Body Composition Assessment

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" measurements 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.

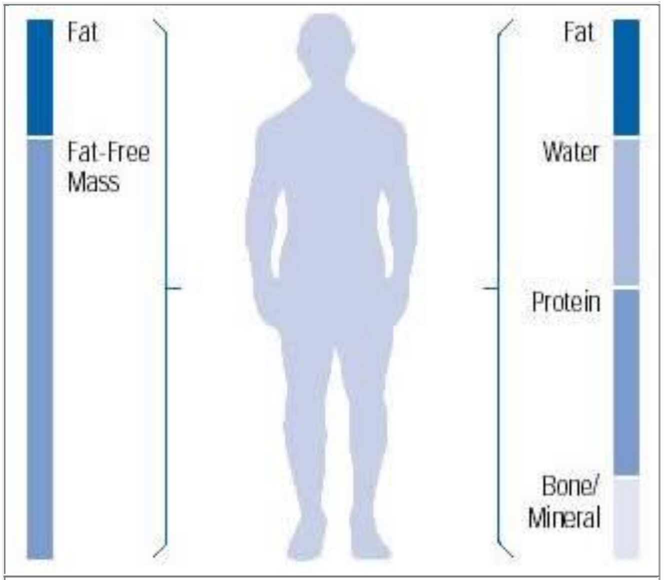
According to the National Institutes of Health, no trial data exist to indicate that one method of measuring body fat is better than any other for following overweight and obese patients during treatment. Good results depend upon accurately taken measurements and an adequate, scientifically derived database. 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 in to 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 absorptiometery) measure the body as multiple compartments. This approach improves the accuracy of the calculation for determining the real density of fat-free mass.

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.



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.

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 the 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.

Bioelectric Impedance

- **Description / Procedure:** There are many devices available that measure body composition through bioelectrical impedance. This method relies on the assumption that fat is a relatively poor conductor of electricity, while lean tissue and water are good conductors. An electric current is passed through the body and, with equations, lean and fat percentages can be calculated. In practice the machines used to measure percent body fat (%BF) this way are either scales, hand-held devices, or electrodes placed on the feet and hands.

- For example, with one of the more complex devices the subject lies on their back on a non conducting surface, with legs apart and arms away from the body. A pair of electrodes are placed on the hand and wrist, and another pair placed on the ankle and foot (usually opposite sides of the body).
- The simplest devices are just slightly more complex than a bathroom scale.

- **Equipment Required:** Bioelectric Impedance Analyser.
- **Advantages:** very simple and quick to perform
- **Disadvantages:** The equipment is relatively expensive (units on the low end of the scale are available for about $75), with prices ranging up to thousands of dollars. The impedance measure is affected by body hydration status, body temperature, time of day, and therefore requires well controlled conditions to get accurate and reliable measurements. However, the low end models can be effectively used to monitor gains or loss of body fat when used consistently over time.
- **Other Comments:** Bioelectric impedance analysis is based on the principle that the resistance to an applied electric current is inversely related to the amount of fat-free mass within the body.
  - This method is possibly the favorite method of gyms as devices are cheap and easy to use. They are also 'fun' and clients like to be measured by an electronic gadget. Accuracy and precision may be poor in bioelectrical impedance used in such circumstances. There are too many assumptions and factors which can skew results; if hydration status is slightly off from normal (basal) level the reading will be incorrect. In practice this method would be accurate and precise if the subject is measured first thing after waking, in good health, has not eaten or drank anything for 12 hours and has consumed no caffeine or alcohol for 24 hours. While these facts favor the use of a bathroom-scale-type home model, they make use in the gym setting less desirable. Many times gym staff measure subjects often after a hard sweaty workout.

