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# How does High Intensity Interval Exercise Affect Fat Loss?

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## Abstract

US survey trends show that since the 1970's there has been a decline in energy intake, (consumption of food) and a rise in the prevalence of obesity. This suggests that there must have been a dramatic decrease in total energy expenditure. Energy expenditure is the sum of energy (or calories) the body needs to carry out physical functions such as breathing and digestion, as well as the energy used in physical activity. As the rate of obesity in the US increases, it is becoming more and more important to find ways to increase energy expenditure, specifically through physical activity. Physical activity is often thought of as the key to fat loss because it is the component of energy expenditure that is most variable and can lead to the greatest total energy expenditure. The issue that follows is that many overweight individuals lack the motivation to invest time and energy into a substantial amount of exercise. To overcome this problem and to help make exercise more manageable, high intensity interval exercise (HIIE) can be a practical solution. HIIE is an exercise strategy that prescribes short periods of intense exercise alternating with less intense recovery periods. HIIE can potentially, with little time investment, result in energy expenditure equivalent to that of lower intensity continuous exercise done for a longer period of time. The purpose of this review is to examine the effects of HIIE on body composition and fat loss according to the current literature. If HIIE proves to be an effective way to burn fat without the time investment exercise routines typically require, it may make fat loss goals more attainable and lead to better results if implemented into weight loss programs.

## Introduction

### Fuel Source During Exercise

While the human body is at rest, skeletal muscle is responsible for 30% of oxygen consumed. During strenuous exercise, skeletal muscle can account for more than 90% of the total metabolism. ATP is required in order for skeletal muscles to contract and relax during exercise. As such, the purpose of muscle metabolism is to generate ATP via oxidative phosphorylation. Skeletal muscle can use free fatty acids, glucose, or ketone bodies as fuel for ATP production (Garrett et al., 2012). Since cellular respiration involves several complex metabolic pathways, the relative utilization of fat and carbohydrate during exercise can vary enormously and depends strongly on exercise intensity (Loon et al., 2001). Generally, as intensity of exercise is increased, the amount of oxygen available decreases and the muscle carries out anaerobic respiration. This refers to glycolysis, a metabolic pathway that primarily uses carbohydrates as substrate. The increased carbohydrate metabolism (glycolytic flux) limits the transport of long chain fatty acids into the mitochondria where fat oxidation generally occurs. Consequently, increased carbohydrate usage as fuel will inhibit the use of fat as fuel (Christmass et al., 2000). In high intensity intermittent exercise it's often found that carbohydrate breakdown decreases, and fat oxidation increases as the exercise progresses (Talanian et al., 2006). This can be attributed to the interval nature of HIIE and is known as the "substrate-shuttle" effect. (EG Trapp et al., 2007).

### The "Substrate-shuttle" Effect

Intramuscular triglycerides are an important supply of fuel for skeletal muscle. Each one is composed of three fatty acids esterified to a glycerol backbone. When glycerol levels are elevated, it's indicative of an increased reliance on fats for fuel. (Trapp et al., 2007).

Lactate is a waste product of glycolysis, generated from the anaerobic breakdown of glycogen. While exercising steadily, there is normally a balance between lactate production and lactate removal. When the intensity of exercise reaches a point at which there is an abrupt increase in lactate levels, lactate threshold has been reached. If lactate levels are above threshold, the excess blood lactate will inhibit carnitine- acyl CoA transferase, an essential enzyme which enables beta-oxidation to occur. (Trapp et al., 2007) (explain beta oxidation).

Lactate and glycerol levels were analyzed in one particular study of HIIE. 16 women, 8 trained and 8 untrained, participated in two 20 minute short sprint sessions (8 second sprint/12 second recovery) and two 20 minute long sprint sessions (24 second sprint/36 second recovery). After exercising, they found that plasma glycerol levels went up dramatically for both groups ( $P < .0001$ ). Lactate levels rose as well; they were higher during long sprints for trained women than for short sprints ( $P < .01$ ). (Trapp et al., 2007).

