

understanding  
body fat  
analysis

Version 2.1

**TANITA<sup>®</sup>**  
A Step Toward A Healthier Life.

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An Introduction	01
Body Composition	04
Reference Models	06
Basic Terms	08
Determining Obesity	10
Calipers	12
Dunk Tank	14
BIA	16
Tanita BIA	18
NIR	20
DEXA	21
Other Methods	22
In Conclusion	23
A Message for Women	24
Bibliography	25

## Recently, a student asked me what benefits I get from my personal exercise program besides putting in miles on my bicycle...

I was tempted to say that exercising outside in the fresh air always makes me feel good, but instead, I replied: In addition to the cardiovascular benefits I've gained in the last six months, I've lost eight pounds of fat—I've reduced my body fat level from 18% of my total weight to 14%.

This is the kind of definitive statement you can make after adding body composition analysis to your exercise and diet program as I have. If weight loss or maintenance is your goal, accurate body fat testing is a terrific and more precise way to monitor your progress while you're making slow but gradual gains. It can be a valuable tool—if you understand it.

This may sound like a contradiction, but you can be overfat but not overweight; or overweight and not overfat. And when you exercise and diet properly, you can lose fat without changing your weight measurement on a scale. With strength training or intense aerobic exercise, you can actually gain a few pounds of muscle while at the same time losing pounds of fat. Most individuals never know this kind of information because they simply measure weight. I believe that the more information and biofeedback you have on improvements to your health and fitness, the more likely you are to stay motivated toward your goals.

See recommended  
Body Fat Ranges  
chart on page 11  
and the Message  
for Women on  
page 24

Everyone needs some body fat and there are recommended healthy ranges. The ranges for men and women are different because women are anatomically designed to have about 5% more fat than men of equal fitness.

For both sexes, however, being severely overfat or obese can lead to health problems. Obesity is linked to increased risk of diabetes, hypertension, heart disease, stroke, certain cancers, and other debilitating conditions.

If you're an athlete carrying excess pounds, it's going to slow you down. But excessive thinness can also lead to trouble. While a lean body may improve your appearance, strength and speed, many athletes lower their body fat levels to such an extreme that they become susceptible to illness. Many athletes that I have worked with tell me that when they drop below a certain weight and percent body fat they often experience chronic fatigue. Female athletes face an additional problem in that too low a percentage of body fat (12% or under) can disrupt their menstrual cycles. So remember, the thinnest and leanest athletes are not always the strongest. The body needs an adequate amount of fat to be healthy and to use as an energy source during hard exercise.

When participating in any exercise and diet program you probably know that exercise increases metabolism or your body's ability to burn calories for energy. Weight control is a question of balancing how much food we eat against how much energy we expend; and weight loss requires taking in fewer calories and burning off even more. Dieting alone slows down your metabolism, while eating the right foods plus a program of exercise will help you burn off calories—even when you're resting.

As measuring body fat becomes easier and cheaper, and the results of tests more accurate, naturally more people want to know their measurements. And, as I have successfully learned, keeping tabs on my body composition can be an important index of my health and state of fitness. Personally, I measure my weight and body fat twice a week, and use these measurements in addition to my training mileage as tools to help me reach and maintain my fitness goals.

Before you put yourself to the test, understand the principles of body fat testing. There is more than one way to measure body fat, and each method has its strengths and weaknesses. Choose one that feels right for you and, more importantly, one that you can use on a regular basis. While conclusions on the best test for body composition may differ, remember that it is more important to use the same one—consistently—over time.

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Dr. Burke's research interests include sports nutrition, cycling performance, fitness and adaptations to training. Personally, he enjoys cycling and hiking and is an experienced international competitor. He is a Fellow of the American College of Sports Medicine and a Certified Strength and Conditioning Specialist (CSCS).

Scientists have been studying body composition since the beginning of the 20th century, but research has increased dramatically in the last 25 years as methods for measuring and analyzing the body have grown in accuracy.

There is growing evidence that clearly links body composition with health risks and the development of certain diseases. New research indicates that fat loss, not weight loss, can extend human longevity.

Adding further to the acceptance of this practice is the importance of body composition in athletic performance and its move from being a laboratory-only procedure to one used in ordinary medical practice and now health clubs or at home. By measuring body composition, a person's health status can be more accurately assessed and the effects of both dietary and physical activity programs better directed.

