COMPARISON OF THE EFFECTS OF HIGH-INTENSITY INTERVAL RUNNING, HIGH-INTENSITY INTERVAL CIRCUIT TRAINING AND STEADY-STATE RUNNING ON BODY COMPOSITION AND GLUCOSE TOLERANCE IN RECREATIONALLY ACTIVE ADULTS

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ABSTRACT

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Introduction. The measurement of body composition is important for several reasons, but nowadays when obesity and overweight are common problems all over the world even more attention should be given to body composition. Excess amount of fat is itself a risk for health, but it also predisposes to many diseases, one of which is diabetes. It has been shown that with regular physical activity and exercise the body composition and body's glucose regulation can be improved. In common activity guidelines the amount of traditional endurance and resistance training takes hours per week to perform to fill the recommendations. However, since it has been shown that one of the most common reasons for not participating in exercise is lack of time, therefore high-intensity interval training (HIIT) might be one option. HIIT takes less time to perform, since it consists of short, high-intensity work periods separated often by even shorter, lower intensity recovery periods. Altogether one HIIT session takes in average 30 minutes. In studies it has been shown that with HIIT type of training similar and even greater improvements have been gained in different study populations regarding body composition and glucose tolerance as with traditional endurance and resistance training. Therefore, the purpose of this study was to investigate and compare the effects of eight weeks of high-intensity interval running (HIRT), high-intensity interval circuit training (HICT) and steady-state endurance running (SSE) on body composition and glucose tolerance.

Methods. Subjects were recreationally active adults, with normal glucose tolerance, weight and body mass index (BMI). After medical evaluation and electrocardiograph (ECG) test they were randomly divided into three training groups. All subjects participated in pre and post measurements, which included body composition measurement with dual-energy x-ray absorptiometry (DXA), oral glucose tolerance test (OGTT), and for another thesis maximal oxygen consumption (VO_{2max}) test (with cycle ergometer) and measurement of excess post exercise oxygen consumption (EPOC). In between they performed three exercise sessions every week for eight weeks. The training consisted of 8–10 x 1 min submaximal running intervals separated with 30 s active recovery for HIRT, 8–10 exercises performed maximally as circuit training (one minute per exercise) separated with 30 s recovery between the movements for HICT and for SSE 40–60 minutes steady state running. In addition, the subjects filled out a food diary twice during the study period and the diaries were analyzed with NUTRI-FLOW -program.

Results. After the training period, the SSE group had a statistically significant decrease in weight (63.21 ± 5.51 vs. 62.49 ± 5.24 kg, p = 0.043) and BMI (22.63 ± 1.31 vs. 22.19 ± 1.21, p = 0.028). In DXA results, the only significant findings were a decrease in the fat-free percent of the SSE group (77.80 ± 9.93 vs.74.40 ± 9.82 kg, p = 0.028) and a decrease in fat mass of the arms in the HICT group (1.51 ± 0.88 vs. 1.47 ± 0.87 kg, p = 0.046). In OGTT the only significant findings were decreases in the HICT group in blood insulin concentration at 60 minute time point (400.29 ± 134.24 vs. 347.28 ± 133.69 mmol/l), p = 0.046) and in fasting insulin in the combined high-intensity interval training group (HIRT & HICT) (76.17 ± 26.73 vs. 51.20 ± 17.56 mmol/l, p = 0.034). There were no significant changes in the food diary results.

Discussion and conclusions. Based on the result it seemed that SSE was the most effecting training mode to gain decrease in weight. However, the subjects had a tendency to lose both, fat and fat-free mass, and the decrease in fat-free percent was significant, and no significant changes were observed in HIRT or HICT. This indicates that with more intense training the subjects in the HIIT groups were able to maintain their fat-free mass better. It also seemed that the HICT program was especially loading for the arms, since the fat mass decrease in arms was significant. In previous literature, it has been noted that site specific fat loss would not happen along with training, but the result of the HICT group in this study indicates the opposite. This aspect needs to be studied more in the future. The results of OGTT suggest that the high-intensity interval training was more effective regarding glucose tolerance. Only few statistically significant findings were made in this study and no significant differences between the groups were found. However, that can be seen as a positive result, since the benefit of moderate intensity, steady-state exercise is well recognized in previous literature, and the high-intensity interval training groups did not differ from SSE.

Key words: Body composition, glucose tolerance, steady-state training, high-intensity interval training

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1 INTRODUCTION

Nowadays, more attention should be paid on body composition, because in contemporary society obesity and excess amount of fat in body are common problems. There are many factors that have an effect on person's body composition and obesity, such as genes, environmental factors and nutritional habits. Obesity and overweight also predispose people to many diseases and health problems. (McArdle et al. 2015, 788 – 792.) According to the World Health Organization (WHO) among the top five leading global risk factors for mortality worldwide are high blood glucose, physical inactivity and overweight and obesity. WHO also states, that these factors also account for the increased risk of chronic diseases, like heart disease, diabetes and cancers. These problems concern both undeveloped and developed countries. (World Health Organization 2009, 9.) Moreover for example diabetes, according to research data, it seems that it will continue to be large and increasing global health burden. It is even probable that in the next decades the prevalence of diabetes still grows significantly. The increase in the prevalence of diabetes is strongly affected by fast development and changes in people's lifestyle. (Guariguata et al. 2014.)

In previous research, it has been seen that high-intensity interval training (HIIT) has positive effects on insulin sensitivity. Thus it might be useful in decreasing insulin resistance, which is also a major factor in the development of type-2 diabetes. (Klika & Jordan 2013.) Richards et al. (2010) showed that only eight minutes per week of HIIT (at intensity more than 100% of maximal oxygen consumption (VO_{2max})) was sufficient to induce positive changes in insulin resistance. It is noted that especially for many industrialized nations, it is a national health priority to increase people's participation in regular physical activity. Research shows, that two commonly mentioned barriers to physical activity participation among both men and women are lack of time and lack of facilities. (Trost et al. 2002.) All in all, HIIT might be one option to solve these problems.

HIIT consists short high-intensity periods with usually active recovery periods between (Gibala et al. 2012). The historical scientific background comes from the study by Karlsson et al. (1972) in which the researchers described various high-intensity short interval running exercises. Since that time there have been very exact classifications of the high-intensity and low intensity endurance exercises in sport training all over the world (e.g. Mujika 2012, Nummela 2012). HIIT applies very well inside maximal oxygen uptake exercises (Karlsson et al. 1972) and also in submaximal or maximal lactic speed endurance exercises (e.g. Nummela 2012). Using the term HIIT, these exercises have been studied more and marketing particularly well all over the world.

Because outside of sports lack of time has been noted to be the most frequent reason for not participating in exercise (Kimm et al. 2006; Stutts 2002), HIIT might be a useful exercising option for many people, because the time consumed is far less than in the traditional exercise recommendations. For example in Finland recommended weekly physical activity for sedentary adults consists of activities that promote bone health (jumping, resistance training etc.) 3 – 5 times per week 10 – 20 minutes at a time, as well as one hour lasting resistance training 2 – 3 times per week and also 3 – 5 times per week endurance exercise (such as running, swimming, cycling) from 30 minutes to 60 minutes at a time (UKK-institute 2014).

The American college of Sports Medicine (ACSM) have similar recommendations. According to their recommendations, resistance training should be performed separately from aerobic training typically on two or three non-consecutive days each week. The resistance training should consist of 8 to 12 repetitions and two to four sets for each major muscle group, and the intensity should be from 40% to 80% of a one-repetition max (RM) depending on the training level of the participant. To ensure proper recovery, two to three minutes of rest between the sets is recommended. Regarding aerobic training, the guideline is to perform 150 minutes/week exercise at moderate intensity (46% to 63% of maximal oxygen uptake (VO_{2max})) of duration from 30 to 60 minutes/session and/or 75 minutes/week with vigorous-intensity exercise (64% to 90% of VO_{2max}), which can be divided into separate session of duration from 20 to 60 minutes. (Klika & Jordan 2013.) So altogether the recommended training would take several hours in a week to perform. In addition to the time-saving point of HIIT, Bartlett et al. (2011) found that high-intensity interval running was perceived to be more enjoyable way of training than moderate-intensity continuous running.

HIIT can also be performed as circuit resistance training (high-intensity circuit training, HICT) using own body weight. The benefits of this kind of training are for example that one does not have to pay for any special equipment or facilities to do the training. To get the whole benefits by using only body weight as resistance, the training intensities must be sufficient. Commonly used movements are for example different squats, pus-ups and jumps (Klika & Jordan 2013.)

However, in the case of individuals who are obese or overweight, detrained, previously injured or elderly, it must be taken into account that HICT protocols demand elevated exercise intensity and this might cause some problems with the mentioned populations. (Klika & Jordan 2013.) High-intensity interval training can, though, be prescribed and performed also for them, but aerobic intervals could be a better option. Indication of this gives for example a study performed by Gosselin et al. (2012). They compared different types of interval training protocols by changing the work-to-rest ratios. They found that high-intensity training performed about 90% of VO_{2max} was not physiologically more strenuous than steady-state exercise performed at 70% of VO_{2max}. They noted that with the help of this work-to-rest ration manipulation, the subjects were able to do several minutes of high-intensity exercise without the feelings of discomfort or fatigue.

In particular, one submaximal HIIT protocol, consisting of 10 × 1 minute cycling intervals at an intensity from 85% – 90% of maximal heart rate (HR_{max}) and 1 minute of recovery in between intervals has been found to suit for a wide range of target groups (Gillen & Gibala 2014). The training protocol has been successfully used in studies investigating healthy individuals (e.g. Little et al. 2010) as well as populations with some health problems, such as overweight or obesity (Gillen et al. 2013), older sedentary individuals with possibly higher risk for cardiac metabolic disorders (Hood et al. 2011), and also diseased populations such as patients with coronary artery disease (CAD) (Currie et al. 2013) and type two diabetes (non-insulin dependent diabetes) (Little et. al 2011). Even though the intervals in this protocol are a bit longer duration, this type of HIIT protocol can be considered as time-efficient, because one training session takes altogether about 25-minutes, including warm-up, training (10 minutes of higher intensity exercise and recovery periods) and cool-down (Gillen & Gibala 2014).

Time and energy management is also important for elite athletes, and to sustain high performance, they need to pay attention to these matters. Athletes are constantly facing new demands, and that poses challenges to their ability to manage and even expand physical energy. The overwhelming loading might result in sustained fatigue and feeling of disengagement in different areas of life, which can result in performance failure eventually. That is why incorporating high-intensity interval training into athlete’s training programme might be beneficial. It saves time, but also might help in the energy management and so prevent fatigue. (Klika & Jordan 2013.)

Variation within the exercise in intensity and duration of work and rest intervals also alters the relative demands on different metabolic pathways within muscle cells. This also has an effect on the system of oxygen delivery to muscle cells. The following adaptations from the training that occur in the cellular- as well as systemic -level, are specific to the certain characteristics of the implemented training program. (Laursen & Jenkins 2002.) Even if the amount of work is similar, modifying the work-to-rest ratio has significant impact on the metabolic and heart rate responses of interval exercise (Gosselin et al. 2012).

Researchers have argued for a long time if an exercise program without dietary manipulation has an effect on weight loss and body composition, particularly for women. It has been noted that when diet is not controlled, the greatest weight loss results are gained with intensive or long duration training. On this basis it indicates that light to moderate intensity and short duration exercise programs may not be adequate to desirably change the body composition or to produce significant weight loss. (Bryner et al. 1997.) Bryner et al. (1997) noted already a fairly long time ago, that the intensity of the exercise has a great impact on the results. They compared high intensity training and low intensity training and saw a decrease in body fat in normal weight young women after high heart rate intensity training. Interestingly, there was no weight change in either group. This might indicate that high intensity training also helps to maintain the lean mass, or even increase it somewhat.

The purpose of this study was to investigate and compare the effects of three types of training protocols; high-intensity interval running, high-intensity interval circuit training and steady-state running with healthy recreationally active adults. In this study the aim was specifically look into changes in body composition and glucose tolerance.

2 HUMAN BODY COMPOSITION

The main parts of the human body are muscles, fat and bones. (McArdle et al. 2015, 738). There are also other components, such as water. Water makes up 40 – 70% of human body weight, depending on age, sex and body composition. Muscles contain a lot more water (65 – 75%) than adipose tissue (10%). (McArdle et al. 2015, 72.) There are altogether about 206 bones in human body (Enoka 2002, 211) and their percentage of the whole body weight is about 12 to 14 (McArdle et al. 2015, 740). The bones act as levers in power generation, but their purpose is also to protect organs and support the body (Enoka 2002, 211).

The adipose tissue (body's fat content) can be divided into two parts, the necessary fat and storage fat. The necessary fat is located in heart, lungs, liver, kidneys, other inner organs, muscles as well as in central nervous system and bone marrow. The necessary fat is needed in normal physiological function of the body. Among men, the average normal fat percentage is around 15%, from which 3% is necessary fat and the rest is storage fat located in the adipose tissue. Women can have even 12% of necessary fat. The normal fat percentage for women is hence around 20 – 25%. It must be taken into account that among women, the sex related necessary fat affects the total amount of fat. The sex related necessary fat can be from 5 to 9%. In relation to the whole bodyweight, women have more fat than men and the percentage of muscle tissue is on the contrary smaller than in men. (McArdle et al. 2015, 738 – 740.)

As earlier noted, sex has an essential role when considering body composition, and therefore the test results got from men and women in body composition measurements should not be compared with each other. Other aspects that should be considered when studying body composition are age and heritage, because these two also have a great effect on body composition. For example, the amount of adipose tissue in body depends on heritage as well as on the amount of exercise carried out and food consumed by the person. (McArdle et al. 2015, 788 – 792.)

Nowadays obesity and high amount of fat in body are increasing and common problems all over the world. This is why attention should be given even more than before to body composition and things related to it. Obesity and increased fat percentage can predispose to and be a cause of many health related problems and diseases. There are many different aspects that influence obesity, such as genes, environment and nutritional habits. (McArdle et al. 2015, 788 – 792.) With physical activity and exercise the body composition can be influenced significantly. However there are differences on the responses to exercise between individuals and not everyone response on the same way to the same training stimulus. For example differences between over-weight and normal weight persons as well as between men and women have been seen. (McArdle et al. 2015, 464, 823 – 824, 830)

2.1 Measurement of body composition

It is very important to measure and analyze body composition to get information of the proportion of fat and fat-free mass of both, healthy and unhealthy populations. (Dolezal et al. 2013). The straight forward body composition measurements can't be used for living, so there are many measurements in use that evaluate the body composition. (McArdle et al. 2015, 732). There are many benefits from accurate and reliable evaluation of human body composition, such as helping in the assessment of health-related physical fitness and weight management. In many studies it has been noted that excess body fat increases the risk for many diseases, such as coronary artery disease, different cancers, hypertension, depression, hypercholesterolemia and type-2 diabetes. Body composition is also related to successful performance of many physical activities and sport. (Mikat 2007.)

2.1.1 Division of the body composition evaluation methods

There are two main categories of body composition measurement systems, the field and the laboratory methods (Mikat 2007). The most common field methods are bioelectrical impedance analysis (BIA), near-infrared interance (NIR), skinfold thickness and anthropometric circumference measurements (Wagner & Heyward 1999). One also commonly used and very simple field evaluation method is the body mass index (BMI), in which the fatness of the person is evaluated by using the weight and height of the person (BMI = (length in meters)^2 ÷ weight in kilograms)). However, the BMI does not separate the different components of the body in any way, for what reason it does not apply for example the evaluation of body composition among athletes or children. (McArdle et al. 2015, 735 – 736.) Laboratory techniques include for example hydrodensitometry (underwater weighing), air-displacement pletysmography (POD BOD), isotope dilution and dual-energy x-ray absorptiometry (DXA) (Wagner & Heyward 1999). Also different radiographic tomography measurements are used (Mikat 2007). The laboratory techniques are generally used as reference methods in clinical and research settings (Wagner & Heyward 1999) and DXA is frequently considered as the golden standard (Mikat 2007). There are pros and cons in both, laboratory and field techniques used. Laboratory techniques are usually more valid and reliable, but the measuring is more expensive, time-consuming and in some cases may be difficult to administer and tolerate when compared to field techniques. However in field techniques the main problems are the accuracy and precision. (Mikat 2007.)

The body composition evaluation methods can be further divided into 2-, 3- or 4-compartment models based on how they divide the body composition. The basic 2-compartment models (such as underwater weighing, BIA, BOD POD) have been used in research for more than 50 years and they divide the body in two parts, fat and fat-free mass (FFM), that consists of all the remaining tissues. It is not easy to directly measure body fat mass, but the FFM can be determined and then the fat mass can be calculated indirectly from the difference between body weight and total FFM. The 3-compartment models (such as DXA) divide the body in three parts, fat mass and FFM, which is further divided into two parts: the water content and the remaining solids (protein and minerals). These models make use of the known densities of water, fat and body solids. By combining these different methods (e.g. under water weighing and DXA) a 4-compartment model can be produced. (Ellis 2000.) Few of the mentioned methods are briefly described below.

2.1.2 Commonly used methods in research

Hydrostatic weighing is based on the law of Archimed which says that density is mass divided by volume. Research data supports the validity of the hydrostatic weighing in estimating the fat content of the body. The density of the body is calculated from the amount of water that bodyweight displaces and after this, different formulas for calculating the body's fat percentage can be used. One formula, which is commonly used, is the Siri formula (body's fat percentage = (495 ÷ density of the body) – 450). There are also formulas that enable calculation of percentage fat mass and fat-free mass. The BOD POD is also based on measuring the volume, but it uses an air-chamber instead of water. The body density is determined by measuring the volume of an empty chamber and the volume of the chamber, when there is a person inside. The two measured volumes are then compared to each other. Skinfold thickness measurement is also one commonly used method. This is because it is very cheap and quick to perform. This method provides information about the amount and distribution of subcutaneous fat in the body. (McArdle et al. 2015, 742 – 749.) Bioelectrical impedance analysis (BIA) uses the total body water (the sum of extracellular and intracellular water) as an index for body composition and measures the electrical impedance of the body to determine the distribution of fat and fat-free mass. The impedance to the electric current (resistance) is related to the fat-free mass of the subject measured and the fat percentage is then derived from an equation: (total body mass – fat-free mass) ÷ total body mass. (Dolezal et al. 2013.)

One method that gives actual information about the thickness of different tissues (such as the cross-sectional area) is the ultrasound measurement. However, it is not suitable for measuring wide areas of the body. In ultrasound measurement electrical energy is transformed into high-frequency sound-waves through a probe. These sound-waves permeate through the skin surface and travel into the tissues underneath. The waves pass through fat tissue and travel to the level of muscle tissue and reflect from the fat-muscle interface (after reflection from the bone surface). They produce an echo, which returns to receiver placed on the probe. Depending on the model, either the rate of the sound-wave transport speed or from a picture, the tissue thickness can be determined. (McArdle et al. 2015, 755 – 756.) Accordingly, with ultrasound the thickness between fat as well as muscle and skin surface can be determined (Duz et al. 2009).

2.1.3 Dual-energy x-ray absorptiometry

In dual-energy x-ray absorptiometry, two low-energy x-ray beams, that have a different frequency, pass through the body. In different tissues, the diversion of these beams is different and based on that, the DXA can divide these tissues from each other. DXA-machine is also very suitable for measuring bone density. The advantages are, among other things, a small radiation doze, ease of the measurement (to the person measured as well as for the measurer) and also that the measuring is fast. (McArdle et al. 2015, 761.)

