The effect of endurance training on body composition and blood lipids in older adults: A randomized controlled trial

Tina Oddli Sundli

Master's thesis in Human Movement Science
Faculty of Medicine
Department of Neuroscience

Trondheim, Spring 2016

NTNU
Norwegian University of
Science and Technology

Acknowledgements

This master thesis was a part of my master in Human Movement Science at Department of Neuroscience, Faculty of Medicine at Norwegian University of Science and Technology (NTNU). The work with the master thesis has given me so much and I owe my gratitude to all the people who have made this possible.

First of all I would like to thank my excellent supervisor Beatrix Vereijken and my co-supervisor Jorunn L. Helbostad for their guidance and support in the process of writing and implementing the study. I am very grateful for all your help and valuable assistance.

I also thank Cardiac Exercise Research Group (CERG) for letting me use the data materials for my thesis, and Per Bendik Wik for good help and support during the research project.

I thank my fellow students for all the good moments we have shared through these two years and a special thanks to Tone Hanstad for good cooperation in collecting and interpreting the data.

A big thank to my family, my mum, dad and sister, for their encouragement and support. This would have been impossible without you. I especially thank my older sister for always answering my many funny questions through this process. You never get tired of me.

Last but not least, thanks to my dear, Even Krokstad, for all your patience and unwavering confidence in me. You are the best!

Trondheim, May 2016

Sammendrag

Bakgrunn: Aldring medfører endringer i kroppssammensetning og lipid profil. Tap av muskelmasse og økt kroppsfett kjennetegner aldringsprosessen. Høyt kolesterol er også en vanlig konsekvens av økende alder. Studier har vist at økt kroppsfett er assosiert med unormale lipid verdier. Få studier har undersøkt effekten av utholdenhetstrening på blodlipider hos eldre, og effekten av utholdenhetstrening på kroppssammensetning. Denne studien har som hensikt å undersøke effekten av tre år med utholdenhetstrening på kroppssammensetning og blodlipider hos eldre. **Material og metode:** Dette var en populasjonsbasert randomisert kontrollert studie. Kroppssammensetning og blodlipider ble vurdert hos 400 friske hjemmeboende eldre (204 kvinner og 194 menn med en gjennomsnittsalder på 71.9 ± 1.36). Kroppssammensetning ble målt med bioelektrisk impedans analyse, og blodlipider ble målt ved en blodprøve i fastende tilstand.
Resultat: Tre år med utholdenhetstrening resulterte i små reduksjoner i kroppsvekt, med større nedgang i høy-intensiv treningsgruppe sammenlignet med moderat-intensiv treningsgruppe ($p<0.01$). Visceralt fett økte over en tre års periode i kontroll og moderat-intensiv treningsgruppe, men ikke i høy-intensiv treningsgruppe ($p<0.01$). Utholdenhetstrening hadde ingen effekt på blodlipider ($p>0.05$). Det var markante kjønnsforskjeller i kroppssammensetning og blodlipider ved oppstart, og i interaksjon med gruppe og tid ($p<0.05$). Kvinner viste en større reduksjon i midjeomkrets og BMI i høy-intensiv treningsgruppe sammenlignet med menn ($p<0.015$), mens menn viste en større reduksjon i LDL-kolesterol og visceralt fett i kontroll og moderate-intensiv treningsgruppe sammenlignet med kvinner ($p<0.05$). Menn og kvinner endret seg også ulikt i muskelmasse og triglyserider over tid ($p<0.05$), hvor menn hadde en større nedgang enn kvinner.
Konklusjon: Disse resultatene demonstrerer at tre år med utholdenhetstrening har en liten effekt på kroppssammensetning og ingen effekt på blodlipider. Det er tydelige kjønnsforskjeller i kroppssammensetning og blodlipider ved oppstart. Det er også forskjeller mellom kjønnene i respons av trening og i endringer over tid.

Abstract

Background: Ageing is associated with changes in body composition and blood lipids. Reduced muscle mass and increased body fat are inevitable consequence of the ageing process. In addition, total cholesterol is known to increase with age, and increased body fat has shown associations with abnormal lipid values. Limited information is available regarding the effects of endurance training on blood lipids in elderly, and the effect of endurance training on body composition. The present study examines the effects of three years of endurance training on body composition and blood lipids in older adults. Possible gender differences will also be investigated. **Materials and methods:** This was a population-based randomized controlled trial. Body composition and blood lipids were determined in 400 healthy community-dwelling men and women (204 women and 194 men with a mean age of 71.9 ± 1.36). Body composition was measured using bioelectrical impedance analysis and blood lipids were measured by taking a blood sample from an arm vein in a fasted state. **Results:** Three years of endurance training resulted in modest reduction in body weight, with larger reduction in the high-intensity training group compared with the moderate-intensity training group ($p<0.01$). Visceral fat increased over the three year period in the control and moderate-intensity training groups, but not in the high-intensity training group ($p<0.01$). Endurance training did not affect blood lipids ($p>0.05$). Gender differences were prominent in body composition and blood lipid measures at baseline and in interaction with group and time ($p<0.05$). There were gender differences in response to endurance training in terms of waist, BMI, visceral fat and LDL-cholesterol ($p<0.05$). Women showed a larger reduction in waist and BMI in the high-intensity training group than men ($p<0.015$), and men showed a larger reduction in LDL-cholesterol and visceral fat the control and moderate-intensity training groups than women ($p<0.05$). Men and women also changed differently in muscle mass and triglycerides over time ($p<0.05$), with men decreasing more than women. **Conclusion:** These results demonstrate that three years of endurance training has modest effect on body composition and no effect on blood lipids. Gender differences in body composition and blood lipids were prominent at baseline. In addition, few gender differences were seen in response to training. Women reduced waist and BMI more than men in the high-intensity training group, whereas men reduced LDL-cholesterol and visceral fat more than women in the control and moderate-intensity training groups. Men and women also changed differently in muscle mass and triglycerides over time, with men decreasing more than women.

Table of contents

1.0 INTRODUCTION

The population in the western world is rapidly ageing.[1] This demographic trend is also seen in Norway.[2] It has been estimated that the proportion of elderly 70 years or older will rise from approximately 11 % of the population today to 19 % in 2060. Consequently, every fifth inhabitant in Norway will be 70 years or older in 2060.[3] Increased age has been associated with a decline in the level of physical activity and with changes in functional and physiological parameters.[4-6] The prevalence of many chronic diseases and disease risk factors increases with age. Obesity is a global health problem and studies indicate that overweight and obesity at all ages and both sexes are harmful.[7-9] These health outcomes present challenges in terms of increased risk for physical disability and other age-related health problems.[10] Declining health and advanced age will increase the future demands for healthcare services. In order to prevent functional limitations, delay senescence and reduce the morbidity and mortality among the elderly population, it is important to understand the underlying mechanisms and contributing factors of age-related problems.

1.1 Age-related changes in body composition

Body composition is a key component of health and physical fitness and refers to the proportion of fat and fat-free mass in the body.[11] Men and women are known to differ in body composition. Women tend to have a generally higher percentage of body fat than men, whereas men tend to have more intra-abdominal fat distribution as a result of ageing compared with women.[12,13] When it comes to skeletal muscle mass, the most obvious gender difference is that men have a larger muscle mass than women in general, and that the gender difference is largest in the upper body.[14]

The ageing process brings about many adverse changes in body composition.[15,16] The reduction in skeletal muscle mass, also known as sarcopenia,[17] and increased fat mass are both hallmarks of the ageing process [18] and have been hypothesized to be involved in the onset of frailty and disability in the elderly.[17-19] The loss of skeletal muscle mass with age is often accompanied by a decrease in muscle strength and function [20] which is among the causes of poor balance and falls and thereby loss of independent living.[21]

Moreover, elevated levels of body fat, especially abdominal fat, are important risk factors in the development of a number of chronic disease and metabolic abnormalities.[22,23] Evidence suggests that overweight and obesity increase the risk for cardiovascular disease, type 2 diabetes, hypertension, dyslipidemia and mortality.[24-26] It appears that sarcopenic-obesity in particular is a major risk factor for functional impairment.[27,28] An increase in muscle fat infiltration is associated with muscle weakness and poor function.[19] As both increased body fat and low muscle mass and strength are predictors of cardiovascular disease in elderly, it is possible that the combination of these two would be associated with an even larger risk. These health implications can have dramatic impact on daily living and quality of life and are known to improve with weight loss even in old age.[29] However, the ageing process may also contribute to some weight loss, partly because fat replaces muscles tissues.[30] Some studies have shown that weight loss and low body mass index (BMI) in elderly are associated with mortality.[31] On the other hand, weight loss in overweight and obese elderly clearly, show a clear reduction in the risk of developing a variety of health problems.[32]

1.2 Age-related changes in lipid profile

Blood lipids include cholesterol and triglycerides, where cholesterol is being transported through the bloodstream by two kinds of components called low-density lipoprotein (LDL) and high-density lipoprotein (HDL). HDL-cholesterol is the more preferred form of cholesterol because studies show that high levels of HDL are associated with lower risk of cardiovascular event,[33] whereas LDL-cholesterol is often called the “bad” cholesterol because some studies suggest that elevated levels of LDL are associated with coronary artery disease.[34] However, the specific links between LDL-cholesterol and coronary artery disease is inconsistent and not clear.