Most people don't realize that there is only one "direct" method of measuring body composition that is close to 100% accurate, and that is an autopsy—performed *Post Mortem*. All other current methods for measuring body composition rely on "indirect" measurement techniques and are called *In Vivo* methods—meaning they are performed on a living body.

*In Vivo* methods give estimates of percentage of body fat, fat-free mass, muscle, bone density, hydration, or other body components. Each method uses one or more measurable body component (such as skinfold thickness, resistance, etc.) to make educated predictions about the other components. These predictions are based on years of research that define statistical relationships between different body components.

According to the National Institutes of Health, no trial data exist to indicate that one method of measuring body fat is better than any other for following overweight and obese patients during treatment. Good results depend upon accurately taken measurements and an adequate, scientifically derived database. Every measurement method has strengths as well as defined sources of error. Most research studies employ several methods used in combination.

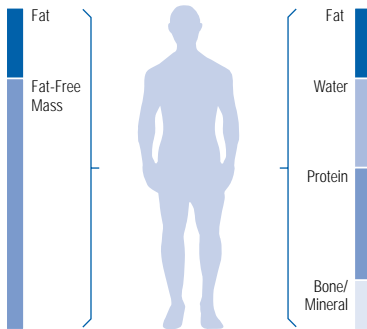
Body composition equipment manufacturers should have scientific studies available to support accuracy claims, but often companies fail to explain the problems encountered in day-to-day use outside of the controlled environment of a research lab. Tanita feels it is very important for people to fully understand the benefits—and limitations—of body composition analysis. This information will enable people to make better decisions about which method is the best or most appropriate for their particular needs.

## Body Composition Models

The more traditional methods are based on a two-compartment model that simply divides the body into fat and fat-free mass.

Hydrodensitometry (underwater weighing) is based on the two-compartment model.

Newer, more sophisticated techniques, such as DEXA (dual energy x-ray absorptiometry), measure the body as multiple compartments. This approach improves the accuracy of the calculation for determining the real density of fat-free mass.



There are two basic body-composition models: the two-compartment model—fat-free mass and fat; and the four-compartment model—bone/mineral, protein, water, and fat.

## Reference Models

Often referred to as “gold standards,” these are clinical techniques that have been validated through repeated scientific studies and against which other clinical and field method results are evaluated. The two main reference models today are Hydrodensitometry and DEXA.



## Prediction Equations

*In Vivo* methods use equations to predict percentage of body fat, fat-free mass, muscle, hydration, etc. Using a form of statistics known as multiple regression analysis, this allows an unmeasurable component, such as body fat, to be predicted from one or more measured variable, where studies have proved there is a correlation. For example, calipers use external skinfold measurements (a method that estimates fat found just under the skin) to calculate total body fat. BIA measures the body's impedance (resistance) to an electrical signal to estimate total body fat.

Equations can be population-specific (developed for specific types of people, including such categories as gender, age, ethnicity, fitness level, disease, etc.) or generalized to cover a wide range of people types. A given equation is validated according to how well the results match the results of the reference method.

It is important to note that results of reference methods themselves do not agree 100 percent. Therefore, when comparing different methods or products, you should consider which reference method was used and the appropriateness of both the method and particular product for the body type being analyzed.

*Weight* refers to the total weight of the body including bones, muscle, fat, water, etc.

*Overweight* is defined as a body weight that exceeds the acceptable weight for a particular person, based on individual height and/or frame size. Standards are usually determined solely on the basis of population averages that can and do change over time. Standards may also vary with gender and ethnicity. An overweight person does not necessarily have too much fat nor increased health risks if the excess weight is due to an above-average amount of muscle.

*Obesity (Overfat)* is the condition where the individual has an excessive amount of body fat. Over 30 specific diseases have been linked to obesity.

*Percentage Body Fat* is the percentage of total body weight that is fat (see page 11 for recommended body fat ranges).

*Fat Mass* means the actual fat mass (in pounds or kilos) in the body.

*Body Fat* functions as insulation, protection and energy reserve. When the percentage is too high, fat increases a person's risk of high blood pressure, elevated cholesterol, diabetes, heart disease, and some forms of cancer. It can also interfere with the immune system, prevent heat loss, stress the musculoskeletal system, cause sleep problems, and may affect self-esteem.

