Body Composition

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Obesity: A Worldwide Health Issue

Obesity has been labeled a pandemic due to the prevalence of high body fat in the American population and the rising occurrence of weight gain throughout the world (63). According to the World Health Organization, 1 billion people world-wide are overweight and 300 million are clinically classified as obese, using BMI criteria (37). The health consequences of maintaining elevated levels of body fat are significant. Obesity is independently classified as a disease, but it is more commonly considered to be a comorbidity, meaning it is linked with the development of other diseases. According to the Department of Health and Human Services, the incidence of heart disease including heart attack, congestive heart failure, sudden cardiac death, angina or chest pain, and abnormal heart rhythm increases in persons who are overweight or obese (BMI > 25) (4; 20). For individuals who are obese (BMI > 30) there is a 50% - 100% increased risk of premature death from all causes, compared to individuals with a healthy weight (3; 19; 35). Estimates suggest that 300,000 deaths per year may be attributable to obesity, with the risk of death increasing proportionately with gains in fat mass. Moderate weight gain of even 10-20 lbs. increases the risk of death, particularly among adults aged 30 to 64 years (30).

Body Composition

Body composition is a component of physical fitness and an important part of an individual’s overall health profile. It is defined as the ratio of fat mass to fat-free mass, suggesting that the relationship of fat-free mass to fat mass is more relevant than the independent measure of adiposity (the total amount of fat) when expressed in pounds. For instance, a 200 lb. man with 40 lbs. of body fat experiences a higher risk for disease than a man who weighs 220 lbs. and maintains the same quantity (40 lbs.) of fat on his body because the ratio is less.

Body composition is most commonly expressed as the percentage of body weight composed of fat. Using the same example as above, the 200 lb. man has a body fat of 20%, whereas the 220 lb. man has a body fat of 18%. The percentage of fat is categorized into health risk by gender. The need for body fat differs between men and women, with males requiring less total body fat mass for normal physiological function than females. The reason that females require more fat relates to child birth and the endocrine regulations of their body functions.

Essential Body Fat Levels

Men and women have minimal values of body fat required to facilitate important physiological activities. The lowest level of body fat for proper homeostasis is referred to as essential body fat. Essential levels are necessary for key body functions.

Essential body fat levels for males are between 3% and 5%. When levels drop below these values, increased problems with thermoregulation and metabolic functions occur. Females generally need between 11-14% body fat to maintain normal menstrual cycles. Endocrine disturbances associated with low female body fat include oligo- or amenorrhea (64). This reduction impairs homogenous estrogen levels and may...
Body Fat Distribution

Body fat and distribution are both gender and genetically dependent. Often referred to as fat depots, significant evidence suggests that fat storage distribution may be a more important determinant than the degree of adiposity for predicting health risks. Where adipose tissue is stored on the body depends on several variables which include genetic predisposition, age, gender, and level of fat (31; 39; 82).

The Role of Hormones

Several differences exist in the actual fat cells located in the different regions of the body (45; 89). It is likely most differences exist due to the androgenic hormone concentrations in the body. Each area has a hormone sensitivity and acts in response to endocrine mediation. Gynoid fat patterning is enhanced by estrogen in women, whereas testosterone and other androgens affect android storage characteristics in males (6).

~Key Terms~

**Body Mass Index (BMI)** - A measure which takes into account a person’s weight and height to gauge health risk for disease.

**Essential Body Fat** - Fat required for normal physiological functioning.

**Subcutaneous Fat** - Fat found just below the skin.

**Visceral Fat** - Fat stored in and around the organs.

**Android Obesity** - Male pattern or abdominal fat storage associated with an “apple-shaped” physique (higher risk of heart disease).

**Gynoid Obesity** - Female pattern or gluteral fat storage associated with a “pear-shaped” physique (lower risk of heart disease).
Increased testosterone concentrations during and following puberty are accompanied by increased abdominal fat storage. Likewise, females increase in gynoid body storage with increasing estrogen and progesterone levels following the hormonal shifts related to puberty.

When the regions are compared by lipolytic behavior (fatty acid release), additional differences become evident (8; 74; 77). Males have elevated beta-adrenergic receptors in lower body fat cells, which increase the release of free fatty acids from lower body storage in response to catecholamines. Females have higher concentrations of alpha-adrenergic receptors in lower body fat stores, which reduce the lipolytic response to catecholamines (1; 13; 81). This suggests that lower body fat stores in females resist freeing fatty acids into circulation for oxidation, making it harder to lose lower body fat in females compared to males (1; 14; 16; 76; 79).

