7 Fat burning: how and why?

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Introduction

Fat burning is a very popular and often used term amongst endurance athletes. There are fat burning workouts, fat burning nutrition supplements (fat burners), exercise machines in the gym have fat burning options and heart rate monitors tell you when you are in the fat burning zone. The term fat burning refers to the ability to oxidise (or burn) fat and use fat as a fuel instead of carbohydrate. Often fat burning is associated with weight loss, decreases in body fat and increases in lean body mass. However, it must be noted that such changes in body weight and body composition can only be achieved with a negative energy balance: you have to eat less calories than you expend, independent of the fuels you use! It is important to realise that increasing fat oxidation does not mean losing body fat or body weight! Here we will discuss the importance of fat burning and the most important factors that influence fat burning as well as nutrition supplements that claim to increase fat burning.

The importance of fat metabolism

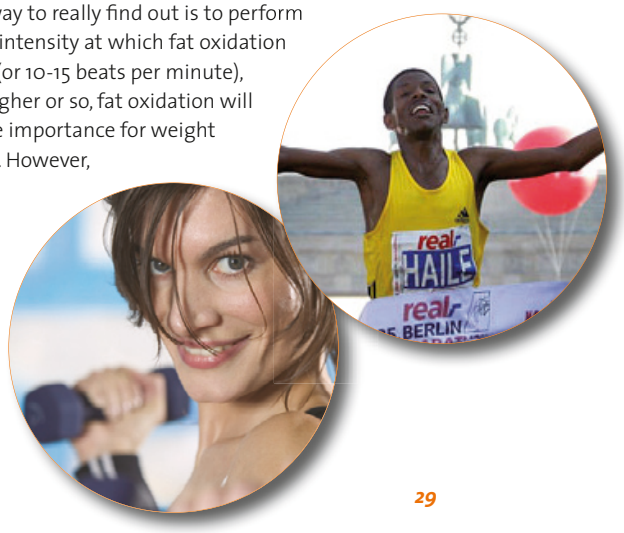
It is becoming increasingly clear that the ability to oxidise fat is important for both performance and health. It is also well established that well-trained endurance athletes have an increased capacity to oxidise fatty acids. This enables them to use fat as a fuel when carbohydrate stores become limited. In contrast, patients with obesity, insulin resistance and type II diabetes may have an impaired capacity to oxidise fat. As a result fatty acids may be stored in the muscle and in other tissues. This accumulation of lipid in the muscle and its metabolites may interfere with the regulation of metabolism. Although evidence for this is not available it is also attractive to think that an increased capacity to oxidise fat may aid those who want to loose weight and in particular body fat if used in combination with a negative energy balance.

Factors that affect fat oxidation

Exercise intensity

One of the most important factors that determine the rate of fat oxidation during exercise is the intensity. Although several studies have described the relationship between exercise intensity and fat oxidation, only recently this relationship was studied over a wide range of intensities (2) (Figure 1). In absolute terms, carbohydrate oxidation will increase proportionally with exercise intensity, whereas the rate of fat oxidation will initially increase but will decrease again at higher exercise intensities (Figure 1). So although it is often claimed that you have to exercise at low intensities to oxidise fat, this is not necessarily true.

In a series of recent studies we have defined the exercise intensity at which maximal fat oxidation is observed as Fatmax. In a group of trained individuals it was found that exercise at moderate intensity (62-63%VO2max or 70-75%HRmax; Figure 1) was the optimal intensity for fat oxidation, whereas it was around 50%VO2max for less trained individuals (2, 8)). However, it must be noted that the inter-individual variation is very large. A trained person may have his maximal fat oxidation at 70%VO2max or 45%VO2max and the only way to really find out is to perform one of these Fatmax tests in the laboratory. However, in reality the exact intensity at which fat oxidation peaks may not be that important because within 5-10% of this intensity (or 10-15 beats per minute), fat oxidation will be similarly high, and only when the intensity is 20% higher or so, fat oxidation will drop rapidly (Figure 1). This exercise intensity (Fatmax) or "zone" may have importance for weight loss programs, health-related exercise programs, and endurance training. However, very little research has been done.



