Our study had several strengths that add to its reliability. The number of subjects was sufficient for adequate statistical comparisons and the randomized groups were comparable. The exercise dose was controlled with supervision, heart rate monitors, exercise diaries and pedometers. Adherence was high and the dropout rate was small. The muscular exercise program was of short duration, simple with very little equipment and easy to perform. Our study included both HRT users and non-users and exercise was equally beneficial for both. A weakness of our study was that the selected balance test that was not demanding enough for our study population.

We conclude that our 15 weeks' exercise program, consisting of brisk walking in one, or two daily sessions five days a week combined with a moderate muscular training program twice a week improved lower limb muscular strength and walking performance in previously sedentary, early postmenopausal women. The training program was equally beneficial for hormone users and non-users. The training programs were feasible and safe. Fractionating walking in two daily exercise bouts caused less leg complaints than one continuous exercise. The training program may serve as one means to start to be physically active and thus promote healthy aging with preservation of mobility function and independent life. Our results also encourage the use of everyday possibilities for multiple walking bouts as part of daily chores. The impact of exercise on health on population level is largest when those, who are most inactive become at least moderately active[43].

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Walking trials in postmenopausal women: effect of low doses of exercise and exercise fractionization on coronary risk factors

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We studied the fractionization of walking training and searched for the minimum dose to affect coronary risk factors in two randomized controlled trials. Altogether 134 (Study I) and 121 (Study II) healthy, sedentary postmenopausal women started the trials, and 130 (Study I) and 116 (Study II) completed them. In Study I the exercise intensity was 65% of the maximal aerobic power (VO_{2max}) and a total of 300 kcal was expended in one (Group W1) or two (Group W2) daily walking bouts. In Study II the exercise was continuous, and the exercise intensity (% of VO_{2max}) and energy expenditure (kcal session^{-1}) were 55% and 300 kcal (Group W3), 45% and 300 kcal (Group W4), 55% and 200 kcal (Group W5) and 45% and 200 kcal (Group W6). All the subjects walked 5 days a week. The outcome measures were blood pressure, serum lipoproteins and blood glucose and plasma insulin in fasting state and also during 2-h oral glucose tolerance test in Study I. There was no change in diastolic pressure in the original study groups, but in the combined exercise group (W1+W2) in Study I, the mean diastolic pressure declined by −3.0 mmHg (95% confidence interval (CI) −5.5 to −0.4) ($P = 0.025$) in comparison with that of the controls. The mean blood glucose declined by −0.21 mmol L^{-1} (CI −0.33 to −0.09) in Group W1 and −0.13 mmol L^{-1} (CI −0.25 to −0.01) in Group W2 compared to controls ($P = 0.03$). Also the 2-h glucose concentration decreased in Groups W1 and W2 compared to controls. Systolic blood pressure, serum lipoproteins and insulin levels did not change in Study I or Study II. We conclude that our training program with the greatest exercise dose, exercise intensity 65% of VO_{2max} and weekly expenditure of 1500 kcal had a minimal, positive effect on diastolic pressure and blood glucose, and the effect was similar in one or two daily exercise session groups. This exercise dose is probably close to the minimum to affect coronary risk factors in healthy postmenopausal women. To get a more pronounced and clinically relevant effect, a greater exercise dose is needed.

Coronary heart disease (CHD) is the leading cause of death among postmenopausal women in the western world (Goodman & Kirwan, 2001). Abdominal obesity, postmenopausal estrogen deficiency and physical inactivity are associated with reduced insulin sensitivity and impaired glucose homeostasis, which leads to the entity of "menopausal metabolic syndrome". In turn, metabolic syndrome is associated with CHD and type 2 diabetes. Weight loss, especially loss of abdominal adipose tissue and increased physical activity, and also hormone replacement therapy (HRT) can reverse this syndrome (Spencer, 1997). The American Heart Association has given preventive guidelines for women (Mosca et al., 1999) with exercise recommendations supporting the physical activity recommendation for health (Pate et al., 1995). The statement suggests that every adult accumulate 30 min or more of moderate-intensity physical activity on most, but preferably, all days of the week. This corresponds to an exercise volume of approximately 200 kcal day^{-1} and 1000–1400 kcal week^{-1}.

Epidemiological studies indicate a linear dose–response relationship between physical activity and all-cause mortality, consisting mostly of CHD (see Kesäniemi et al., 2001). The energy expenditure of physical activity, needed to induce a 30% reduction in mortality for sedentary subjects, is around 1000 kcal week^{-1}. The minimum effective amount of exercise for health effects is not known, but it is estimated to be lower. Even exercise doses as low as 500 kcal week^{-1} are claimed to have some beneficial effect on all-cause mortality (Kohl, 2001; Lee & Skerret, 2001). In their follow-up study of almost 40 000 women, aged 45 years or over, Lee et al. (2001) found that the time spent in walking was more important than exercise intensity, and at least 1 h of light to moderate activity weekly decreased the CHD risk. This amount is less than the recent recommendation of physical activity for health suggests (Pate et al., 1995). More studies are needed to clarify the matter especially on women, because most studies have been conducted on men (Lee & Skerret, 2001; Wilmore, 2001).