Catecholamine-mediated release in upper body fat cells is somewhat comparable between sexes; however, males have a higher free fatty acid release from subcutaneous abdominal fat in response to exercise, although some equivocal data exists (7; 15; 17; 78). Additionally, there are indications that basal fat oxidation, when adjusted for fat free mass, is lower in females as compared to males, partially explaining the higher fat storage in women (18). When compared by internal layer distribution, women commonly show higher levels of subcutaneous fat storage, where males have shown greater susceptibility to visceral fat storage (80). This information suggests that both males and females can change their abdominal storage with appropriate exercise and diet, but females will experience difficulty in reducing gluteofemoral (around the hips, buttocks and legs) storage due to a natural resistance to fat mobility (9; 38).

Another obstacle to lower body weight loss is that fat patterning in this region tends to be more attributed to hyperplasia of mature adipocytes and therefore, increases in the number of fat cells. Since mature fat cells contain lipids, whereas preadipocytes do not, larger numbers of cells increase one’s propensity to store more fat in a particular region. In contrast, abdominal fat deposition increases primarily via hypertrophy of the cell and does not seem to proliferate in response to increased energy balance and fat storage. Therefore, android male-fat patterning is altered more easily with exercise and dietary strategies than gluteofemoral fat stores.

The measures of fat mass, distribution, and risk for disease can be determined using several indirect methods. Since disease risk is the greatest consequence of obesity, identifying total fat mass and regional distribution is important to predict risk and need for intervention. The methods of assessing body fat by mass and distribution range from simple to complex techniques. In some cases, the assessment techniques use anthropometric measures to provide predictions. Included in this category are height-weight tables and stature-weight indexes.

**Height Weight Tables**

Height-weight tables (HWT) were originally designed to predict mortality rates associated with a person’s size for insurance premiums. If a person was short and heavy their predicted risk was elevated and so were...
their insurance costs. Data collected in the 1940’s and 50’s was used to identify the most desirable weight for each height related to the lowest mortality rates. The 1959 tables established weight ranges for different frame sizes to better identify the weight composition with respect to bone thickness. In more recent years, height-weight tables have established a criterion method to determine frame size using elbow breadth. The frame size measures were determined from the first two National Health and Nutrition Examination Studies and tabled by gender for reference. The United States Department of Agriculture also publishes height-weight ranges as part of the Dietary Guidelines for Americans, but the table fails to identify frame size and does not separate gender in the weight ranges.

Height-weight tables have significant deficiencies for health guidance because they incorporate far too many assumptions. Likewise, valuable data that cannot be collected using a scale and a ruler is important to exercise prescription and behavior modification. When using Metropolitan Life height-weight tables, it is important to consider the following:

Body Mass Index (BMI)

Another stature weight index that has all but replaced height-weight tables is the Body Mass Index (BMI). BMI is the ratio of body weight to height squared. BMI is more practical because it utilizes anthropometric measures to predict risk for disease and health complications rather than all-cause mortality. Similar limitations to the HWT exist due to the fact that body composition is not assessed. Muscular individuals, for instance, may have lean measures of body fat but may be considered very high risk due to their height to weight ratio. On the contrary, someone with very little lean mass may present as low risk, when they actually have an unhealthy body composition. Certain height ranges also decrease the accuracy of prediction. Individuals measured at less than five feet in height often have higher BMI scores than their mass represents.

BMI may have some downsides, but it certainly holds some level of merit for health assessment purposes. BMI is more accurate at predicting risk than weight alone and is relatively easy to calculate, even for the nonprofessional (66). Males and females use the same table, so predictive values are somewhat universal, and it takes very little time to calculate and track changes. Ideal values (lowest mortality) for BMI are 22 kg/m² for males and 21 kg/m² for females (65). Values between 18.5 and 24.5 kg/m² are considered to be within the healthy weight range. Once BMI becomes greater than 25 kg/m², health risk increases, with values over 27 kg/m² reflecting the greatest number of related health complications. A BMI less than 18.5 kg/m² is defined as underweight, 25-29.9 kg/m² is considered the overweight range, and a measure of 30 kg/m² or greater is considered obese. BMI is the reference value used when population segments are defined by percentage of people who are over weight or obese. In the United States, more than one third of the population has a BMI greater or equal to 30 kg/m² (72). It is important to understand that BMI predicts risk within a population but may over- or underestimate risk for a given individual.