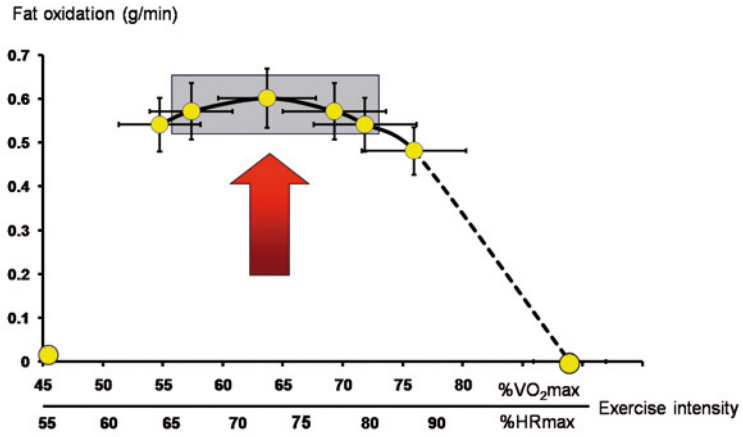


Figure 1:
Exercise intensity (expressed as %HRmax and %VO2max) and fat oxidation. Fat oxidation increases from low to moderate exercise intensities, peaks at Fatmax and decreases as the exercise intensity increases further. The grey area represents the Fatzone: a range of exercise intensities where fat oxidation is high.

Dietary effect

The other important factor is diet. A diet high in carbohydrate will suppress fat oxidation and a diet low in carbohydrate will result in high fat oxidation rates. Ingesting carbohydrate in the hours before exercise will raise insulin and subsequently suppress fat oxidation by up to about 35% (1). This effect of insulin on fat oxidation may last as long as 6-8 hours after a meal and this means that the highest fat oxidation rates can be achieved after an overnight fast. Exercise without breakfast has often been used by endurance athletes as a way to increase the fat oxidative capacity of the muscle. Recently a study was performed at the University of Leuven in Belgium in which they investigated the effect of an endurance training program (6 wk, 3 day/wk, 1–2 h) (5). The participants trained in the fasted or carbohydrate fed state. The investigators observed a decrease in muscle glycogen use and the activity of various proteins involved in fat metabolism was increased after training in the fasted state. However, fat oxidation during exercise was the same in the two groups. It is possible though that there are small but significant changes in fat metabolism after fasted training but in this study changes in fat oxidation might have been masked by the fact that these subjects received carbohydrate during their experimental trials. It must also be noted that training after an overnight fast may reduce the exercise capacity and may therefore only be suitable for low to moderate intensity exercise sessions. The efficacy of such training for weight reduction is also not known.

Duration of exercise

It has been established for a long time that fat oxidation becomes an increasingly important fuel as exercise progresses. During ultra-endurance exercise fat oxidation can reach peaks of 1 g/min although fat oxidation may be reduced if carbohydrate is ingested before or during exercise. In terms of weight loss the duration of exercise may be one of the key factors as it is also the most effective way to increase energy expenditure.

The mode of exercise

The exercise modality also has an effect on fat oxidation. Fat oxidation has been shown to be higher for a given oxygen uptake during walking and running compared with cycling (3). The reason for this is not known but it has been suggested that it is related to the greater power output per muscle fibre in cycling compared to running.

Gender differences

Although some studies in the literature have found no gender differences in metabolism, the majority of studies now indicate higher rates of fat oxidation in women compared with men. In a study in which 150 men and 150 women were compared over a wide range of exercise intensities, it was demonstrated that the women had higher rates of fat oxidation over the entire range of intensities and fat oxidation peaked at a slightly higher intensity (9). The differences however are small and may not be of great physiological significance.

Environment

Environmental conditions can also influence substrate utilisation. It is known that exercise in a hot environment will increase glycogen use and reduce fat oxidation and something similar can be observed at high altitude. Similarly when it is extremely cold and especially when shivering, carbohydrate metabolism will be stimulated at the expense of fat metabolism.