*Basal Metabolic Rate (BMR)* is the rate at which the body burns calories to maintain normal body functions while at rest. It is affected by the amount of muscle you have. Body weight remains constant when you burn up the same number of calories that you eat. A 3,500 calorie difference between dietary intake and energy expenditure is necessary to gain or lose one pound of fat. Weight loss by diet alone may result in a loss of muscle, and this will slow your metabolic rate, making it more difficult to keep the weight off. Exercise,

however, increases your metabolic rate for hours even after exercise, and can increase the amount of muscle you have.

*Weight  
Versus  
Body Fat*

Weight measurement alone cannot always accurately determine the body fat status of a person because it does not differentiate between the fat-free mass and fat mass in the body. The relationship between three categories of body weight and body fat can be described according to five different people categories.

Weight	Under	2 Underweight and lean e.g.: runners		5 Obese not overweight, e.g.: inactive elderly
	Average		3 Average, healthy weight and body fat	
	Over	1 Overweight not obese, e.g.: bodybuilders		4 Overweight and obese
		Lean	Medium	Obese
		<b>Body Fat</b>		

- 1 Athletic or muscular body types (bodybuilders) who have normal or low body fat even though they are overweight according to standard charts.
- 2 Lean, thin or linear body types with low amounts of fat-free mass (endurance athletes) who can be underweight according to the weight charts and extremely low in body fat yet physically very healthy.
- 3 People of average weight and average body fat mass.
- 4 Big, heavy and soft body types who are overweight and obese from large amounts of fat mass and body weight.
- 5 People (often the elderly) who have too much fat mass and are obese but not overweight due to inactive and sedentary lifestyles.

## Determining Obesity

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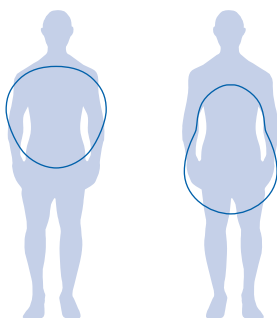
**Height-Weight Tables** were originally developed by insurance companies to establish recommended weight ranges for men and women. The “desirable” weights were those associated with the lowest mortality among large population studies of insured people. Unfortunately, these studies do not accurately represent a cross-section of the entire American population.

**Body Mass Index (BMI)** is a simple calculation that determines height to weight ratio. BMI is obtained by multiplying weight in pounds by 700 and dividing the result by the square of height in inches. This index correlates a person’s physical stature with mortality ratios based on actuarial studies. According to National Institutes of Health (NIH) and World Health Organization (WHO) guidelines, overweight is defined as a BMI of 25–29.9, and obesity as a BMI equal to or greater than 30. A person with a BMI of 30 is about 30 lbs. overweight/overfat. A BMI of 18 or lower indicates that a person is underweight/underfat.

While BMI is widely accepted, it can be misleading. Current guidelines do not differentiate for gender, ethnicity or age, and do not distinguish obesity or leanness for individuals who are extremely muscular. It is, however, more precise than height/weight tables and allows comparisons of population groups. Studies have confirmed that obesity-related health risks start in the BMI range of 25–30.

### **Waist Measurement**

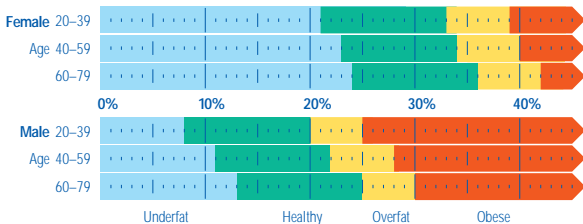
Waist size is an additional, independent risk factor and can be used in conjunction with any other method. It reflects growing evidence that excess visceral fat—surrounding the abdominal organs—on its own increases the chance of heart disease or diabetes.



Android or “apple-shaped” obese people are more vulnerable to disease than those who are gynoid or “pear-shaped.”

Research indicates that visceral fat (waist size) is more important in the disease process than subcutaneous fat which is just under the skin (“love handles,” “pinchable inches”). Abdominal fat cells appear to produce certain compounds that may influence cholesterol and glucose metabolism. In men, a waist size of  $\geq 40$ " and in women  $\geq 35$ " is an indication of increased health risk.