Epidemiological evidence suggests that activities performed on a regular basis, even in several sessions a day, will influence health outcomes if the total energy expended is sufficient (Paffenbarger et al., 1986; Haapanen et al., 1996; Hardman, 2001). To our knowledge only four randomized, controlled studies have been carried out to compare the effects of fractionated exercise vs. continuous exercise on CHD risk factors – two on lipids (Ebisu, 1985; Woolf-May et al., 1999) and two on blood pressure (Jakicic et al., 1995; Murphy & Hardman, 1998) and only one of these included postmenopausal women (Woolf-May et al., 1999).

We conducted two randomized, controlled studies, the first to compare the effects of equivolume brisk walking, once or twice a day, and the second to compare the effects of four low-dose walking programs on selected CHD risk factors in postmenopausal women. We have previously reported that all of these programs increased maximal aerobic power, and some of them also positively affected body composition (Asikainen et al., 2002a, b). In our present report, our hypothesis was that equivolume exercise would improve coronary risk factors equally in exercise groups with one or two sessions a day. In addition, low-dose walking programs would show small improvements in risk factors, and the minimum effective dose would be approached.

Materials and methods

Design

Study I was a randomized, controlled trial with three parallel groups: exercise with one or two daily walking sessions and a control group (Asikainen et al., 2002b). Study II was a randomized, controlled trial with five parallel groups, four low-dose exercise groups and a control group (Asikainen et al., 2002a). The exercise in Study I started in September 1995 and continued for 15 weeks. The exercise in Study II started in November 1996 and continued for 24 weeks. The outcome measures were blood pressure, fasting serum lipoproteins, and blood glucose and plasma insulin in fasting state, and in Study I, also during a 2-h oral glucose tolerance test. The study plan was approved by the independent Research Ethics Committee of the UKK Institute for Health Promotion Research. All the subjects gave their written informed consent.

Subjects

The subjects were recruited through announcements in the local newspapers. The recruitment processess have been described in detail previously (Asikainen et al., 2002a, b). The eligibility criteria were (1) female, (2) 2–10 years past the onset of menopause, (3) 48–63 years of age, (4) no chronic diseases or regular medication except for possible HRT, (5) nonsmoker, (6) body mass index (BMI) $<32\,kg\,m^{-2}$, (7) systolic pressure <160 mmHg and diastolic pressure <100 mmHg, and (8) not engaged in strenuous work or regular brisk leisure-time exercise more than once a week. An equal number of women with and without HRT were accepted.

Randomization

We randomly assigned the subjects to exercise or control groups. The HRT users and nonusers were randomized separately in order to get an approximately equal number of both in each group. The procedure yielded 46, 43 and 45 subjects in the two exercise groups and the control group, respectively, in Study I and 21, 21, 18, 21 and 40 subjects in the four exercise groups and the control group, respectively, in Study II. The randomization processes were computer based and have been described in detail previously (Asikainen et al., 2002a, b). The baseline characteristics of the subjects are shown in Table 1.

Exercise intervention

The exercise groups walked 5 days a week. In Study I the exercise intensity was 65% of the maximal aerobic power

Table 1. Baseline characteristics of the subjects in Study I and Study II*; means (SD)

Parameter	Study I			Study II				
	Group W1	Group W2	Group C1	Group W3	Group W4	Group W5	Group W6	Group C2
N	46	43	45	21	21	18	21	40
Age (years)	58 (4.4)	58 (4.2)	57 (4.2)	57 (3.8)	55 (3.7)	54 (3.5)	55 (4.2)	56 (3.8)
Body mass (kg)	67.6 (8.2)	67.9 (8.5)	67.0 (8.5)	67.9 (10.4)	68.7 (9.5)	67.5 (10.9)	66.1 (8.5)	70.8 (9.3)
VO_{2max} (mL kg^{-1} min^{-1})	29.0 (3.8)	28.4 (3.6)	27.7 (3.5)	30.3 (5.0)	30.8 (4.2)	29.4 (4.1)	30.2 (4.1)	29.3 (3.6)
Systolic pressure (mmHg)	126.6 (14.7)	124.8 (12.3)	125.1 (17.1)	125.3 (14.6)	121.8 (15.1)	127.6 (16.7)	124.1 (14.6)	128.1 (15.8)
Diastolic pressure (mmHg)	80.5 (7.1)	80.1 (7.5)	82.3 (7.4)	80.3 (9.1)	79.6 (11.6)	80.4 (9.3)	75.9 (9.3)	81.1 (7.4)
Total cholesterol (mmol L^{-1})	5.53 (1.00)	5.78 (0.99)	5.72 (0.98)	5.39 (0.63)	5.34 (1.02)	5.31 (0.97)	5.15 (0.79)	5.49 (0.94)
HDL-cholesterol (mmol L^{-1})	1.56 (0.32)	1.54 (0.43)	1.56 (0.33)	1.68 (0.41)	1.60 (0.28)	1.55 (0.44)	1.62 (0.41)	1.57 (0.32)
LDL-cholesterol (mmol L^{-1})	3.46 (0.95)	3.55 (0.94)	3.53 (0.88)	3.06 (0.53)	3.22 (1.02)	3.19 (0.98)	2.97 (0.72)	3.36 (0.84)
Triglycerides (mmol L^{-1})	1.12 (0.34)	1.60 (1.63)	1.39 (0.57)	1.28 (0.53)	1.15 (0.29)	1.14 (0.45)	1.34 (0.42)	1.25 (0.41)
Glucose (mmol L^{-1})	4.46 (0.30)	4.48 (0.32)	4.44 (0.32)	4.78 (0.33)	4.75 (0.26)	4.96 (0.44)	4.88 (0.30)	4.82 (0.35)
Insulin (mU L^{-1})	6.3 (2.0)	6.9 (2.5)	6.9 (2.0)	7.1 (1.7)	7.1 (1.8)	8.2 (4.0)	7.4 (1.8)	7.9 (2.3)

*Study I: Groups W1 and W2 were the exercise groups and Group C1 was the control group.

