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Benefits of moderate-intensity exercise during a calorie-restricted low-fat diet

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Abstract

Objective: Despite the health benefits, many people do not undertake regular exercise. This study investigated the effects of moderate-intensity exercise on cardiorespiratory fitness (lung age, blood pressure and maximal aerobic power, VO_2max), serum lipids concentration and BMI in sedentary overweight/obese adults consuming a calorie-restricted low-fat diet. **Design:** Randomised diet and exercise intervention. **Setting:** Lincolnshire, UK. **Methods:** Sixty overweight/obese (BMI $\geq 25kgm^{-2}$) adults were randomised to either a calorie restricted low-fat diet (20% of total energy as fat) or the same diet with the addition of moderate-intensity physical exercise (30 minutes, twice a week) for 8 weeks; 20 completed the study. Participants' serum lipids concentrations, BMI, blood pressure, resting pulse rate, VO_2max and lung age were measured before the start of the intervention and during the 4^{th} and 8^{th} weeks. **Results:** Reductions in blood pressure (10% vs. 1%), pulse rate (13% vs. 8%) and weight (5% vs. 2%) were greatest for the diet with exercise group. Exercise resulted in a significant ($p \leq 0.05$) increase in average VO_2max (by 17%) and reduction in average lung age by about 19 years. Further, reduction in participants' lung age ranged from 1 to 37 years. However, there was no significant difference in BMI, blood pressure and serum lipids concentration between groups. **Conclusion:** Although exercise on most days of the week would result in maximum health benefits, 30 minutes of moderate-intensity exercise, twice a week could significantly improve cardiorespiratory fitness (blood pressure and lung age) and the risk of cardiovascular diseases in previously sedentary overweight/obese adults.

KEY WORDS: Cardiorespiratory fitness: Lung Age: VO_2max: Blood Pressure: Overweight/Obese

Introduction

Increased physical activity and a healthy diet have been widely reported to reduce death from cardiovascular diseases (CVD) by improving cardiorespiratory fitness (including lung function, blood pressure), serum lipids concentration and reduce excess weight[1-4]. Lack of cardiorespiratory fitness is one of the strongest markers of early onset of CVD and its associated metabolic disorders[5]. The general recommendation for physical activity is at least 30 minutes of moderate-intensity exercise on most days (≥ 5 days) of the week[6,7]. Despite the reported health benefits of exercise and public health campaigns, less than half the world's population currently meet this recommendation[8]. A range of factors can be used to predict cardiorespiratory fitness but research has been focused on maximal aerobic power, electrocardiogram, respiratory volume and peak oxygen uptake[9] The effects of lung function including measurements of lung age on CVD have not been fully investigated. The aim of the study was to investigate the effects of moderate-intensity physical exercise on cardiorespiratory fitness (maximal aerobic power, lung age, blood pressure and pulse rate), body weight and CVD risk factors in sedentary overweight and obese adults consuming a calorie-restricted low-fat diet. The health benefits of the calorie-restricted low-fat diet consumed by participants in the current study have been described in detail by Apekey et al.[10]

Methods

Sample Size

The sample size of participants recruited into the study was determined by t-test using the statistical software PS-Power and Sample Size Calculation Program, Version 2.1.30[11]. This method takes into account;

a. the difference in mean (between groups) one wishes to detect
b. independent t-test situation
c. standard deviation from findings of a pilot study or published studies

d. two-tailed hypothesis
e. allocation ratio of 1:1

Under these assumptions, statistical significance was defined as $p \leq 0.05$ and a power of 80% was selected (at least a power of 80% is usually considered to be sufficient, and at the 0.05 level of significance is conventional practice in sample size estimation) to detect a difference of about 4% between groups. The expected 4 ± 3% difference between groups was based on average change in serum lipids concentration and weight loss reported by similar studies (low-fat diet, about 20% energy from fat and diet with exercise) by Nieman et al. [12] , Janssen et al. [13] and Pelkman et al. [14]. However, it is acknowledged that there is a tendency for such published studies to overestimate effect sizes. It was estimated that to detect a difference of about 4% between the two study groups using a t-test, 10 participants were required in each group. However, drop out in diets studies may be as high as 80% [15]. For the current study about 50% drop out was anticipated and for this reason, an additional 5 participants were required per group. Thus, 30 participants were required in total with at least 10 completions per group. The sample size of participants in the current study is similar to those of Nieman et al. [12], Kraemer et al. [16] (1997) and Pelkman et al.[14].