Both age and gender seem to have a strong influence on lipid levels. Levels of total cholesterol and LDL-cholesterol increase slightly with age.[35,36] The changes in lipid levels that occur with age can result in dyslipidemia and continue to contribute to cardiovascular risk. Dyslipidemia is characterized by elevated levels of triglyceride (TG), low-density lipoprotein (LDL) levels and reduced high-density lipoprotein (HDL) levels.[37]
In women, cholesterol concentrations differ depending on whether hormonal preparations are used. Women taking hormonal preparations have higher cholesterol levels than woman not on hormones.[35] It appears that LDL-cholesterol levels increase progressively in men and women between 20 and 60 years.[38] However, menopause may cause an increase in LDL-cholesterol

levels in women and after middle-age, women seem to have higher total cholesterol levels than men.[39,40] Moreover, it has been shown that HDL-cholesterol levels decrease in males during puberty, but in elderly they are unchanged or may even show a small increase.[41] HDL-cholesterol levels remain constant in women throughout life, however menopause may cause a decrease in HDL- cholesterol.[42] When it comes to triglycerides, these levels increase gradually in men, reaching a plateau at middle-age, and thereafter decline. In women, triglycerides seem to increase throughout life and are higher in those who use hormonal preparations.[35,40]

Interestingly, findings suggest that an accumulation of excess body fat may result in unfavourable lipid levels. Studies support a link between total body fat and adverse lipid levels in adolescents,[43,44] which in turn continues to track into adulthood.[45] Abnormal lipid levels along with obesity have been hypothesized to contribute to atherosclerosis, the underlying cause of coronary artery disease.[34,46] Coronary artery disease is the most common form of cardiovascular disease in which the coronary arteries become blocked due to an accumulation and deposition of fat and plaques that limits the blood flow to the myocardium (i.e the heart muscle).

1.3 Endurance training and elderly

Several studies have shown a beneficial effect of exercise training on both body composition and blood lipids. However, research on exercise training and body composition focuses mainly on resistance training and not endurance training. Habitual physical activity may serve as the first strategy to delay body composition changes in the elderly population in which a higher level of physical activity is associated with higher muscle mass and less total and central fat.[47] Similarly, Sidney and colleagues reported that endurance training caused a decrease in body fat and an increase in lean muscle mass.[48]

There is evidence that exercise training improves blood lipids in younger and middle-aged adults. However, there are fewer studies regarding exercise training and blood lipids in elderly. Among the available evidence, Knight and colleagues showed that elderly who exercise have higher levels of HDL-cholesterol than their counterparts who do not exercise regularly.[49] Fahlman and colleagues reported that endurance training led to an increase in HDL-cholesterol and a decrease in triglycerides in elderly women without changes in weight or diet.[50] Halverstadt and colleagues found that endurance training raises HDL-cholesterol and lowers total cholesterol, triglycerides and LDL-cholesterol in older men and women independent of diet or changes in body fat.[51] It appears that an increase in HDL-cholesterol is the most frequently observed change due to endurance training. In addition, reductions in total cholesterol, triglycerides and LDL-cholesterol may also occur with training.

1.4 The present study

To maintain good health is essential for elderly in order to live free from disability as long as possible. Healthy body composition may improve physical functioning and a normal lipid profile may reduce the risk for developing chronic disease. Most of the studies done in this field are specific to only weeks or months of exercise training. More studies examining the effect of exercise training over several years are needed. The objective of this study is therefore to investigate the effects of three years of endurance training on body composition and blood lipids in older adults. More specific, the aim is to investigate the effect of endurance training at different intensity levels on body composition and blood lipids, and evaluate potential gender differences.

2.0 METHODS

2.1 Study design

A population-based, randomized controlled trial design was used to investigate the long-term effects of endurance training on body composition and blood lipids in older adults.
Data collection was done as a part of a larger project, Generation 100, a clinical study investigating how regular physical activity affects morbidity and mortality in older adults. Men and women living in Trondheim municipality, born between 1936-1942, were invited to participate in the study. Data collection started in August 2012 (baseline measurement) and will continue until June 2018, consisting of clinical measurement, lab tests and questionnaires. The participants were tested at baseline (before randomization), after one year, after three years and will further be tested again after five years. The subjects were randomized 1:1 to either exercise training or control. The exercise training was further randomized to a high-intensity training group or a moderate-intensity training group. The study protocol was approved by the Regional Committee for Medical Research Ethics (REK).

2.2 Participants

Nearly 7000 elderly living in Trondheim municipality, born between the period 1936-1942, were invited to participate in the Generation 100 study (6966 people, 3721 women and 3245 men). The invitation letter contained information regarding the study, a health-related questionnaire and a response sheet with a consent form. Inclusion criteria were that the participants had to be between 70-76 years old when they joined the study in 2012 and be able to walk at least 1 km consecutive. Participants with disease or disabilities that prevented them from performing exercise training or completing the study were excluded. Other exclusion criteria were uncontrolled hypertension, symptomatic cardiac valve defects, hypertrophic cardiomyopathy, unstable angina, pulmonary hypertension, heart failure, severe cardiac arrhythmias, diagnosed dementia, chronic communicable infectious diseases and certain cancer diseases that made exercise training or participation impossible. Additionally, participants were excluded if they at the same time participated in another study that was not compatible with the Generation 100 study.

In total, 3212 elderly responded, whereof 1422 were not interested and 1790 wanted to participate. Subsequently, some people actively withdrew, did not show up or got excluded. Eventually, 1567 people (777 men and 790 women) were included. The current study includes data collected at baseline and at year three, from August 2015 to December 2015. After merging the data files total sample size came to 400 that were used in further analyses, 194 men and 206 women. All participants were volunteers and gave their informed consent to the study.

2.3 Equipment and materials

2.3.1 Body composition analyzer

Body composition was measured by using a bioelectrical impedance analysis (InBody 720, BIOSPACE, Seoul, Korea). InBody 720 is a multi-frequency bioelectrical impedance analysis, which takes readings from the body by using a tetrapolar eight-point tactile electrode system, measuring resistance at six different frequencies (1kHz, 5kHz, 50kHz, 250kHz, 500kHz, 1000kHz) and reactance at three different frequencies (5kHz, 50kHz and 250kHz) at each of five segments (right arm, left arm, trunk, right leg, left leg). InBody 720 uses four pairs of electrodes, embedded in the handles and the scale platform of the analyzer.

Figure 1. *Body composition analyzer (InBody 720).*

2.3.2 Blood lipids

Blood lipids were measured by taking a blood sample from an arm vein. The blood measurement was conducted in accordance with standard procedures at St.Olavs Hospital, Trondheim, and included serum total cholesterol, HDL-cholesterol, LDL-cholesterol and triglycerides (TG). At baseline, LDL-cholesterol (mmol/l) was estimated by using the Friedewald equation: LDL = (total cholesterol) - (HDL) - (0.45 x triglycerides).[52] At year three, LDL-cholesterol was measured directly by using the method from Roche, measured in mmol/l.[53] Serum and EDTA-treated plasma were centrifuged at 3000 revolutions per minute for 10 minutes at 20°C. In case new blood markers would be analyzed later, aliquots were stored at -80°C. Additionally, full-blood from EDTA was taken and stored at a Regional Biobank at -80°C for further DNA analysis.[54]

2.3.3 Anthropometry

Anthropometric measurements such as height and waist circumference were taken by using a ruler tape.

2.4 Procedure

All test conditions took place at the Heart and Lung Centre at St.Olavs Hospital. The participants underwent two examination days. Examination day one took place at the clinical research facility and included clinical measurements such as blood sample, blood pressure, body composition analysis, anthropometric measurements and pulmonary lung function test. Examination day two took place at the training laboratory and included physical tests such as measurement of gait, VO_2 max, grip strength, leg strength and cognitive function. Examination day two ended with a conversation where the participants were given feedback on the clinical measurements and the physical tests, as well as a comparison of the previous test year. Only the tests and measurements used for the present study will be further described below.

2.4.1 Body composition

Body composition was determined in the morning, following a 12-hour overnight fast. Fasting was confirmed by asking the participant. Body composition measurements were not taken if a participant had a pacemaker.

Before starting the test, characteristics such as height, age and gender were plotted in the display of the scale. To achieve accurate and reliable results, the participant had to stand in a specific position. Palms, fingers and soles had to be in contact with the electrodes during the entire test. In accordance with the manufacturer's guidelines, the participant removed shoes and sock before entering the measuring instrument. Contents from pockets were removed, as well as watches and jewellery. An initial weight measurement was performed when the subject entered the scale platform. The participant was further instructed to grasp the handles of the analyser and to stand with the arms straight down, approximately 10 cm out from the body, providing contact with all the electrodes. After a few minutes, the scale reported body mass index (BMI in kg/m^2), muscle mass (kg), visceral fat (cm^2), minerals (kg) and fat percentage (%).

2.4.2 Anthropometry

2.4.2.1 Height

The participant was asked to stand barefoot with the body placed against the wall with feet shoulder-width apart. Height was measured to the nearest millimetre with a ruler tape.

2.4.2.2 Waist circumference

When measuring the waist circumference the participant was asked to clear the abdominal region of all clothing and accessories. Men were asked to remove the top garment, while women were asked to roll up the top garment. Pants and belts had to be loosened and lowered to remove any pressure from the abdomen. The participant was further asked to stand with feet shoulder-width apart and the arms crossed over the chest in a relaxed manner. A palpation was done of the participant's hip to locate the top of the iliac crest. A horizontal line was marked with a pen at the top of the iliac crest and the ruler tape was adjusted so that the bottom edge lay horizontal with the marked point. During the process the participant was asked to relax and breathe normally. To help the participant relax, he or she was instructed to take two or three normal breath and the waist circumference was taken at the end of a normal expiration and measured to the nearest millimetre.

2.4.3 Blood lipids

The participant had to sit at rest for 10 minutes before blood sampling. All blood samples were drawn in a sitting position. Before blood collection, thigh clothes from the upper arm were removed. The arm was resting on a pillow or other supportive surface and the arm vein was chosen based on the quality of the blood vessels. Only butterfly needles were used to draw blood. Fasting time was noted by asking the participant. Hand disinfection was always performed before each measurement. The participant had to confirm name and birth number before starting blood sampling and these forms of identification were checked against the requisition paper.