Although stature weight assessments offer a degree of usefulness for predicting risk of disease, circumference measures add value to the prediction by evaluating regional distribution. Abdominal girth and waist-to-hip ratio provide data regarding central adiposity and also contribute to the prediction of body composition. Combining the height-weight data with circumference
values can better identify risk and demonstrate any predictive weakness with either measure when used independently.

**Waist Circumference**

Waist circumference has recently gained support for predicting obesity-related risk for disease. The correlation between abdominal adiposity and disease outcomes has made this simple assessment measure quite valuable for identifying need for weight management intervention strategies (71). For certain populations, including Caucasian males, waist circumferences are even more useful when used in conjunction with BMI to predict disease risk (75). Likewise, the measure assists BMI interpretation because large abdominal circumference is not related to muscle mass hypertrophy and therefore makes a distinction between fat mass and muscle mass (70). Waist circumference is an important reference because it shows behavior-related fat storage. Visceral fat associates with lower levels of physical activity and behavior traits more than genetic predisposition. Waist circumference values above 102 cm (40 inches) for males and 88 cm (34.5 inches) for females are associated with a high risk for cardiovascular and metabolic disease.

<table>
<thead>
<tr>
<th>Category</th>
<th>BMI (kg/m²)</th>
<th>DISEASE RISK RELATIVE TO NORMAL WEIGHT AND WAIST CIRCUMFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Men&lt;102 cm (40 in.)</strong></td>
</tr>
<tr>
<td><strong>Underweight</strong></td>
<td>&lt;18.5</td>
<td>—</td>
</tr>
<tr>
<td><strong>Normal</strong></td>
<td>18.5-24.9</td>
<td>—</td>
</tr>
<tr>
<td><strong>Overweight</strong></td>
<td>25.0-29.9</td>
<td>Increased</td>
</tr>
<tr>
<td><strong>Obese Class I</strong></td>
<td>30.0-34.9</td>
<td>High</td>
</tr>
<tr>
<td><strong>Obese Class II</strong></td>
<td>35.0-39.9</td>
<td>Very high</td>
</tr>
<tr>
<td><strong>Obese Class III</strong></td>
<td>&gt; 40.0</td>
<td>Extremely high</td>
</tr>
</tbody>
</table>
## Relationship Between Body Mass Index and Percentage Body Fat

### Adult Males

<table>
<thead>
<tr>
<th>Age</th>
<th>Increased Risk (BMI &lt; 18.5)</th>
<th>Healthy (BMI 18.5-24.9)</th>
<th>Increased Risk (BMI 25-29.9)</th>
<th>High Risk (BMI 30+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-39</td>
<td>&lt; 7.9%</td>
<td>8-19.9%</td>
<td>20-24.9%</td>
<td>&gt; 25%</td>
</tr>
<tr>
<td>40-59</td>
<td>&lt; 10.9%</td>
<td>11-21.9%</td>
<td>22-27.9%</td>
<td>&gt; 28%</td>
</tr>
<tr>
<td>60-79</td>
<td>&lt; 12.9%</td>
<td>13-24.9%</td>
<td>25-29.9%</td>
<td>&gt; 30%</td>
</tr>
</tbody>
</table>

### Adult Females

<table>
<thead>
<tr>
<th>Age</th>
<th>Increased Risk (BMI &lt; 18.5)</th>
<th>Healthy (BMI 18.5-24.9)</th>
<th>Increased Risk (BMI 25-29.9)</th>
<th>High Risk (BMI 30+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-39</td>
<td>&lt; 20.9%</td>
<td>21-28.9%</td>
<td>29-31.9%</td>
<td>&gt; 32%</td>
</tr>
<tr>
<td>40-59</td>
<td>&lt; 22.9%</td>
<td>23-29.9%</td>
<td>30-32.9%</td>
<td>&gt; 33%</td>
</tr>
<tr>
<td>60-79</td>
<td>&lt; 23.9%</td>
<td>24-31.9%</td>
<td>32-34.9%</td>
<td>&gt; 35%</td>
</tr>
</tbody>
</table>
Abdominal circumference measures are taken from the side of the body with the subject standing in an upright posture with feet located under the hips. The reference site for abdominal circumference measurement is the horizontal line of the umbilicus (belly button). The assessment should be performed against bare skin with the tape lying taut and parallel to the floor. The tightness of the measure should be enough to prevent folds in the tape but should not cause cutaneous indentations.