Recruitment and Screening

This study was approved by the University of Lincoln Research Ethics Committee. Adults (at least 18years old) with body mass index (BMI) ≥ 25 kgm^{-2}, without life threatening illness, who claimed to have no previous experience of dieting and were not actively exercising to lose weight were recruited via advertisement on notice boards at the University of Lincoln. Sixty-five volunteers were screened for eligibility. Exclusion criteria were; participating in any weight control program during the previous three months, the use of cholesterol lowering drugs, pregnancy and breastfeeding. They also completed validated health and physical exercise assessment questionnaires in order to exclude physical co-morbidity which could make it unsafe for participants to take part in the study. Written informed consent was obtained from all eligible participants. The study design and number of participants who completed the 8 weeks study is shown in **Figure** 1. After screening, eligible participants were randomly assigned to either low-fat diet only or low-fat diet with moderate intensity physical exercise by paper ballot of odd and even numbers. Participants with odd numbers were assigned to the low-fat diet group and those with even numbers were assigned to the low-fat diet with exercise group. After randomisation, the electrocardiogram (E.C.G) of those assigned to low-fat diet with exercise group was determined at rest and immediately after 10 minutes brisk walking on a motorised treadmill to further assess their suitability to undertake physical exercise. An exclusion criterion was ST depression ≥ 1mm on the ECG graph after 10 minutes brisk walking on the motorized treadmill.

Study Protocol

Study participants were randomly assigned to either a low-fat diet or the same diet with exercise.

Low-fat Diet

All participants were prescribed a low-fat diet with a daily total energy intake of 5,020kJ for females and 6,694kJ for males (20% of total energy intake from fat). Participants were provided with portable kitchen scale, sample menus and guides to the diet. They recorded the type of each food and drink consumed, portion size and method of food preparation, for 7 days before the start of the diet and exercise programme and during the fourth and eighth week of the study. The researcher held weekly one-to-one discussions with participants concerning their diet, symptoms’ and difficulties experienced.

Low-fat Diet with Physical Exercise

Participants (n=12: 3 males, 9 females) assigned to the low-fat diet with exercise group undertook 30 minutes physical exercise twice a week, on a motorised treadmill. All exercise sessions were supervised by the researcher. Attendance and the energy utilised during each 30 minutes exercise session was recorded. Each participant was fitted with a chest belt pulse rate monitor (POLAR S610; model 1902540, Polar Electro Oy, Finland). They wore a wrist receiver which recorded and transmited the pulse rate of the participant during exercise. This is displayed as pulse rate versus time on the monitor screen of the treadmill. The intensity of exercise undertaken by each participant was based on the Karvonen equation. This equation (HRmax = 220 – age; where HRmax is maximum Heart Rate) is used to calculated the maximum pulse rate for exercise. It defines the level of exercise at which an individual can derive the most health benefit with low risk[17]. The treadmill was set up for each participant by inputting their age and weight, after which the treadmill automatically adjusts its incline and speed to suit the target exercise pulse rate of the participant during exercise. In order for participants to achieve at least 50% of their HRmax, they were encouraged to jog or run on the treadmill.

Measurements

Venous blood samples were obtained from all participants prior to the start of the diet and exercise and during weeks 4 and 8. Samples were analysed for serum total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL) and triglyceride concentration at the Pathology Department of Lincoln County Hospital. Participants weight, blood pressure, BMI, maximal aerobic power and lung age were determined before the start of the diet and exercise and then at weekly intervals. Weight, height, blood pressure and pulse rate were recorded in triplicate and the means were determined.