2.5 Intervention

The participants in the Generation 100 study were part of an endurance training program for five years. At baseline, the participants were randomized 1:1 to either exercise training or control group. The exercise training group was further randomized 1:1 to moderate-intensity training or high-intensity training.

2.5.1 Moderate-intensity training

The moderate-intensity training included 50 minutes of continuous endurance training equivalent to 70 % of maximum heart rate, twice a week. The required intensity corresponded to approximately 13 on the Borg Rating of Perceived Exertion Scale, i.e. a bit strenuous. Every sixth week, the participants were invited to take part in a supervised training session with an instructor and a heart rate monitor at the training unit. In addition, organized training sessions with different types of activities were offered twice a week. The participants could choose themselves whether they would attend these training sessions, or exercise on their own as recommended.

2.5.2 High-intensity training

High-intensity training included interval training, mainly four times four-minute intervals, with a total duration of 30-40 minutes, twice a week. The intensity of the working periods was equivalent to 85-95 % of maximum heart rate, corresponding to approximately 16 on the Borg Scale, interspersed by 3 minutes of active rest breaks. The intensity of the active rest breaks was equivalent to 60-70 % of maximum heart rate corresponding to approximately 12 on the Borg Scale. Every sixth week, the participants were asked to take part in a supervised training session with an instructor and a heart rate monitor. Additionally, organized training sessions with different activities were offered twice a week. Participation in the latter was voluntary. Alternatively, they exercised by their own as recommended.

2.5.3 Control group

Participants in the control group were instructed to follow general recommendations for physical activity, that is 30 minutes of moderate intensity of an individually selected activity every day, without further supervision.

2.6 Adherence

The exercise training groups were asked to fill in exercise training sessions in a self-reported diary that was submitted monthly. The control group reported their physical activity through the use of questionnaire, which they were asked to respond to once a year.

2.7 Statistical analyses

SPSS Statistics version 23 for Apple MacBook Pro was used for statistical analyses (SPSS, Inc, Chicago, IL). Data was checked for normality using the Kolmogorov-Smirnov test. Descriptive statistics were used to analyze the characteristics of the study population and presented as frequencies and percentage, or as means with standard deviations (SD). Baseline differences in outcome variables between men and women were explored with independent samples t-tests. Chi-square tests were used for between-group comparisons of categorical variables. Mean change score was calculated by subtracting the post-training value from the baseline value. A three-way multivariate analysis of variance (MANOVA), with repeated measures was used to test for overall main effects and Group (3) × Gender (2) × Time (2) interactions. Group and Gender were between-subject factors and time was a within-subject factor. A separate multivariate analysis of covariance (MANCOVA) was conducted with lipid-lowering medication as a covariate. Post hoc comparisons consisted of paired samples t-test, independent samples t-test and one-way ANOVA Group (3). Data are presented as means ± standard deviation, unless otherwise indicated. For all statistical analyses, significance was accepted at $p<0.05$.

3.0 RESULTS

The results are presented in sections 3.1 sample characteristics, 3.2 endurance training and body composition and 3.3 endurance training and blood lipids.

3.1 Sample characteristics

The total sample size in the present study consisted of 400 participants, 206 women and 194 men. The descriptive data and background characteristics for each gender within each group are presented in Table 1. The background characteristics include physical data such as age, weight and height, and demographical data such as education, smoking status, physical activity level, health status, living situation and history of disease. A chi-square test indicated that the groups were not statistically different on any of the demographical variables (all p's>0.18).

Table 1. Background characteristics of the participants according to group and gender.

	CON (N=204)		**MIT (N=92)**		**HIT (N=104)**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**
N	96	108	41	51	57	47
Characteristics	**Mean ± SD**		**Mean ± SD**		**Mean ± SD**	
Age (years)	72.04 ± 1.34	71.83 ± 1.32	71.83 ± 1.29	71.85 ± 1.40	71.52 ± 1.43	72.06 ± 1.40
Height (cm)	177.65 ± 5.59	163.80 ± 5.48	177.64 ± 5.70	163.66 ± 5.64	175.93 ± 5.49	164.68 ± 4.54
Weight (kg)	80.94 ± 9.97	66.83 ± 9.95	81.52 ± 11.10	69.30 ± 11.31	83.14 ± 11.57	64.59 ± 8.77
	%		**%**		**%**	
Low education	34.3	50	31.7	47	42.2	55.3
Current smoker	11.5	7.4	9.8	5.9	5.3	2.1
Physical activity						
Never	2.1	2.8	4.9	0	1.8	0
< once a week	3.1	7.4	4.9	3.9	8.8	0
2-3 times a week	56.3	11.1	2.4	13.7	8.8	14.9
Almost everyday	56.3	52.8	73.2	52.9	57.9	61.7
Self-rated health						
Poor	0	0	0	0	0	2.1
Not so god	5.2	11.1	7.3	7.8	5.3	10.6
Good	67.7	64.8	63.4	70.6	61.4	72.3
Excellent	26	23.1	26.8	19.6	31.6	14.9
Living alone	12.5	42.6	12.2	41.2	12.3	27.7
Prevalent disease						
CVD	7.3	4.6	12.2	5.9	8.8	2.1
Diabetes	8.3	1.9	2.4	0	8.8	0
Osteoporosis	2.1	11.1	0	11.8	0	8.5
COPD	4.2	2.8	4.9	7.8	1.8	2.1

***Abbreviations**:* CON= control group, MIT= moderate-intensity training group, HIT= high-intensity training group, N= number of participants, CVD= cardiovascular disease, COPD= chronic obstructive pulmonary disease.

Table 2 shows the body composition and blood lipids measures at baseline according to gender and group. Independent samples t-tests indicated that men and women were significantly different at baseline with respect to height, weight, waist circumference, minerals, fat, muscle mass, total cholesterol, HDL-cholesterol and LDL-cholesterol (all p's< 0.01). There were no statistically significant differences between men and women in triglycerides and visceral fat at baseline (both p's>0.06).

Table 2. Body composition and blood lipids measures at baseline according to gender and group.

	CON		MIT		HIT	
Variable	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Weight (kg)	80.9 ± 10.0	66.8 ± 10.0	81.5 ± 11.1	69.3 ± 11.3	83.1 ± 11.6	64.6 ± 8.8
Waist (cm)	97.0 ± 9.0	89.8 ± 9.9	97.0 ± 10.3	90.6 ± 11.0	98.8 ± 9.8	85.5 ± 7.8
BMI (kg/m^2)	25.6 ± 2.7	24.9 ± 3.3	26.2 ± 3.5	26.0 ± 4.0	26.9 ± 3.4	23.8 ± 2.8
Minerals (kg)	4.1 ± 0.5	3.1 ± 0.4	4.1 ± 0.5	3.2 ± 0.4	4.1 ± 0.5	3.1 ± 0.3
Visceral fat (cm^2)	102.0 ± 28.6	111.1 ± 29.8	102.1 ± 31.9	117.1 ± 34.1	111.6 ± 34.2	102.3 ± 25.3
Fat (%)	24.0 ± 6.1	33.8 ± 6.6	23.9 ± 6.3	34.4 ± 7.1	25.3 ± 6.6	32.2 ± 6.0
Muscle mass (kg)	33.8 ± 4.0	23.7 ± 2.6	34.3 ± 3.5	24.3 ± 2.6	34.2 ± 3.5	23.4 ± 2.2
CHOL (mmol/l)	5.5 ± 1.1	6.2 ± 1.0	5.5 ± 1.0	5.9 ± 1.0	5.5 ± 0.9	6.1 ± 1.0
HDL-C (mmol/l)	1.7 ± 0.5	2.0 ± 0.5	1.6 ± 0.4	2.0 ± 0.5	1.6 ± 0.4	2.0 ± 0.6
LDL-C (mmol/l)	3.3 ± 1.0	3.8 ± 1.0	3.4 ± 0.9	3.4 ± 0.9	3.4 ± 0.9	3.6 ± 0.9
TG (mmol/l)	1.1 ± 0.5	1.2 ± 0.6	1.2 ± 0.5	1.1 ± 0.5	1.2 ± 0.5	1.1 ± 0.5

Abbreviations: CON= control group, MIT= moderate-intensity training group, HIT= high-intensity training group, BMI= body mass index, CHOL= serum total cholesterol, HDL-C= serum high-density lipoprotein cholesterol, LDL-C= serum low-density lipoprotein cholesterol, TG= serum triglycerides.

3.2 Endurance training and body composition

Mean change in and body composition components after three years of endurance training for both genders in all three groups are presented in Table 3. As can be seen in the table, muscle mass and minerals decreased for both genders in all three groups, whereas percentage fat increased for both genders in all three groups, except from women in the high-intensity training group. With respect to the different groups, there seems to be a tendency towards better results in the high-intensity training group for weight, waist and visceral fat.

Table 3. Mean change in body composition from baseline to three years. Positive values indicate an increase, negative values a decrease in values from baseline to three years.