Body Mass Index

- **Body Mass Index** or BMI is calculated by taking a person's weight in kilograms and dividing it by his/her height in meters squared. For instance, if your height is 1.82 meters, the divisor of the calculation will be (1.82 * 1.82) = 3.3124. If your weight is 70.5 kilograms, then your BMI is 21.3 (70.5 / 3.3124).
  - To calculate your BMI using weight in pounds and height in inches, either convert the English measurements to metric units or use the following formula.
    - weight (pounds) x 705 ¸ height (inches) ¸ height (inches)
- **Correct Use of BMI:** BMI uses a weight to height ratio to estimate critical fat values at which the risk of disease increases. In truth, BMI does not calculate a percent body fat value, but a number indexed against disease risk. However, the most common uses do not index BMI against risk. You will find both methods in the scoring section below.

The higher the figure the more overweight you are. Like any of these types of measures it is only an indication and other issues such as body type and shape have a bearing as well. Remember, BMI is just a guide - it does not apply to elderly populations, pregnant women or very muscular athletes.

- **Description / Procedure:** BMI is calculated from (M) and (H).

BMI = M / (H x H), where M = body mass in kilograms and H = height in meters.
The higher the score usually indicating higher levels of body fat.

- **Scoring:**

Classification	Disease Risk	BMI
Underweight	**Moderate to Very High**	**<20**
Healthy Range	**Low** **Very Low**	**20 - 21.99** **22 - 24.99**
Overweight	**Low** **Moderate**	**25 - 26.99** **27 - 29.99**
Obese	**High** **Vey High**	**30 - 39.99** **³40**

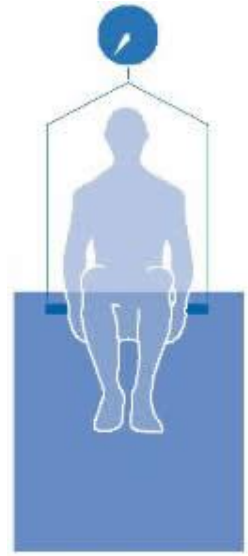
- **Equipment Required:** scales and a yard stick or tape measure for determining weight and height.
- **Target Population:** BMI is often used to determine the level of health risk associated with obesity.
- **Advantages:** simple calculation from standard measurements
- **Disadvantages:** BMI can be inaccurate, for example with large and muscular though lean athletes scoring high BMI levels which incorrectly rates them as obese.

◆**Other Comments:** There are a number of flaws with the BMI measurement. To start with, BMI only indicates the degree of being over- or underweight, and does not reveal what the underlying problems are. It also makes no account for the distribution of obesity; indeed, where fat is distributed on the body has been linked to increased risk of certain diseases. BMI is more reliable for assessing disease risk (such as cardiovascular diseases and some cancers) when used in conjunction with waist-hip ratio (WHR). Other measures of body composition would be preferable if available.

◆**Calculate Your BMI Here**.

◆**BMI Tables for Children Ages 2-20** in Adobe Acrobat format are also available.

Hydrostatic Weighing



◆**Note:** Commonly called "under water weighing" by laymen

◆**Description / Procedure:** The dry weight of the subject is first determined. The subject, in minimal clothing, then sits on a special seat, expels all air from the lungs and is lowered into the tank until all body parts are emerged. Underwater weight is then determined.

◆**Scoring:** Body density = Wa/(((Wa-Ww)/Dw)-(RV + 100cc)), where Wa=body weight in air (kg), Ww=body weight in water (kg), Dw=density of water, RV=residual lung volume, and 100cc is the correction for air trapped in the gastrointestinal tract.

◆**Equipment Required:** Hydrostatic weighing tank, including scale, weighted belt, nose clip.

◆**Advantages:** Underwater weighing is the most widely used test of body density and is the criterion measure for other indirect measures.

◆**Disadvantages:** The equipment required to do underwater weighing is expensive. The tanks are mostly located at university or other research institutions, and there is generally not easy access for the general population.

◆**Other Comments:** Residual lung volume is required for the calculations. For more accuracy it should be measured, though there are calculation for RV estimation. One estimation of residual volume is one third of forced vital capacity (FVC).

