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The Big Fat Lie About Burning Fat

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Abstract
Carrying excess fat is a serious health concern, and yet many do not understand the basic principles of fat metabolism. This article explores the rate and path by which fat is excreted from the body, how this relates to exercise habits, and shows that it is not possible to reach a state in which only fat is metabolised for energy.

Introduction

Obesity is a serious global health concern that lowers the life expectancy of individuals and puts strain on healthcare systems. Many people attempt to lose weight by using pre-set "fat-burning options' on cardio equipment, which tend to be low intensity workouts. This paper will look into the viability of burning large amounts of fat under these conditions. The term 'weight loss' is a misnomer, as most people are concerned with fat loss rather than weight in general. Fat does not simply disappear; it must be metabolised and have the waste products removed from the body. The most abundant fat molecule in the human body, palmitoyl-stearoyl-oleoyl-glycerol ($C_{55}H_{104}O_6$)[1], is mostly carbon by mass. Carbon cannot be excreted by the body in sweat or urine, and fecal matter mostly consists of undigested food. Rather, carbon from fat and other energy storing molecules is exhaled as carbon dioxide [2]. If the body were to run purely on fat oxidation for energy, then fat would provide nearly all of the carbon dioxide exhaled in each breath. Theoretically, it is possible to calculate the amount of breaths needed to excrete the carbon in 1kg of fat under these conditions.

Determining the Amount of Carbon Exhaled

The potential mechanism for complete metabolism of fat could be described by [2, 3]:

$$C_{55}H_{104}O_{6(aq)} + 78O_{2(aq)} \rightarrow 52H_2O_{(l)} + 55CO_{2(aq)} + 34MJ$$

Metabolism of fat involves a variety of intermediates, such as Acetyl CoA, and is more complex than the previous equation. This equation describes the overall process, and will be used for simplicity sake. The mass of carbon dioxide produced from 1kg of fat can be determined stoichiometrically.

$$moles = \frac{mass}{molar\ mass}$$

Molecule	$C_{55}H_{104}O_6$	CO_2
$mass$	1.000x10^{3}g	2.810x10^{2}g
$molar\ mass$	8.614x10^{2}g/mol	4.401x10^{1}g/mol
$moles$	1.161x10^{-3} mol	6.385x10^{-2} mol

Table 1: Molecular data used for palmitoyl- stearoyl-oleoyl-glycerol and carbon dioxide [4].

From this, the volume of carbon dioxide is calculated assuming standard pressure conditions and an internal body temperature of 37°C [5] (or 310.15K) by employing the ideal gas law.

$$V = \frac{nRT}{P}$$
$$= \frac{(6.39\text{x}10^{-2}\text{mol})(8.21\text{x}10^{-2}\text{L atm K}^{-1}\text{mol}^{-1})(310.15K)}{1\text{ atm}}$$
$$= 1.63L$$

Determining the Number of Breaths

The average breath of a person at rest only uses part of the lungs' total capacity. This partial capacity is known as the tidal volume, and is typically 7ml/kg [6].

For the purposes of this example we will assume our subject has a mass of 70 kg.

$$Tidal\ volume\ = (7ml\ kg^{-1})(70kg) = 490ml$$

The average human expiratory breath contains about 5% carbon dioxide, while an inspiratory breath contains about 0.05%. This gives a net 4.95% of carbon dioxide expelled with each breath [7]. We can then use the tidal volume to calculate the volume of carbon dioxide in each breath.

$$V_{CO_2} = (490ml)(0.0495) = 24.3ml$$

In order to exhale the carbon dioxide formed in the metabolism of 1kg of fat (i.e. 1.63L of CO_2) they would need to take just over 67 breaths.

This calculation assumes that the person is burning fat while at rest. Burning fat at rest is caused by having a net deficit of calories, either as a result of diet or exercise [8]. However, if the subject is burning fat while exercising they would not be exhaling carbon dioxide in at the tidal volume. Rather they would be exhaling the expiratory reserve volume. Using our 70kg subject, we can predict their expiratory reserve volume to be about 1.0L [9], which is approximately double their normal tidal volume. Using the previously demonstrated method, we find that the subject will exhale about 49.5ml of carbon dioxide per breath. To expire the 1.63L of carbon dioxide from 1kg of fat would require a little less than 33 breaths. The exact number of breaths required would vary based on the subject's mass, sex, age, cardiovascular fitness, and health [10, 11].

Discussion

These calculations show it is theoretically possible to exhale the carbon of a kilogram of fat in only 33 to 67 breaths. However, this is obviously impossible in real life. If all exhaled carbon dioxide was the waste product of fat oxidation, then the body would have to be metabolising fat at a ridiculously rapid pace in order to produce 1.63L of carbon dioxide in this short time period. Thus, the body does not rely purely on fat oxidation, and so there must be other processes contributing to the carbon dioxide. The majority of carbon dioxide produced by the body comes from waste products of metabolism of glucose and glycogen for energy. Exhaled carbon dioxide comes from a combination of these processes at any given time [12].

Evidence shows that the body uses a higher percentage of fat in 'the fat-burning zone', which is reached by doing low intensity exercise at 55% to 65% of maximum heart rate [13]. Many models of cardio exercise equipment have 'fat-burning' settings that help the exerciser stay in this range. Unfortunately, there is a common misconception in the public that the body only uses fat for energy in this zone. Although the *percentage* of fat oxidation in this zone is higher than at other ranges, the total amount of energy used is less than in higher intensity exercise. This results in less fat loss over the same period of time [13]. For example, brisk walking (5.5km/h) may use a higher percentage of fat for energy than jogging (10km/h), but walking for half an hour only burns about 130 calories, while jogging would burn about 400 calories [14]. To overcome the fatigue brought on by high intensity exercise, interval training can be used. By taking short breaks between bouts of exercise the person can reoxygenate and reduce lactic acid build up, but still maintain a high heart rate for long periods of time [15].

The previous calculation supports this evidence. Carbon dioxide concentration in breath does not significantly change during exercise [7], so if all exhaled carbon dioxide was the waste product of fat oxidation, we would expect to see results similar to the previous example, in which the subject exhaled a kilogram of fat in 33 breaths. This would indicate that fat loss was occurring at a ridiculously rapid pace, and so it is clear that the body does not resort to metabolising only fat during exercise.

Conclusion

It is unreasonable to assume that the body can reach a state of using only fat for energy under normal conditions. Rather, fat oxidation works in conjunction with other metabolic processes. Although low intensity exercise does burn fat, high intensity workouts, particularly those that employ interval training, are expected to be more effective in causing fat loss and improving overall health.

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