Waist-to-Hip Ratio

Waist-to-Hip ratio (WHR) is another circumference measure that predicts risk for negative health consequences. The predictive value of WHR is better than BMI, but may be not as good as waist circumference because additional variables reduce the assessment’s ability to identify the level of central adiposity (60). This occurs because the measurement is expressed as a comparison between hip girth and waist girth. If a person maintains high amounts of fat through the hips, the subcutaneous fat mass makes the waist mass less evident. Since lower body storage is not as detrimental to health as visceral fat storage, the ability of the test to detect changes in visceral fat accumulation is reduced. Similarly, excessive fat in both the stomach and lower body regions may cause reduced identification of visceral fat mass storage (22). Prepubescent children cannot be accurately assessed using waist-to-hip ratio due to the fact that hormonally mediated storage has not yet occurred. Additionally, individuals who engage in resistance training may have larger hip measurements due to muscle hypertrophy, which can reduce predictive value.

Waist-to-hip ratio is measured like the abdominal assessment, but unlike the waist circumference measurement, there is no single, universal standard for the measurement sites. The World Health Organization recommends measuring the waist circumference midway between the lower rib margin and the iliac crest of the pelvis. For the hip measurement, they suggest using the widest point over the greater trochanter. The Anthropometric Standardization Reference Manual recommends using the narrowest part of the torso for the waist measurement and the level of the largest part of the buttocks. Since the norms for WHR were formed from the Anthropometric Standardization Reference Manual, it makes logical sense to use their reference sites.

The ratio is calculated by dividing the waist measurement by the hip measurement. The closer the value is to 1.00, the greater indication of central adiposity and greater determination for risk. Although ranges exist which are age and gender specific, values above 0.9 for men and 0.8 for women seem to present the greatest increase in risk for negative health outcomes.

Body Composition Assessment

Assessment of body composition provides compartment specific data that categorizes tissue by relative percentage of body weight. This type of measurement identifies the actual fat mass by predicting body density. The advantage of body composition over stature weight and circumference references is that it

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Men</th>
<th>Women</th>
<th>Men</th>
<th>Women</th>
<th>Men</th>
<th>Women</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-29</td>
<td>&lt;0.83</td>
<td>&lt;0.71</td>
<td>0.83-0.88</td>
<td>0.71-0.77</td>
<td>0.89-0.94</td>
<td>0.78-0.82</td>
<td>&gt;0.94</td>
<td>&gt;0.82</td>
</tr>
<tr>
<td>30-39</td>
<td>&lt;0.84</td>
<td>&lt;0.72</td>
<td>0.84-0.91</td>
<td>0.72-0.78</td>
<td>0.92-0.96</td>
<td>0.79-0.84</td>
<td>&gt;0.96</td>
<td>&gt;0.84</td>
</tr>
<tr>
<td>40-49</td>
<td>&lt;0.88</td>
<td>&lt;0.73</td>
<td>0.88-0.95</td>
<td>0.73-0.79</td>
<td>0.96-1.00</td>
<td>0.80-0.87</td>
<td>&gt;1.00</td>
<td>&gt;0.87</td>
</tr>
<tr>
<td>50-59</td>
<td>&lt;0.90</td>
<td>&lt;0.74</td>
<td>0.90-0.96</td>
<td>0.74-0.81</td>
<td>0.97-1.02</td>
<td>0.82-0.88</td>
<td>&gt;1.02</td>
<td>&gt;0.88</td>
</tr>
<tr>
<td>60-69</td>
<td>&lt;0.91</td>
<td>&lt;0.76</td>
<td>0.91-0.98</td>
<td>0.76-0.83</td>
<td>0.99-1.03</td>
<td>0.84-0.90</td>
<td>&gt;1.03</td>
<td>&gt;0.90</td>
</tr>
</tbody>
</table>

**Waist-to-Hip Ratio Norms for Men and Women**
compartmentalizes lean mass and fat mass. Since lean mass contributes positively to metabolism, it is important to distinguish lean mass from fat mass. Excess fat mass becomes deleterious when stored in abundance. Identifying the actual amount of fat on the body can help to determine health risk and the adjustments necessary to reduce the risk that is associated with excess fat storage.