Study II: Groups W3, W4, W5 and W6 were the exercise groups and Group C2 was the control group.

VO_{2max} = maximal aerobic power, HDL = high-density lipoprotein, LDL = low-density lipoprotein.

(VO_{2max}) and the estimated exercise energy expenditure was 300 kcal. Walking was performed in one (Group W1) or two daily sessions (Group W2). In Study II the exercise was carried out in one daily session, and different combinations of exercise intensity (% of VO_{2max}) and energy expenditure (kilocalories per session) were used: 55% and 300 kcal (Group W3), 45% and 300 kcal (Group W4), 55% and 200 kcal (Group W5) and 45% and 200 kcal (Group W6).

The target heart rate and duration of exercise were determined individually on the basis of a maximal exercise test (Asikainen et al., 2002a, b). Two weekly exercise sessions were supervised and conducted on an inside track, and other sessions were performed outdoors. The supervised exercise sessions of Groups W1 and W2 started with a light dynamic muscle workout for the main muscle groups. A few minutes of stretching was recommended before and after the exercise sessions for all the exercisers. Heart rate monitors (Polar Edge, Polar Electro, Kempele, Finland), step counters (Fitty 3, Kasper & Richter, Uttenreuth, Germany) and exercise diaries were used. The dietary and exercise habits and HRT use of all the subjects were checked with a questionnaire, followed by an interview, at the beginning and end of the intervention. Groups W3, W4, W5 and W6 also completed 3-day food diaries at the beginning and end of the intervention.

Measurements

All the measurements were conducted before and after the training period. Blood pressure was measured twice with a random zero sphygmomanometer (Hawksley & Son Ltd., England) as the subject sat after 5 min rest. The lowest of the two measurements with a 2-min interval was used.

Venous blood samples were obtained at 7 to 9 AM after a 12-h overnight fast, after a 15-min rest, while the subject was supine. The preceding exercise was approximately 48 h before the sampling. Fasting blood samples were taken for serum lipoproteins, baseline glucose and insulin determinations. In Study I an oral glucose tolerance test (OGTT) was carried out with a glucose dose of 75 g. Blood was sampled at 30, 60 and 120 min during OGTT for glucose and insulin measurements. In Study II the fasting blood samples were taken twice with a 1- week interval. The mean of the two measurements was used.

In both studies all analyses except glucose were made from frozen (−70 °C to −20 °C) samples, and all samples from each subject were analyzed within a single batch to minimize analytical variations. Total serum cholesterol and triglyceride concentrations were measured using routine enzymatic methods. High-density lipoprotein cholesterol (HDL-cholesterol) was determined by dextran sulfate precipitation. Low-density lipoprotein cholesterol (LDL-cholesterol) was calculated by the equation of Friedewald et al. (1972). Blood glucose was assessed by the glucose dehydrogenase method. Plasma insulin determinations were carried out by radioimmunoassay (Phadeseph Insulin RIA, Pharmacia, Sweden).

The analytic variations (interassay CV) calculated from human serum-based quality control materials were 0.8–1.1% for total cholesterol, 1.9–1.1% for HDL-cholesterol at the concentration level 1.4–1.6 mmol L^{-1}, 4.2–4.6% at a very low HDL-cholesterol level 0.50 mmol L^{-1}, 1.1–3.8% for triglycerides, 0.8–3.4% for glucose and 2.1–5.0% for insulin.

Sample size and statistical analyses

The sample size calculations were originally performed for VO_{2max}, which was the main outcome of the study. Power calculations and statistical analyses have been described in detail previously (Asikainen et al., 2002a, b). On the basis of the widths of calculated confidence intervals of group differences, it can be concluded that sample size was adequate also in order to sufficiently find group differences of the risk factors. The intention-to-treat principle was used, and all the subjects were asked to participate in the end measurements, in spite of adherence to the exercise program or change in HRT use.

The results are given as means and standard deviations (SD). An analysis of covariance (ANCOVA) with the baseline measurements as the covariates was used to analyze the training effects, which were determined as net differences, i.e., mean differences between the changes in each walking group and the control group adjusted for baseline values. We also calculated the 95% confidence intervals (CI) for the mean net changes. In addition, the possible modifying effect of the HRT use was analyzed by an ANCOVA with the exercise groups and HRT group as factor variables. Additional ANCOVA analyses were performed in Study II with the groups combined according to exercise intensity or energy expenditure, with the baseline measurements as covariates.