In the actual scanning, the measured subject is lying in supine position on the DXA scanning table, and with rectilinear scanning the body is divided into a series of pixels. The pixel division is based on the photon attenuation. This attenuation is measured with the two different energies. DXA gives an R value, which reflects the ratio of the attenuation of the two energies. As mentioned, the assumption in DXA measurement is that the body consists of three components – fat, bone mineral and fat-free (lean) soft tissue – and that these are separable by their different X-ray attenuation properties. However, in reality only the proportions of two components can be sorted out within any pixel. The photon flux is reduced much less in the soft tissue than in the bone mineral. This is because soft tissues consist mainly of water and organic compounds. Therefore the separation between pixels containing bone from those with no bone is relatively easy to do. With suitable calibration it is possible to divide fat and lean fractions from soft tissue in the areas where there is no bone. To produce total body fat and lean soft tissue estimates, the composition of the areas of soft tissue with no bone is extrapolated to the soft tissue overlying bone. (Plank 2005.)

Even though there are of course some disadvantages in DXA, as in any other body composition measurement methods used, it is still considered to be fairly accurate and reliable in estimating the body composition of different populations. It can be easily used to evaluate the body composition of people of all ages. Other advantages are the small radiation doze, which ranges from 0.04 to 0.86 mrem (rem = roentgen equivalent in man/mammal = 0.01 sievert), depending on the instrument used and the size of the subject. Also the reproducibility is good and with DXA, information about whole body as well as regional body composition and nutritional status can be obtained. (Lee & Gallagher 2008.)

2.2 Effects of traditional endurance and strength training on body composition

Traditionally the purpose of resistance training is to develop and increase the strength of muscles and their supporting parts. The strength of the muscle depends on the cross-sectional area of the muscle, the absolute power that can be produced by the muscles, structural factors, such as the angle of the muscle cells in relation to the tendon (pennation angle) and the relative power index from body compositional values (the mass of the body or lean body mass). (McArdle et al. 2015, 506.) It is well recognized in studies that high-resistance strength training induces substantial increases in muscle strength. This increase is associated with many neurobiological and morphological adaptations. The main morphological adaptations are increase in the cross-sectional area of the individual muscle fibers and so of the whole muscle. (Folland & Williams 2007.) So along with the strength training, the muscles grow, and therefore the whole body muscle mass increases.

When considering traditional endurance training, there have been seen differences on the responses depending on the form of the training (e.g. running, cycling, swimming). Besides the form of the training also other things influence on the response from endurance training. These things include the output level/starting level of the aerobic condition, the intensity, the frequency and the duration of the training sessions. On the point of view of body composition the general conception is that long-lasting and low-volume exercise oxidizes fat relatively more during the exercise. (McArdle et al. 2015, 27, 462 - 463, 477.) There have been shown differences between individuals and sexes. Hormone action explains partly the differences between men and women. Among women there have been seen weaker performances in endurance sports (as in time) compared to men, but after training the differences have decreased. It has also been noted that with resistance training both men and women can increase their power producing ability. However, the absolute power production doesn’t grow as high in women as with men, although there are no huge differences when the results are in proportion on body weight. (McArdle et al. 2015, 240 – 241, 507 – 509.)

When investigating the effects of training on body composition, it has been noted that especially the intensity of the training is in important part. It has been detected, that training performed with smaller intensity (45% of VO_{2max}) results in greater weight loss. But instead with greater intensity training (72% of VO_{2max}) it is possible to maintain the share of fat-free mass unchanged. With both, low and high intensity, it is possible to bring out notable and significant loss of fat tissue and also there has not been seen a significant differences between persons training on low or high intensity results regarding fat mass loss (figure 1). (Mougios et al. 2006.) Slentz et al. (2004) made a notion that in addition to the intensity also the amount of training has great impact on the changes gained from training regarding the body composition. They saw in their study, that training done in abundance and with great intensity has the most effect on body composition changes, reducing body weight and adipose tissue. The difference between groups training high or low amount in low intensity were not significant.

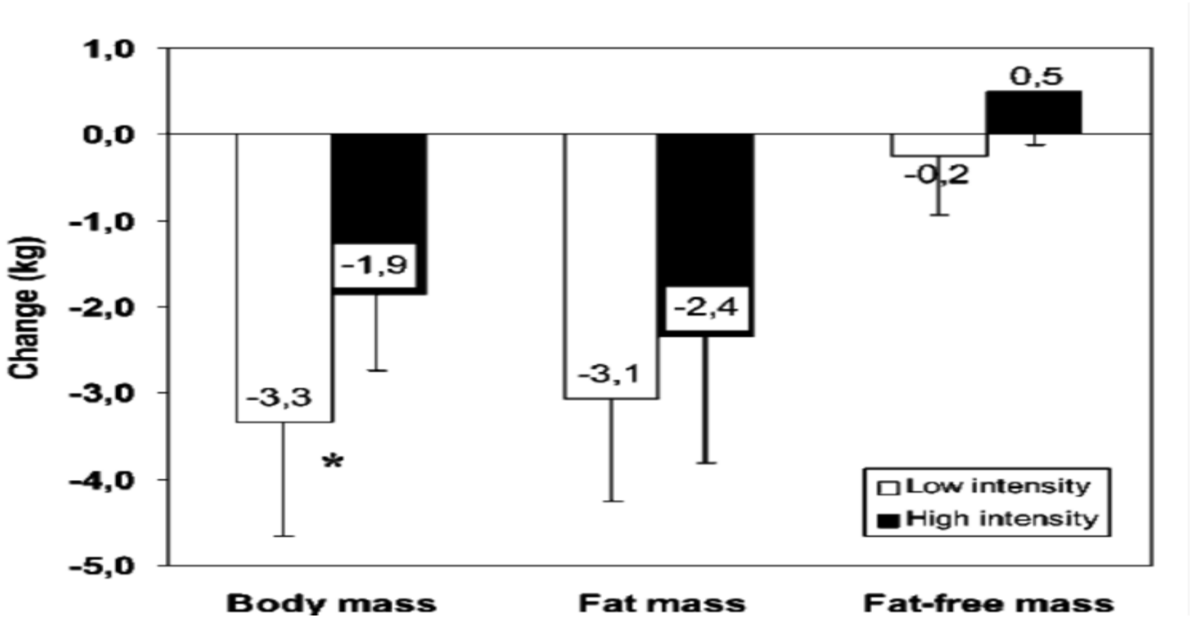


FIGURE 1. The effect of intensity of training on body composition changes. (Mougios et al. 2006).

In general, in previous literature it has been seen that via training of some specific body part the fat loss is not greater in that part, so site-specific fat reduction is not likely to happen. This is explained by hormone action, since the fatty acid mobilization is stimulated by physical activity via hormones and enzymes, which affect the fat depots in the whole body. (McArdle et al. 2015, 829 – 830.) The circulating hormones don't influence selectively on adipose tissue near the contracting muscles, but on all adipose tissue depots throughout the body (Stallknecht et al. 2007). The areas in the body that contain most fat (greatest fat concentration) and/or where the activity of the fat mobilizing enzymes is the greatest use the greatest share of this energy (McArdle et al. 2015, 829 – 830). For example Vispute et al. (2011) saw in their study that six weeks of abdominal exercise training alone did not result in any regional fat loss, or other body composition changes. However, there is some indication that site specific fat loss could be induced with exercise. Stallknecht et al. (2007) found, that at least spot specific lipolysis is possible. They saw higher blood flow and lipolysis in the subcutaneous adipose tissue of contracting muscle when compared to resting muscle. Though, they also note, that it is not possible to predict based on that, if the site specific exercise can induce spot reduction in fat depots. This is because between exercise sessions, the triaglycerol stores could be replenished. (Stallknecht et al. 2007.)

3 GLUCOSE METABOLISM

Almost all carbohydrates ingested in food are absorbed in the form of monosaccharides. Glucose is the most plentiful of the monosaccharides absorbed, accounting normally for more than 80 percent of carbohydrate calories absorbed. This is because glucose is the final digestion product of the starches, the most abundant carbohydrate food. The remaining 20 percent comes almost entirely from galactose (from milk) and fructose (from cane sugar). (Guyton & Hall 2000, 761.)

Glucose is transported from the intestinal membrane by co-transport with active transport of sodium. Sodium and glucose bind to the same transport protein and that will cause the transportation of both sodium and glucose to the interior of the cell. Other transport proteins and enzymes cause facilitated diffusion of the glucose through the cell's basolateral membrane into the paracellular space. (Guyton & Hall 2000, 761.) With the sodium co-transportation glucose can be absorbed against a concentration difference, but it works only in certain epithelial cells that are particularly adapted for active absorption of glucose. In other cell membranes, glucose is transported by facilitated diffusion from higher concentration to lower concentration by special binding properties of membrane glucose carrier protein. (Guyton & Hall 2000, 773.)

After glucose has been absorbed into the cell, it can be either used as energy immediately or stored in the form of glycogen, which is a large polymer of glucose. The formation of glycogen is called glycogenesis. It involves several chemical reactions and enzymes. The most important reactions are the conversion of glucose-6-phosphate to glucoe-1-phosphate and its formation to uridine diphosphate glucose, which is converted to glucose. (Guyton & Hall, 2000, 774.) The stages of aerobic energy production are briefly described below and shown in figure 2.

Glycolysis. The most important reaction cascade to form energy from glucose is called glycolysis. In glycolysis the glucose molecule is split to form two molecules of pyruvic acid. This involves 10 different chemical reactions, which are catalyzed by different enzymes. (Guyton & Hall 2000, 775.) Even though the formation involves so many reactions, only a small amount of the free energy in glucose molecule is released at most steps. And indeed, the total amount of energy as ATP released in these reactions is 2 moles for each mole of glucose utilized. The next step that follows is a two-step conversion of the pyruvic acid molecules into acetyl coenzyme-A molecules. No energy (ATP) is formed. (Guyton & Hall 2000, 775.)

Citric acid cycle. Next step is the citric acid cycle, in which through series of chemical reactions the acetyl potion of acetyl coenzyme-A is transformed into carbon dioxide and hydrogen atoms. Only two molecules of ATP are formed as a result of each molecule of glucose metabolized. (Guyton & Hall 2000, 776.)

Dehydrogenation. Altogether 24 hydrogen atoms are released for every molecule of glucose (4 during glycolysis, 4 during formation of acetyl coenzyme-A from pyruvic acid and 16 in citric acid cycle). These hydrogen atoms are released in pairs and dehydrogenaze enzyme acts as a catalyst. 20 hydrogen atoms instantly combine with nicotinamide adenine nucleotide (NAD^+) and the rest pass from dehydrogenase straight into the oxidative process. (Guyton & Hall 2000, 776.)

Oxidative phosphorylation. Most of the energy (almost 90%) is formed in the reactions called oxidative phosphorylation and electron transport chain. The hydrogen atoms released in the early stages of glucose degradation are used here. In the mitochondria, the hydrogen atoms are split into a hydrogen atom and an electron in reactions catalyzed by enzymes. The electrons are then used to form hydroxyl ions by combining dissolved oxygen of the fluids with water. After this, the hydroxyl and hydrogen ions combine and form water. During these oxidative reactions, large amounts of energy are released to form ATP. (Guyton & Hall 2000, 777.)

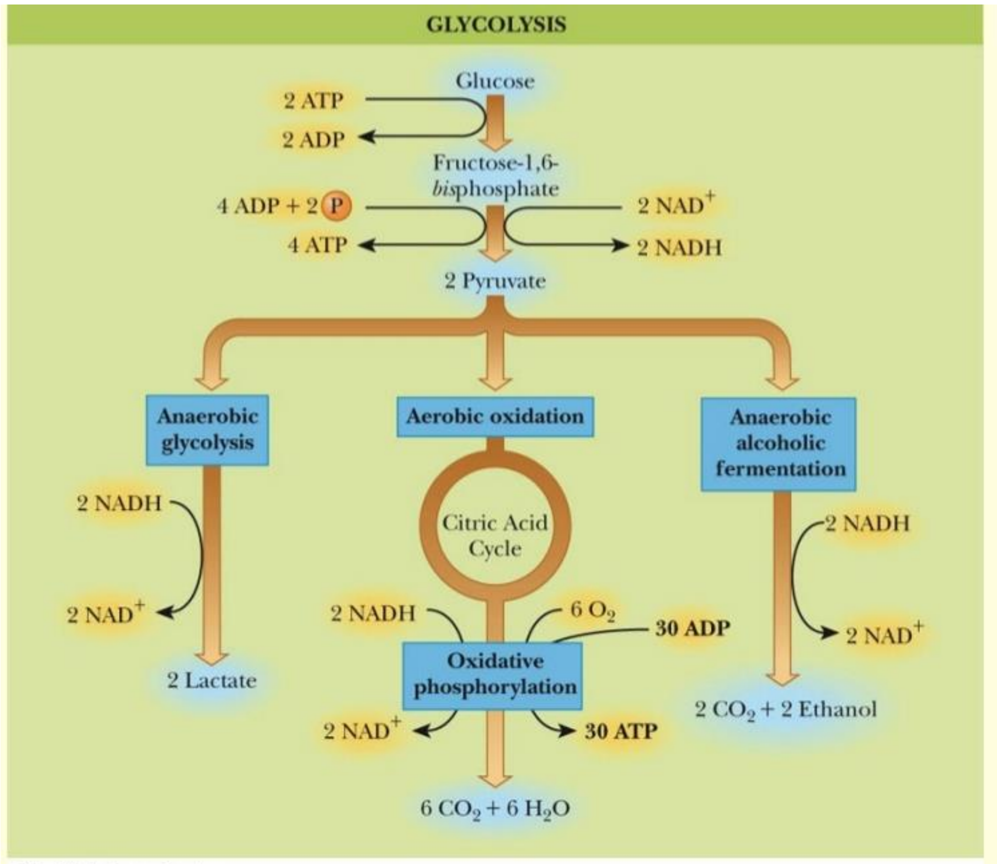


FIGURE 2. The main steps of glycolysis (Campbell & Farrell 2014, 494).

Anaerobic glycolysis. Under anaerobic conditions, the fermentation reaction of lactate and alcohol is stimulated. Lactate fermentation takes place in the exercising muscles, and the most important reaction is when pyruvate is degraded into lactate and NAD^+ is produced to keep the glycolysis going. Lactate dehydrogenase catalyzes this reaction. (Guyton & Hall 2000, 778.) This is also shown in figure 2.

Glycogenolysis. The stored glycogen can be broken down to re-form glucose. This reaction is called glycogenolysis. The re-forming of glucose from glycogen happens via phosphorylation reaction. The glucose molecules on the branches of glycogen polymer are split away by phosphorylation and this reaction is catalyzed by phosphorylaze enzyme. (Guyton & Hall 2000, 774.)

3.1 Glucose tolerance

After 3 to 4 hours fasting, a normal blood glucose concentration for human is about 90 mg/dl (5 mmol/l). If blood glucose regulation is normally functioning, the level rarely reaches values above 140 mg/dl (~7.8 mmol/l) even after a carbohydrate-rich meal. Two pancreatic hormones, insulin and glucagon, are directly related to the regulation of blood glucose concentration. (Guyton & Hall 2000, 780.) The pancreas has an important role in glucose metabolism and regulation of glucose concentration in blood (glucose tolerance) as it secretes these two important hormones, insulin and glucagon. Two main types of tissues in pancreas are the acini and the islets of Langerhans, from which the second one secretes insulin and glucagon into the blood. There are three main types of cells in the islet of Langerhans, the alpha, beta and delta cells. Alpha cells (25% of all the cells) secrete glucagon and beta cells (60% of all the cells) in turn insulin. (Gyuton & Hall 2000, 884.)

Insulin is a key hormone in energy abundance and also in storing the excess energy (Guyton & Hall 2000, 884). When the blood glucose concentration rises, insulin is quickly secreted from pancreas. That follows a rapid uptake, storage and use of glucose, in particular by the muscle, adipose tissue and liver. The resting muscle cells pass through only small amounts of glucose, except when stimulated by insulin. So in the resting state, the main energy source is fatty acids. However, during moderate to heavy exercise the muscles become more permeable to glucose without insulin and therefore use large amounts of glucose. (Guyton & Hall 2000, 886.) Glucagon has many opposite effect to insulin. It is secreted when the blood glucose concentration falls and its function is to raise the concentration back to normal. It causes the breakdown of liver glycogen (glycogenolysis) and also increases the formation of glucose from amino acids and glycerol portion of fat (gluconeogenesis) in the liver. These actions increase the availability of glucose to be used by the body. (Guyton & Hall 2000, 891 – 892.) For maintaining a normal blood glucose concentration, the secretion of both, insulin and glucagon, act as feedback control systems. The function of insulin feedback is more important under most normal conditions. (Guyton & Hall 2000, 893.)

It is very important to control the blood glucose concentration at all times for several reasons. Even though most tissues and organs in the body are able to use fats and proteins as energy sources when glucose is not available, there are few exceptions. For the brain, retina and germinal epithelium of the gonads, glucose is the only nutrient that can be used in order to meet their optimal energy requirements. (Guyton & Hall 2000, 893.)

The oral glucose tolerance test (OGTT) is commonly used to evaluate the glucose tolerance (body's ability to regulate blood glucose concentration) and also insulin action (Stumvoll et al. 2000). The OGTT is also used to test if person has pre-diabetes (impaired glucose tolerance) or diabetes. In the test one blood sample is taken after an overnight fast. Then the person to be tested drinks a high-glucose beverage and blood samples are taken at intervals for 2 to 3 hours. From the test results can be seen if the use of glucose over time in the body is normal when compared to standard values. If the glucose disposal is normal, the value should be less than 140 mg/dl (~7.8 mmol/l) after two hours. If the glucose tolerance is impaired the value ranges from 140 to 199 mg/dl (~7.8 – 11.1 mmol/l), and if it goes above that, it predicts diabetes. (American diabetes association 2014.)

3.2 Effects of traditional endurance and strength training on glucose tolerance

When taking into account that skeletal muscle is the main source for insulin stimulated glucose uptake, any kind of activity that has the purpose to improve glucose uptake in this tissue will also improve the glucose homeostasis of the whole body (Hawley & Lessard 2008). It is well known, that significant adaptations are brought about in skeletal muscle after regularly performed endurance exercise. Firstly, the mitochondrial content and respiratory capacity of the muscle fibers increase. It follows, that the homeostasis of the trained muscles is less disturbed at the same exercise intensity than the homeostasis of the untrained muscles. Secondly, the muscles start to rely more on fat oxidation as a source of energy production, which is caused by major metabolic changes. These include increase of the levels of enzymes needed in the fatty acid oxidation pathway. Correspondingly, the use of muscle glycogen and blood glucose is decreased. Also, less lactate is produced during exercise at a given intensity. These adaptations mean that it is possible to produce more energy from fatty acid oxidation also during strenuous exercise, and this slows the glycogen depletion. (Holloszy & Coyle 1984.)

A single exercise session can induce same kind of results in skeletal muscle glucose transport as insulin, which means that in the contracting muscle, the rate of glucose uptake increases. This process is regulated by the translocation of GLUT4 glucose transporter to plasma membrane and transverse tubules. The number of GLUT4 expression has also found to increase after exercise training in humans, which results in better responsiveness of muscle glucose uptake to insulin. And so, better control of the blood glucose levels (improved glucose tolerance). This is not only beneficial for healthy persons, but also for people who have problems with controlling glucose tolerance, so to those with non-insulin-dependent diabetes mellitus (type-2 diabetes) and insulin-dependent diabetes mellitus. The positive effects of exercise to these people might be explained with that exercise and insulin utilize different signaling pathways, but both lead to the activation of glucose transport. (Goodyear & Kahn 1998.) In addition, for persons with insulin resistance, there is an increased risk for lipid accumulation in skeletal muscles. Lipid buildup is a direct inhibitor to insulin action on glucose metabolism. This is because it alters the level of substrate competition, enzyme regulation, intracellular signaling and possibly gene transcription. In studies it has been well documented that aerobic endurance training improves glucose tolerance and insulin action in the muscles of a person with insulin resistance. The mechanisms are most likely related to improved muscle oxidative capacity, decreased lipid content, and improved lipid metabolism in the whole body level. All of these are induced by exercise. (Bruce & Hawley 2004.)