### Body Fat Ranges for Standard Adults<sup>1,2</sup>



<sup>1</sup> Based on NIH/WHO BMI Guidelines.

<sup>2</sup> As reported by Gallagher, et al., at NY Obesity Research Center.

To determine the percentage of body fat that is appropriate for your body, consult your physician.

## Anthropometry (Skinfold Measurements)

Using hand-held calipers that exert a standard pressure, the skinfold thickness is measured at various body locations (3–7 test sites are common). Then a calculation is used to derive a body fat percentage based on the sum of the measurements. Different prediction equations are needed for children and specific ethnic groups (over 3,500 equations have been validated). This approach usually uses underwater weighing as a reference method (*see page 14*). The caliper method is based upon the assumption that the thickness of the subcutaneous fat (found just under the skin) reflects a constant proportion of the total body fat (contained in the body cavities), and that the sites selected for measurement represent the average thickness of the subcutaneous fat.

This approach is based upon the assumption that the thickness of fat found just under the skin reflects a constant proportion of the total body fat.

Skinfold measurements are made by grasping the skin and underlying tissue, shaking it to exclude any muscle and pinching it between the jaws of the caliper. Duplicate readings are often made at each site to improve the accuracy and reproducibility of the measurements. Often to save time in large population studies, a single skinfold site measurement is made to reduce the time involved. Such a test should be used only for a rough estimate of obesity.

Generally speaking, skinfold measurements are easy to do, inexpensive and the method is portable. Overall, results can be very subjective as precision ultimately depends on the skill of the technician and the site measured. The quality of the calipers is also a factor; they should be accurately calibrated and have a constant specified pressure. Inexpensive models sold for home use are usually less accurate than those used by an accredited caliper technician. The more obese the subject, the more difficult to “pinch” the skinfold correctly, requiring even more skill to obtain an accurate measurement.

Grasp the skin,  
shake it,  
and pinch it  
between the jaws  
of a caliper.



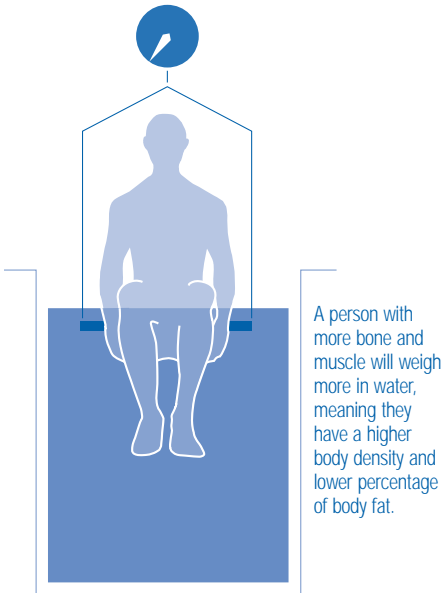
# The Dunk Tank

## Hydrodensitometry (Underwater Weighing)

This method measures whole body density by determining body volume. There is a variety of equipment available to do underwater weighing ranging in sophistication from the standard stainless steel tank with a chair or cot mounted on underwater scales, to a chair and scale suspended from a diving board over a pool or hot tub.

The underlying assumption with this method is that densities of fat mass and fat-free mass are constant.

This technique first requires weighing a person outside the tank, then immersing them totally in water and weighing them again. The densities of bone and muscles are higher than water, and fat is less dense than water. So a person with more bone and muscle will weigh more in water than a person with less bone and muscle, meaning they have a higher body density and lower percentage of body fat.





The volume of the body is calculated and the individual's body density is determined by using standard formulas. Then Body Fat Percentage is calculated from body density using standard equations (either *Siri* or *Brozek*).

The underlying assumption with this method is that densities of fat mass and fat-free mass are constant. However, underwater weighing may not be the appropriate gold standard for everyone. For example, athletes tend to have denser bones and muscles than non-athletes, which may lead to an underestimation of body fat percentage. While the body fat of elderly patients suffering from osteoporosis may be overestimated. To date, specific equations have not been developed to accommodate these different population groups.

An important consideration in this method is the amount of air left in a person's lungs after breathing out. This residual lung volume can be estimated or measured, but it is established that a direct measure is desirable and it should be taken in the tank whenever possible. Another consideration is that the water in the tank must be completely still; there can be no wind or movement.