The elevated glycerol levels indicate that there was an increased fat oxidation for fuel. This enhanced fatty acid oxidation, seems contradictory to the fact that lactate levels were elevated above threshold (3.5mmol/L - 4.0mmol/L). The solution proposed for this contradiction is the intermittent nature of HIIE. The intervals in HIIE create a "substrate shuttle" with alternating anaerobic and aerobic energy sources. During the high intensity periods, ATP and creatine phosphate are broken down to produce energy. During the rest periods, they are resynthesized aerobically. However, since the rest interval isn't that long, it is likely that the resynthesis is incomplete and anaerobic glycolysis provides the rest of the needed energy. This is verified by

Bangsbo et al. 1991, who found that glycogen, the substrate for anaerobic glycolysis, was shown to be progressively diminished over the course of HIIE. Eventually, repeated exercise results in an accumulation of cytosolic citrate which inhibits phosphofructokinase activity and impairs glycolysis. It is suggested that the progressive depletion of glycogen and phosphocreatine along with the increased levels of cytosolic citrate, act together to inhibit glycolysis, and allow for repeated bouts of high intensity exercise, while reducing lactate accumulation. The aerobic metabolism that accompanies lower lactate levels may enhance fatty acid oxidation. (Trapp et al., 2007).

### Methods

This comprehensive review is based on critical analysis of literature obtained using the Touro College Online library and Google Scholar. References in these articles were retrieved and served as additional points of reference for further research. Review articles were useful in helping provide additional references to source material.

### Discussion

Many studies have been performed in an effort to establish the relationship of HIIE with increased fat loss. The studies examine whether HIIE causes enhanced fat loss, and via which mechanisms this may occur. Since the mechanisms of carbohydrate metabolism, fat oxidation, and fat loss in general are complex and detailed, there are many different ways to determine if fat loss occurred as a result of exercise. The study of energy expenditure, the analysis of skeletal muscle, the catecholamine response, and the respiratory exchange ratio can all provide useful information regarding whether enhanced fat oxidation occurred as a result of HIIE.

### Energy Expenditure and Fat Loss

The volume of physical work done is often the factor that plays the greatest role on energy expenditure (EE). This volume is based on the duration and intensity of the exercise done. For example, more energy is expended when walking 5 miles than when walking 3. Generally, as long as the activity is done at the same intensity, there is a linear relationship between EE and work carried out. However, when exercise intensity is changed, it affects how efficiently work can be performed. There is a negative relationship between exercise intensity and efficiency (Hunter et al., 1998). For example, for the same amount of cycling, EE was 22% greater when it was carried out at a high intensity than at a low intensity (Treuth et al., 1996). The exact reasons behind this inverse relationship between efficiency and exercise intensity are unknown. In any case, it seems to be that the best way to increase EE is to carry out a high volume of work at high intensity. However, this kind of exercise can bring about fatigue very quickly. Therefore, high intensity exercise

interspersed with rest intervals seems to be an ideal way to increase EE by combining high intensities with multiple rest intervals (Hunter et al., 1998).

The question that follows is if two exercises have equal EE, yet one was reached via HIIE and the other via low intensity continuous exercise, will HIIE generate more fat loss?

One study that compared results of high and moderate intensity exercise programs with equivalent EE found that this was indeed the case. This 15 week intervention study was performed on 34 healthy women aged between 18 and 30 years old. They were divided into an HIIE group, a continuous exercise group, and a control group. The HIIE protocol consisted of 8 seconds sprinting on an ergometer(?), alternating with 12 seconds of turning the pedals slowly. As each subject was able to complete 20 minutes of HIIE at a resistance of .5kg, the resistance for that subject was increased by increments of .5kg. The continuous exercise protocol consisted of a five minute warmup and cooldown, and a 15-20 minute (later increasing to 40 minute) work session pedaling at a continuous intensity of 60%  $\text{VO}_2$  peak.  $\text{VO}_2$  peak is the point when a subject's oxygen consumption plateaus at  $\leq 150$  ml/min  $\text{VO}_2$  as the test progressively gets more difficult. When this happens, it's indicative of the fact that the subject is close to his actual  $\text{VO}_2$  max capacity, or maximal oxygen intake. In the continuous exercise group as well, the resistance was raised by increments of .5kg as the fitness of each subject improved. The control group was instructed to maintain their usual diet and physical activity. Total EE for the continuous exercise group and HIIE group was  $36.3 \pm 3.4$  MJ and  $41.5 \pm .81$  MJ, respectively. This is considered a non-significant difference. Nevertheless, there was a substantial decrease in total body mass for the HIIE group compared to the other groups. The HIIE group also displayed a significant decrease in fat mass while the other two groups had a fat mass gain. (Trapp et al., 2008). Not only did the HIIE group expend the same amount of energy in a shorter amount of time, that equivalent EE caused more fat loss when reached via higher intensity exercise.