Lung age of participants in the diet with exercise group was determined with a Micro Medical Microlab Spirometre ML3500. Using the method of Morris and Temple[18], the spirometry readings were checked for internal reliability. In order to determine the lung age of all participants, their age, gender, height and race were input into the equipment and both the Relaxed (RVC) and Forced Vital Capacity (FVC) tests were performed. For the RVC, participants breathe in until their lungs are completely full, seal their lips around the mouthpiece, and blow out at a comfortable rate until they cannot push out any more air. To determine the FVC, participants breathe in until their lungs are completely full, seal their lips around the mouthpiece and blow out as hard and as fast as possible until they cannot push any more air out and then breathe in fully immediately after the expiratory manoeuvre; the lung age was displayed on the screen in years. The procedure was repeated 3 times and the best of the 3 measurements was recorded.

Maximal aerobic capacity ($V0_2max$) was calculated using the University of Houston non-exercise test (validated questionnaire), BMI version, which correlates (80%) with direct laboratory measurements[17].

Analysis

Microdiet version 2.3 software was used to analyse food intakes. The food composition data used by the software comes from the McCance and Widdowson dataset[19]. SPSS version 15 was used for analysis of the results obtained. Wilcoxon matched pair test was performed to test for significant differences within groups. Mann-Whitney's test was used to compare mean values between the two groups. Statistical significance was defined as $p \leq 0.05$ (two-sided).

RESULTS:

Baseline Characteristics

Participants were males (n=5) and premenopausal females (n=17) aged 18 to 38 years. Before the introduction to the diet or diet with exercise programme, significant difference between groups was only found in mean LDL cholesterol concentration ($p \leq 0.04$). For both groups, their mean serum lipids concentration, blood pressure and resting pulse rate were within the acceptable range but their mean BMI was in the overweight range (**Table** 1).

Food Intake and Exercise

The mean energy intake of participants was between 188 and 1347kJ less than the prescribed amount. This could be attributed to under reporting of food intake and inaccurate estimation of foods consumed outside their homes (**Table** 2). The mean cholesterol composition of their diet was low and the ratio of polyunsaturated to saturated fatty acid (PUFA/SFA) was high. Participants attended all exercise sessions during the first 4 weeks but attendance declined to 80% after this time. Mean energy expended per week during exercise was 1912 ± 368kJ by the end of week 4 and 2033 ± 330kJ by the end of week 8. Percentage of target maximum exercise pulse rate attained was 61± 6% and 63 ± 9% by weeks 4 and 8 respectively.

Cardiorespiratory fitness

For individuals with acceptable pulmonary and ventilatory functions, the lung age should be the same as their chronological age[18-20]. The change in average lung age of participants is shown in **Figure** 2. At week 0, participants had lung ages ranging from <20 to 100 years and for 8 out of 12 participants it was 10 or more years above their chronological age. After weeks of moderate intensity exercise, average lung age reduced by 19 years by week 4 and by 18 years in this group when measured at week 8. Reduction in the lung age of participants was in the range of 1 to 37 years. In addition to the decline in exercise sessions attended after week 4, two participants were diagnosed with chest infection, which affected their breathing and therefore resulted in an increase in their lung age explaining the slight increase in average value for this period as shown in **Figure** 2. At the end of the study, the lung age of all participants was reduced with about 50% of participants having lung age less than 10 years over their chronological age. For two participants, it reduced to their chronological age.

VO_2max increased significantly (by 13%; p=0.001) from 33.56 ± 5.21 $mL.kg^{-1}.min^{-1}$ at week 0 to 37.99 ± 5.75 $mL.kg^{-1}.min^{-1}$ when measured at week 4 and to 39.08 ± 6.38 $mL.kg^{-1}.min^{-1}$ (by 17%; p=0.002) by week 8.

Anthropometric and Metabolic Factors

Mean reduction in BMI and weight by participants in the diet with exercise group was higher than for those in the diet only group (5% vs. 2%) but this did not reach a statistical significant level (**Table** 1). Between groups, there was no significant difference in the mean blood pressure and pulse rate of participants at the beginning of study. Mean systolic blood pressure and pulse rate were significantly reduced in the diet with exercise group during week 4 and 8 and the diet only group at week 4. Significant reduction in diastolic blood pressure was only observed for the diet with exercise group. Within and between groups, there was no significant change in participants' mean serum lipids concentration.

