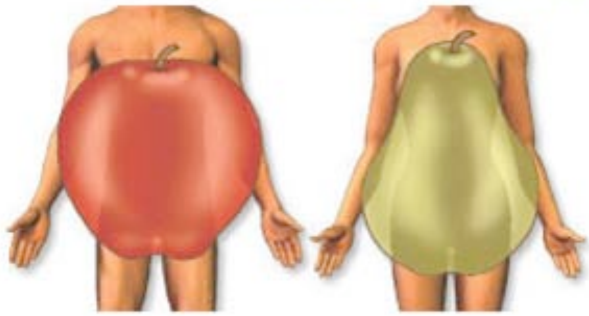
Fat Metabolism

and Gender Differences



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Course Objectives

At the completion of this Online Quick Course you will be able to

- Discuss the physiology of fat storage in the body.
- Calculate and explain fat mass and relative body fat.
- Discuss the differences between hypertrophy and hyperplasia of fat cells.
- Outline various methods of assessing fat deposition in the body.
- Explain fat metabolism, mobilization, lipolysis, and oxidation.
- Discuss the roles of the main hormones and enzymes in fat metabolism.
- Explain the role of estrogen in fat metabolism.
- Discuss gender differences in fat metabolism.
- Design an exercise program for optimizing fat metabolism.

CHAPTER 1: All About Body Fat

The two types of fat in the body are: *essential* fat and *nonessential* fat, or storage fat. Essential fat is needed for normal physiological and biological functioning. It is found in bone marrow, the brain, the spinal cord, cell membranes, muscles, and other internal organs. The level of essential fat is approximately 3% of total body weight for men and 12% of total body weight for women. Women have a higher essential body fat requirement because of gender-specific fat deposits in breast tissue and the area surrounding the uterus. When essential fat drops below a critical level, normal physiological and biological function may be impaired (Heyward and Wagner 2004).

Nonessential fat has three main functions:

1) As an insulator to retain body heat.
2) As an energy substrate during rest and exercise.
3) As padding against trauma.

Nonessential fat, known as storage fat, is typically layered below the skin and is referred to as *subcutaneous* fat. Storage fat is also found surrounding internal organs in the abdominal cavity and this fat is referred to as *visceral* fat. Older people tend to have less subcutaneous fat and more visceral fat than younger people (Heyward and Wagner 2004).

Relative Body Fat

The absolute amount of body fat, termed *fat mass*, includes all lipids from adipose and other tissues. Fat-free mass consists of all residual chemicals and tissues in muscle, bone, connective tissue, water, and internal organs. To classify body fatness, *relative* body fat or *percent* body fat is calculated. The terms relative body fat and percent body fat are used interchangeably. Relative fat is the fat mass that is expressed as a percent of total body weight. For example, %BF = fat mass ÷ body weight x 100. A person who weighs 175 lb and has a fat mass of 35 lb has relative body fat of 20% (35 ÷ 175 = .20 x 100 = 20%). Assessment of relative fat is commonly used for categorization in health and sports performance.

How Is Body Fat Gained?

Storage fat is found in adipose tissue. Adipose tissue is a form of connective tissue composed of fat cells, called *adipocytes,* that are separated by a matrix of collagenous (white fibrous protein) and elastic fibers. Body fat accumulates in two ways:

(1) *Hypertrophy* of fat cells: filling existing adipocytes, causing an increase in their size.

(2) *Hyperplasia* of fat cells: forming new fat cells.

Fat cells normally increase in size (hypertrophy) and number (hyperplasia) from birth to maturity. Obese adults typically have 60 to 100 billion fat cells compared with 30 to 50 billion fat cells found in nonobese adults (Pollock and Willmore 1990). Previous research indicates that the number of fat cells increased markedly during the first year of life, gradually until puberty, and then modestly for a period of several years, with the maximum number of cells becoming fixed by adulthood. Current evidence suggests that the size and number of fat cells can increase at any age. The exact mechanism for hyperplasia is still unknown; however, it is hypothesized that fat cells have a certain "size" capacity and once that capacity is reached a new cell is formed via hyperplasia (Liebman 2004). Fat cells can increase or decrease in size, but once a fat cell develops it is permanent and can be removed only by liposuction.

How Is Body Fat Stored?

Fat in the body is in the form of *triglycerides*. Triglycerides (TG) are made up of three free fatty acid (FFA) molecules held together by a molecule of glycerol (not a fat but a type of alcohol) (Brown, Miller, and Eason 2006) (figure 1).