Exercise training

The only effective way to increase fat oxidation during exercise at present is to perform regular physical activity. Exercise training will upregulate the enzymes of the fat oxidation pathways, increase mitochondrial mass, increase blood flow etc. all of which will enable higher rates of fat oxidation. Research has shown that as little as 4 weeks of regular exercise (3 times per week 30-60 min) can increase fat oxidation rates and cause enzymatic changes (6). Too little information is available to draw any conclusions about the optimal training programme to achieve these effects.

Exercise programmes to lose weight or body fat

The optimal exercise type, intensity, and duration for weight loss are still unclear. Current recommendations are mostly focused on increasing energy expenditure and increasing participation in exercise. Finding the optimal intensity for fat oxidation might aid in losing weight (fat loss) and support weight maintenance but evidence for this is currently lacking. It is also important to realise that the amount of fat oxidised during exercise is only small. Fat oxidation rates are on average 0.5 g/min at the optimal exercise intensity. So in order to oxidise 1 kg of fat mass, more than 33 hours of exercise is required. Walking or running exercise around 50-65%VO2max seems to be an optimal intensity to oxidise fat. The duration of exercise however, plays a crucial role with an increasing importance of fat oxidation with longer exercise. Of course this also has the potential to increase daily energy expenditure. If exercise is the only intervention used the main goal is usually to increase energy expenditure and reduce body fat. When combined with a diet program, however, it is mainly used to counteract the decrease in fat oxidation often seen after weight loss (4).

Nutrition supplements

There are many nutrition supplements on the market that claim to increase fat oxidation. These supplements include caffeine, carnitine, hydroxycitric acid (HCA), chromium, conjugated linoleic acid (CLA), guarana, citrus aurantium, asian ginseng, cayenne pepper, coleus forskholii, glucomannan, green tea, psyllium and pyruvate (a selection of supplements is listed in Table 1). With few exceptions, there is limited to no evidence that these supplements marketed as fat burners actually increase fat oxidation during exercise (7). We will discuss three supplements below. The rest is summarised in the table.

Carnitine

Carnitine is one of the most popular fat burners. It has been around for a long time and became very popular in the 90s after the Italian football team won the world champion and revealed that they had used carnitine. Carnitine is a substance produced by the body but also obtained via daily food intake. It is found mostly in meat and plays a crucial role in fat metabolism. Carnitine is responsible for the transport of fats into the mitochondria (the powerplants in the cells that provide the muscle with the energy to contract). Patients who cannot synthesize carnitine are unable to use fat as a fuel and they rely solely on carbohydrate. The entire theory that carnitine supplementation helps fat metabolism, however, is badsed on the premise that when you ingest carnitine that this carnitine enters the muscle the concentration of carnitine in the muscle increases. Studies in the 90s showed however, that even with large dose of carnitine the muscle carnitine concentration is unaffected and therefore carnitine cannot expected to have an effect on fat metabolism. The interest in carnitine disappeared (at least amongst scientists because athletes were still buying carnitine!). Recently however, there is some renewed interest in carnitine. Professor Paul Greenhaff and his coworkers at the University of Nottingham showed that IF you can increase the muscle carnitine, this can increase fat metabolism. They increased muscle carnitine by simultaneously increasing the insulin concentration and providing carnitine. So possibly carnitine may have some effects, especially long term if it is used in combination with carbohydrate. However, it is probably too early to draw any conclusions and the fact remains that most studies have not observed any effects of carnitine.

Green tea

Green tea has many suggested medicinal properties and there is actually some evidence that is does protect against various diseases. More recently research has focused on its effects on fat metabolism and although 90% of the research is on animals and not in humans the results are promising. We recently showed that ingesting a green tea extract the night before and an hour before a 30 min cycling bout increased fat metabolism by 20% (10). The green tea extract contains mainly Epogalocatechin gallate or EGCG, the active ingredient in green tea. EGCG is one of most powerful polyphenols with anti-oxidant properties, increased the activity of the enzyme responsible for the breakdown of catecholamines (adrenaline and noradrenaline). This in turn may result in higher concentrations of catecholamines and stimulation of lipolysis making more fatty acids available for oxidation. There is also some evidence that EGCG increases metabolic rate suggesting that it could help with weight loss. The green tea extract contains the active ingredient in a concentrated form and the dose that we used to see the 20% improvement in fat metabolism was fairly large. It would equate to drinking a liter of green tea. Whether smaller doses of green tea will still have an effect we don't know but this is something we are studying at the moment.