Results

Compliance

All the subjects attended 88–95% of the prescribed exercise sessions in both studies. There were few injuries or other complications. Three of the 88 exercising subjects discontinued the exercise program in Study I, and three of 81 did so in Study II. There were four dropouts from the end measurements in Study I and eight in Study II. No changes in diet were reported in the questionnaire. For food diaries in Study II, four persons were missing, and seven were disqualified because of recording inaccuracies. The results showed no statistically significant quantitative or qualitative changes in the diet of the study groups. The mean estimated daily energy intake was 7.5 (1.5) MJ in the exercise groups and 7.6 (1.3) MJ in the control groups before the training and 7.5 (1.4) MJ and 7.3 (1.4) MJ after the training. Six subjects changed their use of HRT in Study I, and none did so in Study II.

Maximal aerobic power and body mass

In both studies, maximal aerobic power of the exercise groups improved statistically significantly ($P<0.001$) when compared with that of the controls. Mean net changes in VO_{2max} were 2.5 mL min^{-1} kg^{-1} (CI 1.5–3.5), 2.5 mL min^{-1} kg^{-1} (CI 1.5–3.5), 2.9 mL min^{-1} kg^{-1} (CI 1.5–4.2), 2.6 mL min^{-1} kg^{-1} (CI 1.3–4.0), 2.4 mL min^{-1} kg^{-1} (CI 0.9–3.8) and 2.2 mL min^{-1} kg^{-1} (CI 0.8–3.5) in Groups W1, W2, W3, W4, W5 and W6, respectively. The mean body mass decreased when compared with that of the controls ($P=0.001$) in Study I, −1.2 kg (CI −1.8 to −0.5) in Group W1 and −1.1 kg (CI −1.8 to −0.4) in Group W2, but in Study II there were no statistically significant body mass changes (Asikainen et al., 2002a, b).

In Study I the VO_{2max} and body mass changes were similar in the one-session (W1) and two-session (W2) walking groups (Fig. 1). In Study II, combining the exercise groups according to exercise intensity (Group W3+Group W5 and Group W4+Group W6) or exercise energy expenditure (Group W3+Group W4 and Group W5+Group W6) showed similar results in combined groups (Fig. 1). The subgroup analysis of the HRT users and nonusers showed similar results for VO_{2max} and body mass in both subgroups.

Changes in CHD risk factors

There were no statistically significant changes in blood pressure, total cholesterol, HDL-cholesterol, LDL-cholesterol or the triglycerides in any of the exercise groups compared to controls (Table 2).

When we combined the exercise groups W1 and W2 in Study I and exercise groups W1, W4, W5 and W6 in Study II, we found a statistically significant reduction of diastolic blood pressure of -3.0 (-5.5 to -0.4) mmHg ($P = 0.025$) in Study I, but not in Study II.

The mean fasting blood glucose declined by -0.21 mmol L^{-1} (CI -0.33 to -0.09) in Group W1 and -0.13 mmol L^{-1} (CI -0.25 to -0.01) in Group W2 when compared with that of the controls in Study I ($P = 0.003$). In Study I the mean 2-h glucose in the glucose tolerance test declined by -0.48 mmol L^{-1} (95% CI -0.89 to -0.08) in Group W1 and -0.43 mmol L^{-1} (95% CI -0.83 to -0.02) in Group W2 when compared with that of the controls ($P = 0.039$). No statistically significant changes occurred in the fasting plasma insulin in either of the studies or in the 2-h insulin in the glucose tolerance test in Study I.

In Study I the changes in the CHD risk factors in one-session (W1) and two-session (W2) walking groups compared to controls were quite similar (Fig. 1). The similarity of the groups can be concluded from the overlap of confidence intervals and estimated means. In Study II the results of combined exercise groups according to exercise intensity or energy expenditure, both compared to controls, also showed similarity between combined groups (Fig. 2). The subgroup analysis of the HRT users and non-users did not show any differences in any of the results for the CHD risk factors.

Discussion

We have previously reported that maximal aerobic power improved in all of our exercise groups of healthy, sedentary postmenopausal women, and in Study I also body mass declined (Asikainen et al., 2002a, b). In Study I we found that maximal aerobic power and body mass were equally affected by fractionated exercise. In Study II we found that even the lowest exercise dose improved maximal aerobic power, but it was not enough to decrease body mass. The main purpose of our present report was to focus on the effects of these exercise programs on CHD risk factors, to test the effect of fractionated exercise and to search for the minimum effective dose on blood pressure, blood lipids, glucose and insulin in our study subjects.

A recent meta-analysis of 54 randomized, controlled trials of 2419 adults, mostly men, concluded that systolic and diastolic blood pressure can be lowered by approximately 4 and 2 mmHg in normotensive subjects and approximately by 5 and 4 mmHg in hypertensive subjects, respectively, with dynamic physical training (Whelton, 2002). Kelley & Sharpe Kelley (1999) suggested, on the basis of a meta-analysis of 21 randomized and nonrandomized, controlled studies on women, that the training effect would be smaller for women, approximately 2 mmHg in systolic and 1 mmHg in diastolic blood pressure. The studies in the above meta-analyses used training regimens of 2–5 days per week, 15-60 min per session, with an intensity of 40–80% of VO_{2max}. The optimal exercise intensity remained unclear, but low intensities gave positive results in the studies and higher intensity did not improve the result.