Although this method has long been considered the laboratory "gold standard," many people find it difficult, cumbersome, and uncomfortable, and others are afraid of total submersion or cannot expel all the air in their lungs. Clinical studies often require subjects to be measured three to five times and an average taken of the results.

This method uses an impedance reading along with a person's height, weight, and body type to calculate the percentage of body fat.

### Bioelectrical Impedance

Body impedance is measured when a small, safe electrical signal is passed through the body, carried by water and fluids. Impedance is greatest in fat tissue, which contains only 10–20% water, while fat-free mass, which contains 70–75% water, allows the signal to pass much more easily. By using the impedance measurements along with a person's height, weight, and body type (gender, age, fitness level), it is possible to calculate the percentage of body fat, fat-free mass, hydration level, and other body composition values. Conventional BIA normally uses underwater weighing as its method of reference (*see pages 7 and 14*).

Using BIA to estimate a person's body fat assumes that the body is within normal hydration ranges. When a person is dehydrated, the amount of fat tissue can be overestimated. Factors that can affect hydration include not drinking enough fluids, drinking too much caffeine or alcohol, exercising or eating just before measuring, certain prescription drugs or diuretics, illness, or a woman's menstrual cycle. Measuring under consistent conditions (proper hydration and same time of day) will yield best results with this method.

Because BIA can be affected by body hydration, many professionals may use this method as a means of tracking the hydration status of their patients. This is especially important for athletes who are training or performing, as well as for the chronically ill.

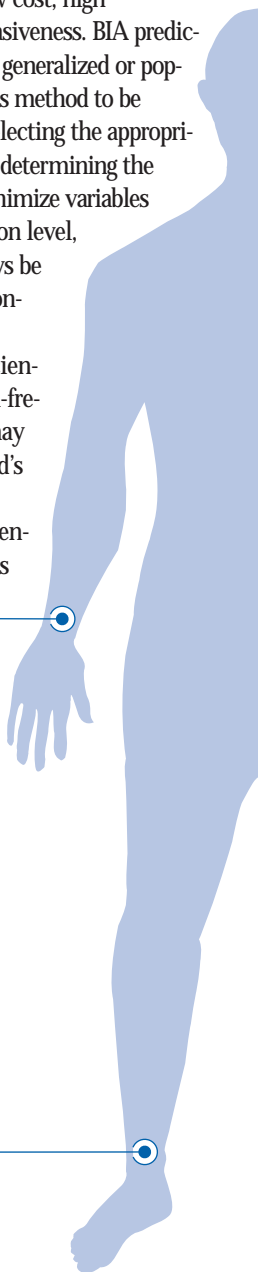
In the traditional BIA method, a person lies on a cot and spot electrodes are placed on the hands and bare feet. Electrolyte gel is applied first, and then a current of 50 kHz is introduced. BIA has emerged as a promising technique

because of its simplicity, low cost, high reproducibility and non-invasiveness. BIA prediction equations can be either generalized or population-specific, allowing this method to be potentially very accurate. Selecting the appropriate equation is important in determining the quality of the results. To minimize variables caused by a person's hydration level, measurements should always be taken under constant and controlled conditions.

For clinical purposes, scientists are developing a multi-frequency BIA method that may further improve the method's ability to predict a person's hydration level. New segmental BIA equipment that uses more electrodes may lead to more precise measurements of specific parts of the body.



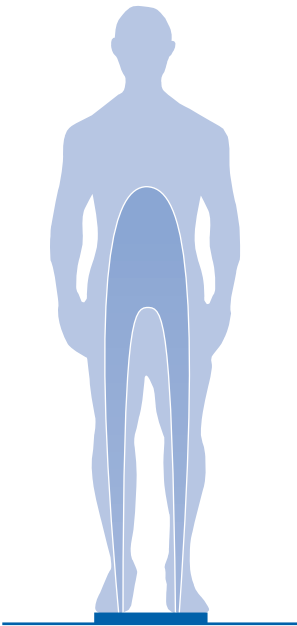
Spot electrodes are placed on the hands and bare feet. Electrolyte gel is applied first, and then a current of 50 kHz is introduced.