As already noted, in previous studies it has been well recognized that exercise training induces positive effect on insulin and glucose action. It has been seen to decrease muscle and hepatic insulin resistance and increase glucose disposal. These changes might occur even without reduction in body weight, and a number of mechanisms that are not associated with changes in body weight are found. These mechanisms include increased post receptor insulin signaling, increased glucose transporter and messenger RNA, increased activity of glycogen synthase and hexokinase, decreased release and increased clearance of FFAs, increased muscle glycogen delivery that is caused by increased muscle capillary density, and favoring changes in muscle fiber composition for glucose disposal. (Boule et al. 2001.) All in all it has been seen that endurance training has positive effects on glucose metabolism as it affects the muscle-structural factors as well as metabolism and enzyme action in the muscle.

In many studies it has been shown that muscle contraction is an independent stimulus for glucose intake. There are separate pathways through which insulin and muscle contraction stimulate glucose transport and their combined effects are additive. In previous studies it has been noted that after an exercise session the skeletal muscles are more persistent for glucose for prolonged period of time. The muscle glycogen stores can be super-compensated to a level that can be even twofold when compared to a fed sedentary state. This requires an adequate carbohydrate supplementation during the post-exercise recovery period. (Hawley & Lessard 2008.)

The encouragement for resistance training is justified, especially for individuals with problems in glucose metabolism. This is because the contraction of muscle increases the glucose uptake in skeletal muscle. Large muscle groups are active, usually for extended periods of time, during aerobic exercise training. However resistance training may provide as high or even higher recruitment of skeletal muscle mass in the same amount of time, when performed as whole body resistance training. Furthermore, an assumption is that resistance training and thereby increased skeletal muscle mass potentially provide an improved response to glucose load. However, this might be true only for individuals with abnormal glucose metabolism. In studies it has been noted that resistance training doesn't usually have effect on glucose tolerance or glycemic control unless the glucose tolerance is abnormal to begin with. (Braith & Stewart 2006.)

Physical activity clearly is beneficial for health and improves skeletal muscle metabolism. Especially these responses are clearly shown in disease states, such as type-2 diabetes. It has both acute and long term effects. The most important acute effect is the increased uptake of glucose by the muscles. Long term effects change the metabolic gene expressions of the genes that regulate the muscle fiber type, mitochondrial biogenesis and GLUT4 protein levels. (Röckl et al. 2008.) So it can be said that especially people with impaired glucose tolerance, the increased muscle mass via resistance training seems to provide improvement to glucose regulation, because the muscles can more efficiently take up and use the glucose and also as the amount of active muscle tissue grows the amount of glucose that can be taken into the muscles without insulin also grows.

4 HIGH-INTENSITY INTERVAL TRAINING

4.1 HIIT as a training method

High-intensity interval training (HIIT) consists of short high-intensity periods with usually active recovery periods between. HIIT studies have been implemented with supra-maximal (intensity › 100% of VO_{2max}) short work periods (~30 seconds) as well as with longer (30 seconds to 4 minutes), but lower intensity (~85 – 95% of VO_{2max}) work periods. In studies where supra-maximal HIIT is used the recovery periods have been about 4 minutes whereas with submaximal work periods the recovery periods have been from 30 seconds to 3 minutes. HIIT that consists of lower intensity but longer work periods is considered to be more suitable for larger population. (Gibala et al. 2012.) In many studies it has been noted that aerobic HIIT induces many physiologic changes in cardiovascular system as well as in muscles, which are beneficial to health (e.g. Gibala et al. 2006; Burgomaster et al. 2005; Rakobowchuk et al. 2008.) The changes in some parameters (such as muscle oxidative potential) have been even greater with HIIT than with traditional aerobic training (Burgomaster et al. 2005). HIIT has been shown to be beneficial for not only healthy population but also for populations with for example cardiovascular or metabolic -diseases (Munk et al. 2009; Wisloff et al. 2007; Hwang et al. 2011; Little et al. 2011).

High-intensity interval training can also be considered as a time efficient training model. For example in the study of Gibala et al. (2006), where they compared effects of sprint interval training and traditional endurance training, the time consumed to sprint interval training was only 2.5 hours a week , which was far less than the time consumed to traditional endurance training (10.5 hours/week). In this study they found that only six session of sprint interval training was efficient enough to induce improvements in muscle oxidative capacity, muscle buffering capacity and exercise performance. These improvements were similar with changes noted after same amount of traditional endurance training, even though the time consumed to sprint training was far less. Burgomaster et al. (2005) found same kind of results, also after only six sessions of sprint interval training. They noted that muscle oxidative potential increased and cycle ergometer endurance capacity was doubled in such short training period on recreationally active adults.

4.2 High-intensity circuit training

Most of the HIIT studies have been executed on a treadmill or with a cycle ergometer. However the training can also be done as resistance training either using weights or own body weight as a resistance. In these cases the training can be carried out as high-intensity circuit training (HICT). (Klika & Jordan 2013.) High-intensity interval circuit training that is done with high intensity and short recovery periods has been proven to increase the post exercise oxygen consumption and due to that resting energy expenditure more than traditional resistance training where the recovery periods have been longer (1 – 2 minutes). (Paoli et al. 2012; Paoli et al. 2013). HICT technique might be more efficient than endurance training alone or low-intensity circuit training in improving many variables, such as body composition, blood lactate and muscle strength (Paoli et al. 2010). Because basically no exercise equipment is necessary to perform HICT program and only a little time is needed to complete one exercise session, HICT programs that loads the whole body could make exercising at home easier and lower the barrier to start moving. This might increase the exercise participation and thus people's health. (McRae et al. 2012.)

McRae et al. 2012 studied the effects of very low-volume high-intensity interval circuit training on aerobic fitness and muscular performance in young, healthy recreationally active women. The training program lasted for four weeks and consisted of 8 x 20 s intervals separated by 10 s of rest four times per week. The exercise involved movement such as burpees, mountain climbers, jumping jacks, and squat, to load the whole body and big muscle groups. They also wanted to compare this type of training with traditional endurance training. For that they had another group who did endurance training 4 times per week for 30 minutes (85% of VO_{2peak}) also for 4 weeks.

McRae et al. (2012) found that the improvements in aerobic fitness (VO_{2peak}) were similar in HICT and endurance training groups. But only the HICT group improved their muscular endurance as well. They had higher scores in lower-body, upper-body, and core muscular endurance after the four weeks of training. So according to them, it seems that this type of HICT done as whole-body interval training adds the benefits got from traditional endurance training.

The typical improvements in skeletal muscle oxidative capacity due to high-intensity interval training are probably linked to a decrease in use of substrate level phosphorylation. This accounts decreased phosphocreatine (PCr) breakdown, glycogen turnover, and lactate accumulation, which in turn delays the development of muscle fatigue. (McRae et al. 2012.)

According to Klika and Jordan (2013) HICT can be time saving and efficient way to lose both excess body weight and as well as body fat. They note that when resistance training is included in the workout, it contributes significantly the amount of fat burned during a training session. Both aerobic and metabolic benefits can be gained when resistance training exercise is done using multiple large muscle groups and with very short resting periods between sets. Research shows that the metabolic responses can be present even up to 72 hours after an exercise bout done with high-intensity has been done. (Klika & Jordan 2013.)

Paoli et al. (2010) compared HICT with traditional endurance training and low-intensity circuit training. They found that HICT was the most effective in gaining changes in the body composition; the reduction in body weight, percentage of fat mass and waistline were the greatest. Also, after training period, the HICT group had greater improvements in the strength tests (6 RM horizontal leg press and underhand pulldowns) than the other groups. (Paoli et al. 2010.)

There might be even a greater impact on subcutaneous fat loss with HICT-style resistance training when compared to traditional steady-state sustained –effort aerobic training or traditional resistance training. This might be because both during and after HICT exercise it has been found that levels of cathecolamines and growth hormone in the blood are increased. (Klika & Jordan 2013; Murphy & Schwarzkoph 1992.) In HICT programs where shorter rest periods are used, the overall time spent on training is also shorter than in traditional strength training (Murphy & Schwarzkopf, 1992). This might attract people who want to spent minimal time on training but get maximal results (Klika & Jordan 2013). Klika and Jordan (2013) note that HICT seems to be an efficient way of training to help improve muscular fitness, VO_{2max} as well as to improve body composition (decrease body fat) and insulin sensitivity, and in that way to help people improve their health and also recover from stress via exercise that doesn't take too much time to perform.

4.3 Body responses to HIIT

HIIT has been found to be a potential option for a moderate intensity continuous training and it has produced significant health benefits. It has a positive effect even after a relatively short training period on central (cardiovascular) as well as peripheral (skeletal muscle) adaptations. (Gibala et al. 2012.) In regards to VO_{2max}, which is a well-recognized marker of the cardio-pulmonary health, HIIT seems to be very applicable and effective to increase it. When compared to traditional steady-state exercise programs, it has been noted that HIIT programs have produced similar and even greater increases in VO_{2max} values, even though the training volume is much lower. (Klika & Jordan 2013.)

Rakobowchuk et al. (2008) found that HIIT induces same kind of improvements in cardiovascular function as endurance training. In their study, either six weeks of HIIT or traditional endurance training induced the popliteal artery distensibility and endothelial function to the same extent in young, healthy men and women. It has also been noted that HIIT is not only beneficial for healthy populations, but also for those who have had some problems with their cardiovascular system (e.g. cardiovascular disease, heart failure, stent replacement etc.). Munk et al. (2009) found that after high-intensity interval training programme reduced in-stent restenosis in patients who had had angina and were treated with percutaneous coronary intervention, and also that endothelial function was improved and levels of hr-CRP (C-reactive protein) were reduced in these patients. Also Wisloff et al. (2007) found that HIIT program with a bit longer intervals (4 x 4 minutes at 90 to 95% of HR_{peak} with 3 minutes active recovery periods between) was suitable for patients with post infraction heart failure. The patients' benefit from the HIIT, because after it their aerobic capacity, endothelial function, left ventricle remodelling and also quality of life (measured by a questionnaire) were improved. These parameters were improved to a greater extent when compared to moderate continuous training. (Wisloff et al. 2007.)

In many studies the benefits of HIIT on increasing working capacity and endurance performance related factors, such as muscle oxidative capacity and maximal or peak oxygen consumption (VO_{2max}, VO_{2peak}) have been recognised (Gibala & McGee 2008). The main objective of HIIT is to load the physiological systems that are used in endurance-type exercise time after time beyond the limit that is truly needed during that specific endurance activity. It has been seen that HIIT can improve endurance performance more that continuous submaximal training alone in sedentary and recreationally active individuals. Partly this improvement happens, because the contribution of both aerobic and anaerobic energy production pathways, are up-regulated. That improves the energy status in the working muscles because more ATP is available. The most common response to a HIIT in untrained or recreationally active persons is an improved capacity for aerobic metabolism, favoring changes in the relation of fiber types in the muscle, improved muscle capillarisation and increased oxidative enzyme activity. (Laursen & Jenkins 2002.)

It has also been noted that HIIT has an influence on different hormone levels. Shing et al. (2013) noted a significant increase in the circulating adiponectin levels after a four-week training period and a large increase in the resting adiponectin levels. Adiponectin is a protein mainly secreted by adipose tissue. For example skeletal muscle and liver are its target tissues and it functions in the regulation of energy metabolism and insulin sensitivity. In studies it has also been shown to play a part in the activation of adenosine monophosphate-activated protein kinase (AMPK) in skeletal muscle. There are indications that increase in the activity of AMPK stimulates the increase in number and also oxidative capacity of muscle mitochondria. Increase in the activity of AMPK can also enhance the oxidation of fatty acids, by improving oxidative phosphorylation. This might be beneficial for endurance type exercise performance, because blood glucose and muscle glycogen would be spared. (Shing et al. 2013.)

In studies where comparison between high-intensity interval training and traditional endurance training has been done, it has been noted that the effects are similar (for example Burgomaster et al. 2008; Gibala et al. 2006). Burgomaster et al. (2008) showed that with low volume sprint interval training it is possible to gain similar cardiorespiratory and metabolic adaptations as with traditional endurance exercise. In their study the VO_{2peak} and peak power output increased in both training groups, with no difference between groups. But only in the interval group the mean power output was increased. They also saw similar increases in many enzymes (mitochondrial markers) linked to skeletal muscle carbohydrate and lipid oxidation, which suggest that also high-intensity interval training is efficient to improve muscle oxidative capacity. (Burgomaster et al. 2008.)

Gibala et al. (2006) got same kind of results from their study as Burgomaster et al. (2008). Gibala et al. (2006) had physically active males as participant in their study. They found similar increases in muscle oxidative capacity, and training-induced increases in muscle buffering capacity and glycogen content. Short term, low-volume sprint interval and high-volume endurance training induced similar improvements in muscle oxidative capacity, muscle buffering capacity and also exercise performance (Gibala et al. 2006).

Nybo et al. (2010) compared the effects of intense interval running, prolonged running and strength training in untrained men in their study. They saw better improvement of cardiorespiratory fitness in the interval running group compared to the other groups. The increase in VO_{2max} was almost twofold higher in the interval group compared to the moderate intensity prolonged running group. Also, they saw similar improvements in the glucose tolerance test after the training in interval and prolonged running groups. Regarding body composition, the moderate intensity prolonged running was more efficient to lower the fat percentage, and the changes in interval group were not as great. However, in the interval group the total body mass remained unchanged. This might infer that the with interval training the participants were able to sustain their lean mass. However, when compared with the strength training group, whose total body mass increased, the interval training had no significant impact on muscle mass or markers of skeletal health. (Nybo et al. 2010.)

5 HIIT AND BODY COMPOSITION

There is some discrepancy in the results from researches concerning changes in body composition as a result of HIIT. In some studies there have not been seen any changes in body composition (e.g. Astorino et al. 2013; Astorino et al. 2012; Smith et al. 2009), but in other studies the changes have been very clear and significant (e.g. Gremeaux et al. 2012; Shing et al. 2013; Trapp et al. 2008). Shing et al. (2013) noticed statistically significant decrease in the body fat percentage after four weeks of HIIT. According to Trapp et al. (2008) 15 weeks of HIIT had more effect on body composition than training at a steady speed. Gremeaux et al. (2012) also saw positive changes in body composition after a prolonged period of HIIT. The duration of the training period might have an impact on the fact that not all studies show the positive effects of HIIT on body composition (Gremeaux et al. 2012).

Whyte et al. (2010) saw changes in body composition, measured as waist and hip circumference, which both significantly decreased after only two weeks of HIIT. Although, it must be taken into account, that the participants were overweight or obese sedentary men. This probably had a great effect on the results. But this just proves in a way that HIIT might be a great option for regular weight losing training modes used. The results from a study conducted by Gremeaux et al. (2012) also refer to that. They investigated also overweight people and had a long-term intervention (total nine months), which included diet counselling, high-intensity intermittent exercise (HIIE) training and resistance training (circuit training). After the intervention all anthropometric characteristics were significantly decreased, excluding muscle mass which did not differ from baseline values. Based on their results, they suggested that combined HIIE and resistance training with controlled diet might be an optimal method for preserving muscle mass while promoting loss of adiposity. (Gremeaux et al. 2012.)

Tremblay et al. (1994) found that long-term HIIT produced significant reduction in the body fat (measured as skinfold thickness) in young men and women. They compared interval training and steady-state training, and even though the estimated total energy cost in the interval training program was less than in the steady-state program (about half of that), only the HIIT produced changes in body composition. And they counted that for a given level of energy expenditure, a greater loss of subcutaneous fat is achieved with HIIT than with moderate intensity training.

Trapp et al. (2008) studied normal weight young women and saw also positive changes in body composition after 15 weeks of HIIT. They also compared interval training, steady-state training and control group (no training). The total body mass and fat mass decreased significantly in high-intensity intermittent exercise group compared to the other two groups as shown in figure 3. They also noticed a trend in the fat loss from legs in favor for the HIIT group, who tended to lose more fat from legs when compared to the other groups. HIIT caused a significant decrease in central abdominal fat and when compared to steady state group, the HIIT group had a significant increase in trunk lean tissue. Other lean tissue changes were not significant, but in the legs the trend was that HIIT group gained and the two other groups lost leg lean mass as a result of the training. All in all it seemed that for young, healthy women the HIIT was more efficient way to bring about positive changes in the body composition. The results indicate that HIIT loaded more the muscles of trunk and legs compared to steady state training. (Trapp et al. 2008.)

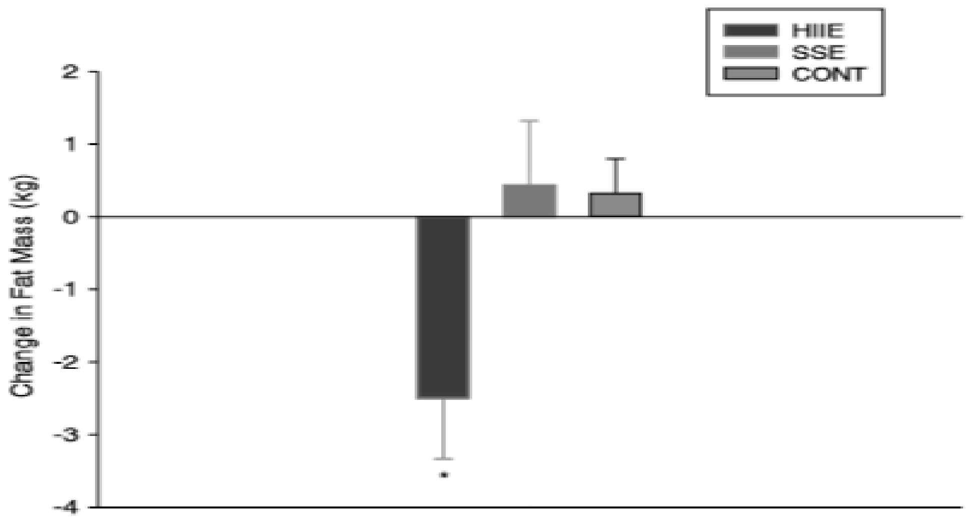


FIGURE 3. Change in fat mass after 15 weeks of high-intensity interval training, steady-state training or no training period. HIIE; high-intensity interval exercise, SSE; steady-state exercise, CONT; control group with no training. (Trapp et al. 2008).

Interestingly, in the study of Trapp et al. (2008) there was no difference in the total estimated energy expenditure of the two training groups during the 15-week training period, even though the time commitment in the HIIT (20 min x 3/week) was far less that in the steady-state training (40 min x 3/week). On the other hand, the training HR significantly differed between the two training groups, being higher in the HIIT group. They also noted that, there were responders and non-responders in the HIIT group considering fat loss. The ones who were leanest also lost less fat mass and had significantly lower initial fat mass than the other women. They noted a moderate correlation between fat loss and initial adiposity levels, which also pointed out that subjects with lower initial fat levels tended to lose less fat and vice versa.

Shing et al. (2013) saw a significant decrease in body fat percentage after only four weeks of HIIT (figure 4) even though their subjects were in fairly good condition to begin with (state representative rowers). So it is possible to get changes in body composition even in fairly short training period also with this type of training. They also compared the interval training with traditional endurance training and saw that only the interval training caused significant changes in the body composition.