Jakicic et al. (1995) compared the effects of 20–40-min brisk walking in one continuous session or multiple 10-min bouts combined with a reducing diet in a 20-week trial on 56 obese (mean BMI approximately 34 kg m^{-2}) 35–46-year-old women. The multiple-bout group had better adherence and exercised more than the continuous exercise group. There was a mean decrease of 2.6 and 5.6 mmHg in systolic and diastolic pressure, respectively, in multiple-bout exercise group, and the corresponding values for the continuous exercise were 3.9 and 4.1 mmHg, while the data for the control groups were not shown. Murphy & Hardman (1998) studied 47 women, aged 44.4 (SD 6.1) years, during 10 weeks of brisk walking at an intensity of 70–80% of the maximal heart rate, 5 days a week, in one 30-min session vs. three 10-min sessions, and found no statistically significant changes in blood pressure. Staffileno et al. (2001) studied the effects of intermittent, moderate exercise with intensity of 50–60% of of VO_{2max}, 3 times 10 min a day, 5 days per week for 8 weeks in 18 hypertensive, postmenopausal women, and found that systolic pressure was reduced by 8 mmHg and diastolic by 5 mmHg in exercise group compared to controls. Staffileno et al. (2001) did not have a continuous exercise group.

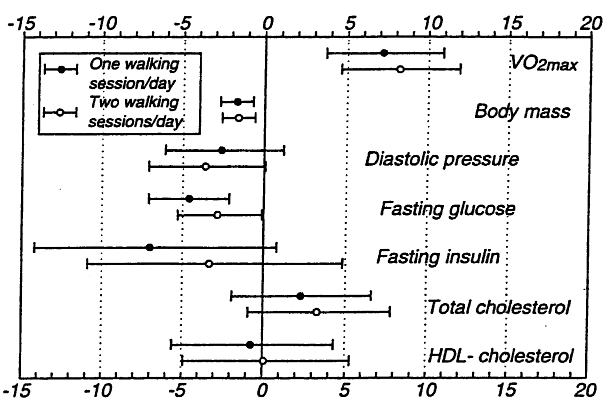
Table 2. Coronary risk factors before and after training, means (SD) and the net change (95% CI) between the exercise and control groups in Study I and Study II*[a]

Risk factor	N	Before	After	Net change (95% CI)	P[b]
Systolic pressure (mmHg)					
Group W1	44	126.3 (14.7)	131.5 (14.0)	1.2 (−3.9 to 6.3)	
Group W2	43	124.8 (12.3)	130.2 (13.8)	0.8 (−4.4 to 5.9)	
Group C1	43	124.5 (16.8)	129.3 (16.7)		0.90
Group W3	20	125.3 (14.6)	126.6 (17.0)	4.4 (−1.3 to 10.2)	
Group W4	21	121.8 (15.1)	124.1 (11.9)	4.0 (−1.7 to 9.7)	
Group W5	15	127.5 (17.3)	124.8 (13.0)	1.3 (−5.0 to 7.7)	
Group W6	20	124.1 (14.6)	127.8 (14.0)	6.4 (0.6–12.1)	
Group C2	37	128.9 (15.6)	124.3 (13.3)		0.21
Diastolic pressure (mmHg)					
Group W1	44	80.5 (7.2)	79.6 (6.6)	−2.6 (−5.5 to 0.4)	
Group W2	43	80.1 (7.5)	78.6 (7.3)	−3.3 (−6.3 to −0.4)	
Group C1	43	82.1 (7.5)	83.3 (11.5)		0.071
Group W3	20	80.3 (9.1)	76.8 (7.6)	−2.7 (−6.0 to 0.6)	
Group W4	21	79.6 (11.6)	81.0 (7.8)	1.8 (−1.4 to 5.1)	
Group W5	15	80.8 (9.4)	79.7 (7.6)	−0.6 (−3.7 to 3.6)	
Group W6	20	75.9 (9.3)	76.6 (9.4)	−0.4 (−3.7 to 3.0)	
Group C2	37	81.4 (7.5)	80.1 (7.4)		0.20
Total cholesterol (mmol L^{-1})					
Group W1	46	5.53 (1.00)	5.47 (0.98)	0.13 (−0.09 to 0.34)	
Group W2	42	5.72 (0.94)	5.67 (1.00)	0.16 (−0.05 to 0.38)	
Group C1	44	5.72 (0.98)	5.50 (0.88)		0.30
Group W3	20	5.32 (0.54)	5.20 (0.47)	0.11 (−0.16 to 0.38)	
Group W4	21	5.34 (1.02)	5.22 (0.82)	0.11 (−0.16 to 0.37)	
Group W5	15	5.13 (0.94)	5.03 (0.91)	0.08 (−0.22 to 0.39)	
Group W6	19	5.21 (0.77)	5.13 (0.82)	0.12 (−0.15 to 0.40)	
Group C2	39	5.49 (0.95)	5.23 (1.00)		0.87
HDL-cholesterol (mmol L^{-1})					
Group W1	46	1.56 (0.32)	1.55 (0.35)	0.00 (−0.08 to 0.07)	
Group W2	42	1.56 (0.42)	1.57 (0.45)	0.01 (−0.07 to 0.09)	
Group C1	44	1.56 (0.33)	1.56 (0.33)	0.92	
Group W3	20	1.72 (0.39)	1.73 (0.28)	0.01 (−0.09 to 0.10)	
Group W4	21	1.60 (0.28)	1.70 (0.30)	0.08 (−0.01 to 0.17)	
Group W5	15	1.56 (0.45)	1.59 (0.50)	0.01 (−0.09 to 0.11)	
Group W6	19	1.63 (0.42)	1.65 (0.44)	0.00 (−0.09 to 0.10)	
Group C2	39	1.57 (0.33)	1.59 (0.38)		0.51
LDL-cholesterol (mmol L^{-1})					
Group W1	46	3.46 (0.95)	3.41 (0.90)	0.10 (−0.10 to 0.30)	
Group W2	41	3.56 (0.94)	3.51 (0.96)	0.12 (−0.09 to 0.33)	
Group C1	44	3.53 (0.88)	3.38 (0.94)	0.48	
Group W3	20	3.06 (0.53)	2.95 (0.52)	0.07 (−0.17 to 0.30)	
Group W4	21	3.22 (1.02)	2.98 (0.83)	−0.03 (−0.26 to 0.21)	
Group W5	15	3.06 (0.84)	2.96 (0.76)	0.08 (−0.19 to 0.34)	
Group W6	19	2.97 (0.72)	2.92 (0.75)	0.11 (−0.13 to 0.35)	
Group C2	39	3.36 (0.84)	3.12 (0.82)		0.84
Triglycerides (mmol L^{-1})					
Group W1	46	1.12 (0.34)	1.12 (0.41)	0.03 (−0.11 to 0.16)	
Group W2	41	1.30 (0.52)	1.23 (0.42)	0.03 (−0.11 to 0.16)	
Group C1	44	1.39 (0.57)	1.25 (0.47)		0.90
Group W3	20	1.21 (0.43)	1.16 (0.41)	0.02 (−0.12 to 0.16)	
Group W4	21	1.15 (0.29)	1.19 (0.42)	0.10 (−0.04 to 0.25)	
Group W5	15	1.13 (0.46)	1.05 (0.43)	−0.02 (−0.18 to 0.14)	
Group W6	19	1.36 (0.42)	1.24 (0.40)	−0.02 (−0.16 to 0.13)	
Group C2	39	1.24 (0.42)	1.16 (0.44)		0.55
Fasting glucose (mmol L^{-1})					
Group W1	46	4.46 (0.30)	4.41 (0.33)	−0.21 (−0.33 to − 0.09)	
Group W2	43	4.48 (0.32)	4.51 (0.32)	−0.13 (−0.25 to −0.01)	
Group C1	44	4.44 (0.32)	4.62 (0.36)	0.003	
Group W3	20	4.76 (0.33)	4.60 (0.31)	−0.16 (−0.29 to −0.02)	
Group W4	21	4.75 (0.26)	4.62 (0.24)	−0.13 (−0.27 to 0.00)	
Group W5	15	4.93 (0.40)	4.75 (0.41)	−0.13 (−0.28 to 0.01)	
Group W6	19	4.89 (0.30)	4.78 (0.27)	−0.08 (−0.21 to 0.06)	
Group C2	39	4.83 (0.35)	4.81 (0.38)		0.093
2-h glucose (mmol L^{-1})					
Group W1	44	4.76 (0.86)	4.88 (0.91)	−0.48 (−0.89 to −0.08)	
Group W2	41	5.01 (1.30)	5.08 (1.10)	−0.43 (−0.83 to −0.02)	
Group C1	41	4.98 (1.07)	5.49 (1.41)		0.039