DISCUSSION:

The study demonstrates the beneficial effects of moderate intensity physical exercise on cardiorespiratory fitness, particularly lung age. Two groups were compared; diet with exercise and diet without exercise. There was no exercise only group, hence the findings have to be interpreted with caution. Similarly, the beneficial effects of weight loss as a result of the calorie-restricted diet may have a positive effect on respiratory function but this was not investigated in the current study. Impaired lung function is an established risk factor for cardiovascular disease. However there is limited information on lung age which is an indicator of lung function. Information on the effects of physical exercise on lung function is essential for the provision of advice to the population and to inform health professionals and epidemiological research. The data presented are preliminary findings which will be more fully supported by a follow-on study with a larger sample size and which will address limitations to the current study; limited number of participants, short duration, and underreporting of food intake.

From the current study, the mean serum lipids concentration, blood pressure and pulse rate of participants were within the acceptable range prior to the intervention, but they were overweight or obese and led sedentary lifestyles which put them at increased risk of CVD in the future. Participants had difficulty making and maintaining changes to their diet beyond 4 weeks. This may be due to a decline in motivation after the initial period and the reasons cited were busy schedule and extreme hunger. Although compliance was not complete, participants significantly reduced their mean BMI and the greatest decrease was in the exercise group.

Exercise depending on the intensity has been shown to favourably influence serum lipids profile by altering intravascular enzyme activities[21]. However, in this study, although physical exercise twice a week improved cardiorespiratory fitness it did not have a significant effect on mean serum lipids concentration. This may have been due to participants having had acceptable serum lipid profiles prior to the study and hence they showed no further improvement. It is also possible that more frequent exercise than that prescribed was necessary to improve their lipid profile.

The addition of physical exercise to a calorie-restricted low-fat diet also resulted in significant reductions in average blood pressure and pulse rate. Other researchers have shown beneficial effects of significant weight loss (5 to 10% reduction in weight) and physical exercise (over 30 minutes sessions for at least 4 days per week) on blood pressure[22-25]. The current study showed that modest weight loss (2 to 5%) and exercise at 60% of maximum exercise pulse rate, twice in a week could significantly reduce blood pressure. Apart from improvement in blood pressure, pulse rate, serum lipids concentration and cardiorespiratory fitness, effects of physical exercise on other cardiovascular disease risk factors include improvement in insulin and glucose metabolism[26-28].

Significance

The prescribed exercise was less than the general recommendation of 30 minutes of moderate-intensity physical activity on most days (≥ 5 days) of the week[6]. However, exercise at the level in this study significantly increased participants' VO_2max, reduced lung age and therefore improved their cardiorespiratory fitness. Lung age above the chronological age of an individual is an indication of premature aging of the lungs or reduction in lung function due to poor cardiorespiratory fitness[18]. There was no scientific data on the effects of exercise on lung age, which is an indicator of cardiorespiratory fitness. In this study, 8 weeks of moderate-intensity physical exercise reduced the lung age of previously sedentary overweight/obese adults. Given that lung function is an indicator of cardiovascular health and that CVD is the leading cause of death worldwide, there is a need to increase awareness of the benefits of exercise. Although it is well documented that regular moderate-intensity exercise would result in greater health benefits, public health messages targeted at sedentary individuals could indicate the benefits of low levels of exercise and this might lead to more regular uptake of exercise within such populations. The level of exercise undertaken by these participants could be undertaken by most people and easily fitted into daily schedules.

The addition of exercise to a calorie-restricted low-fat diet also resulted in significant reductions in blood pressure and pulse rate. A review by Neter et al.[22] showed beneficial effects of physical exercise and 5 to 10% reduction in weight on blood pressure. This study showed that modest weight loss (2 to 5%) and exercise at 60% of maximum exercise pulse rate, twice in a week could significantly reduce blood pressure.