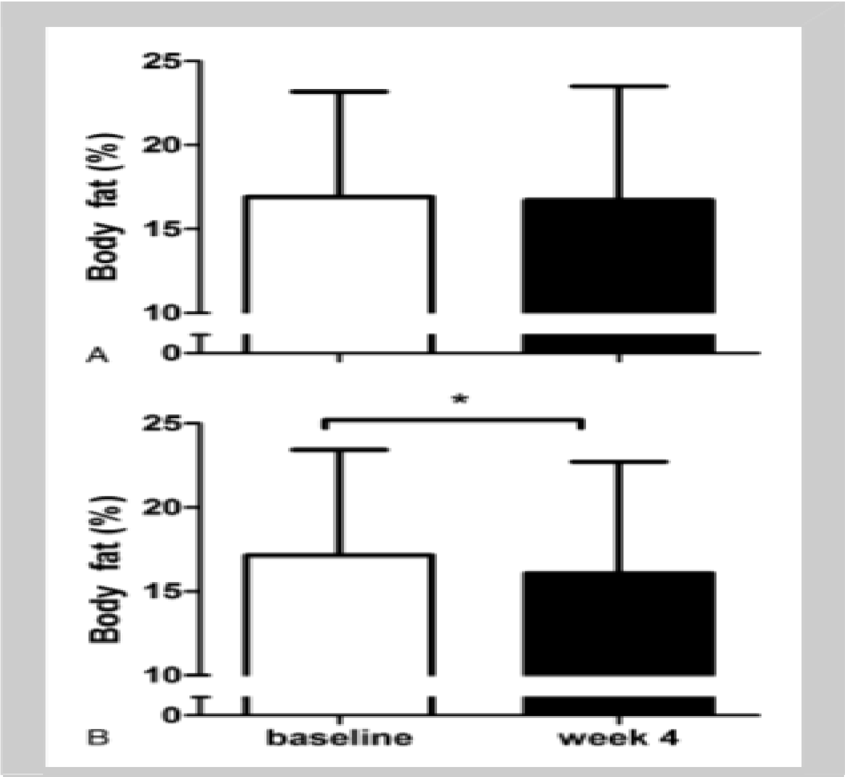


FIGURE 4. The changes in body fat percentage after four weeks of traditional endurance training (A) or high-intensity interval training (B) (modified Shing et al. 2013).

6 HIIT AND GLUCOSE TOLERANCE

The metabolic adaptations attached to traditional aerobic training correlate with increased insulin action and glycemic control. In previous studies it has been noted that these changes appear to be independent of changes in body composition and there is also some evidence that with increased training intensities the increase in insulin sensitivity might be even greater. Because high-intensity interval training reduces muscle glycogen stores, it is reasonable to make assumptions that it will have positive effect on insulin action. The current physical activity recommendations to improve glycemic control include several hours of aerobic and resistance training at a medium or hard intensity. However there is evidence that many people don’t follow these recommendations due to a lack of time, motivation or commitment. The asset in HIIT compared to traditional aerobic training is for example that HIIT is much less time consuming. (Babraj et al. 2009).

Babraj et al. (2009) discovered that for sedentary young men even a short, two weeks long, few minutes at a time lasting HIIT period is sufficient to produce significant improvements in insulin action and glucose homeostasis. Also in other studies there have been seen the benefits of the HIIT to the glucose regulation and carbohydrate metabolism (Perry et al. 2008; Little et al. 2011; Hood et al. 2011). Perry et al. (2008) reported that two weeks of HIIT had a positive influence on the activity of enzymes influencing carbohydrate metabolism (e.g. pyruvate dehydrogenase (PDH)) as well as on the content of proteins participating in glucose metabolism. In their study the amount of GLUT4 protein, which participates on glucose transport, increased for 21%. Also in the study of Hood et al. (2011) the total GLUT4 protein content increased significantly (by 260%) after two weeks of HIIT (figure 5). In this study the training was low-volume, constant load HIIT and the training was performed in submaximal intensity. Notwithstanding the training improved insulin sensitivity and glucose transport capacity of sedentary, healthy middle-aged adults. (Hood et al. 2011.)

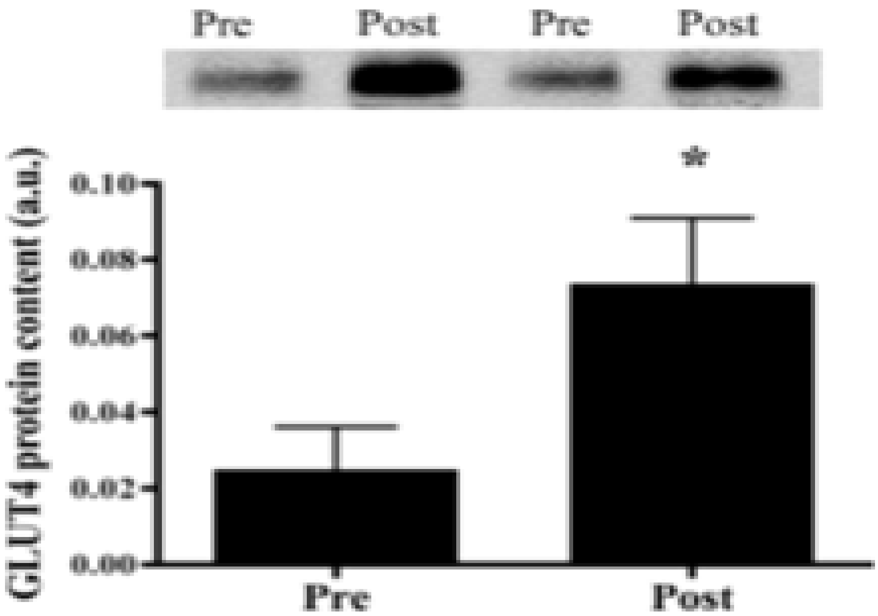


FIGURE 5. GLUT4 -protein content changes after 2 weeks of HIIT (Hood et al. 2011).

It has also been shown, that only a short period of sprint interval training can have a positive effect on resting muscle glycogen content. Only six sessions of sprint interval training has been found to increase the muscle glycogen content in rest to a magnitude comparable to what gas been seen after five to seven sessions of traditional endurance exercise training. (Burgomaster et al. 2005.)

HIIT has been shown to be beneficial also for diseased population and people with higher risk to develop cardiovascular or metabolic diseases. Little et al. (2011) investigated how two weeks of HIIT effects on glucose metabolism on patients with type-2 diabetes, and found that interval training reduces hyperglycemia. As shown in figure 6, the average blood glucose concentration and area under the glucose curve after training were significantly lower than before training. This implies that short-term, low-volume HIIT improved glycemic control, particularly glycemic excursions after meals. Whyte et al. (2010) noted that HIIT might be beneficial for overweight or obese men. Although they did not notice any differences in glucose action before and after training, two weeks of interval training improved their insulin sensitivity significantly compared to baseline.

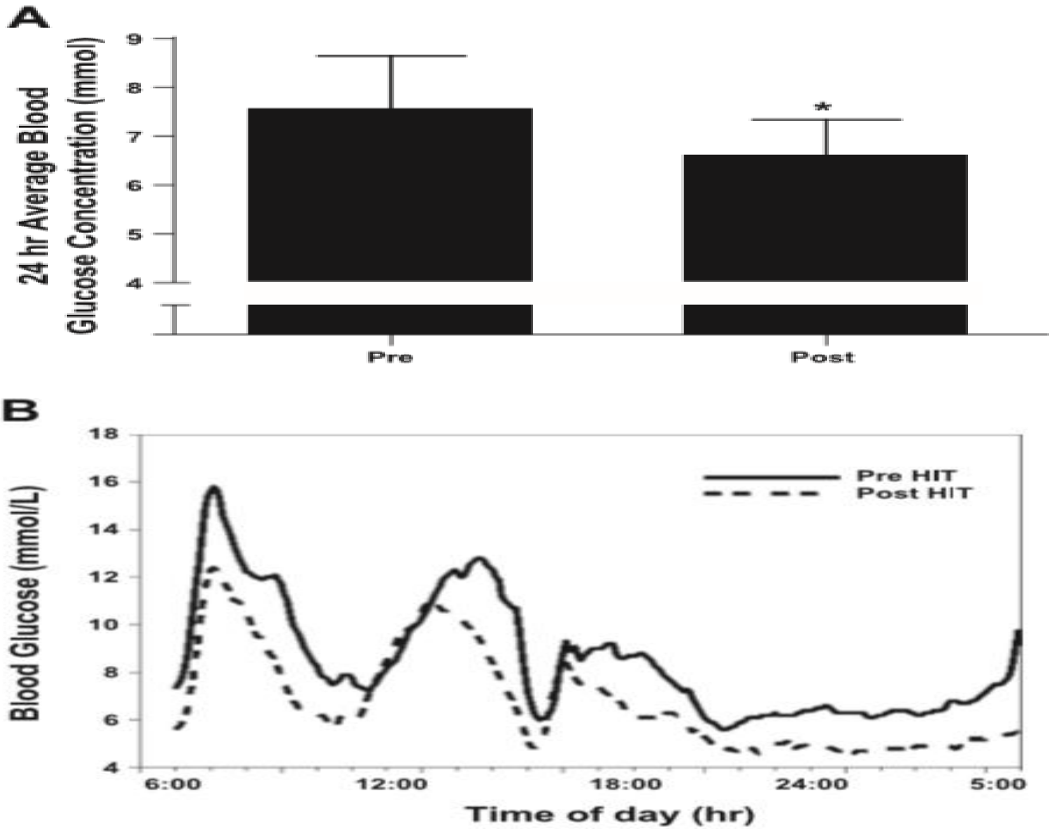


FIGURE 6. Effects of two weeks of HIT training on average blood glucose concentration (A) and blood glucose changes during a day (B) (modified Little et al. 2011).

In the study of Trapp et al. (2008) no changes were seen in the fasting glucose levels. But what they found was that 15 weeks of high-intensity intermittent exercise (HIIE) or steady-state exercise decreases fasting insulin of young, healthy women with average body composition. The decrease in HIIE group was 31% and in steady state training group 9%. However, only in the HIIE group the decrease significantly differed from the control group, who did no prescribed exercise during the 15 week study period.

7 PURPOSE OF THE STUDY

The purpose of the study was to investigate the effects of eight weeks of submaximal high-intensity interval running (HIRT) and (maximal) high-intensity interval circuit training (HICT) on body composition and glucose tolerance in recreationally active adults, and also to compare these two with steady state endurance running.

7. 1 Study questions and hypotheses

For this study the main study questions were:

1. How do HIRT, HICT and SSE affect on the body composition of the subjects?
2. Are there differences between the three training methods regarding effects on body composition?
3. How do HIRT, HICT and SSE influence glucose tolerance?
4. Are there differences in the effects on the glucose tolerance between the training methods?

Hypotheses based on the previous literature:

Hypothesis 1: HIRT reduces the fat content of the body and possibly alters the lean mass (muscle mass) also, by increasing it.

Hypothesis 2: HICT increases the lean mass (muscle mass) and decreases the fat mass.

Hypothesis 3: SSE has positive effects on body composition, especially on the fat content of the body. SSE reduces the fat mass.

Hypothesis 4: Previous literature where straight comparison between high-intensity interval running and resistance (circuit) training would have been done doesn’t exist. But based on the literature of aerobic training and resistance training it might be possible that HIRT has more effect on the fat content of the body, whereas HICT might alter the lean body mass more. When compared to steady-state running, the changes in body composition in HIRT may be similar, but possibly bigger, because the intensity of the training is higher. HICT possibly alters the lean body mass more than steady-state training.

Hypothesis 5: High-intensity interval training has been seen to have a positive effect on glucose tolerance. Both HIRT and HICT have the potential increase the sensitivity of the muscles to glucose.

Hypothesis 6: HIRT and HICT (interval training) might have even greater positive effect on glucose tolerance than steady-state training.

8 METHODS

8.1 Subjects

Twenty-four recreationally active volunteers served as subjects in the study. The age of the subjects ranged from 21 to 39 years. They had different backgrounds concerning exercise and training, but none of them was sedentary or professional athlete. There were 20 women and 4 men at the beginning of the study, but five women dropped out during the study because of various reasons, such as change in medical status or injury. We recruited the subject via informal letters that they received through e-mail or saw at info tabloids at University area. Before the beginning of the study we arranged an info lecture about the study to the subjects.

8.2 Study design

The study was approved by the Ethical Committee of the Central Hospital of Jyväskylä. At first all the subjects filled up a health questionnaire (appendix 1) and had an ECG-measurement and doctors evaluation done. After that, few possible subjects dropped out. All the remaining subjects were randomly divided into one of the three training groups; high-intensity interval running group (HIRT), high-intensity interval circuit training group (HICT) or steady-state running group (SSE). All subjects went through pre-measurements that included body composition measurement with DXA, oral glucose tolerance test. Also the measurement of VO_{2max}, and measurement of excess post exercise oxygen consumption (EPOC) were done, but the results were used in another master's thesis work. The first training sessions were supervised. We wanted to make sure that the subjects in the HICT group knew how to perform all the movements included in their training. Before the first actual training session, to the running groups the speed of the running session (SSE) or running intervals and rest periods (HIRT) were defined individually.

After the first, supervised training session the subjects did the training on their own for the 8 week training period. All groups did 3 training sessions per week and the training was planned to be progressive. So altogether, every group did 24 training sessions during the study. In the HIRT group the subjects performed the first 8 trainings with 8 running intervals, the next 8 trainings with 9 and the last 8 trainings with 10 intervals. HICT group had at first 8 movements to perform, later 9 and at the end 10. The control group ran at first for 40 minutes, later 50 minutes and at the end of the training period the time increased to 60 minutes. Both interval groups did one minute intervals with 30 second rest periods in between. At the middle of the training period the running speeds were redefined for the running groups' subjects (HIRT and SSE). The running groups did the training mainly on treadmill. After the training period the subjects went through post-measurements, which included all the same measurements as the pre-measurements.

In addition the subjects filled out a food diary (appendix 2) twice during the experimental period. The first diary was filled out at the beginning of the study (during the first two weeks of the study) and the second at the middle of the study. The idea was that from the first diary it was possible to see how the subjects normally ate, and give instructions to healthy, normal diet based on Finnish nutritional recommendations if needed. The aim was to make sure that all of the subjects would be eating similarly. The second diary was made to check if the eating pattern had stayed the same. The study design is shown in figure 7.

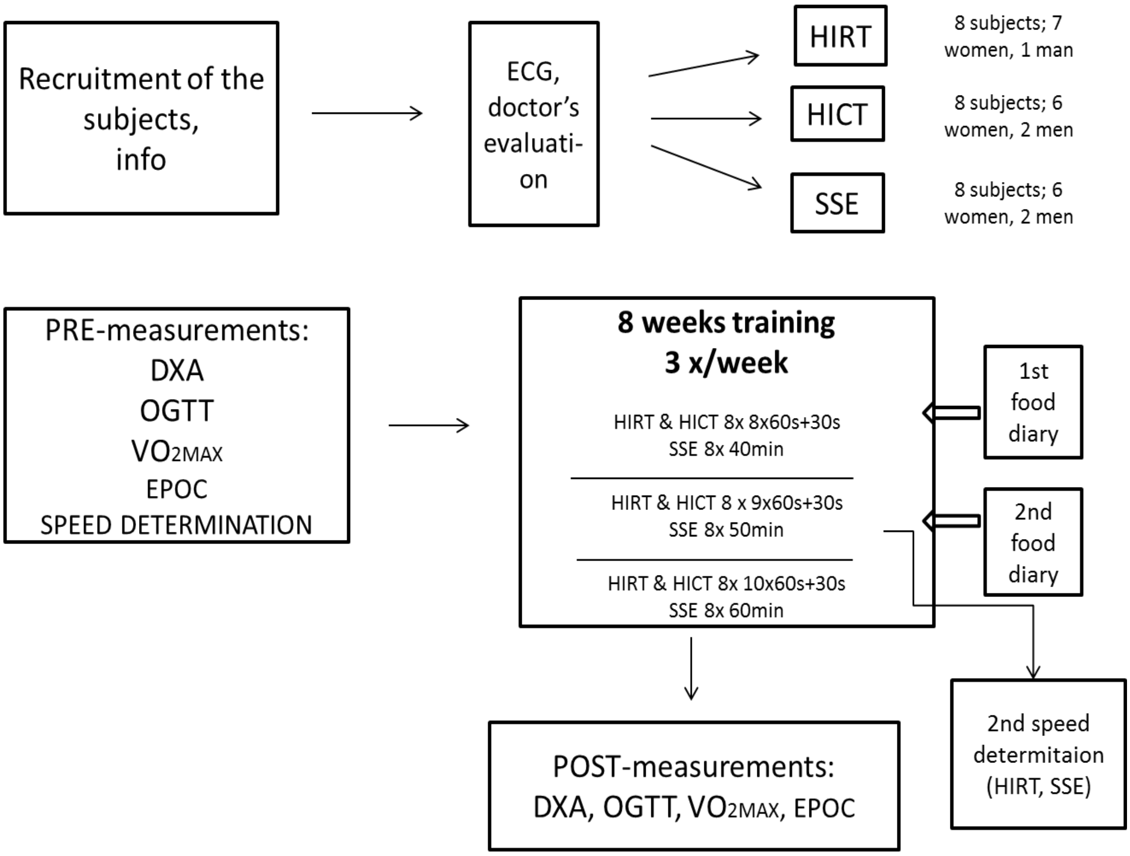


FIGURE 7. Study design. PRE; before training, POST; after training, ECG; electrocardiography, DXA; dual energy x-ray absorptiometry, OGTT; oral glucose tolerance test, VO_{2max}: maximal oxygen consumption measurement, EPOC; excess post exercise oxygen consumption, HIRT; high-intensity running training, HICT; high-intensity circuit training, SSE; steady-state training.

8.3 Training

As mentioned earlier, every group did the training 3 times per week for eight consecutive weeks. The single training sessions were divided at least one rest day in between. The training was planned to be progressive, so that interval groups did 8 training sessions with eight intervals (HIRT) or 8 movements (HICT) or ran for 40 minutes (SSE). For the next 8 training sessions the amount of intervals or movements was increased to 9 and the running time in SSE to 50 minutes. The last 8 training sessions were performed with 10 intervals or movements in the HIRT and HICT groups or 60 minutes of running in the SSE group. Below is more detailed description of the training in every group.

HIRT-group. At the beginning of every training session there was 5 minutes self-paced warm up. Then 8 – 10 times 1 minute intervals at the intensity of 85 – 95% of VO_{2max} were performed. These intervals were divided by 30 seconds active recovery periods at intensity of 40 – 60% of VO_{2max}. The VO_{2max} values were evaluated from the heart rates based on the VO_{2max} test. The training sessions were done by running, mainly on the treadmill. After performing the needed amount of intervals, a five minutes cool down (self-paced) was included at the end of every training session.

HICT-group. Before starting the training a five minutes warm up took place. Every subject was allowed to do it as they wished (e.g. by running, cycling or performing jumping jacks etc.). Then 8 – 10 times one minute exercise was performed, which included 8 – 10 different movements. Every movement was done for one minute. The instruction and goal was to perform as many repetitions as possible in the one minute time. In between the movements there was 30 seconds recovery period. As a resistance in the training was each subjects own body weight.

The movements included in the training program were a jumping jack, push-up with a jumping jack, burbee, spider push-up, jumping lounge, rotating plank, skating jump, mountain climber, long jump from a spot and squat. This was also the order in which the movements were performed.

SSE-group. The training consisted of steady-state endurance running (or walking in some cases) mainly on the treadmill. The duration of the training session was increased from 40 – 60 minutes during the study period. The intensity of the training was 65 – 75% VO_{2max}, which was evaluated based on heart rates from the VO_{2max} test.

8.4 Data collection and analysis

ECG and blood pressure. The ECG-measurement done at the beginning of the study was performed with CardioSoft –program (GE Medical systems, information technologies). The subjects lay down at the examination table with their upper body and ankles uncovered. 10-

electrode standard placement was used. Six electrodes were placed on the chest and one in each wrist on the palmar side and one in each ankle. After the placement of electrodes, the measured the blood pressure was measured with automatic measuring device (OMRON). Then the strings were attached to the electrodes and the subject was instructed to lie down as still as possible, not to tone their muscles and to keep their breathing as normal and steady as possible for the time of the measuring.