Table 2. *(Continued)*

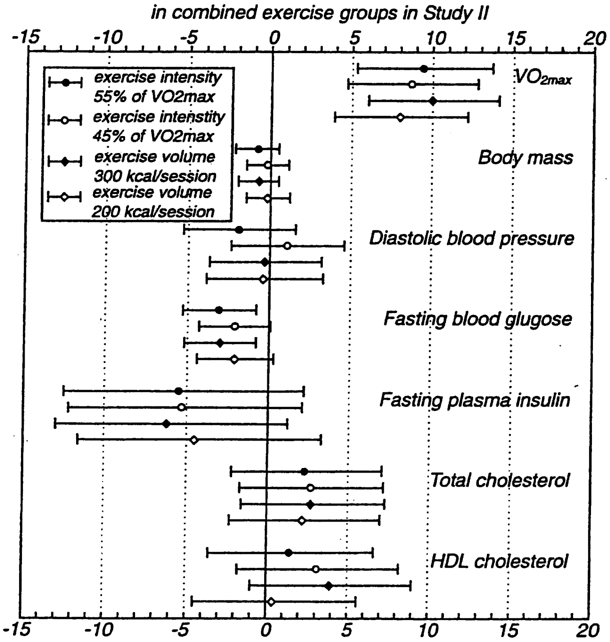
Risk factor	N	Before	After	Net change (95% CI)	P^b
Fasting insulin (mU L^{-1})					
Group W1	46	6.34 (1.98)	6.01 (1.94)	−0.48 (−1.05 to 0.09)	
Group W2	43	6.92 (2.50)	6.59 (2.09)	−0.35 (−0.93 to 0.22)	
Group C1	44	6.91 (2.03)	6.93 (2.45)		0.23
Group W3	20	6.92 (1.62)	6.77 (1.46)	−0.61 (−1.40 to 0.17)	
Group W4	21	7.09 (1.79)	7.02 (2.03)	−0.48 (−1.25 to 0.29)	
Group W5	15	8.07 (4.36)	7.67 (2.93)	−0.55 (−1.40 to 0.31)	
Group W6	19	7.42 (1.85)	7.30 (1.83)	−0.44 (−1.23 to 0.34)	
Group C2	39	7.91 (2.37)	8.10 (2.60)		0.47
2-h insulin (mU L^{-1})					
Group W1	44	30.30 (12.65)	30.08 (14.93)	−5.05 (−12.06 to 1.95)	
Group W2	42	33.36 (12.13)	33.52 (23.78)	−3.90 (−10.96 to 3.16)	
Group C1	41	33.42 (13.33)	37.46 (19.92)		0.33