## Tanita BIA

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Tanita has developed a simplified version of BIA that uses leg-to-leg bioimpedance analysis. In this system, two footpad electrodes (pressure contact) are incorporated into the platform of a precision electronic scale. A person's measurements are taken while in a standing position with the electrodes in contact with bare feet. The body fat monitor/analyzer automatically measures weight and then impedance. Computer software (a microprocessor) imbedded in the product uses the measured impedance, the subject's gender, height, fitness level, and in some cases age, (which have been pre-programmed), and the weight to determine body fat percentage based on equation formulas. Tanita's reference method is DEXA (*see page 21*).



Tanita's footpad design sends a safe, low level electrical signal through the body. As easy as stepping on a traditional scale, it measures weight and body fat percentage within 30 seconds.

A person's measurements are taken while in a standing position with the electrodes in contact with bare feet



Through multiple regression analysis, Tanita has derived standard formulas to determine body fat percentage. Tanita's equations are generalized for standard adults, athletes, and children.

The Tanita method has all the advantages of traditional BIA as well as greater ease of use, speed, and portability. Professional versions of the product can be found in hospitals, health clubs, and research labs and include computer printouts of comprehensive data such as BMI, fat percent, fat weight, total body water, fat-free mass, and BMR. The concept has been adapted for use as an affordable home monitoring device. Now ordinary people along with fitness enthusiasts and patients with health risks can measure body fat as part of a regular healthy lifestyle. The same variables apply with regard to hydration levels, and measuring should be done under consistent conditions.

This method is based on studies that show optical densities are linearly related to subcutaneous and total body fat.

### Near-infrared Interactance

A fiber optic probe is connected to a digital analyzer that indirectly measures the tissue composition (fat and water) at various sites on the body. This method is based on studies that show optical densities are linearly related to subcutaneous and total body fat. The biceps is the most often used single site for estimating body fat using the NIR method. The NIR light penetrates the tissues and is reflected off the bone back to the detector. The NIR data is entered into a prediction equation with the person's height, weight, frame size, and level of activity to estimate the percent body fat.

This method has become popular outside of the laboratory because it is simple, fast, noninvasive, and the equipment is relatively inexpensive. However, the amount of pressure applied to the fibre optic probe during measurement may affect the values of optical densities, and skin color and hydration level may be potential sources of error. To date, studies conducted with this method have produced mixed results; a high degree of error has occurred with very lean and very obese people; and the validity of a single-site measurement at the biceps is questionable. Numerous sources report that more research is needed to substantiate the validity, accuracy and applicability of this method.



Illustration is based on the Futrex-5000/XL

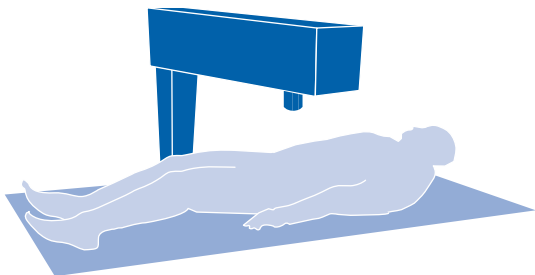
### Dual Energy X-ray Absorptiometry

A relatively new technology that is very accurate and precise, DEXA is based on a three-compartment model that divides the body into total body mineral, fat-free soft (lean) mass, and fat tissue mass. This technique is based on the assumption that bone mineral content is directly proportional to the amount of photon energy absorbed by the bone being studied.

DEXA uses a whole body scanner that has two low-dose x-rays at different sources that read bone and soft tissue mass simultaneously. The sources are mounted beneath a table with a detector overhead. The scanner passes across a person's reclining body with data collected at 0.5 cm intervals. A scan takes between 10–20 minutes. It is safe and noninvasive with little burden to the individual, although a person must lie still throughout the procedure.

DEXA is fast becoming the new “gold standard” because it provides a higher degree of precision in only one measurement and has the ability to show exactly where fat is distributed throughout the body. It is very reliable and its results extremely repeatable; in addition, the method is safe and presents little burden to the subject. Although this method is not as accurate in measuring the extremely obese and the cost of equipment is high, DEXA is quickly moving from the laboratory setting into clinical studies.

This technique assumes that bone mineral content is directly proportional to the amount of photon energy absorbed.



## Other Methods

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### **Magnetic Resonance Imaging (MRI)**

An x-ray based method in which a magnetic field “excites” water and fat molecules in the body, producing a measurable signal. A person lies within the magnet as a computer scans the body. High-quality images show the amount of fat and where it is distributed.