	CON		MIT		HIT	
Variable	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Weight (kg)	-0.02 ± 3.22	0.09 ± 2.82	-0.64 ± 3.57	0.07 ± 2.78	-1.58 ± 2.62	-0.59 ± 3.01
Waist (cm)	0.32 ± 5.04	0.36 ± 5.83	0.06 ± 3.86	0.37 ± 5.27	-1.18 ± 3.95	-0.88 ± 5.31
BMI (kg/cm^2)	0.13 ± 1.02	0.50 ± 4.80	-0.12 ± 0.21	0.09 ± 1.02	-0.36 ± 0.80	-0.07 ± 1.09
Visceral fat (cm^2)	5.77 ± 11.55	4.12 ± 11.10	2.65 ± 12.81	3.45 ± 9.63	-0.09 ± 12.15	1.55 ± 11.49
Minerals (kg)	-0.05 ± 0.28	-0.01 ± 0.20	-0.05 ± 0.22	-0.05 ± 0.24	-0.06 ± 0.24	-0.03 ± 0.12
Fat (%)	1.25 ± 2.94	0.65 ± 2.97	0.72 ± 2.94	0.62 ± 3.45	0.84 ± 2.97	-0.06 ± 2.83
Muscle mass (kg)	-0.60 ± 2.34	-0.37 ± 0.77	-0.79 ± 1.07	-0.46 ± 1.08	-0.99 ± 0.95	-0.38 ± 1.01

Note. Change is computed by subtracting the post-training value from the baseline value.
Abbreviations: CON= control group, MIT= moderate-intensity training group, HIT= high-intensity training group, BMI= Body mass index.

A three-way MANOVA Group (3) x Gender (2) x Time (2) indicated that Group did not have a significant effect on any of the body composition parameters (all p's>0.17) (see Table 4). However, a main effect of Time was observed on weight F (1,382)=7.738, p=0.006, minerals F (1,382)=11.984, p=0.001, visceral fat F (1,382)=21.333, p<0.001, fat F (1,382)=16.326, p<0.001, and muscle mass F (1,382)=59.145, p<0.001, where weight and muscle mass decreased over time, while minerals, visceral fat and fat increased over time. A main effect of Gender was observed on weight F (1,382)=181.493, p<0.001, waist F (1,382)=75.851, p<0.001, BMI F (1,382)=10.752, p=0.001, minerals F (1,382)=547.589, p<0.001, fat F (1,382)=158.687, p<0.001, and muscle mass F (1,382)=1012.176, p<0.001, with men having higher scores in weight, waist, BMI, minerals and muscle mass compared with women, and women having higher scores on fat compared with men. There was no significant effect of Gender on visceral fat (p=0.139).

Table 4. Results from a three-way MANOVA with repeated measures, with data presented as effect size (ES).

	MANOVA					
	Effect size (ES)					
Variable	**Group**	**Time**	**Gender**	**Group x Time**	**Group x Gender**	**Time x Gender**
Weight (kg)	0.007	0.020 *	0.322 **	0.026 *	0.012	0.009
Waist (cm)	0.009	0.001	0.166 **	0.013	0.021 *	0.000
BMI (kg/cm^2)	0.009	0.000	0.027 **	0.008	0.007 *	0.003
Visceral fat (cm^2)	0.003	0.053 **	0.006	0.024 *	0.020 *	0.000
Minerals (kg)	0.003	0.030 **	0.589 **	0.002	0.001	0.002
Fat (%)	0.002	0.041 **	0.293 **	0.006	0.013	0.007
Muscle mass (kg)	0.008	0.134 **	0.726 **	0.005	0.001	0.016 *

Abbreviations: BMI= body mass index.
****: P-value <0.05, **: P-value <0.005.***

In addition, there was a significant Group x Time interaction on weight F (2,382)=5.026, p<0.01 and visceral fat F (2.382)=4,718, p<0.01, indicating that the intervention groups changed differently in weight and visceral fat over time (see Figure 2). The exercise training groups decreased in weight from baseline to three years, whereas the control group were relatively stable. The control and moderate-intensity training groups decreased in visceral fat from baseline to three years, whereas the high-intensity training group were relatively stable. Post hoc paired samples t-tests revealed that there was no significant change in weight from baseline to three years in the control group, t (203)= -0.188, p=0.851, nor in the moderate-intensity group, t (90)= 0.734, p=0.465. However, there was a significant decrease in weight from baseline to three years in the high-intensity training group, t (103)=4.088, p<0.001. Furthermore, there was a significant increase in visceral fat from baseline to three years in the control group, t (202)= -6.160, p<0.001 and a significant increase in visceral fat from baseline to three years in the moderate-intensity training group, t (89)= -2.688, p<0.01. In contrast, there was no significant change in visceral fat from baseline to three years in high-intensity training group, t (102)= -0.567, p=0.572.

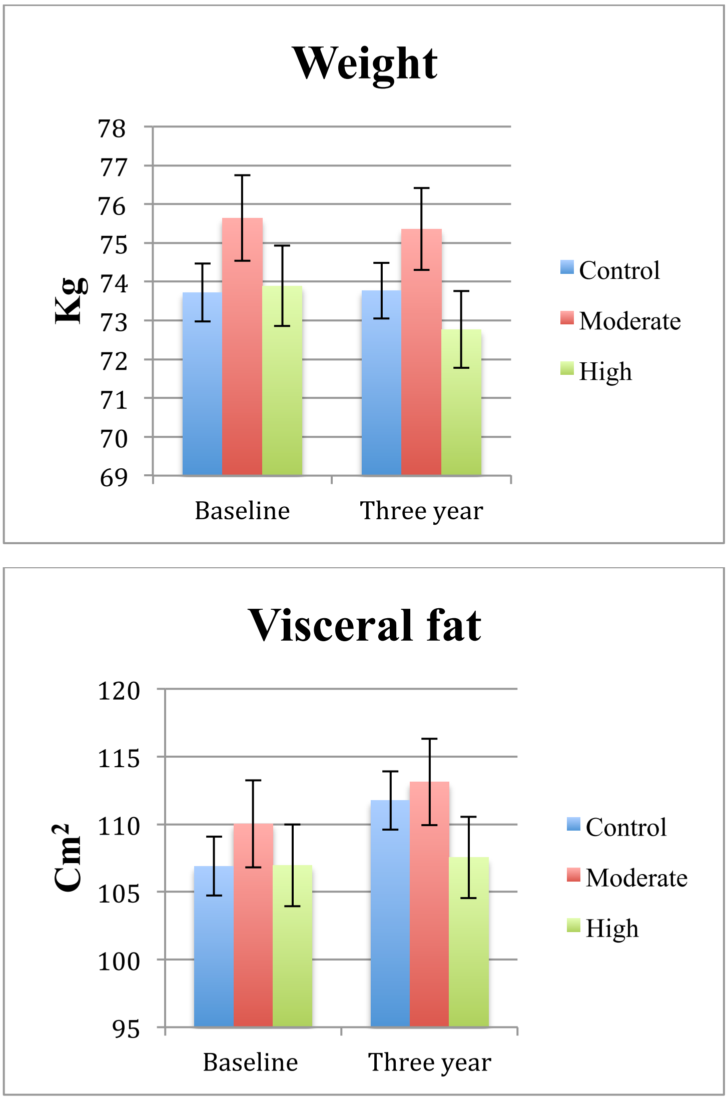

Figure 2. *Changes in weight and visceral fat from baseline to three years of endurance training, illustrating the significant Group x Time interaction for both weight and visceral fat. Data are expressed as mean and standard errors.*

There was also a significant Group x Gender interaction on waist F (2,382)=4.014, $p<0.05$, BMI F (2,382)=4.991, $p<0.01$ and visceral fat F (2,382)=3.954, $p<0.05$, indicating that the effect of the intervention on waist circumference, BMI and visceral fat was different in men compared with women (see Figure 3).

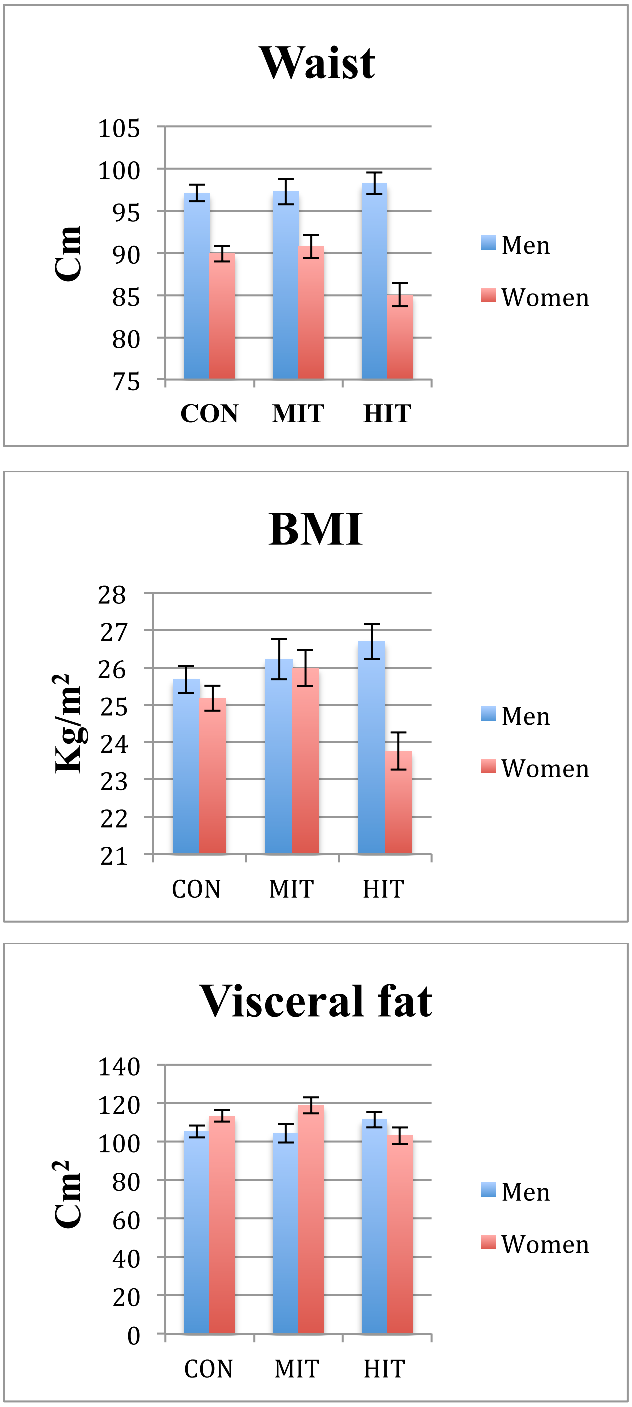

Figure 3. *Weight, BMI and visceral fat for men and women in the different intervention groups, illustrating the Group x Gender interactions. Data are expressed as mean and standard errors.*

Post hoc independent samples t-test showed that waist in all three groups was significantly different in men compared with women (all p's<0.01). Post hoc comparisons (one-way ANOVA Group (3), stratified for gender) indicated that men had equal waist circumference in all three groups, whereas women in the high-intensity training group had significantly smaller waist circumference than women in the other two groups ($p<0.015$).