CONCLUSION:

Two sessions of 30 minutes of moderate-intensity physical exercise (at no less than 60% of target exercise pulse rate) could significantly improved the cardiorespiratory fitness (blood pressure, lung age and VO_2max) and reduced cardiovascular disease risk in overweight and obese sedentary adults. However, physical exercise at this level is not likely to have any significant effect on serum lipids concentration. Currently, there is no scientific data on the effects of exercise on lung age, which is an indicator of cardiorespiratory fitness. This study therefore contributes to literature on cardiorespiratory fitness which is also a major cardiovascular disease risk indicator.

Acknowledgments

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Conflicts of Interest

There were no conflicts of interest.

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List of Tables:

Table 1 Change in anthropometric and metabolic factors

Variable	Diet	Diet & Exercise	P value
Weight (kg)			
Week 0	75.9 ± 10.2	83.0 ± 15.6	0.90
Week 4	74.2 ± 10.3†	79.9 ± 15.3†	0.37
Week 8	72.6 ± 7.6†	75.8 ± 14.4†	0.79
BMI (kgm^{-2})			
Week 0	27.7 ± 1.8	28.6 ± 3.8	0.10
Week 4	27.0 ± 1.7†	27.6 ± 3.7†	0.69
Week 8	26.8 ± 1.6†	26.8 ± 3.6†	0.44
Systolic BP (mm Hg)			
Week 0	128±6	134±9	0.62
Week 4	123±9†	121±12†	0.44
Week 8	125±12	122±9†	0.79
Diastolic BP (mm Hg)			
Week 0	80±6	85±11	0.87
Week 4	78±7	77±8†	0.66
Week 8	79±9	78±8†	0.54
Resting Pulse Rate (bpm)			
Week 0	83±18	85±15	0.15
Week 4	76±19†	75±11†	0.86
Week 8	76±13	78±12†	0.88
Total Cholesterol (mmol/L)			
Week 0	5.0 ± 0.8	4.3 ± 1.0	0.11
Week 4	4.8 ± 1.1	4.2 ± 0.9	0.12
Week 8	4.8 ± 0.9	4.6 ± 1.0	0.54
LDL Cholesterol (mmol/L)			
Week 0	2.9 ± 0.6	2.3 ± 0.7	0.04‡
Week 4	2.7 ± 0.9	2.2 ± 0.7	0.09
Week 8	2.7 ± 0.8	2.3 ± 0.7	0.32
HDL Cholesterol (mmol/L)			
Week 0	1.5 ± 0.2	1.4 ± 0.4	0.43
Week 4	1.6 ± 0.4	1.4 ± 0.3	0.37
Week 8	1.6 ± 0.5	1.6 ± 0.2	0.94
TC/HDL Ratio			
Week 0	3.4 ± 0.6	3.1 ± 0.9	0.27
Week 4	3.1 ± 0.9	3.0 ± 0.6	0.75
Week 8	3.3 ± 1.0	3.0 ± 0.8	0.59
Triglyceride (mmol/L)			
Week 0	1.3 ± 0.5	1.1 ± 0.3	0.91
Week 4	1.3 ± 0.6	1.2 ± 0.5	0.75
Week 8	1.6 ± 0.9	1.4 ± 1.0	0.76

Mean ± SD

Week 0 Denotes measurements taken in the week prior to the introduction of the diet and diet with exercise programme

†Significantly differen*t from baseline (p ≤ 0.05*; Wilcoxon)

‡ *Significantly different between groups (p ≤ 0.05*; Mann-Whitney)

Table 2 Mean energy intake before and during diet only and diet with exercise programmes