It should be noted that studies have indicated a direct correlation between initial adiposity and amount of fat lost. Research has shown that subjects with higher fat levels to begin with, tend to lose more fat (Trapp et al., 2007), (Trapp et al., 2008). This would support the notion that HIIE would generate a more significant loss of fat in overweight individuals than in thinner subjects. That being said, there were four lean women in the HIIE group of the aforementioned study who possessed significantly lower fat mass than the rest of the group. With these four women removed, the HIIE group displayed a 4.3% decrease in total body mass, a 14.7% decrease in total fat mass, and a 9.5% decrease in central abdominal fat. Conversely, the continuous

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exercise group displayed a 10.5% increase in central abdominal fat. (Trapp et al., 2008). These results further demonstrate that for a given expenditure of energy, fat loss is greater when intensity is high.

Another study was performed on 21 middle aged obese women with the metabolic syndrome, displayed similar results. During this 16-week exercise intervention program, the women were divided into 3 groups – control, low intensity exercise training (LIET), and high intensity exercise training (HIET). The LIET group trained five days a week at an intensity at or below their lactate threshold. The duration of each session was adjusted so that the participants expended a specific amount of energy per week. The HIET group also exercised 5 days a week, with high intensity sessions for three of the days and moderate intensity exercise sessions for the remaining two. Participants exercised at an intensity between their lactate threshold and  $VO_{2peak}$  on the high intensity days and at an intensity at or below their lactate threshold on the lower intensity days. Again, the duration of sessions was modified based on the progression of caloric expenditure as the training intervention proceeded. The findings indicate that exercise of higher intensity generates greater fat loss compared to exercise of lower intensity under isocaloric training conditions. (Irving et al., 2008).

It should be noted that the HIET group in this study likely had a total EE that was slightly greater than that of the LIET group. This is because the total EE per session was a combination of the kcal expended during training as well as resting metabolism. Therefore, on HIET days when the duration of exercise was slightly shorter, the resting metabolism would contribute to a lower fraction of the total EE. This caused a 25 kcal difference between the HIET and LIET groups per week, totaling a difference of 400 kcal over the course of the training intervention. (Irving et al., 2008).

The previous studies examined the difference in fat loss when EE was equal between groups. Overall, greater fat loss was noted when exercise was done at higher intensities. Research has also been done to compare HIIE and continuous exercise when EE is not equivalent.

In one study, the mean estimated total energy cost was 120.4 MJ for the continuous/endurance training (ET) exercise program, and 57.9 MJ for the HIIE program. Nevertheless, the reduction in the sum of six skin folds was greater after HIIE. Since there is an association between exercise duration and fat loss, the changes in subcutaneous fat were corrected based on the total energy cost of training. As demonstrated when the decrease in the sum of the skinfolds was divided by energy expenditure and expressed as changes in subcutaneous skinfolds per MJ, the

participants in the HIIE program lost nine times more subcutaneous fat than those in the ET program (Tremblay et al., 1994).