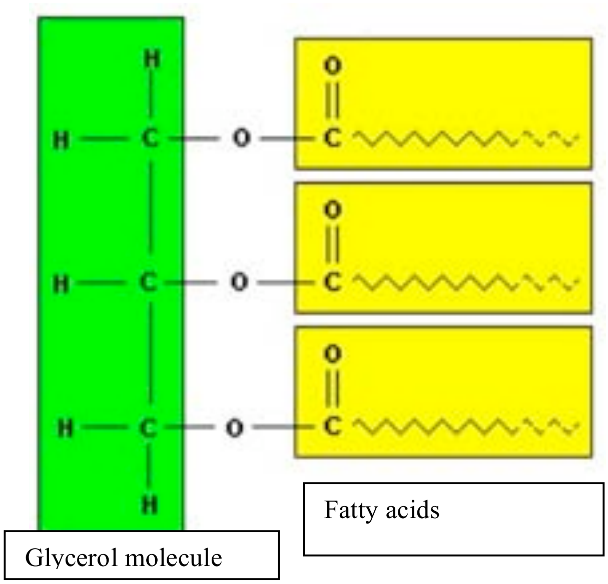

Figure 1. Triglyceride molecule

Most of the body's fat is stored in the adipocytes. Typically, about 50,000 to 60,000 kilocalories (kcals) of energy are stored as TG in adipocytes throughout the body (Manore and Thompson 2000). Fat can also be stored as "droplets" within skeletal muscle cells. These fat droplets are called *intramuscular triglycerides* (IMTG) and they may hold 2,000 to 3,000 kcals of stored energy (Manore and Thompson 2000). In addition to the stores of fat, some TG travel freely in the blood. During exercise, TG in fat cells, muscle cells, and in the blood can be broken down (a process called *lipolysis*) and used as fuel by the exercising muscles.

Gender Differences in Fat Storage

Women generally have a higher percentage of body fat than men (tables 1 and 2). A healthy range of body fat for women 34 to 55 years old is 25% to 32%: A healthy range for men the same age is 10% to 18% (Heyward and Wagner 2004). For this age group, a body fat percentage of over 38% for women and 25% for men is considered an indication of obesity.

Table 1. Recommended percent body fat levels for females

Age	Not Ideal	Low	Middle	Upper	Obesity
18-34	<20	20	28	35	>35
34-55	<25	25	32	38	>38
55+	<25	25	30	35	>35

Source: Adapted from Heyward and Wagner 2004.

Table 2. Recommended percent body fat levels for males

Age	Not Ideal	Low	Middle	Upper	Obesity
18-34	<8	8	13	22	>22
34-55	<10	10	18	25	>25

55+	<10	10	16	23	>23

Source: Adapted from Heyward and Wagner 2004.

Men tend to carry more of their body fat in and around the abdominal area. This type of fat deposition is called *android*, or apple-shaped, body type. The body type most common among females is the *gynoid*, or pear-shaped, body type. This body type is characterized by fat stores in the hip and thigh region (Regitz-Zagrosek, Lehmkuhl, and Weickert 2006). The scientific explanations for the dramatic difference in body fat distribution between men and women are largely unknown, although differences in hormones, hormone receptors, and enzyme concentrations play a contributing role.

Body Type and Health Risk

A person's body type (figure 2) is recognized as an important predictor of risk for hypertension (high blood pressure), hyperlipidemia (high cholesterol), coronary heart disease, type 2 diabetes, and premature death (ACSM 2006). Individuals with more body fat in the abdominal area (android body type; usually males) are at increased risk of developing the above conditions compared with individuals who are equally fat, but have most of their fat in the hip and thigh regions (gynoid body type; usually women).

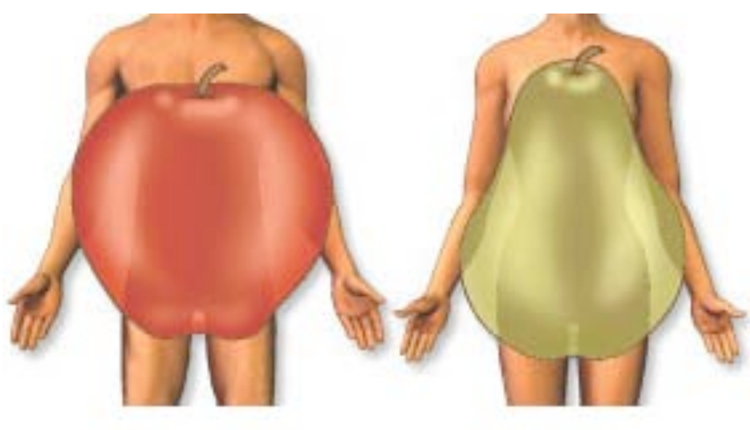

Figure 2. Android (apple) and gynoid (pear) fat deposition patterns in men and women

There are two ways to determine body type and health risk: waist-to-hip ratio and waist circumference. The waist-to-hip ratio is the circumference of the waist divided by the circumference of the hips (table 3). This measurement can be taken in inches or centimeters.

Waist circumference ÷ hip circumference = waist-to-hip ratio 32" (inches) ÷ 44" (inches) = .72

To determine if your client has a healthy waist-to-hip ratio, use a measuring tape to measure the smallest part of the waist (usually above the belly button and below the rib cage) and the largest part of the hips. Make sure the measuring tape is horizontal all the way around the body when taking a measurement. When measuring the hip circumference have your client stand with feet together. Take the measurement while standing next to your client. This will allow you to easily determine the largest and widest part of the hips. The rates for risk vary with age and gender. Ratios above .95 for young men and .86 for young women place the individual at very high risk of disease. Ratios indicating very high risk for ages 60-69 years are above 1.03 for men and .90 for women.