*Study I: Groups W1 and W2 were the exercise groups and Group C1 was the control group.
Study II: Groups W3, W4, W5 and W6 were the exercise groups and Group C2 was the control group.
VO_{2max} = maximal aerobic power, HDL = high-density lipoprotein, LDL = low-density lipoprotein.
[a]Analysis of covariance with baseline measurements as covariates.
[b]Analysis of covariance.



+ Analysis of covariance with baseline measurements as covariates.
VO_{2max} = maximal aerobic power, HDL = high density lipoprotein,
LDL = low-density lipoprotein

Fig. 1. Effect of continuous and fractionated walking on selected variables. Percent net difference (95% CI) during training in the exercise groups vs. the control group in Study I.



+ Analysis of covariance with baseline measurements as covariates.
VO_{2max} = maximal aerobic power, HDL = high density lipoprotein,
LDL = low-density lipoprotein

Fig. 2. Effect of exercise intensity and energy expenditure on selected variables in Study II. Percent net difference (95% CI) in the exercise groups vs. the control group. The exercise groups have been combined according to intensity or volume.

We found no statistically significant effects in blood pressure in our study groups. Combining the exercise groups showed a 3 mmHg reduction of diastolic pressure in Study I, but not in Study II. This could be due to the greater exercise dose of Study I. Our exercise doses were at the lowest border compared with the exercise doses of aforementioned meta-analyses. Approximately one-third of our study subjects had initially elevated blood pressure (130/85–160/100 mmHg). The amount of subjects with elevated diastolic pressure decreased during training in Study I, from 40 to 34 subjects at the end of intervention. Systolic blood pressure seemed to increase in Study I, although the increase was not statistically significant. Forty-four subjects had elevated systolic pressure at the baseline and 52 at the end of intervention. Seasonal variation could be a possible explanation, since this was also seen in the controls. The end measurements were performed in December before Christmas in Study I and in June in Study II. In Study II no changes in blood pressure were found. The minimum dose needed to induce a minimal decrease in diastolic blood pressure in our mostly normotensive study group of sedentary postmenopausal women is probably close to the exercise dose of our Study I, 65% of VO_{2max}, 1500 kcal week^{-1}, and the exercise either continuous or fractionated into two daily bouts. A greater exercise dose is needed to also obtain an effect on systolic blood pressure.

We did not find any statistically significant changes in blood lipoproteins. According to a meta-analysis of 28 randomized, controlled studies mostly on men using endurance training (Leon & Sanchez, 2001), the response between individuals varies greatly for the same training stimulus. Also many confounding factors exist. We found much variability in the responses in our study in spite of good compliance and careful blood sampling. Leon & Sanchez (2001) showed that aerobic exercise increased HDL-cholesterol 4–5%. Most of the studies had an exercise frequency of 3–5 times a week and 30 min or more of exercise per session at moderate to strenuous intensity. There is limited evidence that a higher exercise intensity will give a greater HDL-cholesterol response than moderate or light intensity. The threshold to affect lipids during weekly training seems to be an exercise energy expenditure of 1200–1500 kcal and the minimum length of training should be 12 weeks (Leon et Sanchez 2001). A more recent finding in the 6 month study of 111 overweight men and women of Krauss (2002) suggests that energy expenditure is crucial and more important than exercise intensity, and the most marked effects were observed at an energy expenditure of 2000 kcal with strenuous intensity. The length of training period might also be very important especially in postmenopausal women. In the study of King et al. (1995), 1 year of moderate training in postmenopausal women was not enough, but 2 years showed statistically significant lipid improvements (King et al., 1995).

According to Leon & Sanchez (2001), baseline lipid levels strongly predict response: the lower the baseline HDL-cholesterol, the higher the response to exercise. Premenopausally, women have higher levels of HDL-cholesterol due to their hormonal status, but postmenopausally the levels decrease. HRT affects lipid levels in various ways (Haddock et al., 2000) which must be taken into account in exercise trials. The baseline lipid levels of our subjects were mostly in the normal range, e.g., 95% of the subjects had a baseline level of over 1.00 mmol L^{-1} for HDL-cholesterol. Our study design called for an equal number of subjects with or without HRT in each group.

There are only two randomized, controlled studies on the effect of fractionated exercise on blood lipids. Ebisu et al. (1985) studied the effects of jogging the same distance in one, two or three daily sessions at 80% of the maximal heart rate for 10 weeks in 53 male students. There was a significant increase in HDL-cholesterol only in the three-session exercise group. Ten weeks of exercise may have been too short to reveal a long-term effect on lipids. Woolf-May et al. (1999) conducted an 18-week study on 56 adults, aged 40–60 years, walking 20–40 min in one, two or three daily bouts. LDL-cholesterol decreased in the long ($-$0.29 mmol L^{-1}) and intermediate ($-$0.41 mmol L^{-1}) bout group, but not in the short bout group. However there were no HDL-cholesterol changes in any of the exercise groups.