However, not all studies show HIIE to be superior to ET. Very often, when the EE is not equivalent, HIIE will not bring about more favorable results than ET. Nevertheless, if HIIE brings about the same results with a smaller time investment, it is still extremely worthwhile. In the present study is an example of HIIE that brought about results comparable to ET. Sprint interval training is a form of HIIE where the high intensity intervals involve 30 second “all-out” sprints on an ergometer. 16 active men were separated into a sprint interval training (SIT) group and a high volume endurance training (ET) group. In this study, the SIT protocol consisted of 6 sessions of 4-6 repeats of 30 seconds “all-out” cycling at about 250%  $VO_{2peak}$  with 4 minute recovery periods. The ET program consisted of 90-120 minutes of continuous cycling at 65% of  $VO_{2peak}$ . Total EE was 630 KJ for the SIT group, and 6500 KJ for the ET group. Despite the fact that EE for the ET group was 10 times more than the EE for the SIT group, the results showed that SIT brought about similar improvements in muscle oxidative capacity. (Gibala et al., 2006).

Another SIT study yielded similar results. 20 young men and women were separated into SIT and ET groups for 6 weeks of training. The SIT consisted of 4-6 30 second “all-out” cycling tasks (at 500W) three times a week, and the ET group consisted of 40-60 min of continuous cycling at about 65%  $VO_{2peak}$  five days a week. Total weekly exercise volume was 90% lower in the SIT group. Moreover, since most of SIT exercise time is actually spent in recovery from the 30 second bouts of cycling, actual weekly exercise time was only about ten minutes in SIT, compared to 4.5 hours in ET. Nevertheless, results between the two groups were very similar: whole body fat oxidation was increased and carbohydrate oxidation was decreased. (Burgomaster, 2008).

### Skeletal Muscle Analysis

As mentioned earlier, the “substrate-shuttle” effect supports enhanced fat oxidation by activating aerobic metabolism and enabling the mitochondria to produce ATP. In line with this, it's likely that HIIE will result in increased mitochondrial enzyme activity. Therefore, when studying the effects of HIIE on skeletal muscle, many researchers focus on changes in mitochondrial enzymes. Based on increased activity of mitochondrial enzymes and the fact that aerobic metabolism favors enhanced fatty acid oxidation, it's possible to surmise that an increase in mitochondrial enzyme activity during HIIE will correlate with fat loss.

Citrate synthase and  $\beta$ -HAD (Hydroxyacyl-Coenzyme A dehydrogenase) activity, are important indicators of enhanced fatty acid metabolism, that were significantly increased in an HIIE

intervention in just 2 weeks. In this study, skeletal muscle enzyme activity was measured to confirm an increase in the use of fats as fuel. 8 healthy recreationally active women participated in this study. Each of them performed a  $VO_{2peak}$  test before and after 2 weeks (7 sessions) of HIIE. The  $VO_{2peak}$  tests involved a 60 minute cycling trial at about 60% $VO_{2peak}$ . The seven HIIE sessions consisted of 10 cycles of 4 minutes of high intensity cycling at 90% $VO_{2peak}$  alternating with 2 minute resting periods. Whole body fat oxidation and total fat oxidation were both significantly increased during the 60 minute cycling session after HIIE. Accordingly, there was a significant decrease in whole body carbohydrate oxidation and a 23% decrease in total carbohydrate oxidation. These results were then supported with a skeletal muscle analysis. (See Table 2)

ANALYZED	IN 60 MINUTE SESSION AFTER HIIE
$\beta$ -HAD activity	increased by 32%
citrate synthase activity	Increased by 20%.
HSL protein content	Increased by 13%
FABPpm	increased 25%
FAT/CD36	remained unchanged
Resting muscle glycogen content	Unchanged
Net muscle glycogen utilization	Decreased by 12%
Intramuscular triglycerides	Decreased by 17%
(before HIIE, by 12%)	

**Table 2 Summary of skeletal muscle analysis conducted after a 2 week HIIE intervention study (Talanian et al., 2006).**

Usually, exercise training results in increased fat oxidation from fatty acids stored in adipose tissue and intramuscular triglyceride (IMTG) stores. In this study, however, HIIE did not cause a significant increase in IMTG utilization. HSL (hormone sensitive lipase) protein content was also not seen to be significantly increased. HSL is a key regulatory enzyme in lipolysis of IMTG stores. It's possible that the HIIE protocol in this study was too short to bring about significant adaptations in skeletal muscle (Talanian et al., 2006).