Nutrient	Diet (n=10)	Diet & Exercise (n=12 week 4; n=10 week 8)	P value
Food energy (kJ/d)			
Week 0	6276 ± 435 (6309 ± 874)*	6288 ± 347 (6271 ± 430)*	0.84
Week 4	4652 ± 326 (5347 ± 907)*	4799 ± 401 (6137 ± 259)*	0.18
Week 8	4833 ± 544 (5983 ± 368)*	4757 ± 456 (5472 ± 158)*	0.82
% of total energy intake as fat			
Week 0	24 ± 5	22 ± 3	0.64
Week 4	20 ± 3	21 ± 4	0.89
Week 8	22 ± 3	21 ± 3	0.69
% of total energy intake as carbohydrate			
Week 0	56 ± 7	56 ± 4	0.49
Week 4	57 ± 6	57 ± 7	0.62
Week 8	56 ± 4	55 ± 7	0.62
% of total energy intake as protein			
Week 0	20 ± 4	21 ± 4	0.37
Week 4	20 ± 4	20 ± 4	0.79
Week 8	20 ± 3	21 ± 5	0.52
PUFA/SFA ratio			
Week 0	0.57 ± 0.18	0.52 ± 0.14	0.53
Week 4	0.58 ± 0.19	0.46 ± 0.12	0.12
Week 8	0.70 ± 0.36	0.46 ± 0.13	0.18
Cholesterol (mg)			
Week 0	79 ± 46	82 ± 45	0.97
Week 4	77 ± 49	80 ± 46	0.97
Week 8	74 ± 44	83 ± 41	0.95

*Reported Mean Energy Intake by Males

Mann-*Whitney, statistical significance at* $p \leq 0.05$

Mean ± SD

Week 0 Denotes measurements taken in the week prior to the introduction of the diet and diet with exercise programme

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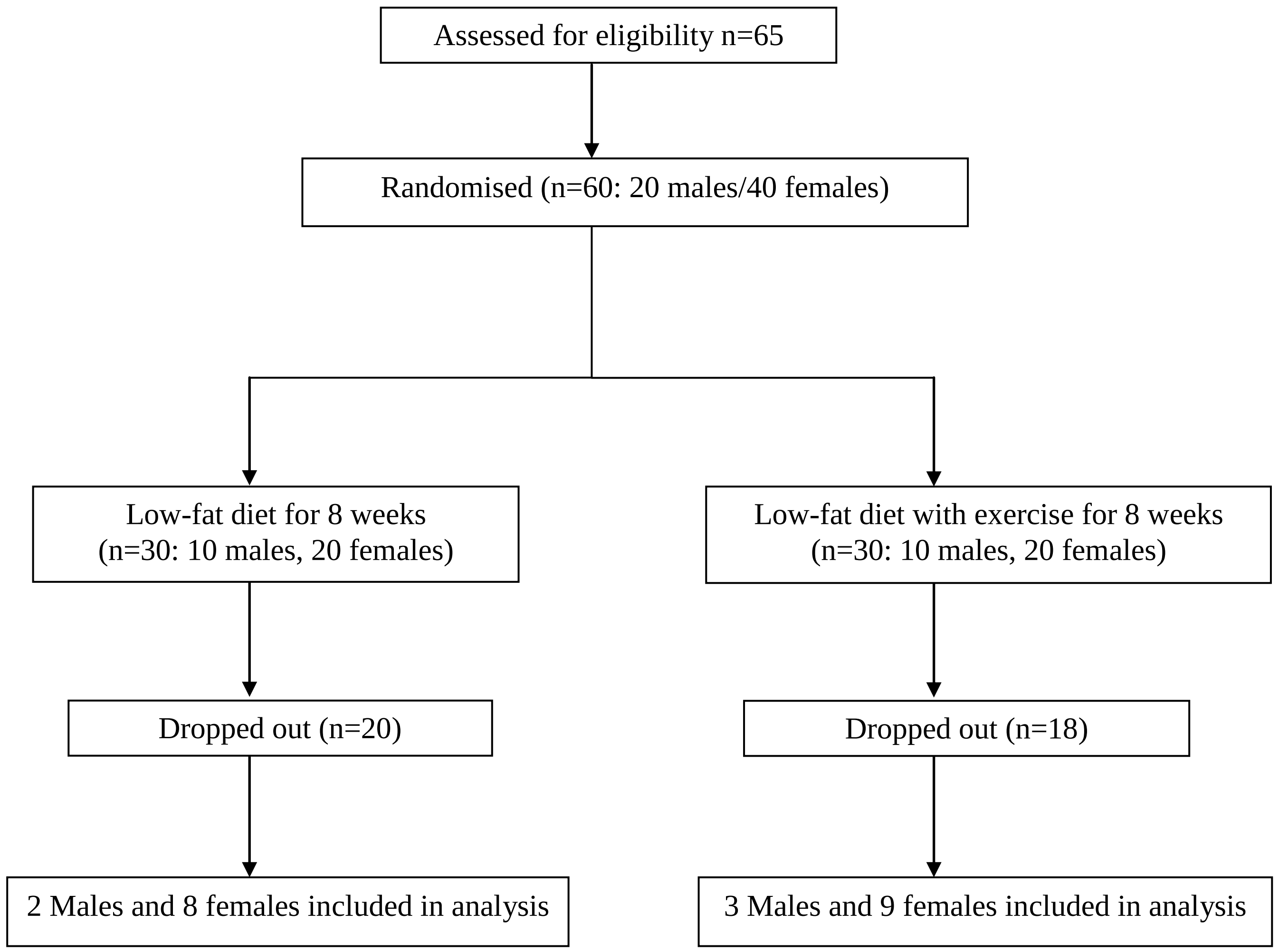