Post hoc independent samples t-tests revealed that there was a near statistically significant difference in mean visceral fat between men and women in the control group, $t(202) = -1.967$, $p=0.051$. There was a statistically significant difference in mean visceral fat between men and women in the moderate-intensity training group, $t(90) = -2.191$, $p<0.05$, with women scoring higher than men (118.46 ± 34.20 vs 103.37 ± 31.05). In the high-intensity training group, there was no statistically significant difference in mean visceral fat between men and women, $t(102)=1.484$, $p=0.141$.

There was no statistically significant difference in mean BMI between men and women in the control group, $t(202)=1.095$, $p=0.275$, or in the moderate-intensity training group, $t(90)= 0.190$, $p=0.850$. However, there was a statistically significant difference in mean BMI between men and women in the high-intensity training group, $t(102)=4.961$, $p<0.001$, with men scoring higher than women (26.69 ± 3.27 vs 23.76 ± 2.60).

There was a significant Time x Gender interaction on muscle mass $F(1,382)=6.033$, $p<0.05$, meaning that men and women changed differently over time, with men decreasing more in muscle mass (-0.78 kg) from baseline to three years compared with women (-0.40 kg).

3.3 Endurance training and blood lipids

Mean change in blood lipids components after three years of endurance training for both genders in all three groups are presented in Table 5. Mean change in total cholesterol and triglycerides decreased for both genders in all three groups. In contrast, HDL-cholesterol and LDL-cholesterol were relatively stable.

Table 5. Mean change in blood lipids from baseline to three years. Positive values indicate an increase, negative values a decrease in values from baseline to three years.

	CON		MIT		HIT	
Variable	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
CHOL (mmol/l)	-0.32 ± 0.69	-0.13 ± 0.66	-0.39 ± 0.81	-0.15 ± 0.68	-0.10 ± 0.75	-0.26 ± 0.65
HDL-C (mmol/l)	0.00 ± 0.20	-0.01 ± 0.23	-0.03 ± 0.21	0.00 ± 0.25	0.09 ± 0.28	-0.01 ± 0.18
LDL-C (mmol/l)	-0.10 ± 0.63	0.09 ± 0.61	-0.11 ± 0.70	0.05 ± 0.59	0.05 ± 0.69	-0.04 ± 0.63
TG (mmol/l)	-0.14 ± 0.38	-0.09 ± 0.43	-0.20 ± 0.54	-0.04 ± 0.38	-0.19 ± 0.38	-0.09 ± 0.33

Note. Change is computed by subtracting the post-training value from the baseline value.
Abbreviations: CON= control group, MIT= moderate-intensity training group, HIT= high-intensity training group, CHOL= serum total cholesterol, HDL-C= serum high-density lipoprotein cholesterol, LDL-C= serum low density-lipoprotein cholesterol, TG= serum triglycerides.

The same three-way MANOVA Group (3) x Gender (2) x Time (2) reported in the previous section indicated that there were no significant main effects of group on any of the blood lipids parameters (all p's>0.05) (see Table 6). A main effect of Time was observed on total cholesterol $F_{(1,382)}=35.333$, $p<0.001$ and triglycerides $F_{(1,382)}=32.070$, $p<0.001$, indicating that total cholesterol and triglycerides decreased over time (-0.23 mmol/l and -0.13 mmol/l, respectively). A main effect of Gender was observed on total cholesterol $F_{(1,382)}=37.257$, $p<0.001$, HDL-cholesterol $F_{(1,382)}=49.269$, $p<0.001$ and LDL-cholesterol $F_{(1,382)}=7.555$, $p=0.006$, with women having higher scores compared with men. There was no significant effect of Gender on triglycerides ($p=0.918$).

Table 6. Results from a three-way MANOVA with repeated measures with data presented as effect size (ES).

	MANOVA					
	Effect size (ES)					
Variable	**Group**	**Time**	**Gender**	**Group x Time**	**Group x Gender**	**Time x Gender**
CHOL (mmol/l)	0.008	0.085 **	0.089 **	0.002	0.011	0.003
HDL-C (mmol/l)	0.001	0.001	0.114 **	0.008	0.004	0.003
LDL-C (mmol/l)	0.006	0.000	0.019 *	0.001	0.017 *	0.004
TG (mmol/l)	0.001	0.077 **	0.000	0.001	0.006	0.013 *

Abbreviations: CHOL= serum total cholesterol, HDL-C= serum high-density lipoprotein cholesterol, LDL-C= serum low-density lipoprotein cholesterol, TG= serum triglycerides.
****: P-values <0.05, **: P-value<0.005.***

In addition, there was a significant Group x Gender interaction on LDL-cholesterol F (2,382)=3.265, p<0.05, indicating that the effect of the intervention on LDL-cholesterol is different in men compared with women (see Figure 4). Post hoc independent samples t-test revealed that there was a statistically significant difference in mean LDL-cholesterol between men and women in the control group, t (195)= -4.328, p<0.001, with women having higher scores than men (3.79 ± 0.94 vs 3.27 ± 0.86). There was no statistically significant difference in mean LDL-cholesterol between men and women in the moderate-intensity training group, t (90)= -0.663, p=0.509, or in the high-intensity training group, t (102)= -0.591, p=0.556.

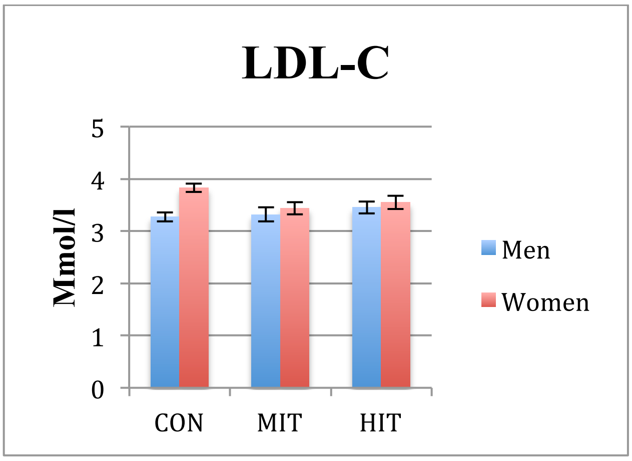

Figure 4. *LDL-cholesterol for men and women in the different intervention groups, illustration the Group x Gender interaction. Data are expressed as mean and standard errors.*

There was a significant Time x Gender interaction on triglycerides as well, $F(1,382)=5.163$, $p<0.05$, indicating that triglycerides changed differently in men and women over time, with men decreasing more in triglycerides (-0.18 mmol/l) from baseline to three years compared with women (-0.08 mmol/l). There was no significant Group x Time interaction on any of the blood lipids parameters (all p's>0.22).

In the present sample, 5.3 % of the participants were taking lipid-lowering medications, which might have an effect on the results. The potential effect of lipid-lowering medications was tested by adding it as a covariate to the above MANOVA. The results showed that there was only one difference, namely a significant difference in men and women in visceral fat after adjusting for lipid-lowering medications, with women having higher levels of visceral fat than men. All other main effects and interactions were the same as without adjusting for lipid-lowering medications.

4.0 DISCUSSION

4.1 Main findings

The main objective of this population-based randomized controlled study was to examine the effect of endurance training on body composition and blood lipids in older adults. The findings demonstrated a beneficial effect of endurance training on body composition in terms of weight and visceral fat. Three years of endurance training did not have a significant effect on blood lipids. The results indicated further that body composition changes in weight and visceral fat were affected by the intensity of endurance training, with better results for high-intensity training group compared with moderate-intensity training group. In fact, only the high-intensity training group decreased significantly in weight after three years of endurance training. Both control and moderate-intensity training groups increased significantly in visceral fat from baseline to three years. The high-intensity training group did not change significantly in visceral fat after three years of endurance training. These results indicate that long-term high-intensity endurance training affects weight and visceral fat positively by reducing body weight and attenuating age-related increases in visceral fat. Visceral fat is a well-established risk factor for cardiovascular disease and even smal differences in the amount of visceral fat can alter the risk.[55,56]

Gender differences were present in most measures of body composition and blood lipids at baseline, and in interaction with intervention group and time. There was a significant gender difference in weight, waist, BMI, minerals, muscle mass, fat, total cholesterol, HDL-cholesterol and LDL-cholesterol. Men had significantly higher values on weight, waist, BMI, minerals and muscle mass compared with women, and women had significantly higher values on fat and lipid values. This is consistent with earlier findings that women generally have a higher percentage of body fat than men and that men have more abdominal fat as measured by waist circumference compared with women.[12,13] There were also gender differences in response to training. Women showed a larger reduction in waist and BMI than men with high-intensity training, whereas men showed larger reduction in LDL-cholesterol and visceral fat than women in the control group and with moderate-intensity training than women. Men and women also changed differently over time with respect to muscle mass and triglycerides, with men starting off with more muscle mass and higher triglyceride levels and decreased more in both over time compared with women.