FABPpm (plasma membrane fatty acid-binding protein) and FAT/CD36 (fatty acid translocase) are two proteins that transport long chain fatty acids (LCFA) across the plasma and mitochondrial membranes. They are useful in determining if skeletal fat oxidation was enhanced or limited during exercise. In this study, FABPpm concentration was increased by 25% after HIIE, and FAT/CD36 concentration remained unchanged. It is true that an inhibition of FABPpm will reduce the uptake of LCFA, but an unchanged FAT/CD36 doesn't necessarily mean the same thing. It's possible that there was a shift in the fractional concentrations

of FAT/CD36 on the mitochondrial and plasma membranes that could have increased LCFA uptake without a notable increase in FAT/CD36 concentration. (Talanian et al., 2006).

The elevated citrate synthase and  $\beta$ -HAD levels indicate increased use of fats for ATP. Citrate synthase is a critical enzyme in the citric acid cycle, a cycle which favors aerobic metabolism, and likely the use of free fatty acids as fuel.  $\beta$ -HAD, or 3-hydroxyacyl-CoA dehydrogenase, is an enzyme that catalyzes an important step in fatty acid metabolism. (Talanian et al., 2006)

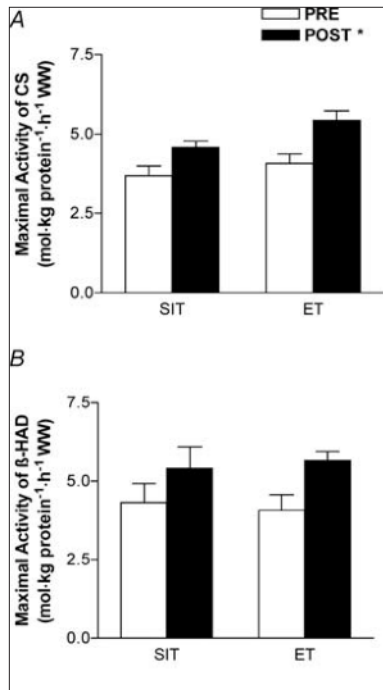
In another SIT program, citrate synthase and  $\beta$ -HAD were analyzed as well. The results after 6 weeks of training showed that both citrate synthase and  $\beta$ -HAD increased after SIT in a similar manner to that of ET (See Figure 1), suggesting that fatty acid oxidation was occurring. This was further proven by the tremendous increase in whole body fat oxidation noted after training (Burgomaster, 2008).

Malate dehydrogenase (MDH) is another enzyme that is needed in the citric acid cycle. Increased MDH is indicative of aerobic conditions, and likely increased fat oxidation. In one particular study that compared HIIE to ET, increased MDH was found in both groups. 27 men and women partook in this study, 8 men and 9 women participated in a 20 week ET intervention, and 5 men and 5 women participated in the 15 week HIIE intervention. The ET program included a 30 minute (increasing to 45 minutes) cycling session, 4 times (increasing to 5) times a week. Intensity corresponded to 60% (and increasing to 85%) of the maximal heart rate reserve. The HIIE intervention consisted of 25 sessions with 30 minutes of continuous exercise at an intensity similar to the endurance training program. Half of these were completed by the fifth week of the program. It also included 16 short interval sessions (10-15 bouts of 15-30 seconds of high intensity intervals, alternating with recovery periods to allow heart rate to return to 120-130 beats per minute), and 19 long interval sessions (4-5 bouts of 60-90 seconds of high intensity intervals alternating with recovery periods to allow heart rate to return to 120-130 beats per minute). The results showed that participants in the HIIE program lost nine times more subcutaneous fat than those in the ET program. These results were supported by the increased MDH activity. Furthermore, there was a substantial increase in  $\beta$ -HAD in the HIIE group alone, another indication of the fact that HIIE leads to better lipid utilization (Tremblay et al., 1994).