DXA. The body composition was measured twice using DXA (GE Lunar Prodigy Advance). The subjects came in to the measurement in the morning after a night fast between 7.30 and 9.00 am. Before every measurement the subjects were asked the necessary questions; if they were pregnant (women), if they had had any large x-ray measurements lately and if they had flown long, between the contents flights. Also all possible medal items were removed before measuring (piercings, pins, glasses etc.).

Glucose tolerance. The oral glucose tolerance test was made always at the same time with DXA if possible. The subjects were taken three venous blood samples. The first was taken before drinking the high-glucose beverage (Glucose Pro, 75 g glucose/250 ml), the second was taken 60 minutes after drinking the solution and the last 120 minutes after. The venous blood samples were taken into Vacuette gelheparin-tube (3.5 ml whole blood) and gelcentrifuge-tube (3.5 ml whole blood). After 15 minutes of blending, the tubes were placed into the centrifuge for 10 minutes (3500 rmp). The plasma was separated from the gelheparin-tube and kept frozen in -20 ºC degrees until analyzed. The glucose was analyzed with chemical analyzer (Konelab 20 XTi) and insulin with immunology analyzer (Immulite 1000). From the OGTT-results the area under the glucose curve (AUC) and the homeostatic model assessment value for insulin resistance (HOMA-IR) were calculated. For the AUC a following calculation model was used $AUC = (Y_n + Y_{n+1})/2 \times (X_{n+1}-X_n)$. The HOMA model is commonly used in research to estimate the insulin sensitivity and β-cell function using fasting insulin and glucose concentrations, and for the HOMA-IR a following calculation model HOMA-IR = (Glucose (mmol/l) × Insulin (pmol/l))/22.5 was used (Wallace et al. 2004).

Food diaries. The food diaries were analyzed with NUTRIFLOW-program. Each subject kept the diary 2 times for five consecutive days, which had to include both weekend days (for example from Wednesday to Sunday or from Friday to Tuesday). The diaries were supposed to be kept at the beginning of the training period and the middle point of the training period to see if the nutritional status of the subjects had stayed the same.

8.5 Statistical analysis

All statistical analyses were done with SPSS -statistical analysis program (PASW Statistics for Windows 22.0).

The nonparametric tests were chosen for the analysis of most of the results, because the number of subjects was so small. The p-value was set at 0.05. The difference within every group between pre- and post-test was measured with related samples Wilcoxon signed rank test. Also the difference between different groups was measured in pre- and post-test. This was done with independent samples Kruskal-Wallis test.

In addition, for the OGTT results of a combined high-intensity interval group parametric tests were done. The tests of normality were performed, and normality was satisfied if the Shapiro-Wilkins test p-value was above .05. Most parameters were normally distributed, and for those that were not, a logarithm transformation was performed to see if that would make it normally distributed. If the samples were normally distributed, the parametric paired samples t-test was performed to look into differences within every group in pre and post situation. The difference was considered to be significant if the p-value was under .05. If a sample was not normally distributed, even after logarithm transformation, a non-parametric related samples test was used to see if there were significant differences between pre and post measurements within group.

To look into the differences between groups, the General linear model with Bonferroni and Tukey tests was performed as well as one-way analysis of variance (ANOVA).

9 RESULTS

The results include all subjects, both men and women. Results for only women are shown in appendix 3. Anthropometric data is shown in table 1. There were no differences between groups before or after the study. All of the participants were normal weight and had a normal BMI before and after the study. The small changes in the height can be explained with difference in the participant number in the pre and post measurements. There were five drop-outs during the study, who all were women. Three were from the HIRT group, and one from each HICT and SSE. There were different reasons for dropping-out, such as pain in the feet and lack of time to commit the study or final measurements.

There were small changes in the weight. There was a small increase in weight in HIRT and HICT as well as in BMI for both of these groups. The changes were not significant. In SSE there was a decrease in both weight and BMI. Even though the changes were small, they were significant (pre-post weight $p = 0.043$, BMI $p = 0.028$).

TABLE 1. Height, weight and BMI before (PRE) and after (POST) the training intervention for all the subjects in the three training groups. HIRT; high-intensity interval running training, HICT; high-intensity interval circuit training, SSE; steady-state endurance training, n = number of participants in the group. $^*p \leq 0.05$ significant difference between pre and post measurement.

Group	Height (cm) PRE	Height (cm) POST	Weight (kg) PRE	Weight (kg) POST	BMI PRE	BMI POST
HIRT (n = 5)	170.50 ±6.35	171.00 ±7.11	65.66 ±9.18	65.84 ±9.28	22.24 ±1.23	22.42 ±1.48
HICT (n = 7)	172.50 ±9.62	173.43 ±10.00	69.10 ±11.32	69.37 ±11.21	22.89 ±2.49	22.99 ±2.63
SSE (n = 7)	167.00 ±5.76	167.71 ±5.82	63.21 ±5.51	62.49 ±5.24 *	22.63 ±1.31	22.19 ±1.12 *

Body composition. The results from body composition measurements done with DXA are shown in table 2. There were no significant differences between the groups.

TABLE 2. PRE and POST DXA whole body measurement results for all subjects. Significant difference between pre and post measurement is marked with * ($p \leq 0.05$). FFM; fat-free mass.

Group	Fat mass (kg)		Fat %		FFM (kg)		FFM %	
	PRE	**POST**	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**
HIRT	14.91	15.25	24.08	24.58	47.90	47.65	72.40	72.04
n=5	±0.58	±1.20	±3.38	±3.59	±8.84	±8.80	±3.21	±3.25
HICT	16.87	17.01	25.21	25.31	49.31	49.45	71.57	71.51
n=7	±7.85	±8.40	±9.85	±10.65	±9.82	±10.21	±9.03	±9.86
SSE	13.00	12.91	21.79	22.01	47.48	46.84	77.80	74.40
n=7	±5.52	±6.04	±9.34	±10.51	±8.58	±9.16	±9.93	±9.82 *

Fat mass and fat percentage. The changes in fat mass and fat% are shown in figures 8 and 9. There were no significant differences between groups before or after the training intervention. Also there were no significant changes in any of the groups in these parameters after the training.

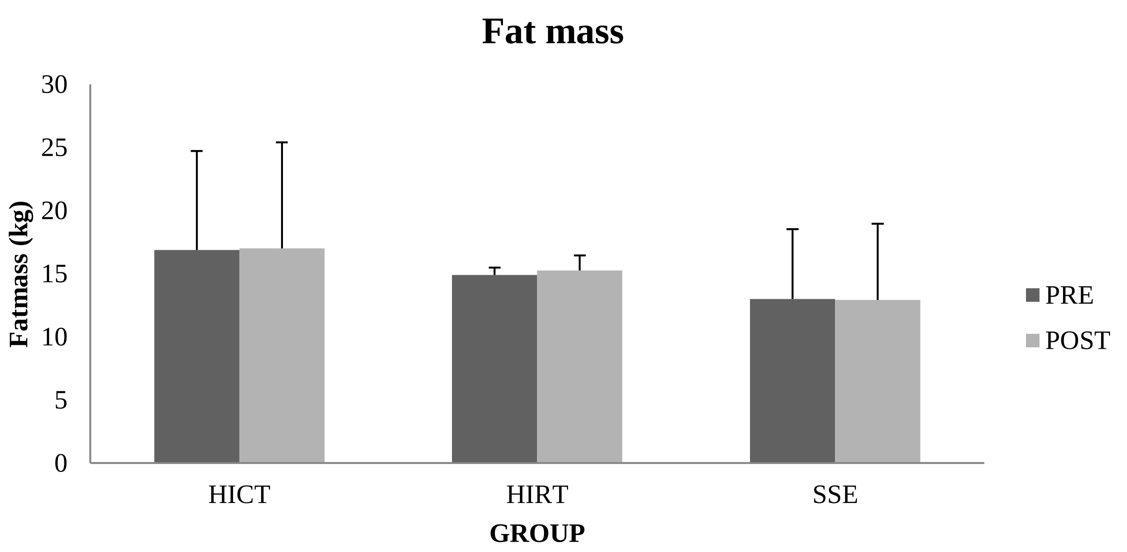


FIGURE 8. Fat mass in kilos before and after the training intervention in the three training groups.

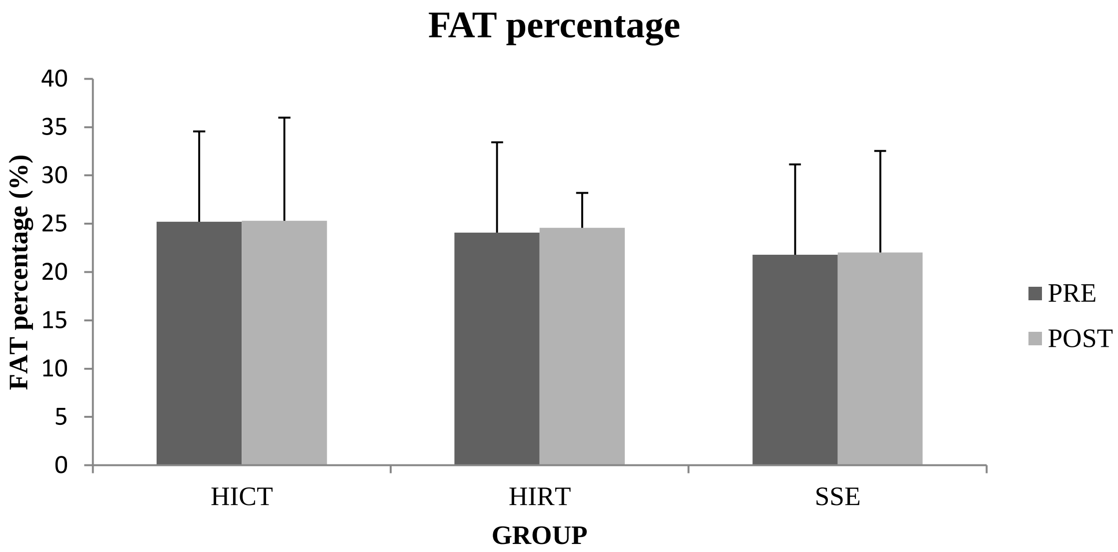


FIGURE 9. Fat percentage before and after the training intervention in the three training groups.

Fat-free mass and percentage. There were no significant differences between groups in absolute fat-free mass or percent. The only significance found in these parameters was in SSE group, where decrease in absolute fat-free mass was not significant but the difference (pre-post) in fat-free percent was significant ($p = 0.028$, see table 2). The absolute fat-free mass changes are shown in the figure 10 and for the fat-free percent in figure 11 for all of the participants and for only women in appendix 3.

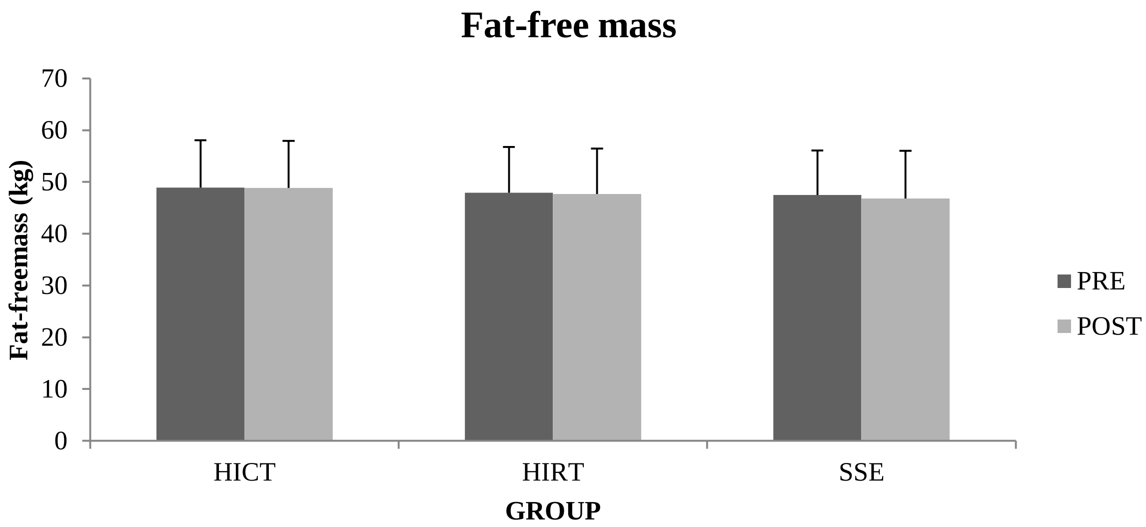


FIGURE 10. Fat-free mass in kilos before and after the training intervention in the three training groups.

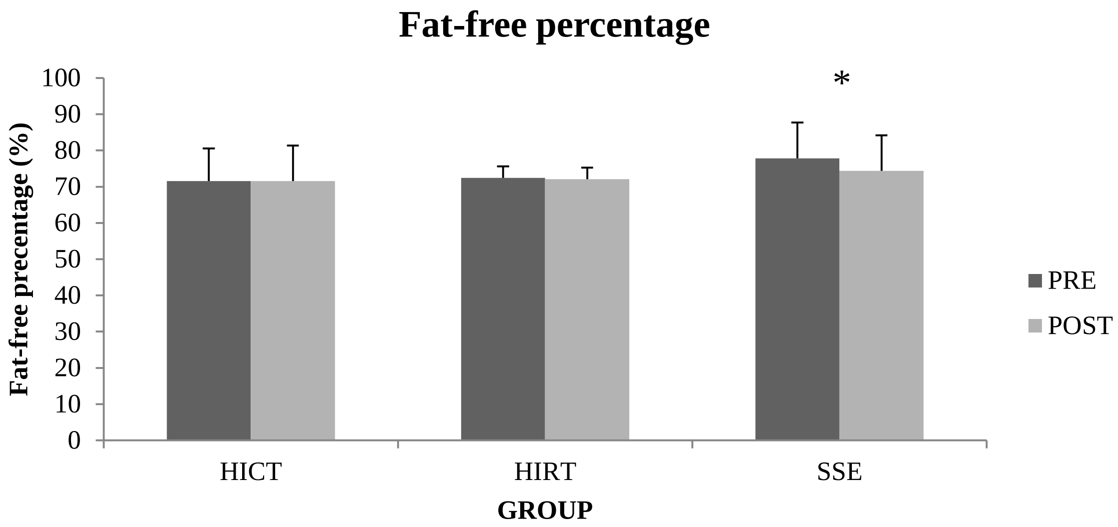


FIGURE 11. Fat-free percentage before and after the training intervention. * $p \leq 0.05$, significant difference between pre- and post-measurement. In SSE-group the fat-free percent decreased significantly ($p = 0.028$).

Regional body composition. The regional body composition results are shown in table 3 and also in figures 12A, 12B, 13A, 13B, 14A and 14B and only women in appendix 3. There were no significant differences between groups at any region in pre- or post-measurements. There was either significant difference within any group between pre- and post-measurement at any region. However, in HICT-group the difference in the fat mass of arms between pre- and post-measurement was significant ($p = 0.046$) when one of the subjects in this group was excluded. The reason for exclusion was that the subject revealed after the study that before the training period she had lost several kilos in weight in short period of time by dieting and exercising.

TABLE 3. Regional body composition results from DXA measurement before and after the training intervention. * $p \leq 0.05$, significant difference between pre and post results.

Group	**TRUNK**				**LEGS**				**ARMS**			
	Fat (kg)		**FFM (kg)**		**Fat (kg)**		**FFM (kg)**		**Fat (kg)**		**FFM (kg)**	
	pre	**post**	**pre**	**post**	**pre**	**post**	**pre**	**post**	**pre**	**post**	**pre**	**post**
HICT	8.70 ±4.40	8.77 ±4.56	23.94 ±4.38	23.95 ±4.50	6.12 ±2.74	6.20 ±3.04	16.38 ±3.23	16.44 ±3.31	1.51 ±0.88	1.47 ±0.87*	5.41 ±1.96	5.41 ±2.03
HIRT	7.50 ±0.83	7.69 ±1.23	22.86 ±3.34	22.80 ±3.52	5.52 ±0.93	5.65 ±1.08	16.31 ±3.32	16.13 ±3.11	1.35 ±0.17	1.37 ±0.22	5.19 ±1.83	5.19 ±1.89
SSE	6.43 ±3.05	6.48 ±3.44	22.77 ±3.70	22.44 ±4.38	4.81 ±1.99	4.70 ±2.06	15.71 ±3.03	15.59 ±3.01	1.28 ±0.63	1.24 ±0.63	5.45 ±1.71	5.31 ±1.59

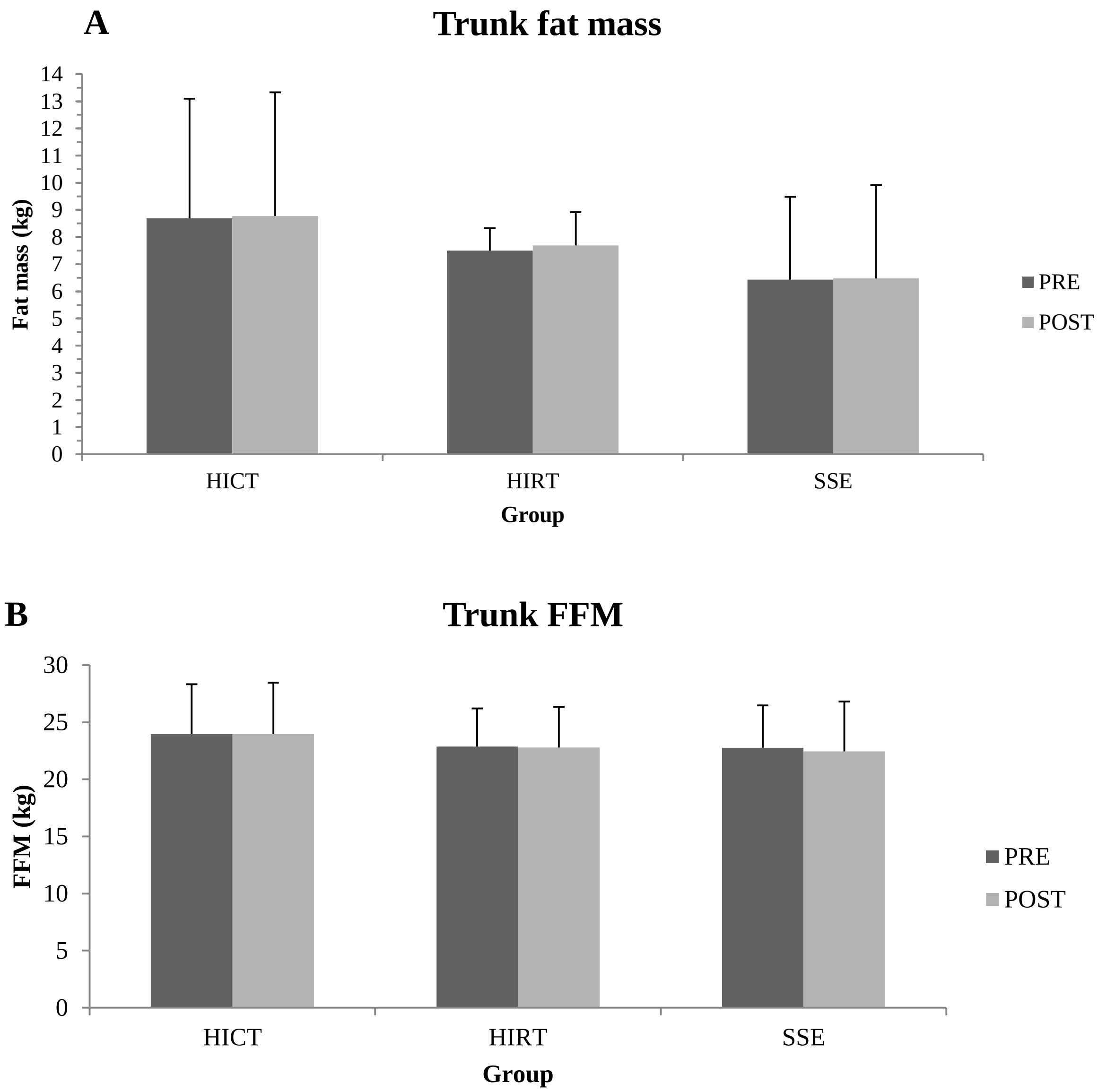


FIGURE 12A. Trunk fat mass before and after the training intervention. B. Trunk fat-free mass (FFM) before and after the training intervention.