Body composition assessment also allows personal trainers to track the specific changes in the tissue when weight loss or gain occurs. When combined with circumference values, the predictability of disease risk is dramatically enhanced. Total body fat and regional distribution can be evaluated, and the data can be used to provide direction to the formulation of the exercise prescription and identify any need for dietary changes.

Body composition assessments use different measures to ascertain the body’s density. Once body density has been determined, regression equations predict body fat. The tests generally fall into two categories: clinical assessments and field tests. Clinical assessments require precision instruments and controlled clinical settings to measure body density. Common clinical tests include hydrostatic weighing, air displacement plethysmography, and Dual X-ray absorptiometry. Field tests require less sophisticated equipment and are generally easier to implement. Common field tests include girth measurements, skinfold assessment, bioelectrical impedance, and near-infrared interactance.

**Hydrostatic Weighing**

Clinical assessments are not commonly used in traditional personal training settings due to the equipment costs, technician expertise required, and labor involved. A brief review of each is warranted because they are often used as the criterion reference value by which standard estimation error is determined for field tests. Both hydrostatic weighing and air displacement plethysmography (ADP) are densitometric methods which estimate body density from the ratio of body mass to body volume. Hydrostatic weighing uses Archimedes principle of buoyancy to calculate density. Fat mass is less dense than water, and therefore it floats. Individuals who maintain more fat mass weigh less underwater. The assessment method has the test subject exhale maximally before being submerged and weighed on an underwater scale. Adjustments for water density are made based on the temperature and residual air in the body. The weight lost under water is proportional to the volume of water displaced by the body volume. Calculations determine body density, which is then converted to body fat percentage using a population-specific conversion formula.

**Air Displacement Plethysmography**

Air displacement plethysmography (ADP), as the name implies, uses air displacement instead of water to estimate volume. This method requires minimal time, client compliance, and technical skill. The Bod Pod is the most recognized commercial whole body plethysmography chamber. It works via a pressure-volume inverse relationship in accordance with Boyle’s law, which is used to calculate total volume displacement. The predictability of body density using the Bod Pod correlates with hydrostatic weighing, but has shown to under-predict percent body fat compared to multi-component methods and Dual X-ray Absorptiometry (24).

~Quick Insight~

Body composition is often viewed as a psychologically uncomfortable assessment. It is very common for a person to be self-conscious of their body when being evaluated by a personal trainer. With roughly 65% of America being overweight, body image becomes a relevant consideration in fitness training and assessment. People are usually not comfortable wearing tight fitness clothes or participating in assessment techniques that require some level of disrobedment. Likewise, very few people want someone to grab and acknowledge the amount of fat on their body. This fact becomes even more evident when the amount of fat a person carries is significant.

The assessment a personal trainer uses should reflect the client’s size, age, and fitness level and be considerate of the psychological stress the assessment may cause. Using skinfold measurement on an obese client makes very little sense. Skinfold measurement accuracy is inversely proportionate to the person’s level of fatness. Obese people cannot be accurately measured using this technique. Likewise, what benefit would exist from using such an invasive measure on people who are likely embarrassed about their weight. If a person is visibly overweight, use circumference measures or consider bioelectrical impedance with correction factors.

In some cases, it does not make sense to measure fat at all. For some people, the stress of the experience is not worth the data. A visibly obese person is obviously overweight and both the trainer and client know this information. Why subject them to an assessment that will tell you that an exercise prescription aimed at safe weight loss is recommended? For overweight people, clothing fit can be the best assessment to identify body fat changes.
Dual X-ray Absorptiometry

Dual X-ray Absorptiometry (DXA) is commonly used in research settings to assess multiple compartments including bone mineral, fat, and lean tissue. The assessment operates on the principle that the attenuation of X-rays with different photon energies is measurable and depends upon tissue characteristics, including thickness, density, and chemical composition. The body tissues weaken the high and low X-ray energies at different magnitudes based on density and chemical composition called attenuation ratios. The attenuation is measured and the tissue composition is identified. Some researchers suggest that DXA is more accurate than hydrostatic weighing and very close to multi-component estimates, making it a popular method for clinical trials (23; 61; 62).