The doses of exercise in our study were at the lower border of the aforesuggested minimum requirements for lipoprotein improvements. The minimum dose of exercise in healthy, sedentary, normolipemic postmenopausal women with or without HRT seems to be more than the greatest exercise dose of our study.

Manson et al. (1991) found a relationship between vigorous exercise and decreased risk of type 2 diabetes in an 8-year follow- up study of 87 252 women. In the Nurses Health Study, Hu et al. (1999) found that walking reduced the risk, but vigorous exercise reduced it more. We found a statistically significant, small reduction in the fasting and 2-h glucose concentrations in Study I but not in Study II, where the exercise intensity and exercise energy expenditure was smaller. The fasting glucose concentration in Group W2 and 2-h glucose concentration in Groups W1 and W2 improved only when compared to controls, and the absolute values did not improve. There could have been a seasonal variation that caused the rise in control groups fasting glucose just before Christmas, and exercise might have partly prevented this rise in exercise groups. The minimum dose of exercise needed to obtain a minimal effect on glucose in our study group of healthy, normoglycemic, sedentary postmenopausal women is probably very close to our largest exercise dose, 65% of VO_{2max}, 1500 kcal week^{-1}, in one or two daily exercise bouts. To achieve a more clinically relevant effect, more exercise is needed.

When the minimum dose of exercise to affect coronary risk factors is searched, small changes are to be expected, some of them statistically significant and some below the border of statistical significance, although showing a similar trend, but interpreted as no change, according to the dichotomous nature of statistical science. The interpretation of these results raises several questions. What are the smallest changes that can be detected with our measurements? Are the changes caused by regression towards the mean of variables with high interindividual variation? Have the biological day-to-day and seasonal variations been taken into account? We tried to solve these problems in many ways. We estimated the smallest possible change that can be detected with our equipment and estimated that the number of subjects was sufficient for adequate statistical comparisons. We used a control group to minimize systemic errors, e.g., seasonal fluctuations. We used an analysis of covariance in order to be unaffected by possible minor baseline differences and the regression towards the mean. The randomized groups were comparable. The exercise dose was carefully controlled with personal supervision, heart rate monitors, exercise diaries, food diaries and pedometers. The program was closely followed by the participants and the dropouts were few. The measurements were carried out in strictly controlled, similar conditions, exercise group members and controls in mixed order. However, to some of these questions, there are no definite answers; therefore no exact values for minimum effective dose can be claimed based on our studies. To improve the design further, the intervention could have been longer to ensure that all potential effects, especially those on lipids, were detected.

Expending 1500 kcal weekly by walking at 65% of the VO_{2max} for 15 weeks in one or two daily bouts had a minimal positive effect on blood glucose and diastolic blood pressure. Expending 1000–1500 kcal weekly by walking at 45–55% of the VO_{2max} for 24 weeks did not cause any statistically significant improvements in CHD risk factors in spite of improvements in aerobic fitness. Expending 1500 kcal weekly by walking at 65% of the VO_{2max} in one or two daily exercise bouts is probably close to the minimum dose of exercise needed for minimal improvements in some of the CHD risk factors in healthy, sedentary, postmenopausal women, either with or without HRT. A larger exercise dose should be recommended to give greater and more clinically relevant improvements in blood pressure and blood glucose and also to affect lipoproteins.

Perspectives

Our findings support the US physical activity recommendation for public health (Pate et al., 1995). Regular brisk walking, also when fractionated into two daily bouts, can produce minimal positive effects on selected coronary risk factors in sedentary postmenopausal women. Contrary to earlier beliefs, our study shows that, at least in sedentary postmenopausal women, improving coronary risk factors requires a larger exercise dose than improving aerobic fitness.

The clinical short-term relevance of the minimal, but statistically significant, changes in maximal aerobic power, body mass and risk factors in our study is probably small. The exercise dose should be greater if clinically more relevant improvements in coronary risk factors are expected.

However, according to epidemiological studies, the most benefit for public health will come as sedentary subjects become active (Pate et al., 1995). The improvement in VO_{2max} in our study was enough to increase most of the subjects' level of fitness exceeding the VO_{2max} value of 31.5 mL min^{-1} kg^{-1} and therefore move the subjects into a low-risk category for all-cause mortality on the basis of the study of Blair et al. (1989), who followed up 3120 women for 8 years. The VO_{2max} value of 31.5 mL min^{-1} kg^{-1} represented the level of fitness at which the risk level for all-cause mortality fell clearly. In a more recent epidemiological study, Farrel et al. (2002) suggested an even lower VO_{2max} value of 28.0 mL min^{-1} kg^{-1} for 40–49-year old women to be classified as moderately fit and have low mortality. Thus the exercise we used in our study might, after all, have some long-term clinical significance for postmenopausal sedentary women, if exercise is continued. To achieve this, exercise has to be safe and feasible, as ours was, and easy to perform. The characteristics of this exercise regimen suggest that also a part of daily physical chores may meet the requirements of physical activity improving health.

Key words: exercise, dose–response, fractionization, postmenopause, lipoproteins, glucose, insulin, blood pressure, randomized controlled trial.

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