Recently, the expert panel on obesity and health risk developed the waist circumference measurement as an indicator of health risk. The waist circumference measurement is taken the same way as in the waist-to-hip ratio. A healthy waist circumference for of all ages is below 102 cm (40 inches) for men and 88 cm (34 inches) (ACSM 2006).

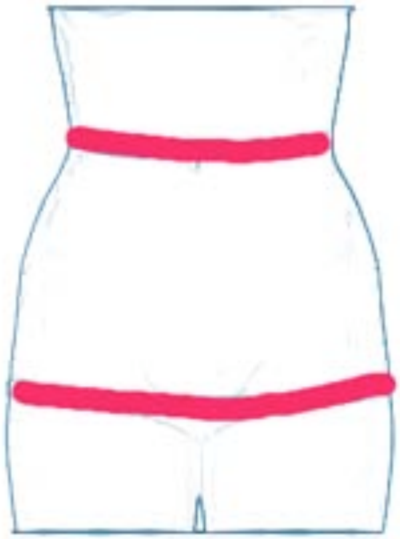

Figure 3. Anatomical sites for waist-to-hip ratio measurement

CHAPTER 2: Fat Mobilization and Metabolism

The *mobilization* of fat refers to the process of releasing fat from storage sites in the body. Two main enzymes regulate the mobilization of free fatty acids: hormone sensitive lipase (HSL) and lipoprotein lipase (LPL). The *metabolism* of fat is the complete biological breakdown, or *oxidation* (which means loss of electrons) of fat into energy that can be used by the body. The primary sites of fat oxidation are cardiac and skeletal muscle and the liver.

Hormone Sensitive Lipase (HSL)

HSL is located directly in the fat cell and is regulated primarily by the circulating concentrations of *epinephrine* and *insulin*. HSL is stimulated by the hormone epinephrine and inhibited by the hormone insulin. When HSL is stimulated, it acts to break apart the triglycerides in the adipose tissue, releasing three free fatty acids (FFA) and glycerol, which are the components of TG, into the blood stream. This process is called *lipolysis* (figure 4). When HSL is inhibited, lipolysis is inhibited. Under most physiological conditions, the rate of lipolysis is determined by the balance between the stimulating effect of epinephrine and the inhibitory effect of insulin.

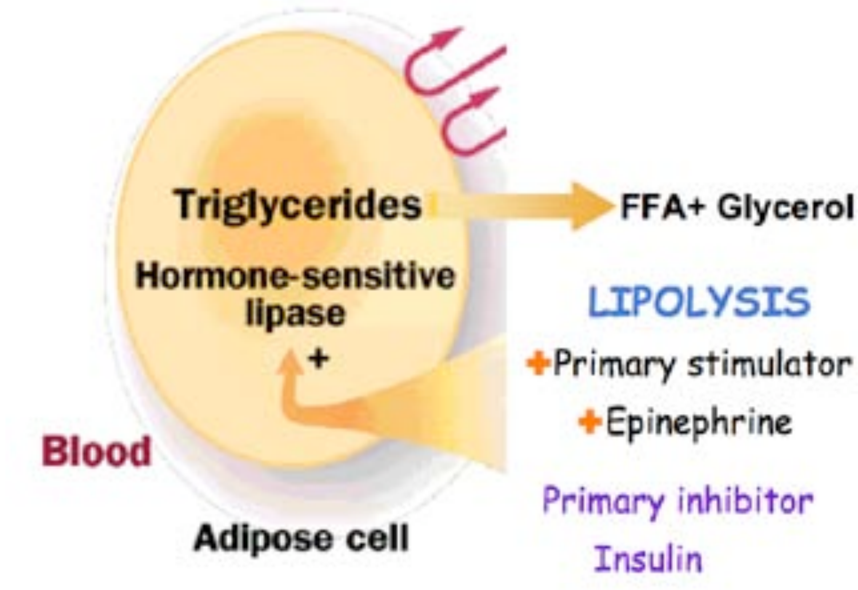

Figure 4. Lipolysis of a triglyceride

Epinephrine, which is released by the sympathetic nervous system during exercise, is the primary stimulator of lipolysis (Rasmussen and Wolfe 1999). Epinephrine binds to specific receptors on the fat cell, which in turn, activate HSL. An individual's physiological state can affect the body's sensitivity to epinephrine. For example, during aerobic exercise HSL responsiveness to epinephrine is enhanced due to an increase in body temperature and a greater concentration of epinephrine in the blood stream. Additionally, in an endurance-trained individual the HSL response to epinephrine is enhanced such that HSL can be activated by a lower concentration of epinephrine compared with a nonendurance-trained individual. *A metabolic training effect of aerobic exercise is an enhanced ability to mobilize and break apart TG for energy use*. In contrast, obesity blunts the HSL responsiveness to epinephrine, meaning that a higher concentration of epinephrine is needed to activate HSL in obese individuals (Rasmussen and Wolfe 1999).