Caffeine

Caffeine is often associated with increased fat metabolism. However, whether caffeine actually has this effect depends on the type of exercise and the dose of caffeine. Effects on fat metabolism are typically seen at lower intensities of exercise and with relatively low doses of caffeine. At high doses of caffeine and at higher intensities of exercise, carbohydrate metabolism may be stimulated and fat metabolism may even be suppressed. Several "fat burners" contain at least some caffeine.

Does a cup of coffee with breakfast work? Probably not a lot! The reason for that is that a breakfast will at least contain some carbohydrate and this will cause the hormone insulin to be released and this in turn will suppress fat metabolism. So although caffeine might stimulate fat metabolism a little, this effect would be completely overruled by insulin.

This is not only true for caffeine but in fact for all supplements. Increased fat metabolism can probably only be observed in the morning, after an overnight fast and before breakfast. Therefore in order to stimulate fat metabolism there probably is no easy option! You still have to exercise; you may have to do this without breakfast. Fat burning exercise sessions can have a place in a weekly training schedule but it is probably not a good idea to do too many of these sessions in one week.

Summary

Higher fat oxidation rates during exercise are generally reflective of good training status whereas low fat oxidation rates might be related to obesity and insulin resistance. Fat oxidation peaks on average at moderate intensities 50-65%VO2max depending on the training status of the individuals (2, 9), increases with increasing exercise duration but is suppressed by carbohydrate intake. Fat oxidation is slightly higher in women than in men. Also altitude and hot (or very cold) environmental conditions can increase carbohydrate and reduce fat oxidation. Many supplements are claimed to improve fat oxidation but most supplements are ineffective. The only highly effective way to increase fat oxidation is through exercise training, although it is still unclear what the best training regimen is to get the largest improvements. Finally, it is important to note that there is a very large inter-individual variation in fat oxidation that is only partly explained by the factors mentioned above. This means that although the factors mentioned above can influence fat oxidation, they cannot predict fat oxidation rates in an individual.

Table 1: *Nutrition supplements and the scientific evidence that the supplement increases fat metabolism*

Nutrition supplement	Evidence	Fat burning properties (claims)
Caffeine	●●●○○	Caffeine stimulates lipolysis and the mobilization of FAs. These actions might occur indirectly by increasing the circulating catecholamine levels or directly by antagonizing adenosine receptors that normally inhibit hormone-sensitive lipase and FA oxidation. In some but not all conditions this can result in increased fat oxidation.
Carnitine	●○○○○	Carnitine is essential for fat oxidation as it is needed to transport fatty acids into the mitochondria. Studies have shown however, that carnitine supplementation may not result in increased muscle carnitine supplementation and therefore it is not surprising that no effects on fat oxidation have been found. Nevertheless it is one of the supplements that is aggressively marketed as a fat burner. New studies may provide new insights and it is possible that
Cayenne pepper (Capsaicin)	○○○○○	Cayenne pepper has been used as a medicine for centuries, and has recently gained attention as a possible fat burning supplement. Cayenne contains capsaicin, which may help increase metabolic rate and stimulate circulation.