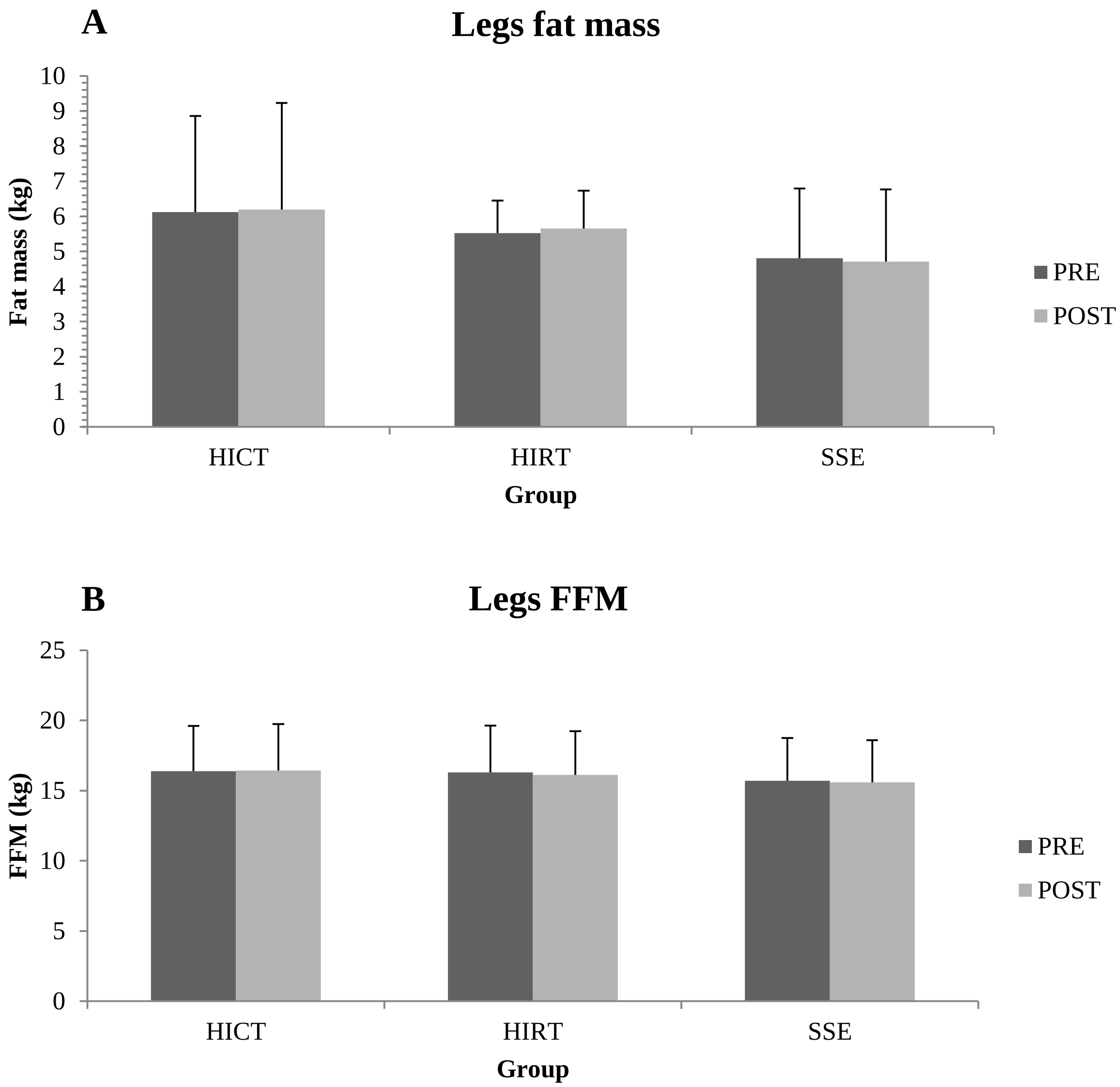
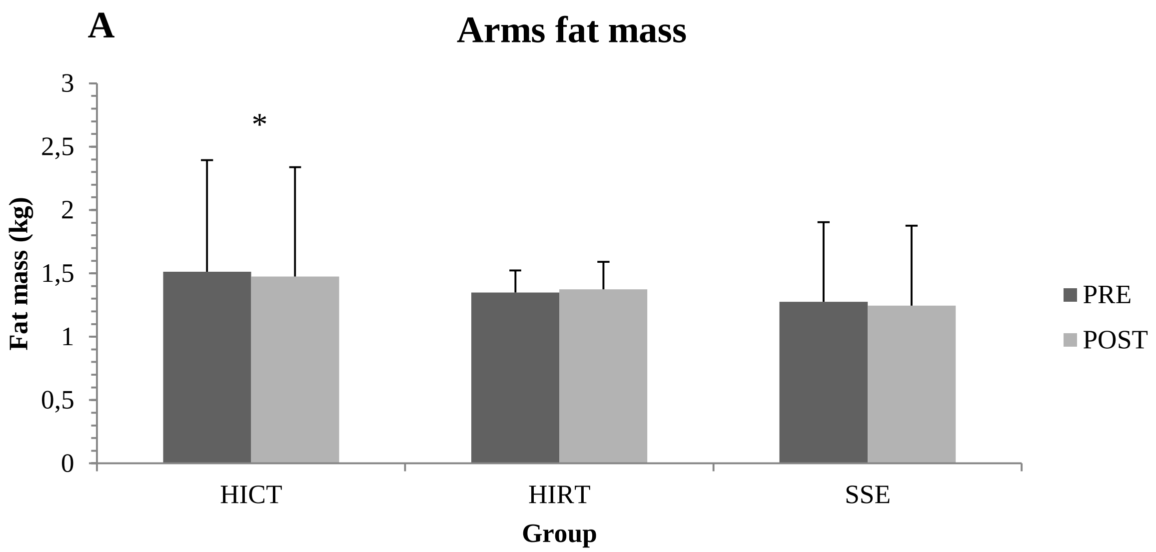


FIGURE 13 A. Legs' fat mass before and after the training intervention. B. Legs' fat-free mass (FFM) before and after the training intervention.



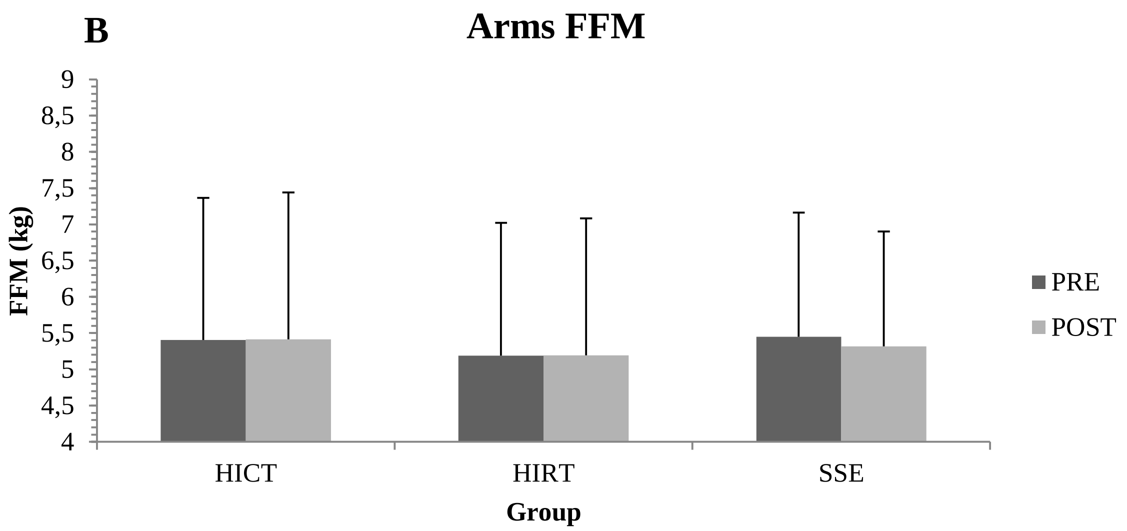


FIGURE 14 A. Arms' fat mass before and after the training intervention. A significant decrease in HICT group was found (p = 0.046). B. Arms' fat-free mass (FFM) before and after the training period in the three training groups.

Glucose tolerance. The results from the oral glucose tolerance test and insulin response are shown in table 4 and for only women in appendix 3. Normal fasting value is from 4.0 to 6.1 mmol/l. There were no significant differences between groups in pre or post situation, or within groups at any time points.

TABLE 4. Blood glucose concentration (mmol/l) from the oral glucose tolerance test results before and after the training intervention (mean ± standard deviation).

Group	Glucose 0 min		Glucose 60 min		Glucose 120 min	
	PRE	POST	PRE	POST	PRE	POST
HIRT (n = 4)	4.82±0.25	4.83±0.39	5.80±1.71	4.80±1.41	4.68±0.94	4.50±0.88
HICT (n = 6)	5.10±0.47	5.18±0.28	5.18±1.54	5.68±1.14	4.60±0.50	4.67±0.69
SSE (n = 6)	4.97±0.41	5.05±0.44	5.85±1.98	5.02±1.40	3.98±0.70	4.70±1.15

Insulin response. The blood insulin responses in oral glucose tolerance test are shown in table 5 and in appendix 3 for only women. Normal fasting value ranges from 18 to 195 mmol/l. There were no significant changes between groups or within groups at any time point in pre and post measurements, except in HICT group at the time point 60 minutes. The post-measurement value at this time point for HICT group was significantly lower than in the pre-measurement ($p = 0.046$). Also, when the two interval groups' results were combined, their blood insulin concentration change was significant at time point 0 minutes (pre vs post, $p = 0.034$). The insulin concentration was lower at the post measurement for this combined group.

TABLE 5. Results of insulin response (mmol/l) during the oral glucose tolerance test before and after the training intervention. * $p \leq 0.05$ significant difference between pre- and post-measurement.

Group	Insulin 0 min		Insulin 60 min		Insulin 120 min	
	PRE	POST	PRE	POST	PRE	POST
HIRT n=2-3	59.95±31.80	41.50±15.52	309.33±127.05	376.67±130.32	302.00±227.69	203.50±33.23
HICT n=5	72.28±31.71	55.74±16.00	400.29±134.24	347.28±133.69 *	338.00±127.68	300.00±118.66
SSE n=4	44.56±26.66	41.25±20.56	178.70±65.168	238.50±94.67	264.00±155.29	281.33±94.48

AUC and HOMA-IR. The AUC and HOMA-IR values calculated from the OGTT results are presented in table 6. There were no significant differences between groups of within groups in pre and post situation.

TABLE 6. The area under the glucose curve (AUC) and HOMA-IR values in pre and post situation for the three training groups.

	AUC		**HOMA-IR**	
Group	**pre**	**post**	**pre**	**post**
HICT	9.71±1.48	10.60±1.0	1.36±0.53	1.02±0.28
HIRT	10.55±2.04	9.46±1.90	1.09±0.58	0.77±0.28
SSE	10.33±2.13	9.89±1.93	0.92±0.26	0.99±0.23

Food diaries. Data from the food diaries is presented in table 7 for energy, protein, carbohydrate and fat intake. There were no other significant differences in any group, nor significant differences between groups.

TABLE 7. Energy, protein, carbohydrate and fat intake based on the food diaries filled by the subjects. 1st diary was filled out at the beginning of the study and the 2nd in the middle of the study.

	Energy intake (kcal/d)		**Protein intake (g/d) (g/kg/d)**		**Carbohydrate intake (g/d) (g/kg/d)**		**Fat intake (g/d) (g/kg/d)**	
Group	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
HICT	2216 ±380	1862 ±389	93.98 ±15.38 1.43 ± 0.40	83.93 ±18.51 1.18 ± 0.29	228.68 ±31.18 3.30 ±1.17	201.13 ±29.38 2.81 ±0.80	87.75 ±4.18 1.36 ±0.30	70.70 ±5.27 0.98 ±0.10
HIRT	2138 ±240	1787 ±418	105.83 ±21.75 1.74 ±0.46	93.90 ±16.91 1.40 ± 0.14	215.65 ±10.63 3.36 ±0.53	183.93 ±21.32 2.72 ±0.39	84.70 ±9.04 1.28 ± 0.16	65.33 ±11.52 0.96 ±0.22
SSE	1931 ±169	1880 ±412	98.67 ±43.62 1.54 ±0.59	102.40 ±32.22 1.61 ±0.42	198. 62 ±45.67 3.14 ±0.70	203.12 ±54.93 3.22 ±0.69	70.52 ±18.86 1.13 ±0.35	59.98 ±13.12 0.96 ±0.20

10 DISCUSSION

The SSE seemed to have the strongest effect on weight loss, as the weight of the subjects in this group was significantly lower after the training than before the intervention. The interval groups did not have significant changes in weight. However, as the SSE group had a decrease in both, fat and fat-free mass (not significant) and the decrease in lean percentage was significant, this might indicate that with more intense training in the interval groups the participants were able to maintain their lean body mass better than the SSE group. Also, there was indication that the HICT program in this study was especially loading for the arms, since the fat mass of arms decreased significantly in this group. Concerning the glucose tolerance and the OGTT the high-intensity interval training seemed to have more effect on the response. In SSE there were no significant changes in the OGTT response (glucose or insulin concentration), but in the HICT the 60 min insulin value was significantly lower after the training intervention. Also, when the results of the interval groups were combined, the fasting insulin concentration was significantly lower in the combined group after the training intervention.

Body composition. In previous studies there has been seen both significant changes in the body composition after high-intensity interval training (Paoli et al. 2010; Gremeaux et al. 2012; Shing et al. 2013; Trapp et al. 2008; Tremblay et al. 1994) and no changes in body composition at all (Astorino et al. 2012; Smith et al. 2009). The results considering body composition changes in this study are mostly in line with previous studies where no significant changes have occurred. In this study, there was a tendency of gaining fat mass in HICT and HIRT groups, where as in SSE the tendency was to lose fat mass. However, the changes were small in every group (100 – 350 g), and not significant. When considering lean mass, it seemed that there was no change at all, or minor decreases in the interval groups, where as in SSE group there was a notable decrease (mean value decreased 3.4 kilos). And even though the changes in the absolute lean mass were not significant, the decrease in lean percentage in SSE group was significant ($p = 0.028$). This might indicate that the interval groups were able to maintain their lean mass better than the SSE group. The results from Mougios et al. (2006) support this, as they noted, that with training done at fairly great intensity (~70% of VO_{2max}) enables to maintain the fat-free mass unchanged better than training done at a lower intensity.

In previous studies the training programs, study population and the length of the training period have varied. In studies where significant changes in body composition have not been seen, the study period has been relatively short, from 2 to 6 weeks (Astiorino et al. 2012; Smith et al. 2009). When looking into the studies, where significant results in body composition have occurred, the training periods have been longer (Gremeaux et al. 2012; Trapp et al. 2008; Tremblay et al. 1994). This might indicate that the training period in this study was not long enough to produce significant changes in body composition. However, there are studies, in which the training period has been relatively short, but significant changes in body composition have still been seen (Shing et al. 2013; Hazel et al. 2014). The difference in these studies as compared to this study is that the amount of training has been greater (Shigh et al. 2013) or the intensity of the training has been greater (Hazel et al. 2014). In the study of Hazel et al. (2014) only six weeks of high-intensity running resulted in significant decrease in body weight, fat mass and fat percent and significant increase in fat-free mass of young healthy women. This might indicate that the intensity of the training was not sufficient for recreationally active adults in this study.

Regional body composition. In the regional body composition the changes were small in every part and in every group. The trunk fat mass did not seem to be affected by the training at all, and same case was in the lean mass of trunk. Although there was again, a tendency for the SSE group to lose lean mass. So, the interval groups seemed to be able to maintain their lean mass of trunk better than SSE. This is in agreement with previous studies, as for example Trapp et al. (2008) also noted indications in their study, that the load for trunk and leg muscles is greater with HIIT than with steady-state exercise. However, when looking the legs' values there were no noticeable changes in the fat mass or in the lean mass, but there could be seen a tendency in HIRT and SSE groups to lose lean mass and HICT to gain lean mass. In previous studies it's been noted that it might take longer time (even over 16 weeks) for significant muscle growth to happen in the legs (Fleck et al. 2006). Also Abe et al. (2000) noticed in their study that the muscles of the lower body might need more time to grow significantly, than the muscles of the upper body. They investigated a dynamic whole body resistance training program and its effects on the muscle growth of lower and upper body muscles, and also the time course of these changes. They saw, that for both men and women, in the upper body the muscle growth took place earlier and was greater when compared to lower extremity.

The fat mass in the arms did not change noticeably in SSE or HIRT groups, but in HICT group there was a significant decrease in the fat mass of arms ($p = 0.046$) (when one subject was excluded, because of massive weight loss before the study intervention). The training program of HICT groups included many movements that loaded arms, such as different push-ups and burpee. So this might be one reason for the significant fat loss seen in HICT. However, the result is interesting, since according to previous literature the general perception is that this kind of spot reduction in fat mass would not happen as a result of training (eg. McArdle et al. 2015; Vispute et al. 2011). Though, some indications have been found that this might be possible. One possible explanation could be the hormone action. Even though the hormones that contribute to fat loss (such as epinephrine and norepinephrine) influence the whole body, the blood flow in the adipose tissue near the active muscles is relatively increased. This might result in larger amount of these hormones to be delivered to this tissue and higher epinephrine concentration might induce the increased lipolysis in this area. Norepinephrine on the other hand is also a neurotransmitter in the sympathetic nervous system. So the selective adipose tissue loss could also happen via the local sympathetic nerves, since in previous studies it has been noted that there occurs regional differences in the activity of the sympathetic nervous system, and that the lipolysis of adipose tissue in certain area is increased, when the cutaneous sympathetic nerves stimulating that area are stimulated. (Stallknecht et al. 2007.) This aspect should be investigated more in the future studies. Considering the lean mass of arms, the interval groups (HICT, HIRT) it seemed to stay the same but tended to decrease in the SSE group. Again, it seemed that the interval groups were able to maintain their lean mass better compared to SSE group.

Gender differences. Some differences between men and women could be noted from the results of body composition measurement. In HIRT groups there was a difference between men and women in the response; women had a decrease in their fat mass and fat %, whereas men had a small increase in these variables. When looking the whole group, the fat mass and fat percentage increased. However, these changes were not significant. Hottenrott et al. (2012) noted also some difference in the response between men and women in their study, so that the improvements on body composition after 12 weeks of high intensity training or moderate intensity training seemed to be greater in men than in women. Also, men have naturally lower body fat percent, so this might partly be reason for the differences noted. Trapp et al. (2008) noted in their study, that for the persons who had the lowest body fat to begin with, also had the least loss in body fat in response to interval training.

However in HICT the results were contradictory, as women had an increase in fat mass and fat % and men had a small decrease. In the whole group level HICT group showed small, but not significant increase in both, fat mass and percentage. The number of men in the HICT group was only two, so this might partly explain why the whole groups' results were parallel to the results of the women in this group. There were simply more women so their effect on the result was greater, because the changes were so small. In SSE groups the result were similar among men and women, both had a minor decrease in fat mass and fat %. This is in line with previous studies (e.g. Hottenrott et al. 2012; Wilmore et al. 1999). In whole group level the fat mass decreased, but fat percentage increased. These changes were not statistically significant.