Once in the blood stream, the FFA molecules bind to *albumin* (figure 5), a blood protein and the main transporter of FFA molecules. FFA molecules are not water soluble and thus require a protein carrier to allow them to be transported to cells and within the blood stream.

Once the FFA molecules are transported to the muscle cell, they are released from albumin and carried across the muscle cell membrane by specific transporters.

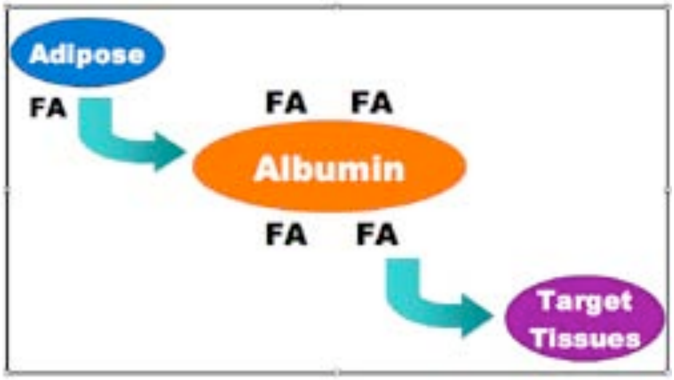

Figure 5. Fatty acids (FA) transported by albumin in blood to target tissues in the body

Three main FFA transporters located on the muscle cell membrane take over at this point: fatty acid binding protein (FABP), fatty acid translocase (FAT), and fatty acid transport protein (FATP) (Turcotte 2000). These proteins bind the FFA molecules and transport them across the cell membrane to the mitochondria (figure 6), the organelle of cells responsible for energy production—for complete oxidation. *Aerobic training can increase the number of FFA transporters on the muscle cell membrane, thus enhancing the ability to metabolize fat*. The glycerol molecule released from the process of lipolysis is circulated to the liver for oxidation and is either used as a molecule in the breakdown of glucose or to make more TG (Robergs and Keteyian 2003).

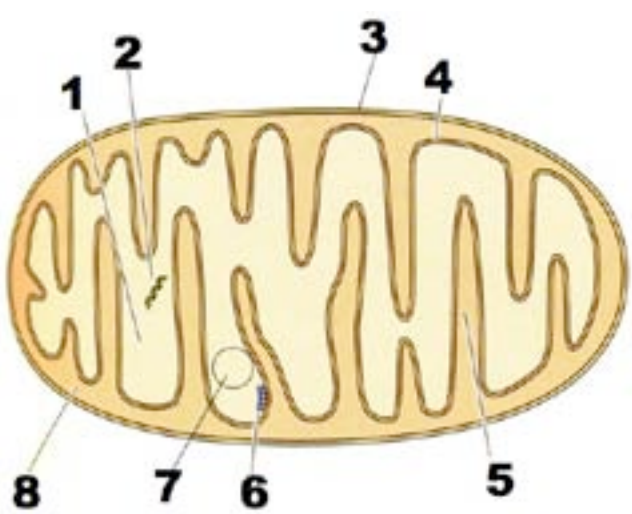

Figure 6. Microanatomy of a mitochondrion
1-matrix, 2-DNA, 3-outer membrane, 4-inner membrane, 5-cristae structures, 6-electron transport chain, 7-krebs or TCA cycle, 8-intermembrane space

Liproprotein Lipase (LPL)

LPL, the second enzyme that regulates the mobilization of FFA, is located on blood vessel walls throughout the body. Both adipose tissue and the liver have large quantities of this enzyme. LPL acts on TG within lipoproteins, special transporters that carry cholesterol and TG through the blood stream to fat storage depots and body cells for fuel and cellular life support. TG are either broken down to FFA molecules and used as fuel by active tissues or they diffuse into fat and liver cells where they are resynthesized into TG and stored. LPL is often referred to as the "gatekeeper" that controls the distribution of fat in the various storage depots of the body.

Epinephrine

Epinephrine is the primary hormone that stimulates lipolysis (the breakdown of triglycerides) (Blaak 2001). Epinephrine binds to receptors on various cells throughout the body, such as adipocytes and muscle cells, and can either activate or inhibit HSL (Blaak 2001). As explained above, when HSL is stimulated, it acts to break apart TG in the adipose tissue and release the three FFA molecules and glycerol into the bloodstream.

The two main types of epinephrine receptors are *alpha receptors* and *beta receptors*. Epinephrine can stimulate lipolysis through the beta receptors and can inhibit lipolysis through the alpha receptors (Blaak 2001). The type of receptor available and its sensitivity to epinephrine determines the response of HSL in any given tissue. Alpha and beta receptors can be located on the same cells; the response of HSL depends on which type is more abundant and available for binding with epinephrine. When the beta receptors are stimulated, HSL is activated (figure 7). In contrast, when the alpha receptors are stimulated, HSL is inhibited (figure 8).