Chromium	○○○○○	Chromium was a very popular supplement a few years ago and was associated with ninsulin sensitivity and fat burning. There is no evidence that chromium has any effect on fat metabolism.
Citrus aurantium	○○○○○	Citrus aurantium (from bitter orange) contains five andrenergic amines including synephrine and tyramine, which stimulate the beta-3 cell receptors, stimulating lipolysis.
Coleus forskholii (Forskolin)	○○○○○	Coleus forskholii is an ancient herb that has gained attention lately as a possible fat burner. An extract called Forskolin present in Coleus has been found to be beneficial in its ability to burn fat. Forskolin activates adenylate cyclase, which in turn triggers an increase in cyclic adenosine monophosphate (cAMP). This increase in cAMP turns on the system responsible for the release of fat from its stores.
Conjugated linoleic acid (CLA)	○○○○○	Fatty acids that have been linked with special properties (especially antioxidant properties) but have also been linked to increases in fat metabolism. Evidence is weak.
Guarana	○○○○○	The active constituent of guarana, guaranine, is nearly identical to caffeine and is likely to have similar properties. There is far less research with guaranine compared with caffeine.
Ginseng (Asian or Panax)	○○○○○	Asian ginseng (Panax ginseng) has been a part of Chinese medicine for over 2,000 years and was traditionally used to improve mental and physical vitality. Evidence for fat burning properties is lacking.
Glucomannan	○○○○○	Glucomannan is a dietary fiber derived from the Konjac plant of South East Asia. It is included in fat burning supplements probably because of its potential effect on food intake. However, the fibre itself has no effects on fat metabolism.
Green tea	●●●○○	The active constituents in green tea are the polyphenols, particularly the catechin, epigallocatechin gallate (EGCG). However green tea also contains caffeine. A recent study showed that fat oxidation during exercise increased by about 20%.
Hydroxycitric acid (HCA)	○○○○○	HCA is a derivative of citric acid that is found in a variety of tropical plants. There is no evidence that it has any effect on fat metabolism
Pyruvate	○○○○○	Pyruvate is an intermediate of carbohydrate metabolism and it is difficult to see how pyruvate intake could increase fat oxidation. Nevertheless, this is one of the claims often made.
Psyllium	○○○○○	Psyllium is a soluble fiber that comes from the small reddish black seeds of the Plantago Psyllium plant. Like glucomannan, psyllium is probably marketed as a fat burner because of its potential effect on food intake. However, the fibre itself has no effects on fat metabolism.
Tyrosine	○○○○○	L-tyrosine is a nonessential amino acid that serves as a precursor to catecholamines. The assumption is that more tyrosine results in chronically elevated catecholamine concentrations and increased lipolysis. There is no evidence to support this.
The scientific evidence is indicated with ●●●●● meaning very strong evidence and ○○○○○ Limited to no evidence.		

References

1. **Achten J, and Jeukendrup AE.**
   The effect of pre-exercise carbohydrate feedings on the intensity that elicits maximal fat oxidation. J Sports Sci 21: 1017-1024, 2003.
2. **Achten J, and Jeukendrup AE.**
   Maximal fat oxidation during exercise in trained men. Int J Sports Med 24: 603-608, 2003.
3. **Achten J, Venables MC, and Jeukendrup AE.**
   Fat oxidation rates are higher during running compared with cycling over a wide range of intensities. Metabolism 52: 747-752, 2003.
4. **Astrup A. Dietary composition,**
   substrate balances and body fat in subjects with a predisposition to obesity. Int J Obes Relat Metab Disord 17 Suppl 3: S32-36; discussion S41-32, 1993.
5. **De Bock K, Derave W, Eijnde BO, Hesselink MK, Koninckx E, Rose AJ, Schrauwen P, Bonen A, Richter EA, and Hespel P.**
   Effect of training in the fasted state on metabolic responses during exercise with carbohydrate intake. J Appl Physiol 104: 1045-1055, 2008.
6. **Holloszy JO, and Coyle EF.**
   Adaptations of skeletal muscle to endurance exercise and their metabolic consequences. J Appl Physiol 56: 831-838, 1984.
7. **Jeukendrup AE, and Aldred S.**
   Fat supplementation, health, and endurance performance. Nutrition 20: 678-688, 2004.
8. **Jeukendrup AE, and Wallis GA.**
   Measurement of substrate oxidation during exercise by means of gas exchange measurements. Int J Sports Med 26 Suppl 1: S28-37, 2005.
9. **Venables MC, Achten J, and Jeukendrup AE.**
   Determinants of fat oxidation during exercise in healthy men and women: a cross-sectional study. J Appl Physiol 98: 160-167, 2005.
10. **Venables MC, Hulston CJ, Cox HR, and Jeukendrup AE.**
    Green tea extract ingestion, fat oxidation, and glucose tolerance in healthy humans. Am J Clin Nutr 87: 778-784, 2008.