Personal trainers are far more likely to utilize field tests due to their ease of implementation in practical environments. Field tests vary by assumption and principle, and therefore have specific procedures for employment. The measurement techniques and equipment needs for each method of assessment are subject to the evaluation protocol. The decision to use a particular assessment should be based on the capabilities of the trainer and the population segment being assessed.

Circumference Measurements

Circumference estimation of body composition employs measurements of select locations to predict body fat. The methods are easy to perform and require minimal equipment. The assessment device is often no more than a common linen or plastic measuring tape. Often referred to as “girth measurements,” this technique simply requires the circumference measurement of specific sites on the body. The measured values are then charted, graphed, or equated based on the particular protocol being used. Depending upon the estimation model, girth measurements can predict body composition and help determine regional fat storage. The estimations are based on the positive linear relationship between the circumference values of particular anatomical areas and the amount of body fat a person carries.

Girth measurements are very practical assessment methods for fitness professionals. When performed correctly with the appropriate prediction equation, circumference estimations of body fat can have a standard error of the estimate (SEE) of as little as ±2.5%-4% (85; 87). They also provide useful information about fat distribution patterns as well as body fat changes during weight loss. Clients can see and understand the quantifiable differences found between measurements, which often serve as a motivator even when body weight remains unchanged. Additionally, the methods are far more useful for measuring and predicting the body fat of obese individuals, where calipers and other methods have a less accurate predictive value (47; 86). One downside is body fatness in muscular individuals may be over-predicted (67).

Skinfold Measurements

Subcutaneous fat is the lipid mass that lies between the skin and the muscle tissue. Technicians can “pinch” select sites using the thumb and index finger to create a fold of skin and fat with equal parallel sides referred to as a skinfold. Skinfolds at specific locations can be measured and summed to predict body density specific to a particular population (59). There are large inter-individual differences in the patterning of subcutaneous adipose tissue. This is true both within and between genders. Skinfolds can be used because a linear

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Hyperinsulinemia- A condition in which there are excessive levels of circulating insulin in the blood.

Beta-adrenergic Receptors- Cell receptors, more prevalent in males, which increase the release of free fatty acids from lower body storage in response to catecholamines.

Alpha-adrenergic Receptors- Cell receptors, more prevalent in females’ lower body fat stores, which reduce the lipolytic response to catecholamines.

Height Weight Tables (HWT) - An assumptive, guidance table, originally designed to predict mortality rates based upon a person’s size.

Waist-to-Hip Ratio (WHR) - A tool that helps determine overall health risks by calculating waist/hip measurements.

Body Composition- Used to describe the percentages of fat, bone, and muscle in human bodies: the relationship of fat mass to fat free mass.

Dual X-ray Absorptiometry (DXA) – A body composition technique in which X-rays are generated at two energies that help estimate three body compartments, consisting of fat mass, lean body mass, and bone mass.

Circumference Measurements- An estimation of body composition employed by measuring select locations to predict body fat.
Cellulite is not a special fat as many people seem to believe. It is characterized by a dimpled or wrinkled appearance that occurs when the tissue pressure is increased from compression (sitting) or muscle contractions. Cellulite is simply subcutaneous fat that has herniated into the dermal layer of the skin beneath the epidermis (2). Irregularities in the connective tissue border between the dermis and the fat cells resulting from tissue weakness allow the fat mass to migrate through the border into the superficial layer.

The sum of skinfolds offers a fairly accurate prediction of fat mass when the regression model is appropriate. Regression equations are either quadratic (generalized) or linear (population specific). Jackson and Pollock developed a generalized model which categorizes large segments of gender specific groups varying by age and level of fat mass (53; 57). Age needs to be factored into the equation because variations in storage patterns are seen when comparing the young and the old (5). As a person ages, their storage of subcutaneous fat is replaced by visceral fat storage. Therefore, regression equations applied to older populations should be adjusted to match the population.