Dual-Energy X-Ray Absorptiometry (DEXA)

◆**Description / Procedure:** The DEXA instruments differentiate body weight into the components of lean soft tissue, fat soft tissue and bone, based on the differential attenuation by tissues of two levels of x-rays.

◆**Equipment Required:** DEXA machine.

◆**Advantages:** DEXA measurements are based on a three compartmental model rather than two compartment as in most other methods. It can also distinguish regional as well as whole body parameters of body composition.

◆**Disadvantages:** The equipment is expensive, and often requires trained radiology personnel to operate.

◆**Other Comments:** If not for the limiting price of measurement, DEXA would be considered the criterion method of body composition analysis.

Skinfold Measurement

◆**Description / Procedure:** Estimation of body fat by skinfold thickness measurement. Measurement can use from 3 to 9 different standard anatomical sites around the body. The right side is usually only measured. The tester pinches the skin at the appropriate site to raise a double layer of skin and the underlying adipose tissue, but not the muscle. The calipers are then applied 1 cm below and at right angles to the pinch, and a reading taken 2 seconds later. The mean of two measurements should be taken. If the two measurements differ greatly, a third should then be done.

- **The Sites:** the following descriptions are for the site at which the skinfold pinch is taken. The caliper is then applied 1 cm below and at right angles to the pinch. I have added some lay terms (in brackets) that may help the non-medical users to find the correct sites for taking the skinfold measurements.

Triceps	A vertical pinch at the mid-point between acromial (boney tip of shoulder) and olecranon processes (pointy bit of elbow) on the posterior (back) surface of the arm.
Biceps	The pinch position is at the same level as for triceps, though on the anterior (front) surface of arm.
Subscapula	The pinch is made 1 cm below the lower angle of the scapula (bottom point of shoulder blade), the fold lifted directed down and laterally (away from the body) at about 45 degrees.
Axilla	The pinch is made at the intersection of a horizontal line level with the bottom edge of the sternum (breast bone), and a vertical line from the mid axilla (middle of armpit). (usually males only)
Iliac Crest	The pinch is made at a site immediately above the iliac crest (top of hip bone), at the mid-axillary line. The fold is directed anteriorly and downward.
Supraspinale	The pinch that is directed anteriorly and downward is made 7 cm above the spinale (front part of iliac crest), on a line from the spinale to the axilla.
Abdominal	The vertical pinch is made 4 cm adjacent to the umbilicus (belly-button)
Thigh	A vertical pinch is made at the mid-point of the anterior surface of the thigh, midway between patella (knee cap) and inguinal fold (crease at top of thigh).
Calf	A vertical pinch is made at the point of largest circumference on medial (inside) surface of the calf.
Chest	A diagonal pinch is made between the axilla and nipple as high as possible on the anterior axillary fold (males only).