**Catecholamine Response**

Epinephrine is a catecholamine known for stimulating lipolysis. As such, elevated epinephrine concentrations after exercise would indicate an increased use of fat as fuel. Trapp et al., 2007 demonstrated this in their study when examining the different responses of trained and untrained women during HIIE.

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**Figure 1 Activity of citrate synthase and  $\beta$ -HAD before and after 6 weeks of SIT training (Burgomaster, 2008).**

It was found that epinephrine and norepinephrine levels both increased after short sprint and long sprint exercise (see Figure 8). The elevated catecholamine levels serve as another explanation of why the glycerol levels in that previously mentioned study were increased despite lactate levels above threshold.

### Respiratory Exchange Ratio (RER)

RER is the ratio of carbon dioxide produced to oxygen consumed. Based on the RER, it is possible to estimate which particular fuel is being oxidized to produce energy. An RER close to .7 is indicative of fat as the energy source, and an RER close to 1.0 is indicative of carbohydrate as the energy source. An RER value between the two indicates a mixture of fat and carbohydrate. Therefore, by measuring RER after an exercise intervention, one can deduce what fuel was oxidized in order to produce ATP.

In one study, 10 obese males participated in 6 sessions of sprint interval training over a 2 week period. After the 2 week intervention, it was noted that the RER decreased from .78 +/- .01 to .73 +/- .01, suggesting that fat was the primary substrate used for oxidation. This was further confirmed by the fact that resting carbohydrate oxidation was significantly lower after training and that resting fat oxidation was increased by 18.2%. Even though significant weight loss wasn't noted in this study, (body mass was somewhat lower ( $P=.055$ ), and waist and hip circumference were reduced by  $\approx 1\%$ ), the magnitude of increase in resting fat oxidation is used in order to predict the extent of exercise-induced fat loss. This estimate is based on resting fat oxidation alone and is independent of exercise energy expenditure and change in

resting metabolic rate. The fact that no noteworthy weight loss was noted in this study is explained by the fact that the intervention was short-term. Based on the increased fat oxidation, it can be inferred that a longer-term intervention would likely yield more substantial weight loss results (Whyte et al., 2010).

### Can HIIE really help the overweight population?

The actual benefits of interval training can be seen when comparing it to another weight loss method. 62 overweight adolescents were divided into two groups- aerobic interval training group (AIT) and multidisciplinary approach group (MTG). The AIT group did HIIE on a treadmill twice a week for 3 months, and were then encouraged to perform at least 2 interval sessions for the next 9 months. The HIIE sessions included 4, 4 minute bouts at 90% of maximal heart rate, alternating with 3 minute lower intensity sessions at 70% maximal heart rate. The MTG were subjected to a 12 month regimen which included meeting every 2 weeks with a doctor, a clinical nutritional physiologist, and a nutritional psychologist. After 3 and 12 months, only the subjects in the AIT group had a decreased percentage of body fat. It's interesting to note that the subjects in the AIT group followed a better diet than those in the MIT group even though they were not given clear guidelines regarding caloric intake. This is possibly because AIT brought about a motivational side effect of improving their aerobic capacity. Indeed, some members commented that they became more conscious of their eating habits after 3 months of the AIT program. (Tjonna et al., 2009).

### Limitations

When analyzing fat loss over an extended period of time, it is difficult to isolate the cause of it. Even though subjects in the HIIE studies were instructed to maintain their regular diets, it's not guaranteed that they did. As a result, it's possible that some of the fat loss displayed after an exercise intervention was partly due to dietary modifications.

Another limitation the study of HIIE poses, is the varying intensities and duration of intervals. Most studies mentioned in this paper prescribed a different HIIE "formula." Since there hasn't yet been a study that tests every combination of intensity and duration of exercise, it is difficult to determine the minimum length and intensity needed in order to bring about the benefits of HIIE. It's possible that the results discussed in this review would not be successfully replicated if done at a slightly lower intensity, or for a shorter amount of time.