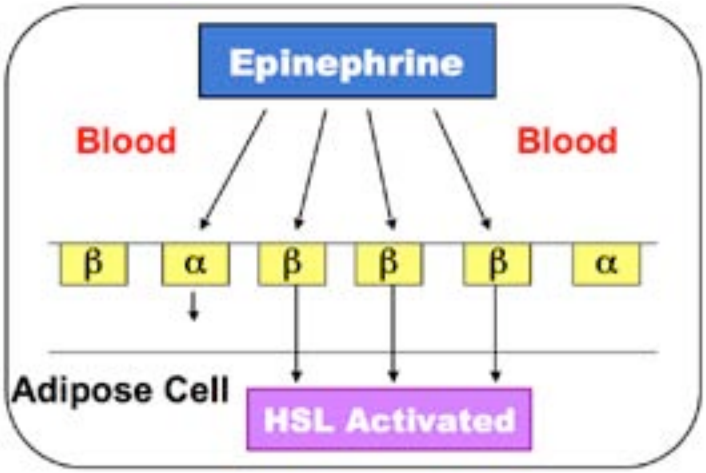

Figure 7. Epinephrine acting on the beta receptors in fat cells

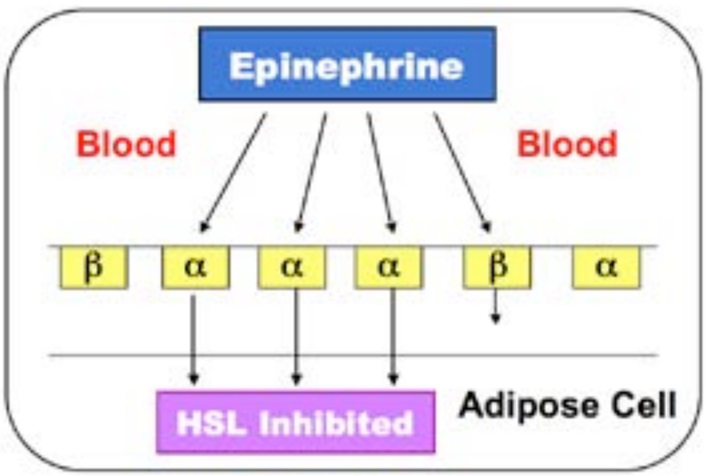

Figure 8. Epinephrine acting on the alpha receptors in fat cells

CHAPTER 3: Gender Differences in Fat Metabolism

Research has shown that in both men and women abdominal adipocytes are more sensitive than hip and thigh adipocytes to beta receptor stimulation by epinephrine (Braun and Horton 2001). This finding suggests that fat around the abdominal area is easier to mobilize than fat in the hip and thigh area. Moreover, women tend to have a greater number of alpha receptors in the hip and thigh region (Blaak 2001), suggesting that in this area fat storage would be favored over fat mobilization. This difference in the type and number of cell receptors may be one of the mechanisms contributing to the differences in fat distribution between men and women (Blaak 2001).

Another mechanism contributing to gender differences in fat distribution may be the concentration of LPL in various tissues. Women have a higher LPL concentration and activity in the hip and thigh region than in the abdominal region. As explained in chapter 2, LPL located near adipocytes break down TG to store as fat when the body does not use it for fuel, so the higher concentration of LPL in the hip and thigh area may help explain why women tend to store more fat in this region than men.

Estrogen and Lipolysis

The female hormone estrogen may have a positive effect on resting and exercise fat metabolism. Although there appears to be a connection between estrogen and increased fat metabolism, the mechanisms are not fully understood. Research has also suggested that estrogen may aid in the mobilization of fat from adipose tissue. Although the mechanisms, again, are not fully understood, several theories have been proposed.

Estrogen has been found to inhibit the hormone LPL (Ashley, Kramer, and Bishop 2000). Remember that LPL is responsible for the breakdown of TG in the bloodstream and storing them in adipose tissue whenever they are not needed as fuel for active tissues. Estrogen has also been shown to enhance epinephrine production. A higher concentration of epinephrine increases the activity of HSL, the hormone responsible for adipose tissue lipolysis.

Estrogen has also been reported to stimulate the production of growth hormone (GH). Growth hormone inhibits the uptake of glucose (carbohydrate) by active tissues and increases the mobilization of FFA from adipose tissue. GH works by inhibiting insulin production from the pancreas and stimulating HSL (Ashley, Kramer, and Bishop 2000). Insulin is the main hormone that promotes glucose transport into muscle cells to be used as energy, and it is a potent inhibitor of HSL. Estrogen may enhance fat metabolism by increasing the production of GH and inhibiting the production of insulin. In turn, this would decrease glucose metabolism and increase FFA utilization (Ashley, Kramer, and Bishop 2000).