4.2 Effect of endurance training

Previous studies have examined the effect of aerobic exercise training on blood lipids in adults and demonstrated quite consistent results. Regarding exercise training and body composition, previous research has mainly focused on resistance training and not aerobic exercise training. Several reviews regarding the effect of exercise training on lipid values have been conducted on adults, 18 years or older, but few have specifically targeted older adults.

An earlier review investigating the effects of endurance training on blood lipids in adults, ranging from 18-80 years of age, found that moderate to hard-intensity exercise training resulted in improvements in blood lipids in terms of increased HDL-cholesterol and to an lesser extent reduction in total cholesterol, LDL-cholesterol and triglycerides.[57] Almost all the studies included performed exercise training at moderate to hard intensity, three to five times per week, with intervention periods ranging from 12 week to 2 year. Most of the studies included consisted of structured aerobic exercise training, such as walking, jogging and bicycling, with few exceptions including studies with home exercises and resistance training. This indicates that the studies included in the review had closer supervision during exercise training compared with the present study, which may be the cause of the inconsistent findings. In contrast to the present study, many of the studies in the review were combined with diary intervention, which enhanced the reductions in lipid values and may interfere with the effect of exercise training. The review included adults with a wide age range and cannot generalize to the elderly population as in the present study.

Another review examining the responses of blood lipids to aerobic, resistance, and combined aerobic with resistance exercise training in adults, ranging from 18-80 years of age, found that aerobic exercise training resulted in improvement in HDL-cholesterol and that high-intensity training resulted in more favourable effects compared with moderate-intensity training.[58] The aerobic exercise training program included mainly walking, cycle ergometer and jogging with interventions lasting from 12 weeks to 2 year. It is unclear to what extent the aerobic exercise training was supervised. As mentioned above, this review also included participants with a wide age range and not only elderly and can therefore not generalize to the elderly population. In addition, it was a fairly heterogeneous group of participants with both abnormal and normal lipid values and including both normal-weight and overweight participants. In contrast, the participants in the present study were relatively healthy with initial normal weight, BMI and lipid values, and can therefore not be directly compared.

A third review investigating the effect of aerobic exercise training on HLD-cholesterol in adults with age ranging from 23-75 years, showed that regular exercise training provoked small increases in HDL-cholesterol.[59] Aerobic exercise training included movements of large muscle groups, such as brisk walking, bicycling and swimming and the mean intervention period was 27 weeks. It is unclear whether the studies included performed supervised or unsupervised exercise training. As mentioned before, this was a more heterogeneous group than in the present study, with both young and older participants.

To our knowledge, there is only one meta-analysis investigating exercise training on lipid values in older adults aged 50 years or older, which found that aerobic exercise training increases HDL-cholesterol.[60] The meta-analysis included aerobic exercise training such as walking, jogging, bicycling and swimming with mean intervention periods of 35 weeks. Half of the studies included performed supervised exercise training, only two of the studies performed unsupervised exercise training and the other remaining studies involved a combination of supervised and unsupervised exercise training. Hence, the vast majority of the studies included had closer supervision than the participants in the present study, which may explain the inconsistent findings.

Overall, the available evidence demonstrates consistent findings in terms of blood lipids.
It is well supported that HDL-cholesterol is the component that is more likely to improve as a result of aerobic exercise training. This does not correspond with the findings of the present study, as here we found no effect of long-term endurance training on any of the blood lipids components. However, total cholesterol and triglycerides decreased significantly over time, but the lack of significant group effect indicates that the exercise training did not contribute to the decrease. The inconsistent findings may be explained by several factors. The fact that the vast majority of the studies have focused on younger adults may be an important factor. In addition, exercise training volume may also be of importance. It appears that most of the studies included in the aforementioned reviews involved a higher frequency of exercise training with a minimum of twice a week and a maximum of seven days a week, that is more than in the present study. Similarly, it is important to point out that the average length of exercise training in the reviews are much shorter than the length of exercise training in the present study, which may also be of relevance. Long intervention periods may have many benefits, but can also lead to a decline in the quality of the exercise training. Differences in controlled variables, such as duration, frequency and intensity, among the studies could account for the different results.

Regarding exercise training and body composition, previous research has mainly focused on resistance training and body composition. The effect of endurance training on body composition is somewhat unclear and more studies are needed on aerobic exercise interventions. A review investigating the effects of aerobic exercise training on visceral adiposity in adults, with mean age ranging from 28-83 years, found that aerobic exercise training is central for exercise programs aimed at reducing visceral adipose tissue.[61] This is comparable with the findings of the present study, where visceral fat levels were relatively stable over time in the high-intensity training group compared with control and moderate-intensity training groups, which increased in visceral fat over time. However, approximately half of the participants included in the review were classified as obese and at different ages and therefore, the results must be interpreted with caution.

4.3 Possible mechanisms

As more people, including the elderly population, are overweight and obese, weight loss may improve the health profile. Evidence suggests that high levels of body fat and BMI values are associated with cardiovascular disease and disability, especially in elderly.[62-64] However, the elderly in the present study had normal weight and BMI values at baseline and weight reduction in this population may not have the same health benefits as in obese elderly. Moreover, body fat distribution has shown to be more associated with cardiovascular risk than high body fat. Visceral fat is known to increase with advanced age, which corresponds with the present results with visceral fat increasing in control and moderate-intensity training groups over a three year period. Visceral fat in the high-intensity training group was relatively stable, indicating that endurance training in terms of high intensity is beneficial in attenuating age-related changes in visceral fat.

It appears that changes in body composition may have an impact on lipid values. There is evidence suggesting that improvements in lipid profile that are reported for exercise training may be dependent on loss of body weight.[65] In the present study, only the high-intensity training group decreased weight significantly over time. However, the decrease was relatively small and might have been insufficient to produce alterations in lipid values. This might explain why exercise training did not produce a favourable change in lipid values in the present study. Moreover, it appears that there is an association between body fat and lipid values,[66] whereby a training volume sufficient to evoke changes in body fat is necessary to elicit improvements in the lipid profile. Previous training studies support this hypothesis and have shown correlations between changes in lipid profile and loss of body fat.[67] This enhances the possibility that improvements in lipid profile values may not be a direct result of the endurance training, but rather a consequence of alterations in body composition components due to endurance training program. It is therefore reasonable to assume that body composition is a determinant factor in the improvement of lipid profile.

Several studies indicate that there is a dose-response relationship between exercise training and blood lipids.[68,69] Effects may not be observed until a certain exercise threshold or certain energy expenditure is met. Consistently, the present data may suggest that total exercise volume is more central for improving lipid profile. Considering that many of the participants in the present study exercised only twice a week without supervision, it might have been insufficient to elicit improvements in blood lipids and a higher exercise training volume, with longer duation per sessions or higher frequency of exercise training, may have elicited the additional benefits observered in previous studies. It is therefore reasonable to assume that in order to prevent and treat dyslipidemia, a certain training volume is needed.

Likewise, the response of exercise training on lipid values may be related to initial cholesterol levels. The participants in the present sample were classfied as non hyperlipidemic due to the fact that overall baseline levels were within the normal range according to reference values used by St.Olavs Hospital.[70] It is debatable whether the women in the present sample had a slightly elevated total cholesterol. Total cholesterol is a common used measure of cholesterol, which include HDL-cholesterol and LDL-cholesterol. Considering that there are different effects of HDL-cholesterol and LDL-cholesterol on cardiovascular risk, total cholesterol can be misleading. Additionally, the risk of cardiovascular disease among the participants will differ depending on total cholesterol and other additional risk factors. It may be that participants with already elevated total cholesterol, will experience a greater lipid-lowering effect of endurance training than the participants in the present study with relatively low baseline values.

Advanced age might contribute to some unintentional weight loss, which in turn can accelerate the age-related loss of muscle mass.[71] In addition, physical activity level declines with advancing age and is believed to be a contributor to the development of sarcopenia. Hence, it is believed that regular physical activity can attenuate these changes in muscle mass and function. However, this does not seem to apply for endurance training. The present result showed that endurance training had no effect on muscle mass and sarcopenia, corresponding to the results of previous studies with resistance training as the primary type of exercise training to prevent sarcopenia.[72] Women might be more susceptible to the negative effects of sarcopenia, because they start out with lower amounts of muscle mass compared with men. It is therefore reasonable to assume that women might have a greater potential for improvements in muscle mass and strength compared with men. Women in the present study started off with lower muscle mass compared with men. However, men decreased more in muscle mass than women over three years. Although, the women showed a smaller decline in muscle mass than men, the consequence of this muscle impairment might be more severe in women due to the fact that they naturally have lower muscle mass at baseline than men. Overall, it could mean that the underlying causes of sarcoponia are different in men and women and it might require a more gender-specific treatment therapy.

4.4 Strengths and potential limitations

The study has several strengths and potential limitations that should be mentioned.
The present study had a randomized controlled trial design, which is often considered as “gold standard” within clinical research. Furthermore, the study is unique due to the large sample size and because of the long intervention period, which is much longer than many of the previous endurance training studies in elderly. Exercise as a medicine is known to have many benefits and few negative side effects and is affordable and accessible for everyone. Body composition was measured objectively with a bioelectrical impedance analysis and thereby avoiding biases that are associated with more subjective measurements. Bioelectrical impedance analysis is a relatively simple and straightforward way to measure body composition in large studies.[73] Similarly, blood lipids were measured objectively by blood sampling and conducted in accordance with standard procedures at St.Olavs Hospital and carried out by professionals. Height and waist circumference were measured by trained personal using standardized procedure and thus reducing the chance for biases that often are associated with self-reported anthropometric data.[74]

This study has some potential limitations as well.
There will always be a possibility for confounding due to unknown or unmeasured variables.