7 Site Skinfolds:

- chest
- triceps
- subscapular
- axilla
- suprailiac
- abdomen
- thigh

3 Site Skinfolds (Men):

- chest
- abdomen
- thigh

3 Site Skinfolds (Women):

- tricep
- suprailiac
- thigh

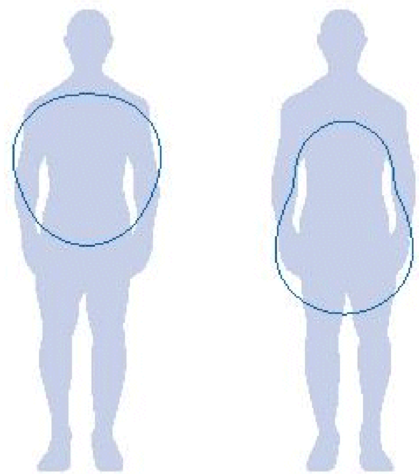
- **Results:** Because of the increased errors involved, it is not appropriate to convert skinfold measures to percentage body fat (%BF). It is best to use the sum of several sites to monitor and compare body fat measures. In order to satisfy many of you who want a %BF measure, I have included a couple of equations for calculating this. There are hundreds of equations available, and it is best to use one that is based on a sample that most closely resembles you. You will find that you get different results depending on the equations you use.
- **Equipment Required:** skinfold calipers (e.g. Harpenden, Holtain, Slimglide, Lange). These should be calibrated for correct jaw tension and gap width.
- **Target Population: suitable** for all populations, though it is sometimes difficult to get reliable measurements with obese people.
- **Validity:** using skinfold measurements is not a valid predictor of percent body fat, however they can be used as a monitoring device to indicate changes in body composition over time.
- **Reliability:** can vary from tester to tester depending on the skill and experience of the tester.

◆**Advantages:** Skinfold measurements are widely utilised to assess body composition. It is a lot simpler than hydrostatic weighing. After the outlay for calipers, the tests costs are minimal.

Waist to Hip Ratio (WHR)

◆**Description / Procedure:** A simple calculation of the measurements of the waist divided by the measurement of the hips.
◆**Scoring:** The table below gives general guidelines for acceptable levels for hip to waist ratio. You can use any units for the measurements (e.g. cm or inches), as it is only the ratio that is important.

gender	*acceptable*		*unacceptable*		
	excellent	**good**	**average**	**high**	**extreme**
male	**< 0.85**	**0.85 - 0.90**	**0.90 - 0.95**	**0.95 - 1.00**	**> 1.00**
female	**< 0.75**	**0.75 - 0.80**	**0.80 - 0.85**	**0.85 - 0.90**	**> 0.90**



◆**Equipment Required:** tape measure
◆**Target Population:** This measure is often used to determine the coronary artery disease risk factor associated with obesity.
◆**Advantages:** A simple measure that can be taken at home by people to monitor their own levels.
◆**Other Comments:** The basis of this measure as a coronary disease risk factor is on the assumption is that fat stored around the waist poses a greater risk to health than fat stored elsewhere.

Apple or Pear and Android or Gynoid

WHR = waist circumference (cm or inches)
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hip circumference (cm or inches)

WHR <1 - gynoid deposition of fat (pear shaped) and reduced risk of diseases
WHR >1 - android deposition of fat (apple shaped) and increased risk of diseases

Other Methods of Measuring Body Composition

Bod Pod Air Displacement
One of the newest forms of body composition testing involving state of the art technology. The use of Bod Pod correlates nicely with the concept of hydrostatic weighing (underwater weighing). Instead of using water to measure body volume, the Bod Pod uses air displacement to measure body volume. Measurement time takes roughly 5 to 8 minutes per individual.

Near Infrared Interactance (NIR) or Near Infra Red Irradiation (NIRI)
This is another convenient and non-invasive 'gym method'. These relatively inexpensive and easy to use devices are strapped to the arm and measure body fat through infrared light as different tissues absorb this light in different extents. The main limitation is the assumption that the local tissue is representative of the whole body fat, which is obviously unlikely on the upper arm. There is also significant observer error.

Magnetic Resonance Imaging (MRI)

Many hospitals have MRI scanners which are extremely expensive. This is possibly the most accurate and useful method of measuring percentage, distribution and actual amounts of all the main body composites. Unfortunately, the procedure is expensive and therefore, not very practical.

Total Body Water (TBW)
This is a laboratory method where the subject is given deuterium oxide (or a similar substance which will distribute through all tissues and is not metabolised). TBW can then be measured and from this fat free mass (FFM) and %BF. There are potential sources of error, it's expensive and again it is not very practical.

Total Body Potassium (TBK)
A gamma counter measures the amount of a type of potassium which is assumed to be a proportion of FFM. Again, the equations are complex and it's impractical and costly.

Body Dissection
Post morteum dissection is an extremely accurate way of measuring percentage and distribution of body fat.