Another factor that could promote a higher fat metabolism in women is an increase in blood flow to adipose tissue, especially during exercise (Braun and Horton 2001). Estrogen has been shown to cause a vasodilation (widening) in blood vessels, but it is not known if this vasodilation is specific to adipose tissue perfusion (flow of blood into the tissue) or a general effect on the entire vasculature in the body. Estrogen also increases the production of the hormone nitric oxide (NO). NO, which is produced by cells that line the blood vessels, causes a relaxation of the smooth muscle that surrounds blood vessels, leading to vasodilation. If women maintained a higher blood flow to the adipose tissue, interaction between epinephrine and adipose tissue beta receptors would be increased. Additionally, this could enhance FFA transport from adipose tissue to active muscles during exercise.

Gender Differences in Fat Metabolism at Rest

The level of fat metabolism at rest is positively correlated with the size of fat cells in the body, with larger fat cells having a higher lipolytic (causing TG splitting) activity (Blaak 2001). Earlier research hypothesized that women might have a higher resting fat metabolism than men because women typically store more body fat than men do. However, recent research has found that resting fat metabolism (adjusted for differences in lean body mass) is actually lower in women than in men (Toth et al. 1998). Although the mechanisms are unclear, this finding suggests that a lower resting fat metabolism may contribute to the increased fat storage in women.

Table 4. Key chapter points

• In both men and women, abdominal adipocytes are more sensitive than hip and thigh adipocytes to beta receptor stimulation by epinephrine
• Fat around the abdominal area is easier to mobilize than fat in the hip and thigh area

• Women have a higher LPL concentration and activity in the hip and thigh region than in the abdominal region

• Research has suggested that estrogen may aid in the mobilization of fat from adipose tissue

• Estrogen has been reported to stimulate the production of growth hormone

• Insulin is the main hormone that promotes glucose transport into muscle cells to be used as energy

• Estrogen may enhance fat metabolism by increasing the production of growth hormone

• Estrogen has been shown to cause a vasodilation in blood vessels

• Larger fat cells have a higher lipolytic activity

• Resting fat metabolism (adjusted for differences in lean body mass) is actually lower in women than in men

CHAPTER 4: Gender Differences in Fat Metabolism during Exercise

Intramuscular triglycerides (IMTG), the fat storage sites within the muscles, are an important source of fuel during moderate- to high-intensity exercise. It's estimated that up to 50% of fat oxidized during moderate to intense exercise (60/65% to 80% VO_2max) is derived from IMTG (Robergs and Roberts 1997). Most of the rest of the oxidized fat comes from adipose tissue, and the least comes from TG in the blood stream. Studies have shown that IMTG stores decrease by approximately 20% to 40% after 1 to 2 hours of moderate-intensity exercise and endurance training can lead to an increased reliance on IMTG for fuel during exercise.

The process of IMTG lipolysis is similar to adipose tissue lipolysis. During exercise, increasing levels of epinephrine activate HSL to begin the breakdown of IMTG. The FFA molecules released from IMTG are located within muscle cells; therefore, the FFA can be transported directly to the mitochondria for oxidation. The glycerol molecule released is either transported to the liver for oxidation or recycled to form additional IMTG stores (Robergs and Roberts 1997).

The majority of the research shows that compared with men, women derive a greater proportion of their energy expenditure from fats during low- to moderate-intensity exercise. Research is ongoing to determine the possible mechanisms leading to this gender difference.

Gender Differences in Fuel Selection

One of the most common methods used to determine fuel selection is the respiratory exchange ratio (RER) measured by gas analysis. The RER (table 5) is a numeric index of carbohydrate (CHO) and fat utilization based on a ratio of carbon dioxide produced to oxygen consumed during rest and exercise conditions. A lower RER is an indication of a greater fat metabolism and a higher RER is an indication of a greater carbohydrate metabolism. Protein is not shown on the RER table because it is only used sparingly as a fuel.

Table 5. Respiratory exchange ratio

RER	FAT%	CHO%
1.00	0	100
.98	6	94
.96	12	88
.94	19	81
.92	26	74
.90	32	68
.88	38	62
.86	47	53
.84	53	47
.82	62	38
.80	68	32
.78	74	26
.76	81	19
.74	88	12
.72	94	6
.70	100	0

Important early research on gender differences in exercise metabolism clearly show that during low- to moderate-intensity exercise, women maintain a lower RER than men. The studies outlined and highlighted here used different protocols but arrived at similar conclusions.

Tarnopolsky et al. (1990). Male and female subjects were matched for training status and performance experience. Throughout the 90-minute run at 65% VO_2max, women had significantly lower RER values than men, indicating an increased reliance on fats for fuel. The calculated energy expenditure (EE) from fat was 428.4 kcals for the women (42% of total EE) and 242.1 kcals for the men (20% of total EE). The results were supported by the muscle biopsy data that showed greater muscle glycogen depletion in the male subjects compared with the female subjects.

Horton et al. (1998). During 2 hours of exercise at 40% VO_2max, women had significantly lower RER values than men. The percent of fat metabolized during exercise averaged 43.7% for the men and 50.9% for the women.

Blatchford, Knowlton, and Schneider (1985). At both 45 and 90 minutes of treadmill walking at 35% VO_2max, untrained women had significantly lower RER values than untrained men. Both groups gradually increased the percent of fat metabolized during exercise, with the 90-minute values being 59% for the men and 73% for the women.