In HIRT group women had no significant changes, but there was a tendency for decrease in lean mass. Despite this their lean percent tended to increase (see appendix 3). This might be because their fat mass and fat percentage decreased, even though the decrease was not significant. Men had a small decrease in both lean mass and lean percent. For the whole group the lean mass and the lean percentage decreased, but not significantly. In HICT group both men and women had small increase in their lean mass. Men's lean percent also increased, but women's lean percent decreased. In whole group level the lean mass increased a little, whereas lean percent decreased. In SSE group the lean mass and percent of men decreased. Even though women's lean percent decreased, interestingly there was a small increase in the absolute lean mass. When including all subjects of this group, both parameters showed a decrease and the decrease in the lean percent was significant. Other changes in any of the groups were not significant. All in all, these results might indicate that the HICT program was affecting more in the lean mass when compared to HIRT and SSE, since both men and women in the HICT had a small increase in the absolute lean mass.

Food diaries. The information gained from the food diaries might partly explain the body composition results of this study. Especially during strength type of training, the requirement for protein intake grows and during high intensity training the need might be from 1.2 to even 1.8 g/kg/d. (McArdle et al. 2015, 32, 38.) In this study, the protein intake seemed to be in sufficient level (see table 7), as the recommendation for daily protein intake is 1.1 – 1.3 g/kg/d (Finnish nutritional recommendations, Ravitsemusneuvottelukunta 2014). However, even if the protein intake was sufficient to enable muscle growth, the total energy intake was possibly too low. According to the Finnish nutritional recommendations, the daily energy requirement for active men aged 18 – 30 years is about 2790 – 3150 kcal/d, depending on the physical activity level. For women the requirement is about 2240 – 2500 kcal/d depending on the physical activity level. (Ravitsemusneuvottelukunta 2014). In every group the mean energy intake was lower already in the beginning of the study. The 1st food diary energy intake for HICT was 2216, for HIRT 2138 and for SSE 1931 kcal/d. In every group the total energy intake decreased from the 1st to the 2nd diary (HICT: 1862 kcal/d, HIRT 1787 kcal/d, SSE: 1880 kcal/d). The decrease in the interval groups was more notable than in the SSE group, but there were no significant differences. However, the differences between energy intake in the 1st and 2nd food diary in the both interval groups were not too far from significance ($p = 0.068$). So, it seems that the total energy intake was too low for significant muscle growth to happen.

The recommended carbohydrate intake varies depending on training status from 4 – 10 g/kg/d (Valtion ravitsemusneuvottelukunta 2014; Mero et al. 2007). Based on that, it seems that also the carbohydrate intake might have been too low to able the subjects to get the most out of the training, especially in the interval groups (see table 6). This is because during prolonged submaximal exercise (over 90 minutes) or intermittent high-intensity exercise, the limiting factor for performance is the carbohydrate availability for the working muscles (and nervous system). The carbohydrates are in a central role in brief high-intensity performance. (Burke et al. 2004.) There was a notable decrease in the carbohydrate intake in both interval groups. The change was not significant, but in both groups it was directional ($p = 0.068$). In the SSE group the intake of carbohydrate stayed at the same level in the 1st and 2nd food diary, but was also very low. The fat intake decreased notably, but not significantly, in every group from the 1st to the 2nd diary. Even though the fat intake decreased it still was most probably sufficient for the subjects (see table 9), hence the recommended fat intake varies between 0.5 – 1.5 g/kg/d, been greater among endurance type of sport participants and lower at interval and power type training (Valtion ravitsemusneuvottelukunta, 2014; Mero et al. 2007). Although it is known that carbohydrates are the primary energy source when training at high intensity or hypoxic conditions at the muscle level, there may be an exercise intensity that enables maximal level of fatty acid oxidation for extended periods of time, which in turn would help to induce body fat loss (Bryner et al. 1997). The level of intensity should be investigated more in the future studies.

OGTT responses. It seemed that the insulin concentration stayed at a lower level at time point 0 and 60 in HICT and at 60 minute time point SSE after the training, and at 0 and 120 minute time points for HIRT group. In contrast the insulin levels were higher at 120 minute time point for HICT, at 0 and 120 minute for SSE and at 60 minute time point for HIRT. There was a significant decrease in insulin concentration for HICT after the training when compared to the pre measurement value at 60 min time point. Other findings were not statistically significant. This might indicate that HICT had more effect on the glucose control than did HIRT or SSE in this study. Also some indication was seen, that interval training would be more effecting than SSE, as the interval groups' results from OGTT were combined there was found a significant decrease in the combined groups' insulin concentration at 0 min time point. This finding is in agreement with previous studies (e.g. Perry et al. 2008; Little et al. 2011; Hood et al. 2011). However, this might also be an indication that more significant results might have been found if the number of subjects would have been higher.

When comparing the glucose and insulin responses in the different time points the glucose levels stayed at a same level in the 0 minute time point in every group, but the insulin levels seemed to be lower after the study in the HICT and HIRT groups, and at the same level as in the beginning of the study in the SSE group. This is in line with a previous study performed by Trapp et al. (2008). In their study they saw no changes in the fasting glucose levels, but after high-intensity intermittent exercise or steady state exercise the fasting insulin of young, healthy women with average body composition had decreased.

At the 60 minute time point the glucose levels showed minor changes when comparing pre and post situation. In HICT group glucose seemed to be a bit higher, and in HIRT and SSE groups a bit lower. In contrast the insulin level was significantly lower in HICT group and a bit higher (not significantly) in HIRT and SSE groups in 60 minute time point. This might indicate that the non-insulin dependent regulation of blood glucose might be improved to some extent in HICT, because even though the glucose levels were higher, the insulin levels were lower, so less insulin was secreted for larger amount of glucose. So possibly the muscles capacity to take the glucose inside the muscle cells had improved. This would be in keeping with previous studies about resistance type of training. It is noted, that resistance training may provide as high or even higher recruitment of skeletal muscle mass in the same amount of time, when performed as whole body resistance training when compared to endurance type of training (Braith & Stewart 2006). Also, for example Braith and Stewart (2006) note that with resistance type of training the skeletal muscle mass can be increased, and that potentially provides an improved response to glucose load.

In 120 minute time point the glucose levels showed only small difference, but the tendency was that HICT and SSE groups had a bit higher levels after training and HIRT group had a bit lower level. The insulin levels showed a decrease in HICT and HIRT groups, in HIRT group the decrease was greater. These changes were not statistically significant. However, the glucose concentration seemed to stay at a more steady level in the post OGTT than in the pre OGTT in every group, which might indicate that the glucose regulation was improved, either because of more optimal insulin response or possibly improved muscle glucose uptake. As earlier mentioned, in previous studies it has been proved that exercise and insulin utilize different signaling pathways, but both lead to the activation of glucose transport (Goodyear & Kahn 1998).

AUC and HOMA-IR. The area under the glucose curve seemed to be bigger in the HICT group and smaller in the HIRT and SSE groups. However, the changes were very small and not significant and there were no significant differences between the groups in either pre or post situation. The HOMA-IR value seemed to decrease in the HICT and HIRT groups, and the decrease in HIRT groups was bigger. In SSE there was a small increase in the HOMA-IR value after the training. However, none of these changes were significant and there were no differences between the groups. And since the cut-off point for insulin resistance for adults is determined to >2.5 (e.g. Keskin et al. 2005), the HOMA-IR value remained under the threshold for insulin resistance in every group.

11 SUMMARY AND CONCLUSIONS

The SSE seemed to be the most effective training mode to bring about weight loss. However as the SSE group had a small decrease in both, fat and fat-free mass (not significant) and the decrease in lean body percentage was statistically significant, this might indicate that with more intense training in the interval groups the participants were able to maintain their lean share of body mass better than the SSE group. Also, there was an indication that the HICT program in this study was especially loading for the arms, since the fat mass of arms decreased significantly in this group. Concerning the glucose tolerance and the OGTT the high-intensity interval training seemed to have more effect on the response. The only significant findings were the significant decreases in the 60 min insulin value in HICT group and combined interval group's fasting insulin.

Although, there were only few significant changes found in this study, it might also be considered as a positive result. As it is well known that steady-state type of training has positive effects on both body composition and glucose tolerance, the fact that the high-intensity interval training groups did not differ from the steady-state group can be considered as a positive finding to some extent. It indicates that the high-intensity interval training programs performed in this study were similar to the steady-state program at most part. Also, as there were no significant negative findings in this study, this can also be considered as a positive aspect.

There are some things that need to be considered, that might have had effect on the results. It might be possible that the training intervals in the HIRT and HICT were not intensive enough after all, even though great results have been seen after this type of training intervals (10 times 1 minute interval). But perhaps the intensity was not enough for recreationally active young adults. And even if the participants seemed to give their best when supervised, it takes a lot to do the same alone, when no one is there to push you to your limits.

One possible reason, that could explain why the changes were so small and almost no significant results were not found, is that the study population was so small. It might have been also better to include only women or only men, because they differ regarding body composition to begin with, and also because some studies have noted differences between the genders in the magnitude of body composition changes in response to training. In this case the selection would have been only women, but because the number of participants was so small we included both sexes.

The food diaries were filled out as planned by most of the subjects. However, not everyone filled out the diary twice, so from some of the subjects only one food diary (the first) was received. This means, that no comparison could not be made in some cases about the food patterns during the study. But all in all it seemed that the food patterns stayed the same, and the subjects that did not fill out the diary twice convinced eating in the same way during most of the study period.

The timing of the study period might have had an effect on the results. This is because Christmas holidays were in the middle of the study. Few subjects admitted to not committing all the training session during their holidays. Also many told that their eating patterns during the holidays were far from the recommendations. These things together might have an effect on the body composition results, even though the holidays did not last long, but because the training period was also relatively short after all, even a short period might have an effect. The timing of the study period could not be changed however for scheduling reasons.

In the future studies, more information is needed about these types of interval training methods and how they affect the body composition and glucose tolerance of recreationally active adults. In the future studies it should be clarified if the supervision of training sessions affects the results. If all the training sessions would be supervised, the control of the training would be better. Also this way it could be made sure that the training sessions are really performed at the given intensity.

Also future studies should include more subjects. This would probably bring about more clear results. The studies should include both men and women, but they could be viewed as separate groups, as there were some differences in the results of this study in the response to the training between genders. This would probably also bring clarity to the results, especially concerning body composition changes, since men and women differ with regards to that to begin with, for natural reasons.

The study period length should also be considered in the future studies. In this study it seemed that the study period might have been too short to bring about significant changes in the body composition. It should be figured out, what is the optimal time for this type of training at these intensities to give rise to body composition changes in recreationally active men and women. Also the intensity of the training might be manipulated to see if this is the optimal intensity, since there were also some indications that the intensity of the training might not have been sufficient.

It would also be interesting to see the timing of the possible changes, so middle point measurements might be included in the future studies. In this study the middle point measurements were excluded because scheduling reasons. And if possible, it would be interesting to take biopsies, to see what really happens in the muscles at cell level.

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APPENDIX 1.

TERVEYSKYSELY

On tärkeää, että tiedämme terveydestäsi, elintavoistasi ja liikuntatottumuksista ennen tutkimuksen alkamista ja siihen liittyviä testejä. Vastaa seuraaviin kysymyksiin huolellisesti. Ota tämä lomake mukaan jo varsinaista tutkimusprojektia edeltävään lääkärintarkastukseen, jossa yhteydessä voidaan keskustella tarvittaessa mahdollisista terveysongelmista tai oireista.

Nimi______________________ Syntymäaika___________ Paino_________ Pituus__________

	Ei	Kyllä
1. Onko sinulla todettu hengitys-, sydän-, tai verenkiertoelimistön sairauksia?	☐	☐
Mitä?__________________________________		
2. Onko sinulla todettu verenpainetautia?	☐	☐
3. Onko sinulla todettu korkea kolesteroli?	☐	☐
4. Onko sinulla muita sairauksia?	☐	☐
Mitä?__________________________________		
5. Onko joku läheinen sukulainen (isä, äiti, veli, sisko) kokenut sydänkohtauksen tai hänelle on tehty sydänkirurginen toimenpide ennen ikää 50?	☐	☐
6. Käytätkö säännöllisesti lääkkeitä?	☐	☐
Mitä?________________________________		
7. Onko sinulla ollut rintakipuja tai hengenahdistustuntemuksia		
a. levossa?	☐	☐
b. rasituksessa?	☐	☐
Miten usein ja millaisia?_______________________		
8. Onko sinulla ollut rasituksen aikana rytmihäiriöitä, huonovointisuutta tai tajuttomuuskohtauksia?	☐	☐
9. Onko sinulla selkävaivoja tai muita tuki- ja liikunta-elinten pitkäaikaisia tai usein toistuvia vaivoja?	☐	☐
Mitä?____		
10. Oletko viimeisen kahden viikon aikana sairastanut jotakin tulehdustautia (flunssa, kuumetauti)?	☐	☐
11. Oletko raskaana?	☐	☐
12. Onko sinulla kehossasi elektronisia laitteita (esim sydämen tahdistin) tai metallisia esineitä (esim. ruuveja)?	☐	☐
13. Tupakoitko?	☐	☐

Jos kyllä, montako savuketta/vrk?____________

Jos olet lopettanut tupakoinnin, milloin (vuosi)?___________

14. Koska olet viimeksi nauttinut alkoholia?____________Kuinka paljon?___________

15. Mikä on nykyisen työsi fyysinen rasittavuus?

- -toimistotyö tai vastaava ☐
- kevyt ruumiillinen työ ☐
- raskas ruumiillinen työ ☐

16. Miten kuljet työmatkasi?_______________ Työmatkan kesto _________min/päivä

17. Kuinka usein olet harrastanut liikuntaa viimeisen kolmen kuukauden aikana?

- -en lainkaan ☐
- -kerran viikossa ☐
- -2-3 krt viikkossa ☐
- -säännöllisesti yli 4 kertaa viikossa ☐

Mitä liikuntaa olet harrastanut?

____

18. Arvio oma kuntotasosi asteikolla 1=heikko, 2=välttävä, 3=keskitasoinen, 4=hyvä, 5=erinomainen

Kuntoarvio:___________________

Vakuutan antamani tiedot oikeiksi, tunnen testaustavan ja osallistun siihen omalla vastuullani.

Jyväskylässä ___________/_________/2013

Allekirjoitus____

FIGURE 15. The health questionnaire used in this study (in Finnish).

APPENDIX 2.

Food diary instructions and a model of a filled food diary (in Finnish).

RAVINTOSEURANTA LOMAKKEET

KORKEATEHOISEN INTERVALLIHARJOITTELUN VAIKUTUKSET TERVEYS- JA KUNTOMUUTTUJIIN 20–40 -VUOTIAILLA KUNTOILIJAMIEHELLÄ JA –NAISILLA

OHJE LOMAKKEEN TÄYTÖSTÄ:

Täytä lomake viitenä peräkkäisenä päivänä niin, että kolme päivistä on arkipäiviä ja kaksi viikonlopun päiviä (esim. torstaista maanantaihin tai perjantaista tiistaihin). Merkitse ylös kaikki päivän aikana nauttimasi ruoat ja juomat sekä määrät ja ruokailuajat mahdollisimman tarkasti. Jos valmistat ruoan itse, merkitse ylös myös valmistustapa (esim. keitetty, paistettu jne.). Merkitse ylös myös (valmis) ruoan valmistaja jos mahdollista (esim. Saarioinen, Atria tms.).

MALLI LOMAKKEEN TÄYTÖSTÄ

Nimi _____________________________________ Syntymäaika ______________ Päivämäärä ________ Viikonpäivä ____________________

Onko päivä tavallinen__ poikkeava__ jos niin miten ____

Aika klo	**Paikka**	**Ruoat ja juomat (valmistustapa, ruoanvalmistuksessa käytetty rasva ja neste)**	**Määrä (kpl, dl, g, viipale, lasillinen jne.)**
17.30	koti	LIHAPULLAT, NAUTA JAUHELIHA, PAISTETTU VOISSA	5 isoa
		PERUNA, KUORINEEN KEITETTY	5 pienehköä
		RASVATON MAITO	2 lasia
		GRAHAMSÄMPYLÄ, TEHTY KEVYTMAITOON	2 kpl
		KEVYT AAMUPALA –JUUSTO	2 viip
		ITALIAN SALAATTI (SAARIOINEN)	1 rkl
		OMENA-KAALI-SALAATTI	2 dl
		MUSTIKKAPIIRAKKA, PULLAPOHJA, LEIVOTTU VOILLA	1 viipale (4 x 5 cm)
20.45	koti	HEDELMÄMYSLI (MYLLYN PARAS)	3 dl
		KAUPAN MUSTIKKAKEITTO (VALIO)	2 dl
		KAHVI	1 kkp
		KAHVIKERMA	1 rkl
		SOKERI	2 palaa
		DIGESTIVE –KEKSIT (MCVITIES)	4 kpl
		OMENATÄYSMEHU (TROPIC)	1 lasia
22.45		OMENA	1 iso

APPENDIX 3.

Figures and tables of body composition and tables of oral glucose tolerance test results for only women of the three training groups.

TABLE 8. Women's height, weight and BMI before and after the training intervention. The number of participants in pre and post measurements differed, and they are shown in the table and separated with /.

Group	Height (cm) PRE	Height (cm) POST	Weight (kg) PRE	Weight (kg) POST	BMI PRE	BMI POST
HIRT (n = 7/4)	168.43 ±2.64	168.00 ±2.71	63.13 ±5.35	61.98 ±3.90	22.23 ±1.44	21.95 ±1.20
HICT (n = 6/5)	167.80 ±4.92	168.20 ±5.40	64.07 ±10.05	66.10 ±11.26	22.65 ±2.55	23.24 ±2.86
SSE (n = 6/5)	164.60 7±3.72	165.20 ±3.90	59.87 ±4.42	60.08 ±3.96	22.42 ±1.29	22.00 ±1.16

TABLE 9. PRE and POST DXA whole body measurement results for women.

Group	Fat mass (kg)		Fat %		Fat-free mass (kg)		Fat-free mass %	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
HIRT	17.63 ±4.26	15.11 ±1.34	29.00 ±5.46	25.63 ±3.15	46.46 ±7.62	44.09 ±4.36	64.26 ±4.26	71.05 ±2.75
HICT	17.87 ±7.82	19.67 ±8.49	28.07 ±7.98	29.9 ±8.68	43.60 ±2.58	43.82 ±3.77	68.93 ±7.24	67.26 ±7.99
SSE	15.43 ±3.70	15.41 ±4.96	26.82 ±5.44	26.72 ±7.84	41.88 ±3.86	42.09 ±4.84	72.70 ±6.12	70.14 ±7.58

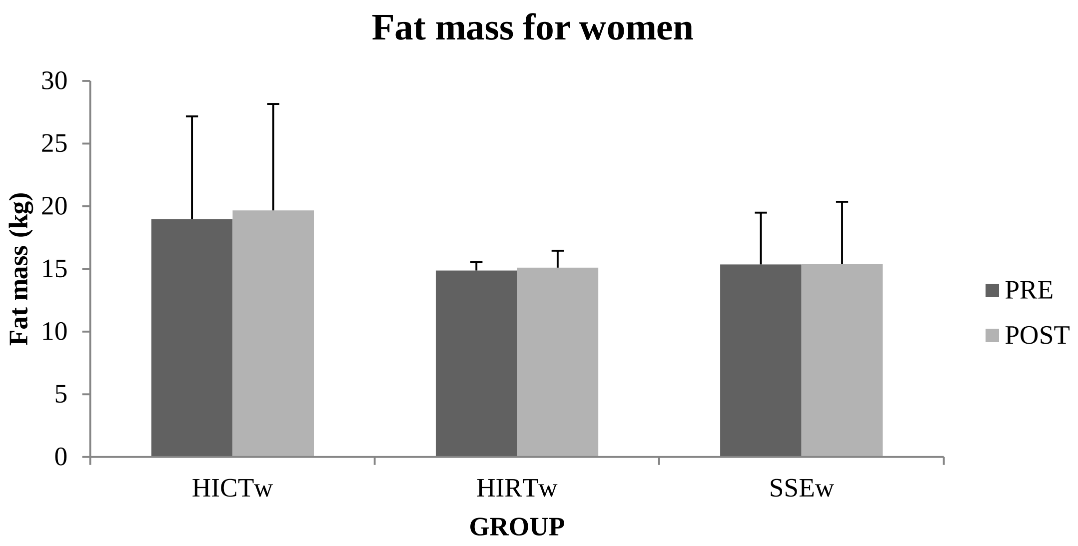


FIGURE 16. Fat mass before and after the training for women in different training groups.