We had for instance not information regarding dietary habits, which might be of importance. Diet is known to be an important predictor of adiposity and this could have influenced the lipid values.[75]

Moreover, the accuracy from the bioelectrical impedance analysis depends on controlling the factors that may increase measurement error. The test results may be influenced by factors such as nutritional status, hydration status, physical activity, patient factors, environmental factors and temperature that can affect total body impedance and estimation of fat free mass. To achieve accurate results, the participant must adhere to standardized guidelines, which are designed to minimize errors. However, in large studies like this, it may be difficult to control all interfering factors. Fasting was confirmed by asking the participants only, and some of the participants reported that they had forgotten to fast. Furthermore, we did not have information about exercise training and alcohol consumption prior to the measurement. Studies have shown that measurement of bioelectrical impedance analysis validated for specific populations and conditions can achieve accurate results in controlled clinical conditions. However, in studies with a heterogeneous population, bioelectrical impedance analyses may not be an appropriate choice for measurement of body composition. In the present study, it was a fairly homogeneous group of elderly with a small age range and overall a good health condition. Thus, bioelectrical impedance analysis for measuring changes in body composition in this population appears to be an appropriate alternative.[76]

The participants in the present study accepted to participate in this exercise training study, which may have caused selection bias in that those who joined the study differ from those who would not join the study. All invitees were asked to respond to a questionnaire sent out with the invitation letter. Analyse of these data has shown that those who agreed to participate reported higher education, better health and less cardiovascular disease than those who would not participate.[54] This suggests that it is the healthiest of the elderly population that participate in this study and the result may therefore not generalize to the entire elderly population.
As mentioned earlier, there can also be limitations to what extent the participants adhere to their exercise training or control schedules. Close monitoring of training sessions may be difficult to control in large studies like this. The exercise training groups only had to meet up for supervised training sessions every sixth week. Organized training sessions were offered twice a week, however, participation was voluntary and they could choose to exercise on their own as recommended. There was no intensity control of the exercise training beyond these

mandatory training sessions. It is therefore no guarantee that the participants were exercising as intended. The participants in any of the three groups could have exercised more or less than they should have. Although, training sessions were logged in a diary that was submitted monthly, such self-reported measures of physical activity through the use of diary and logs might cause information bias and recall bias, even though it was only weeks back in time. Similarly, the motivation for exercise training may have influenced the study results. Because this is a quit healthy group of elderly, they might have been motivated for exercise when they joined the study and those who where was randomized to the control group might have exercised more than national recommendations for physical activity, causing misleading results. In addition, the control group reported their physical activity by using a questionnaire once a year, which often acknowledges misclassification as a limitation.

Obesity is often defined by the use of waist circumference and BMI as in the present study. Waist circumference provides information about fat distribution, and body mass index (BMI) is calculated as weight in kg divided by height squared in m^2. Both waist circumference and BMI are simple measures to assess an individual's body composition. However, there are several factors that can influence the interpretation. BMI may underestimate body fat in elderly who have lost muscle mass and it may overestimate body fat in muscular persons or highly trained athletes because of large muscle mass rather than a high amount of body fat. In addition, BMI does not provide a good indication of the distribution of fat, which has been more associated with cardiovascular disease than high body fat. Measuring anthropometric data such as waist circumference with a ruler tape can lead to random errors, such as how the ruler tape is held during the measurement. However, this will not likely be a problem in the present study due to the large sample size that reduces random errors to zero. In addition, BMI and waist circumference were not the only measures of obesity in the present study. We also had information about weight, muscle mass and percentage body fat as well, which are all rough indicators of body fatness and these uncertainties regarding BMI and waist circumference will therefore not be of major importance.

5.0 CONCLUSION

With respect to body composition, there was a tendency towards better results for exercise training with higher intensity. Three years of endurance training resulted in modest reductions in weight, with larger reduction in the high-intensity training group compared with moderate-intensity training group. Visceral fat increased in control and moderate-intensity training groups, but not in the high-intensity training group. Men and women clearly differed in body composition and blood lipids at baseline. In addition, gender differences were also present in interaction with intervention group and time. Women reduced waist and BMI more than men in the high-intensity training group, whereas men reduced LDL-cholesterol and visceral fat more than women in control and moderate-intensity training groups. Men and women also changed differently in muscle mass and triglycerides over time, with men decreasing more in both. Long-term endurance training failed to induce significant reductions in blood lipid values. Further research with longitudinal design is needed to understand the effects of endurance training on lipid profile in older adults.

References

1. Rosenbloom S. Sustainability and automobility among the elderly: An international assessment. *Transportation.* 2001;28(4):375-408.
2. Statistisk Sentralbyrå. Dette er Norge 2015, hva tallene forteller. 2015; http://www.ssb.no.
3. Statistisk Sentralbyrå. Befolkningsframskrivinger, 2014-2100. 2014; http://www.ssb.no.
4. Baumgartner RN, Waters DL, Gallagher D, Morley JE, Garry PJ. Predictors of skeletal muscle mass in elderly men and women. *Mech. Ageing Dev.* 1999;107(2):123-136.
5. Bijnen FC, Feskens EJ, Caspersen CJ, Mosterd WL, Kromhout D. Age, period, and cohort effects on physical activity among elderly men during 10 years of follow-up: the Zutphen Elderly Study. *J. Gerontol. A. Biol. Sci. Med Sci.* 1998;53(3):M235-M241.
6. Hansen BH, Kolle E, Dyrstad SM, Holme I, Anderssen SA. Accelerometer-determined physical activity in adults and older people. *Med. Sci. Sports Exerc.* 2012;44(2):266-272.
7. Kelly T, Yang W, Chen C-S, Reynolds K, He J. Global burden of obesity in 2005 and projections to 2030. *Int. J. Obes.* 2008;32(9):1431-1437.
8. Hubert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart Study. *Circulation.* 1983;67(5):968-977.
9. Weiss R, Dziura J, Burgert TS, et al. Obesity and the metabolic syndrome in children and adolescents. *N. Engl. J. Med.* 2004;350(23):2362-2374.
10. Salihu HM, Bonnema SM, Alio AP. Obesity: What is an elderly population growing into? *Maturitas.* 2009;63(1):7-12.
11. Wells J, Fewtrell M. Measuring body composition. *Arch. Dis. Child.* 2006;91(7):612-617.
12. Ley CJ, Lees B, Stevenson JC. Sex-and menopause-associated changes in body-fat distribution. *Am. J. Clin. Nutr.* 1992;55(5):950-954.
13. Lemieux S, Prud'homme D, Bouchard C, Tremblay A, Després J-P. Sex differences in the relation of visceral adipose tissue accumulation to total body fatness. *Am. J. Clin. Nutr.* 1993;58(4):463-467.
14. Janssen I, Heymsfield SB, Wang Z, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. *J. Appl. Physiol.* 2000;89(1):81-88.
15. Evans WJ, Campbell WW. Sarcopenia and age-related changes in body composition and functional capacity. *J. Nutr.* 1993;123(2 Suppl):465-468.
16. Beaufrere B, Morio B. Fat and protein redistribution with aging: metabolic considerations. *Eur. J. Clin. Nutr.* 2000;54:S48-53.
17. Evans WJ. What is sarcopenia? *J. Gerontol. A. Biol. Sci. Med. Sci.* 1995;50(Special Issue):5-8.
18. Kyle UG, Genton L, Hans D, et al. Total body mass, fat mass, fat‐free mass, and skeletal muscle in older people: cross‐sectional differences in 60‐year‐old persons. *J. Am. Geriatr. Soc.* 2001;49(12):1633-1640.
19. Visser M, Goodpaster BH, Kritchevsky SB, et al. Muscle mass, muscle strength, and muscle fat infiltration as predictors of incident mobility limitations in well-functioning older persons. *J. Gerontol. A. Biol. Sci. Med. Sci.* 2005;60(3):324-333.

20. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45-to 78-yr-old men and women. *J. Appl. Physiol.* 1991;71(2):644-650.
21. Waters D, Baumgartner R, Garry P, Vellas B. Advantages of dietary, exercise-related, and therapeutic interventions to prevent and treat sarcopenia in adult patients: an update. *Clin. Interv. Aging.* 2010;5:259.
22. Thomas EL, Frost G, Taylor-Robinson SD, Bell JD. Excess body fat in obese and normal-weight subjects. *Nutr. Res. Rev.* 2012;25(01):150-161.
23. Van Pelt R, Evans E, Schechtman K, Ehsani A, Kohrt W. Contributions of total and regional fat mass to risk for cardiovascular disease in older women. *Am. J. Physiol. Endocrinol. Metab.* 2002;282(5):E1023-E1028.
24. Kannel WB, Cupples LA, Ramaswami R, Stokes J, Kreger BE, Higgins M. Regional obesity and risk of cardiovascular disease; the Framingham Study. *J. Clin. Epidemiol.* 1991;44(2):183-190.
25. Nguyen NT, Nguyen X-MT, Lane J, Wang P. Relationship between obesity and diabetes in a US adult population: findings from the National Health and Nutrition Examination Survey, 1999–2006. *Obes. Surg.* 2011;21(3):351-355.
26. Ritchie S, Connell J. The link between abdominal obesity, metabolic syndrome and cardiovascular disease. *Nutr. Metab. Cardiovasc. Dis.* 2007;17(4):319-326.
27. Baumgartner RN. Body composition in healthy aging. *Ann. N. Y. Acad. Sci.* 2000;904(1):437-448.
28. Baumgartner RN, Wayne SJ, Waters DL, Janssen I, Gallagher D, Morley JE. Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. *Obes. Res.* 2004;12(12):1995-2004.
29. Hirani V. Generalised and abdominal adiposity are important risk factors for chronic disease in older people: results from a nationally representative survey. *J. Nutr. Health Aging.* 2011;15(6):469-478.
30. Newman AB, Yanez D, Harris T, Duxbury A, Enright PL, Fried LP. Weight change in old age and its association with mortality. *J. Am. Geriatr. Soc.* 2001;49(10):1309-1318.
31. Locher JL, Roth DL, Ritchie CS, et al. Body mass index, weight loss, and mortality in community-dwelling older adults. *J. Gerontol. A. Biol. Sci. Med. Sci.* 2007;62(12):1389-1392.
32. Anderson JW, Konz EC. Obesity and disease management: effects of weight loss on comorbid conditions. *Obes. Res.* 2001;9(S11):326S-334S.
33. Gordon T, Castelli WP, Hjortland MC, Kannel WB, Dawber TR. High density lipoprotein as a protective factor against coronary heart disease: the Framingham Study. *Am. J. Med.* 1977;62(5):707-714.
34. Castelli WP, Doyle JT, Gordon T, et al. HDL cholesterol and other lipids in coronary heart disease. The cooperative lipoprotein phenotyping study. *Circulation.* 1977;55(5):767-772.
35. Heiss G, Tamir I, Davis CE, et al. Lipoproteins: cholesterol distributions in selected North American populations: the lipid research clinics program prevalence study. *Circulation.* 1980;61(2):302-315.
36. Ericsson S, Eriksson M, Vitols S, Einarsson K, Berglund L, Angelin B. Influence of age on the metabolism of plasma low density lipoproteins in healthy males. *J. Clin. Invest.* 1991;87(2):591.
37. National Cholesterol Education Program. Executive summary of the Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection,

evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). *JAMA.* 2001;285(19):2486-2497.
38. Abbott RD, Garrison RJ, Wilson P, et al. Joint distribution of lipoprotein cholesterol classes. The Framingham study. *Arterioscler. Thromb. Vasc. Biol.* 1983;3(3):260-272.
39. Berg G, Mesch V, Boero L, et al. Lipid and lipoprotein profile in menopausal transition. Effects of hormones, age and fat distribution. *Horm. Metab. Res.* 2004;36(4):215-220.
40. Carroll MD, Lacher DA, Sorlie PD, et al. Trends in serum lipids and lipoproteins of adults, 1960-2002. *JAMA.* 2005;294(14):1773-1781.
41. Walter M. Interrelationships among HDL metabolism, aging, and atherosclerosis. *Arterioscler. Thromb. Vasc. Biol.* 2009;29(9):1244-1250.
42. Kreisberg RA, Kasim S. Cholesterol metabolism and aging. *Am. J. Med.* 1987;82(1):54-60.
43. Lamb MM, Ogden CL, Carroll MD, Lacher DA, Flegal KM. Association of body fat percentage with lipid concentrations in children and adolescents: United States, 1999–2004. *Am. J. Clin. Nutr.* 2011;94(3):877-883.
44. Daniels SR, Morrison JA, Sprecher DL, Khoury P, Kimball TR. Association of body fat distribution and cardiovascular risk factors in children and adolescents. *Circulation.* 1999;99(4):541-545.
45. Lauer RM, Lee J, Clarke WR. Factors affecting the relationship between childhood and adult cholesterol levels: the Muscatine Study. *Pediatrics.* 1988;82(3):309-318.
46. Rimm EB, Stampfer MJ, Giovannucci E, et al. Body size and fat distribution as predictors of coronary heart disease among middle-aged and older US men. *Am. J. Epidemiol.* 1995;141(12):1117-1127.
47. Raguso CA, Kyle U, Kossovsky MP, et al. A 3-year longitudinal study on body composition changes in the elderly: role of physical exercise. *Clin. Nutr.* 2006;25(4):573-580.
48. Sidney K, Shephard RJ, Harrison JE. Endurance training and body compostition of the elderly. *Am. J. Clin. Nutr.* 1977;30(3):326-333.
49. Knight S, Bermingham MA, Mahajan D. Regular non-vigorous physical activity and cholesterol levels in the elderly. *Gerontology.* 1999;45(4):213-219.
50. Fahlman MM, Boardley D, Lambert CP, Flynn MG. Effects of endurance training and resistance training on plasma lipoprotein profiles in elderly women. *J. Gerontol. A. Biol. Sci. Med. Sci.* 2002;57(2):B54-B60.
51. Halverstadt A, Phares DA, Wilund KR, Goldberg AP, Hagberg JM. Endurance exercise training raises high-density lipoprotein cholesterol and lowers small low-density lipoprotein and very low-density lipoprotein independent of body fat phenotypes in older men and women. *Metabolism.* 2007;56(4):444-450.
52. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin. Chem.* 1972;18(6):499-502.
53. Roche Modular P. LDL-Cholesterol plus 2nd generation. https://usdiagnostics.roche.com/products/03038866322/PARAM1203/overlay.html.
54. Stensvold D, Viken H, Rognmo Ø, et al. A randomised controlled study of the long-term effects of exercise training on mortality in elderly people: study protocol for the Generation 100 study. *BMJ open.* 2015;5(2):e007519.

55. Nicklas BJ, Penninx BW, Cesari M, et al. Association of Visceral Adipose Tissue with Incident Myocardial Infarction in Older Men and Women The Health, Aging and Body Composition Study. *Am. J. Epidemiol.* 2004;160(8):741-749.
56. Fox CS, Massaro JM, Hoffmann U, et al. Abdominal visceral and subcutaneous adipose tissue compartments association with metabolic risk factors in the Framingham Heart Study. *Circulation.* 2007;116(1):39-48.
57. Leon AS, Sanchez OA. Response of blood lipids to exercise training alone or combined with dietary intervention. *Med. Sci. Sports Exerc.* 2001;33(6; SUPP):S502-S515.
58. Tambalis KD, Panagiotakos DB, Kavouras SA, Sidossis LS. Responses of blood lipids to aerobic, resistance, and combined aerobic with resistance exercise training: a systematic review of current evidence. *Angiology.* 2008.
59. Kodama S, Tanaka S, Saito K, et al. Effect of aerobic exercise training on serum levels of high-density lipoprotein cholesterol: a meta-analysis. *Arch. Intern. Med.* 2007;167(10):999-1008.
60. Kelley GA, Kelley KS, Tran ZV. Exercise, Lipids, and Lipoproteins in Older Adults: A Meta ‐ Analysis. *Prev. Cardiol.* 2005;8(4):206-214.
61. Ismail I, Keating S, Baker M, Johnson N. A systematic review and meta ‐ analysis of the effect of aerobic vs. resistance exercise training on visceral fat. *Obes. Rev.* 2012;13(1):68-91.
62. Holmgren M, Lindgren A, de Munter J, Rasmussen F, Ahlström G. Impacts of mobility disability and high and increasing body mass index on health-related quality of life and participation in society: a population-based cohort study from Sweden. *BMC Public Health.* 2014;14(1):1.
63. Zamboni M, Turcato E, Santana H, et al. The relationship between body composition and physical performance in older women. *J. Am. Geriatr. Soc.* 1999;47(12):1403-1408.
64. Visser M, Harris T, Langlois J, et al. Body fat and skeletal muscle mass in relation to physical disability in very old men and women of the Framingham Heart Study. *J. Gerontol. A. Biol. Sci. Med. Sci.* 1998;53(3):M214-M221.
65. Sopko G, Leon AS, Jacobs DR, et al. The effects of exercise and weight loss on plasma lipids in young obese men. *Metabolism.* 1985;34(3):227-236.
66. Ingelsson E, Massaro JM, Sutherland P, et al. Contemporary trends in dyslipidemia in the Framingham Heart Study. *Arch. Intern. Med.* 2009;169(3):279-286.
67. Lamarche B, Després J-P, Pouliot M-C, et al. Is body fat loss a determinant factor in the improvement of carbohydrate and lipid metabolism following aerobic exercise training in obese women? *Metabolism.* 1992;41(11):1249-1256.
68. Durstine JL, Grandjean PW, Cox CA, Thompson PD. Lipids, lipoproteins, and exercise. *J. Cardiopulm. Rehabil. Prev.* 2002;22(6):385-398.
69. Williams PT. High-density lipoprotein cholesterol and other risk factors for coronary heart disease in female runners. *N. Engl. J. Med.* 1996;334(20):1298-1304.
70. Rustad P, Felding P, Franzson L, et al. The Nordic Reference Interval Project 2000: recommended reference intervals for 25 common biochemical properties. *Scand. J. Clin. Lab. Invest.* 2009.
71. Newman AB, Lee JS, Visser M, et al. Weight change and the conservation of lean mass in old age: the Health, Aging and Body Composition Study. *Am J. Clin. Nutr.* 2005;82(4):872-878.

72. Mayer F, Scharhag-Rosenberger F, Carlsohn A, Cassel M, Müller S, Scharhag J. The intensity and effects of strength training in the elderly. *Dtsch Arztebl Int.* 2011;108(21):359-364.
73. Buchholz AC, Bartok C, Schoeller DA. The validity of bioelectrical impedance models in clinical populations. *Nutr. Clin. Pract.* 2004;19(5):433-446.
74. Rowland ML. Self-reported weight and height. *Am. J. Clin. Nutr.* 1990;52(6):1125-1133.
75. Shekelle RB, Shryock AM, Paul O, et al. Diet, serum cholesterol, and death from coronary heart disease: the Western Electric Study. *N. Engl. J. Med.* 1981;304(2):65-70.
76. Dehghan M, Merchant AT. Is bioelectrical impedance accurate for use in large epidemiological studies? *Nutr. J.* 2008;7(1):1.