### Conclusion

HIIE is an arduous method of exercising which requires subjects to push themselves to their maximum capacity for short intervals of time. Most studies conducted regarding HIIE involve high

intensity intervals that are extremely difficult and demanding. Although HIIE has been shown to enhance fatty acid oxidation and increase fat loss, it may be dangerous for an obese, non-physically active person to attempt.

That being said, for individuals who could handle the workload of HIIE, the short duration of intense intervals might encourage exercise because there's only a small span of time where they are required to push themselves. Moreover, more people might be motivated to exercise daily since only a few short sessions of HIIE are needed to improve whole body fat oxidation. As mentioned earlier, it took only 7 sessions of HIIE to increase total fat oxidation by 36% in previously untrained women (Talanian et al., 2006), and only 6 sessions of sprint training for overweight men to increase resting fat oxidation by 18.5% (Whyte et al., 2010).

Variable	MTG			AIT		
	Baseline	3 Months (n = 22)	12 Months (n = 14)	Baseline	3 Months (n = 20)	12 Months (n = 13)
<b>Body composition</b>						
Weight (kg)	94.3 ± 15.3	95.4 ± 1.4	96.1 ± 1.7	94.1 ± 23.3	94.4 ± 1.4	94.4 ± 1.7
Height (cm)	168 ± 8.4	169 ± 0.4**	171 ± 0.5**	169 ± 10.4	170 ± 0.4**	173 ± 0.5**
BMI (kg/m <sup>2</sup> )	33.3 ± 4.5	33.1 ± 0.4	32.9 ± 0.5	33.2 ± 6.1	32.5 ± 0.4**	31.4 ± 0.5
Waist (cm)	101.4 ± 10.8	104.2 ± 1.4	100.1 ± 2.3	105.3 ± 10.5	104.9 ± 1.7	98.1 ± 2.2*
Total fat (%)	41.1 ± 4.7	40.8 ± 0.5	39.1 ± 0.6	40.4 ± 5.3	39.3 ± 0.5**	38.4 ± 0.7**
Fat weight (kg)	34.8 ± 7.8	35.1 ± 1.1	34.7 ± 1.3	34.5 ± 12.2	33.6 ± 1.1**	32.1 ± 1.5
Fat weight trunk (kg)	17.7 ± 5.3	17.9 ± 0.6	17.1 ± 0.8	18.3 ± 7.2	17.0 ± 0.6*	16.8 ± 0.8
Lean (kg)	56.1 ± 8.7	57.9 ± 0.6**	58.0 ± 0.8	55.9 ± 11.8	57.9 ± 0.6**	60.0 ± 0.8

**Table 2 Variables related to the overweight adolescents during the experimental period. Values are means ± S.E.M., except baseline values which are means ± S.D. \*P < 0.05 and \*\*P < 0.01, significantly better compared with baseline within the group; †P < 0.05, significantly better compared with the respective time in the MTG group. 1RM; one repetition maximum; nm, not measured (Tjonna et al., 2009).**

Further research is needed in order to determine the minimum intensity and duration required for HIIE-induced fat loss. Because there are a large number of potential variables regarding the kind of exercise, the intensity and duration of the exercise, and the population exercising, it is difficult to create an exact guideline for HIIE. Consequently, more research is needed before HIIE is prescribed, to help decrease fat in overweight individuals.

**Abbreviations**

- AIT – aerobic interval training group
- EE – energy expenditure
- ET – endurance training
- FABPpm (plasma membrane fatty acid-binding protein)
- FAT/CD36 (fatty acid translocase)
- HIET – high intensity exercise training
- HIIE – high intensity interval exercise

- HSL – hormone sensitive lipase
- IMTG – intramuscular triglycerides
- LCFA – long chain fatty acids
- LIET – low intensity exercise training
- MDH – malate dehydrogenase
- MTG – multidisciplinary approach group
- RER – respiratory exchange ratio
- SIT – sprint interval training
- β-HAD – Hydroxyacyl- Coenzyme A dehydrogenase

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