Froberg and Pedersen (1984). Women subjects exercised for a significantly longer period of time than age- and training-matched male subjects at 80% VO_2 max. The women also had significantly lower RER values during exercise than the men. These researchers concluded that the superior performance in women was due to a greater reliance on fats for fuel during exercise and a sparing of muscle glycogen.

Muscle Glycogen Depletion

Muscle glycogen concentration is another common technique used to determine fuel utilization during exercise. Muscle glycogen is the storage form of carbohydrate that is located within the muscle cells and is measured by taking a muscle biopsy.

The study by Tarnopolsky et al. (1990), which compared the RER values of trained men and women during a 90-minute run at 65% VO_2 max, also compared the muscle glycogen depletion patterns. Although muscle glycogen levels were similar in men and women before the exercise bout, postexercise biopsy (removing of tissue for analysis) data indicated glycogen depletion was 25% greater in men than in women. This was in agreement with the lower RER data reported for women, indicating a greater reliance on fats for fuel during submaximal exercise.

Epinephrine Concentrations

Studies examining the hormonal responses to exercise have reported that epinephrine concentrations during submaximal exercise are higher in men than in women. Assuming a lower RER response in women during exercise, these findings indicate that women may be more sensitive to the lipolytic actions of epinephrine and therefore able to metabolize fat more effectively.

Tarnopolsky et al. (1990). This study, which found lower RER values during and less glycogen depletion after submaximal exercise in women than in men, also found lower epinephrine concentrations in females.

Horton et al. (1998). During exercise at 40% VO_2max, epinephrine levels (as well as RER values) were significantly lower in women than in men, again suggesting that women have a greater sensitivity to the lipolytic action of epinephrine.

Free Fatty Acid and Glycerol Concentrations

As adipose tissue lipolysis increases, concentrations of FFA and glycerol increase in the plasma (fluid portion of blood). With this in mind, several investigators have studied the gender differences in plasma FFA and glycerol concentrations in response to submaximal exercise.

Blatchford, Knowlton, and Schneider (1985). When men and women matched for training status exercised at 35% VO_2max there were significant gender differences in FFA and glycerol concentrations. At both 45 and 90 minutes of exercise, plasma FFA values were higher in women than in men. In addition, plasma glycerol levels were significantly higher in women than in men at 45 minutes of exercise.

Horton et al. (1998). This study, which found lower epinephrine and RER values in women when exercising at 40% VO_2max, also found significantly higher plasma FFA and glycerol concentrations in women.

Tarnopolsky et al. (1990). On the other hand, Tarnopolsky and colleagues, who reported significantly lower RER values in women during submaximal exercise, found that these lower RER values were not accompanied by an increase in plasma concentration of FFA or glycerol. The researchers hypothesized that the increase in fat metabolism in women was due to a higher utilization of IMTG (which do not increase plasma concentrations of FFA or glycerol) as opposed to a greater adipose tissue lipolysis.

These findings on gender differences in plasma FFA and glycerol concentrations suggest that in women a higher percentage of fat metabolism during exercise may be due to an increase in beta receptor sensitivity (which would stimulate lipolysis), a decrease in alpha receptor sensitivity, or an increase in the utilization of IMTG.

In addition, it has been reported that IMTG stores are higher in women than in men (Blaak 2001; Braun and Horton 2001). This finding suggests the possibility that a higher IMTG oxidation may contribute to the increased fat oxidation and glycogen sparing in women during exercise. It has also been reported that women have a higher expression (great effectiveness) of FFA transport proteins (FATP, FABP, FAT) in skeletal muscle cells (Blaak 2001). An increase in these transport proteins would augment the number of FFA molecules entering the muscle cells, thereby increasing the FFA available for oxidation in the mitochondria or storage in IMTG.

What Exercise Intensity Burns the Most Fat?

During low-intensity exercise the majority of energy (kilocalories) comes from fat. As exercise intensity increases, the percent of energy derived from fat decreases. However, the absolute amount of energy derived from fat actually increases! As exercise intensity increases, so does total energy expenditure (caloric expenditure). Even though a smaller percentage of the energy expenditure is coming from fat, more kilocalories of fat are burned because there is a greater absolute energy expenditure. Therefore, expressing energy derived from fat as a percentage of energy expenditure without considering the total energy expenditure is misleading.

A very practical application of this scientific knowledge suggests that to attain an optimal fat utilization during an exercise bout a person should strive for the total caloric expenditure. Although this is true for a single exercise session, a more in-depth discussion on designing programs for fat utilization follows.

Another consideration is the effect exercise has on energy expenditure after the exercise bout is completed. Following high-intensity exercise, the rate of metabolism is elevated for slightly longer than it is after low-intensity exercise, and more energy is expended as the body returns to homeostasis (resting conditions). With regular aerobic exercise, this post-exercise energy expenditure contributes positively to weight loss.