Figure 1. Flow chart of study design

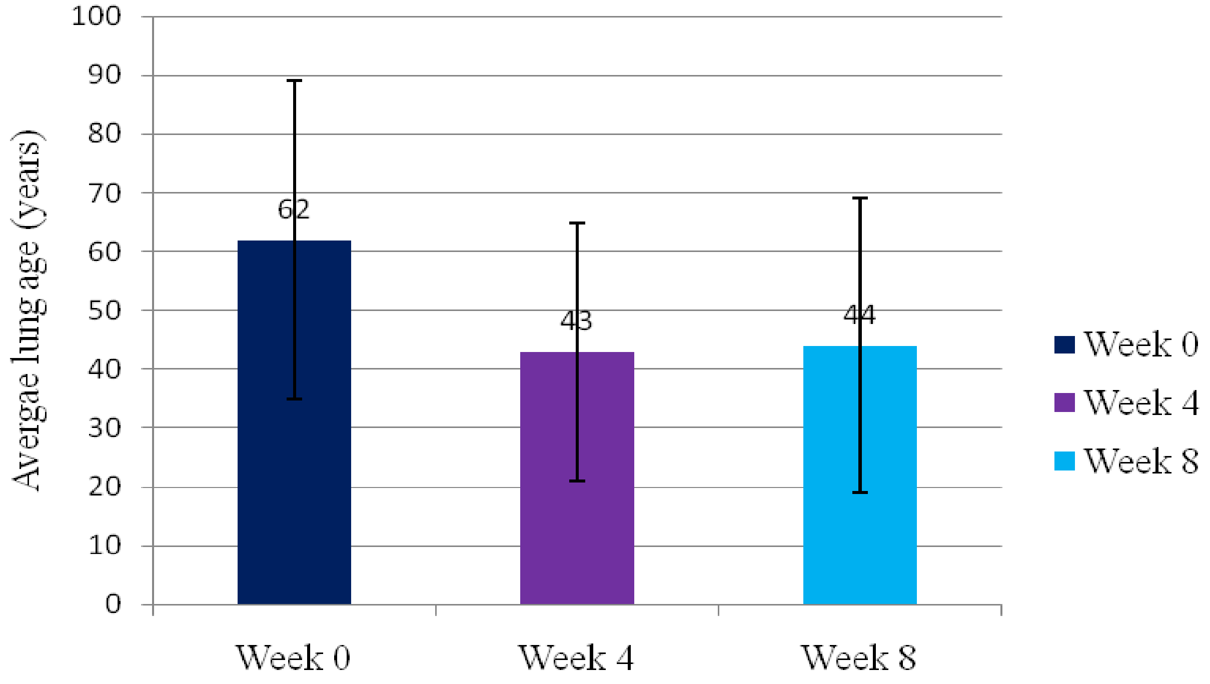

Figure 2. Average lung age of participants on the diet with exercise programme