Clinical data from criterion measures using hydrostatic weighing suggests that skinfold estimation error is approximately 3.5% (21; 52). Skinfold error is most commonly attributed to testing error by the technician. This may be due to inexperience, variations in tissue consistency, too much fat mass at the site, or incorrect site identification. A trainer should perform numerous individual measurements under supervision of an expert before using skinfold assessment to measure body fat on a client to ensure accuracy.

When deciding on the sites and protocols for skinfold assessment, it is important to realize that accuracy does not necessarily increase with more test sites. Slight error on each measurement of a seven-site assessment may add up to a significant inaccuracy. What may be of more value is how well the assessment identifies and exploits total body storage (36). Using the Jackson-Pollock generalized equation, three-site assessment allows for measures at each region of the body (58). This can identify a high storage depot that may be missed when using other skinfold models. A good rule of thumb is that the assessment should at least measure one of the primary storage areas related to gender-specific storage. For women, a lower body site should be included in the assessment, while assessment on males should include either the abdominal or subscapular site due to the propensity for regional storage.

Skinfold assessment should be performed on individuals who are not visibly obese. Individuals who maintain excessive fat mass or those who have large fat depots at select sites are difficult to assess. This is particularly true when they are also muscular. In some cases, accurate folds cannot be made due to high levels of fat or the tightness of the skin, making it difficult to create a fold. If the assessment cannot be performed with accuracy, the data is of little use. In this case, an alternate assessment technique should be used (84). Skinfold predictability can be complemented using additional girth measurements (27). For purposes of reliability, the same tester and test should be used during any follow-up evaluations.

There are numerous calipers on the market for skinfold assessment. They range in price from under $20 to over $300. The pressure of the calipers should be calibrated to 10 g/mm² (56). The particular brand used is often based on professional preference and budget. It is not recommended to use calipers that require the tester to manually pinch the fold with the instrument due to tension variations which may over or under-compress the fold (55).
### Skinfold Guidelines

1. Be sure the test subject did not apply skin cream to the sites, or the skin will become slippery and assessment error may occur.

2. Correctly identify the gender specific sites, and mark the fold location for reliable subsequent measures. Generally, the right side of the body is used for assessment.

3. Using the left hand with a thumb down position, straddle the marked site with the index and thumb and push into the fat mass until the underlying muscle can be felt.

4. Firmly grasp the skinfold and pull away from the muscle. The skinfold should have parallel sides. The pinch width is specific to the amount of fat mass.

5. Holding the calipers in the right hand pull the trigger to open the calipers and place the caliper arms on either side of the fold about ½ an inch below the fingers in the center of the fold. The caliper arms should be held at a level that forms a 90 degree angle perpendicular to the fold.

6. Maintaining the pressure on the fold with the index finger and thumb release the caliper trigger and assess the measurement within 4 seconds. Do not let go of the fold until the reading has been made and the calipers are withdrawn from the fold.

7. Record the value.

8. Measure each site at least twice for accuracy, allowing at least 15 seconds between subsequent measures of the site. If values differ by more than 1-2 mm, reassess a third time. Average the measures.

9. Add the sum of skinfolds and apply the score to the population specific equation, or chart to identify the predicted percentage of body fat.

<table>
<thead>
<tr>
<th>Site Locations</th>
<th>Fold Orientation</th>
<th>Fold Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdomen</td>
<td>Vertical</td>
<td>Taken 2 cm (approximately 1 in.) to the right of the umbilicus.</td>
</tr>
<tr>
<td>Chest (Males only)</td>
<td>Diagonal</td>
<td>The site is one half the distance between the anterior axillary line and the nipple.</td>
</tr>
<tr>
<td>Thigh</td>
<td>Vertical</td>
<td>On the front of the thigh, midway between the hip (inguinal crease) and the superior aspect of the patella (kneecap).</td>
</tr>
<tr>
<td>Triceps</td>
<td>Vertical</td>
<td>Located halfway between the acromion process (shoulder) and the inferior part of the elbow on the rear midline of the upper arm.</td>
</tr>
<tr>
<td>Suprailiac</td>
<td>Diagonal</td>
<td>Taken with the natural angle of the iliac crest at the anterior axillary line immediately superior to the iliac crest.</td>
</tr>
<tr>
<td>Midaxillary</td>
<td>Vertical</td>
<td>Fold is taken on the midaxillary line at the height of the xiphoid (end of sternum).</td>
</tr>
<tr>
<td>Subscapular</td>
<td>Diagonal</td>
<td>Just below the lowest angle of scapula, taken on a 45 degree angle toward the right side.</td>
</tr>
<tr>
<td>Medial Calf</td>
<td>Vertical</td>
<td>Seated with the right knee flexed and sole of the foot on the floor. The fold is taken on the medial side of the calf at its greatest circumference.</td>
</tr>
</tbody>
</table>
Skinfold Sites