CHAPTER 5: Implications for Designing Aerobic Exercise Programs

From this comprehensive review on fat metabolism, some cardiorespiratory training implications for optimal fat metabolism are presented. It is important to clarify that every client and student has a different fitness level and goal (weight loss, weight maintenance, weight gain), and the health/fitness professional and personal trainer needs to design the exercise program for each client.

The foundational research on the development and maintenance of cardiorespiratory fitness recommends performing endurance exercise 3 to 5 days a week on an exercise mode that involves the major muscles groups (in a rhythmic nature) for a prolonged time period (ACSM 2006). Exercise modes include physical activities such as step aerobics, aqua exercise, cardio kickboxing, running, rowing, cycling, and walking. The ACSM recommends an intensity of exercise between 55/65% to 90% of maximum heart rate (or 40/50% to 85% of oxygen uptake reserve) with a continuous duration of 20 to 60 minutes per session. Inherent in the exercise prescription is the concept of individualizing the program for each person’s fitness level, health, age, goals, risk factor profile, medications, behavioral characteristics, and individual preferences.

The ACSM recommendations appropriately serve as the framework for the cardiorespiratory fitness prescription for healthy males and females that follows.

First, the concept of periodizing aerobic training programs, that has become so popular in resistance training, is encouraged. Periodization training is based on an inverse relationship between intensity (how hard) and volume (total repetitions) of training. With aerobic exercise, intensity can be individualized with %heart rate max, %VO_2 max, or ratings of perceived exertion, where volume is differentiated by the duration of the session as well as the frequency of sessions.

Here are some specific periodization suggestions from which to individualize the prescription for optimizing fat metabolism during aerobic exercise:

1) Frequently incorporate cardiorespiratory workouts that are low intensity for a longer duration. **Rationale:** The majority of the research shows that women derive a greater proportion of their energy expenditure from fat during low- to moderate-intensity exercise, relative to men.

2) Include some cardiorespiratory workouts that are of higher intensity for a shorter period of time. This may best be realized with high-intensity, continuous training or with interval training. **Rationale:** As exercise intensity increases, the percent of energy derived from fat decreases. However, the absolute amount of energy derived from fat is actually increased, for men and women. As exercise intensity increases, so does total caloric expenditure. Even though a smaller percentage of the energy expenditure is coming from fat, more kcals of fat are burned because there is a greater absolute energy expenditure.

3) Incorporate various modes of training, often referred to as cross-training (Kravitz and Vella 2002). **Rationale:** The theory of multimode training (employing two or more different modes of cardiorespiratory exercise) implies that different modes of exercise helps to avoid fatigue and overuse of the same muscles in the same movement patterns, aiding in the prevention of muscle soreness and injuries. Cross-training allows a person to safely do more work more frequently, which equates to higher total energy expenditure and fat utilization.

4) Vary the workout designs regularly! Strive to find a satisfactory method for each client, or students in a group-led class, where cardiorespirtory workouts vary either within each week, weekly, bi-weekly, or any combination of all with items 1 to 3 above. **Rationale:** Varying the workouts provides a new stimulus to the body's cardiorespiratory system to avoid the consequences of overuse exercise fatigue. Hans Selye (1976) demonstrated this many years ago in his early research with the general adaptation syndrome.

Novel Interval Aerobic Workout for Variety

Here is a new approach to interval aerobic programming to incorporate into a regular cardiovascular training plan. As stated previously, individualize this program for each client. Interval aerobic training is a form of conditioning that combines segments of high-intensity work with segments of light- to moderate-intensity work. This type of training systematically emphasizes the body's different energy systems to effectively burn fat and carbohydrates. It involves alternating between bursts of high-intensity exercise and light- to moderate -intensity exercise, which is completed on different modes of exercise. The incorporation of interval training within the regular aerobic program optimizes the development of cardiorespiratory fitness as well helps the client attain body composition goals.

Choose several different aerobic activities the client enjoys (walking, jogging, cycling, rowing, stair stepping, elliptical training, etc.). Always begin the aerobic exercise gradually with 3 to 5 minutes of light-intensity work to prepare the heart, lungs, and musculoskeletal system for more strenuous work. Following the warm-up, exercise for 4 minutes at a high intensity followed by 4 minutes at a light to moderate intensity. Alternate these 4-minute intervals for the duration of the workout. This program utilizes ratings of perceived exertion (RPE) to measure workout intensity. During the 4-minute high-intensity interval, have the client push herself/himself to a "comfortably challenged" perceived effort. During the moderate-intensity bout, the client should feel "somewhat challenged." The alternating variations of workout intensity enhances total caloric burning. Depending on a person's fitness level, progress to a range of 20 to 60 minutes of interval aerobic training. For cardiovascular maintenance and improvement, perform this workout 3 to 5 times a week. To help a client achieve weight-control goals, aerobic exercise may need to be performed 5 to 6 times a week, alternating interval training with long, slow-duration training on different exercise modes. Remember, for variety alternate the interval-training format (4 minutes high intensity followed by 4 minutes light to moderate intensity) on the other exercise modalities, and alternate the interval aerobic program with different aerobic programs.

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