MRI takes about 30 minutes and is very safe as it uses no ionizing radiation, but use is limited due to the high cost of equipment and analysis.

### **Total Body Electrical Conductivity (TOBEC)**

This method is based on lean tissue being a better conductor of electricity than fat. A person lies in a cylinder that generates a very weak electromagnetic field. The strength of the field depends on the electrolytes found in the person’s body water. In about 10 seconds, TOBEC makes 10 conductivity readings that estimate lean body mass. Although very accurate, its use is limited due to the high cost of the equipment.

### **Computed Tomography (CT)**

CT produces cross-sectional scans of the body. An x-ray tube sends a beam of photons toward a detector. As the beam rotates around a person, data is collected, stored, and applied to complex algorithms to build images that determine body composition. CT is particularly useful in giving a ratio of intra-abdominal fat to extra-abdominal fat. It is noninvasive, but potential is limited by exposure to radiation and high equipment cost.

### **BOD POD® (Air Displacement)**

Based on the same principle as underwater weighing, the BOD POD uses computerized sensors to measure how much air is displaced while a person sits for 20 seconds in a capsule. It uses a calculation to determine body density, then estimates body fat. The equipment is very expensive and limited in availability.



# At Tanita Corporation, we recognize the importance of education in helping to make the concept of body composition analysis understandable.

We believe people should know what methods of measurement exist and how these techniques work in order to decide which operation is right for their particular needs.

As body composition, rather than body weight, becomes an integral part of a person's health and fitness evaluation, we predict that analytical methods will be driven by scientific research and practical application—each with their own objectives.

Scientifically, body composition analysis will become more complex and precise with prediction equations capable of greater individualization. Various techniques may be combined to create a multi-faceted view of the body where body fat and its distribution is just part of a person's fitness profile.

In terms of practical applications, body composition analysis will become simpler, more accessible, and easily affordable. It will redefine the traditional scale and re-shape how people measure and monitor their bodies.

At Tanita Corporation we are developing products to meet all these objectives. Tanita's goal is to provide people—whether they are medical researchers or consumers—with more information about the human body.

# A Message for Women

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Many women customers have written or called Tanita seeking more specific facts about body fat and the female body. We offer the following additional information for women readers

## Women Have More Body Fat Than Men

By nature, a woman's body is developed to protect her and a potential fetus. As a result, women have more enzymes for storing fat and fewer enzymes for burning fat. Additionally, the estrogen women have activates fat storing enzymes and causes them to multiply.

## It's Possible to Have Too Little Body Fat

Women athletes involved in high performance sports that emphasize low body weight and extremely low body fat percentage often experience a decrease in hormones that causes an interruption in the menstrual cycle. The same condition can occur when a woman is anorexic and her body goes into a semistarvation mode. Over an extended period of time, this can lead to other health risks such as the loss of bone mass.

## Hydration Levels

Women experience more changes in hydration levels than men because of their menstrual cycle, and this can affect body fat measuring, particularly using the BIA method. Retaining fluid may also cause weight to fluctuate day-to-day during this period.

And, because weight is one of the components in determining body fat, it may cause additional variation in the measured body fat percentage.

Female users of BIA products should be aware of their natural monthly body cycles. To establish a baseline for body fat, many women find it useful to monitor and chart their readings daily for a month. Afterward, a monitoring program done at regular intervals can anticipate monthly fluctuations.

Hormonal changes due to pregnancy or menopause may also cause water retention and variations in measuring. Changes in hydration levels can also be due to food, caffeine or alcohol consumption, strenuous exercise, stress or illness, or the taking of prescription drugs, etc.

## Remember

To monitor progress, compare weight and body fat percentage measurements taken under the same conditions over a period of time. Pay attention to fluctuations caused by menstruation. Stay within the Women's—not the Men's—recommended Body Fat Range!

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# Who is Tanita?

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Tanita, the world leader in precision electronic scales, is committed to the research and development of products that help people achieve a healthier life. In 1992, the company introduced the world's first integrated body fat monitor and scale for professional use based on BIA (bioelectrical impedance analysis). Since then, Tanita has adapted this technology for the consumer market.

For more information on Tanita's complete product offering, including a full line of professional and home-use body fat monitors, or answers to technical questions, call toll free 1-800-TANITA-8.



Tanita is a proud sponsor  
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