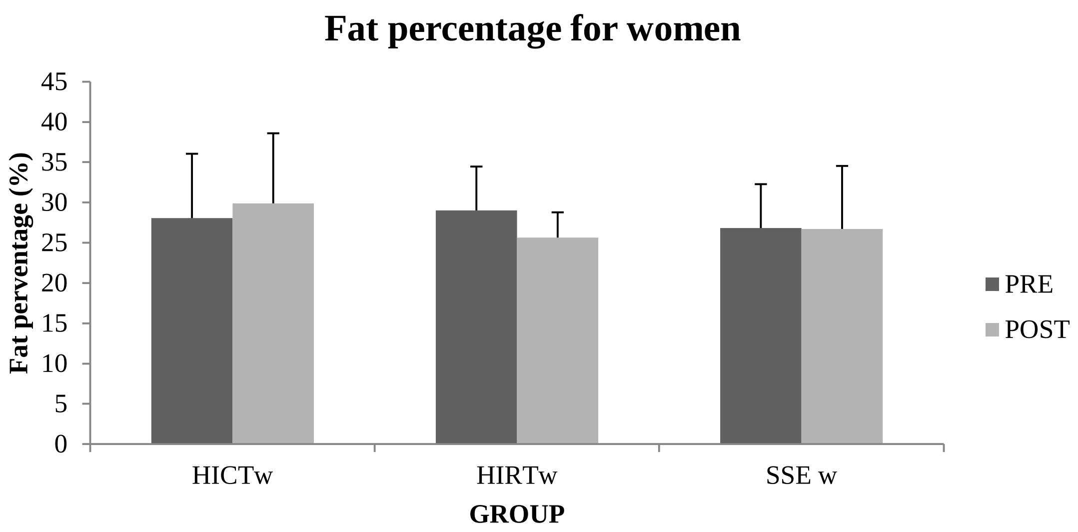


FIGURE 17. Fat percentage before and after the training for women in different training groups.

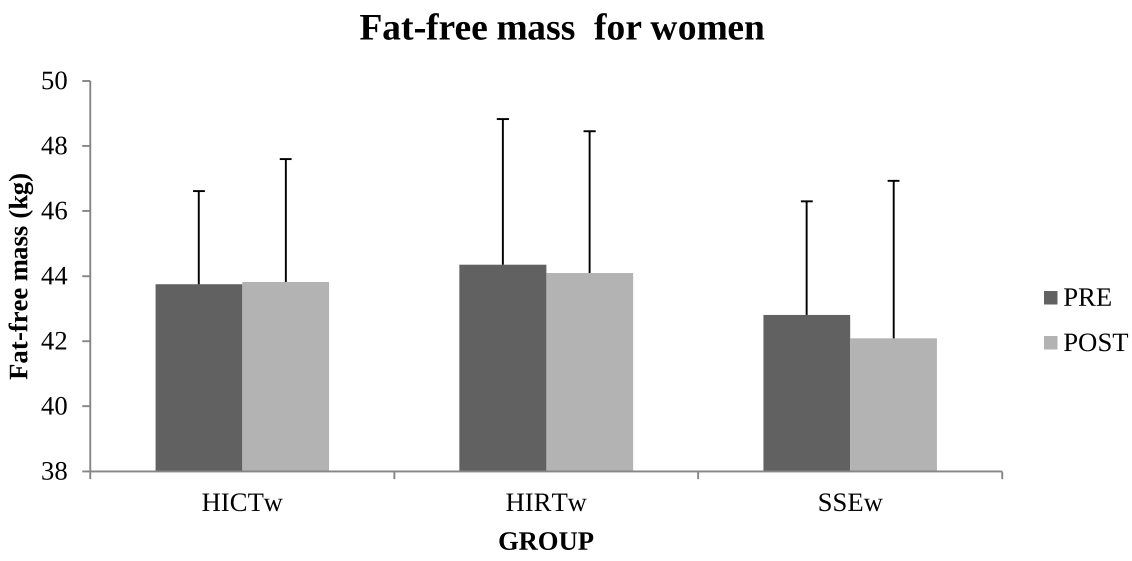
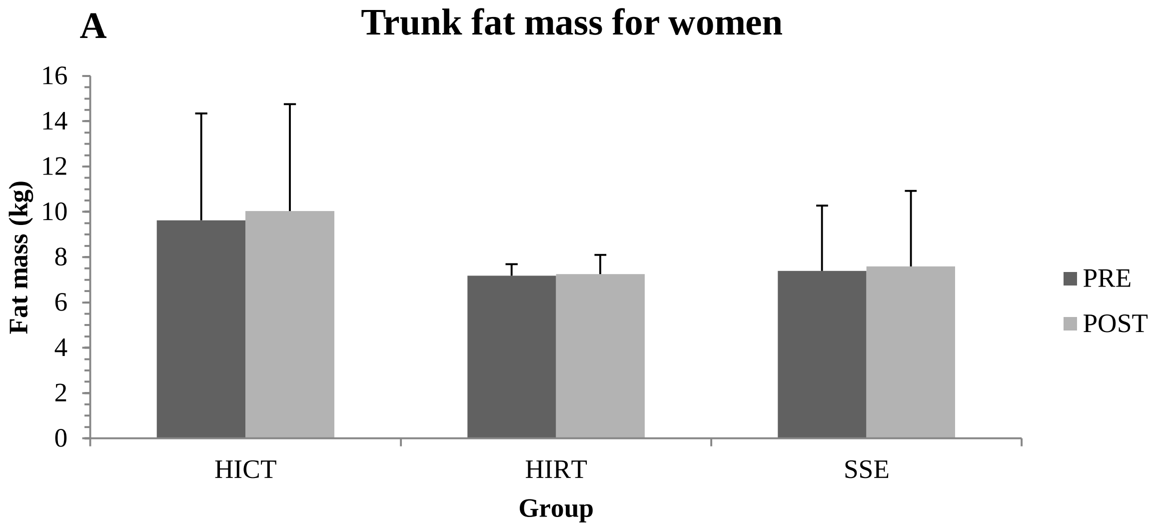


FIGURE 18. Fat-free mass before and after the training for women in different training groups.

TABLE 10. Regional body composition values from DXA measurement for only women.

Group	TRUNK				LEGS				ARMS			
	Fat (kg)		FFM (kg)		Fat (kg)		FFM (kg)		Fat (kg)		FFM (kg)	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
HICT	9.62 ±4.72	10.04 ±4.71	21.45 ±1.22	21.45 ±1.76	7.04 ±2.74	7.29 ±2.94	14.65 ±1.37	14.72 ±1.65	1.73 ±0.90	1.72 ±0.86	4.35 ±0.39	4.33 ±0.54
HIRT	7.18 ±0.50	7.25 ±0,85	21.53 ±1.79	21.37 ±1.73	5.82 ±0.75	5.97 ±0.93	15.02 ±1.89	14.95 ±1.92	1.34 ±0.20	1.35 ±0.25	4.42 ±0.74	4.41 ±0.82
SSE	7.39 ±2.89	7.59 ±3.34	20.30 ±1.36	20.30 ±2.59	5.88 ±0.69	5.79 ±1.01	14.13 ±1.69	14.05 ±1.79	1.54 ±0.51	1.48 ±0.57	4.52 ±0.69	4.46 ±0.61



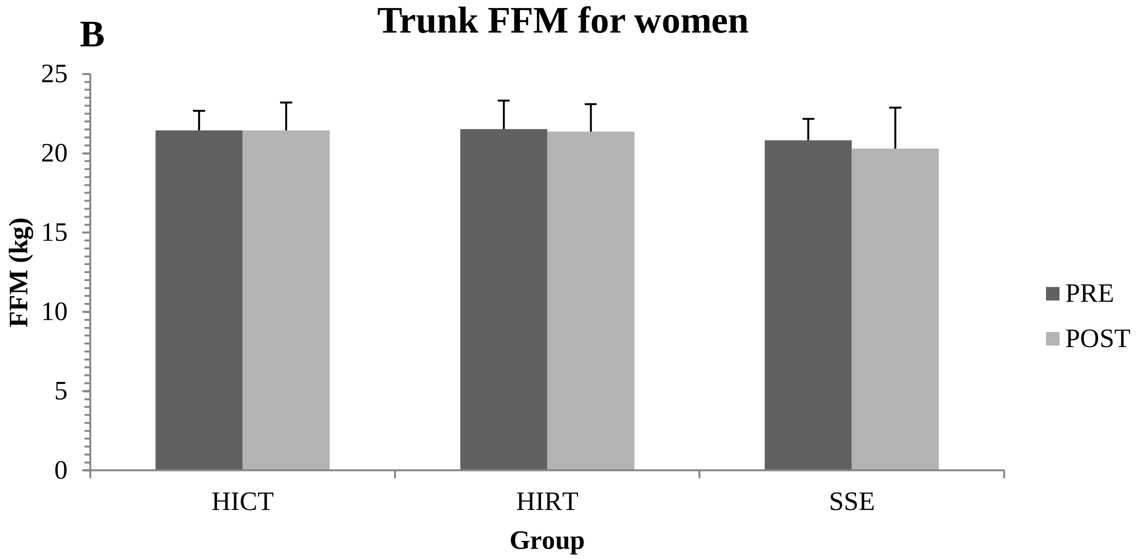


FIGURE 19A. Trunk fat mass in kilos before and after the training period in women of the three training groups.

B. Trunk fat-free mass (FFM) before and after the training period in women of the three training groups.

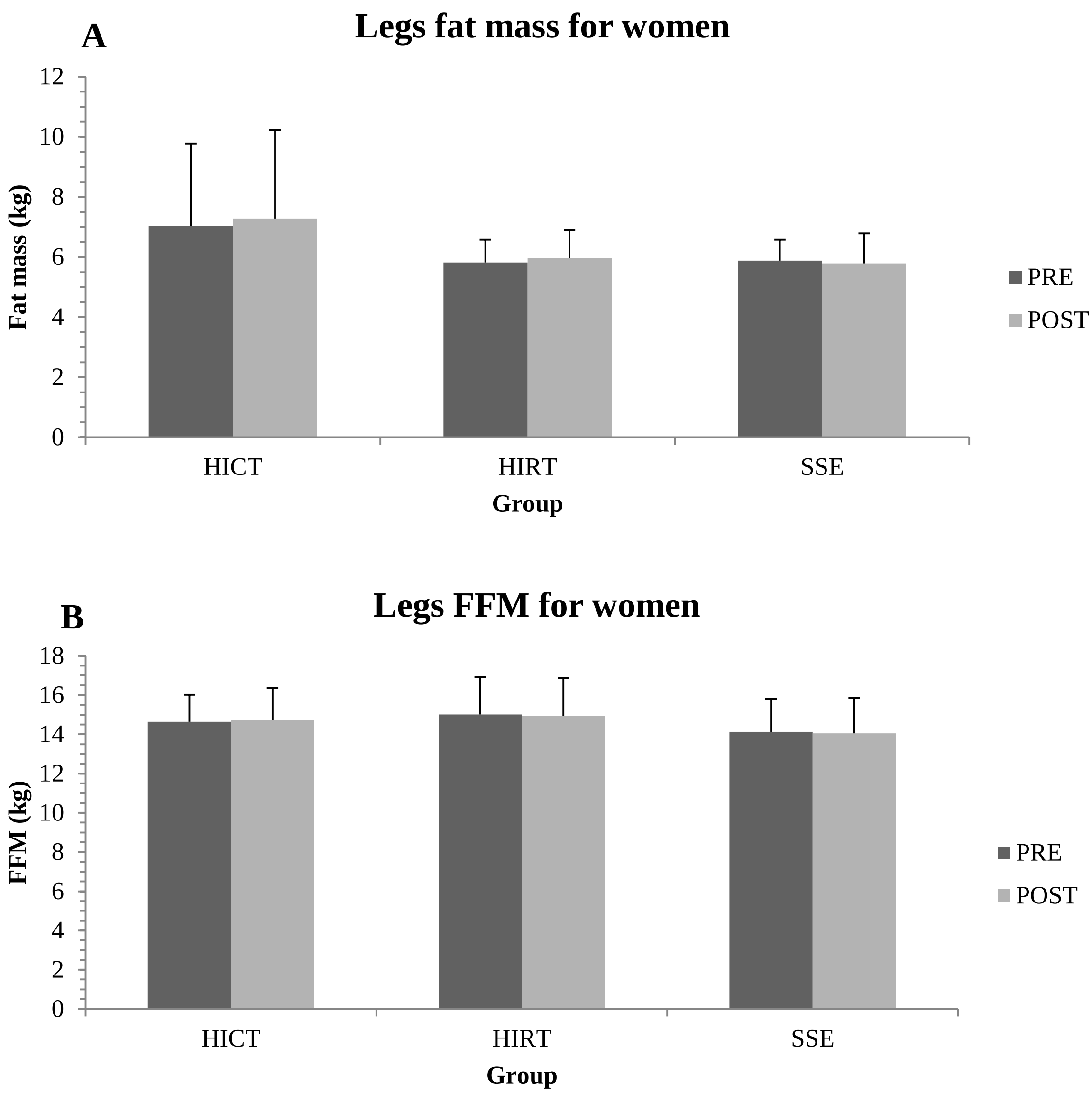
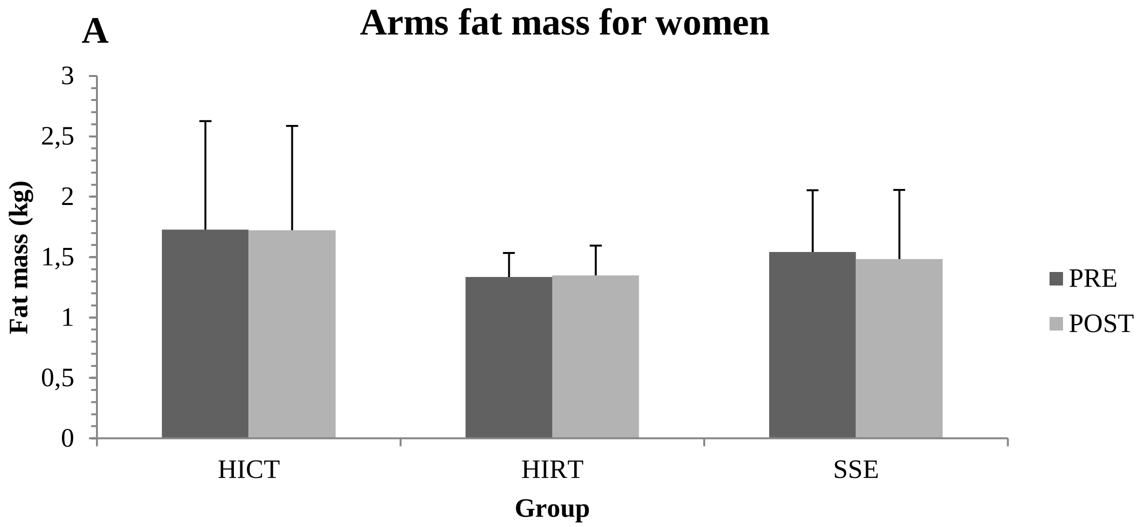


FIGURE 20A. Legs' fat mass in kilos before and after the training period in women of the three training groups.

B. Legs' fat-free mass (FFM) in kilos before and after the training period in women of the three training groups.



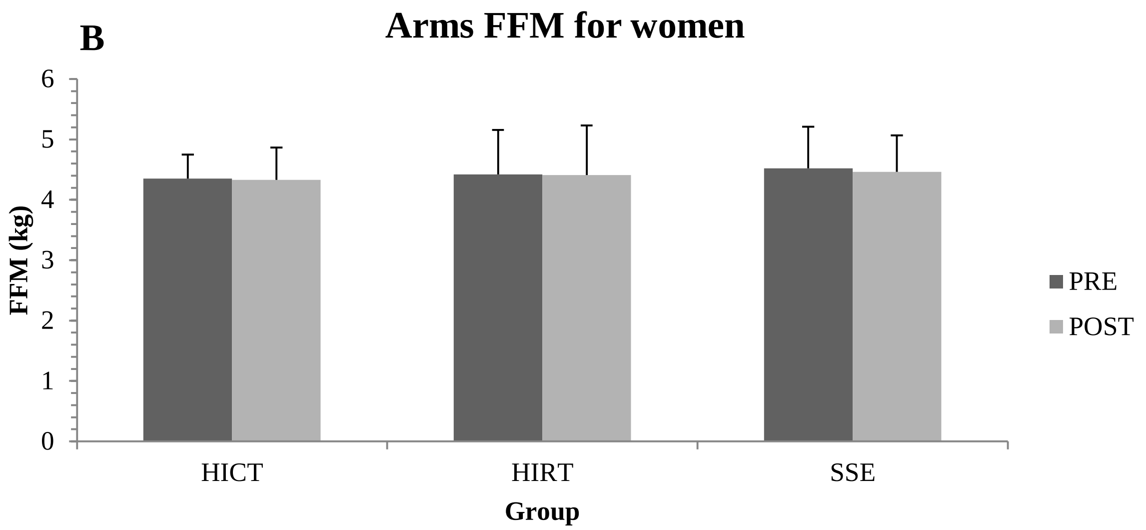


FIGURE 21A. Arms’ fat mass in kilos before and after the training period in women of the three training groups.

B. Arms’ fat-free mass (FFM) in kilos before and after the training period of women of the three training groups.

TABLE 11. Results of insulin response in women in pre- and post-tests. The number of participants differed in pre and post measurements, both are marked in the table and separated by /.

Group	Insulin 0 min		Insulin 60 min		Insulin 120 min	
	PRE	POST	PRE	POST	PRE	POST
HIRT n=3/2	70.60 ±26.50	39.85 ±21.57	309.33 ±127.05	366.00 ±130.32	305.66 ±161.13	203.50 ±33.23
HICT n=5	72.36 ±31.59	55.74 ±16.00	400.00 ±135.34	326.74 ±138.48	338.00 ±127.68	300.00 ±118.66
SSE n=5/4	42.01 ±23.78	41.2 5±20.56	216.96 ±102.49	283.50 ±94.67	182.80 ±78.59	287.25 ±110.89

TABLE 12. Oral glucose tolerance pre- and post-tests from women. The number of participants differed between pre and post tests and between time points. In pre-test in HIRT group Glu60 n was 6, and Glu120 n was 4. In SSE group the Glu60 and Glu120 n was 5.

Group	Glucose 0 min		Glucose 60 min		Glucose 120 min	
	PRE	POST	PRE	POST	PRE	POST
HIRT (n = 4 – 7/3)	4.97 ±0.29	4.67 ±0.29	5.95 ±1.35	4.83 ±1.72	4.63 ±0.91	4.30 ±0.95
HICT (n = 6/5)	4.87 ±0.52	5.14 ±0.29	5.20 ±1.52	5.86 ±1.18	4.32 ±0.77	4.60 ±0.75
SSE (n = 5 – 6/4)	5.32 ±0.23	5.15 ±0.44	5.58 ±2.22	5.53 ±1.50	4.32 ±0.42	4.90 ±1.11