- Triceps
- Abdomen
- Chest
- Medial Calf
**Skinfold Sites Continued**

- **Thigh**
- **Midaxillary**
- **Suprailliac**
- **Subscapular**
Generalized Body Composition Equations

**Males**

7-Site Formula (chest, midaxillary, triceps, subscapular, abdomen, suprailiac, thigh)

**Body density**

\[ 1.11200000 - 0.00043490 \times \text{(sum of seven skinfolds)} + 0.00000055 \times \text{(sum of seven skinfolds)}^2 - 0.00028826 \times \text{(age)} \]

4-Site Formula (abdomen, suprailiac, triceps, thigh)

**Percent body fat**

\[ 0.29288 \times \text{(sum of four skinfolds)} - 0.0005 \times \text{(sum of four skinfolds)}^2 + 0.15845 \times \text{(age)} - 5.76377 \]

3-Site Formula (chest, abdomen, thigh)

**Body density**

\[ 1.10920000 - 0.0008267 \times \text{(sum of three skinfolds)} + 0.00000016 \times \text{(sum of three skinfolds)}^2 - 0.0002574 \times \text{(age)} \]

**Body density** (chest, triceps, subscapular)

\[ 1.1125025 - 0.0013125 \times \text{(sum of three skinfolds)} + 0.00000055 \times \text{(sum of three skinfolds)}^2 - 0.0002440 \times \text{(age)} \]

**Percentage body fat** (abdomen, suprailiac, triceps)

\[ 0.39287 \times \text{(sum of three skinfolds)} - 0.00105 \times \text{(sum of three skinfolds)}^2 + 0.15772 \times \text{(age)} - 5.18845 \]

**Females**

7-Site Formula (chest, midaxillary, triceps, subscapular, abdomen, suprailiac, thigh)

**Body density**

\[ 1.0970 - 0.00046971 \times \text{(sum of seven skinfolds)} + 0.00000056 \times \text{(sum of seven skinfolds)}^2 - 0.00012828 \times \text{(age)} \]

4-Site Formula (abdomen, suprailiac, triceps, thigh)

**Percent body fat**

\[ 0.29669 \times \text{(sum of four skinfolds)} - 0.00043 \times \text{(sum of four skinfolds)}^2 + 0.02963 \times \text{(age)} - 1.4072 \]

3-Site Formula (triceps, abdomen, suprailiac)

**Percent body fat** (triceps, abdomen, suprailiac)

\[ 0.41563 \times \text{(sum of three skinfolds)} - 0.00112 \times \text{(sum of three skinfolds)}^2 + 0.03661 \times \text{(age)} + 4.03653 \]

**Body density**

\[ 1.0994921 - 0.0009929 \times \text{(sum of three skinfolds)} + 0.0000023 \times \text{(sum of three skinfolds)}^2 + 0.0001392 \]

Percent Fat in Men and Women

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Men (% Body Fat)</th>
<th>Women (% Body Fat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential</td>
<td>3-5</td>
<td>11-14.9</td>
</tr>
<tr>
<td>Lean</td>
<td>6-10.9</td>
<td>15-18.9</td>
</tr>
<tr>
<td>Fitness</td>
<td>11-15.9</td>
<td>19-22.9</td>
</tr>
<tr>
<td>Healthy</td>
<td>16-19.9</td>
<td>23-26.9</td>
</tr>
<tr>
<td>Moderate Risk</td>
<td>20-24.9</td>
<td>27-31.9</td>
</tr>
<tr>
<td>High Risk</td>
<td>&gt;25</td>
<td>&gt;32</td>
</tr>
</tbody>
</table>
Bioelectrical Impedance

Developed in the 1970’s, bioelectrical impedance analysis (BIA) assesses body fatness based on water conductivity. Due to the fact that fat contains less water than muscle, the speed of conductivity of an electrical impulse provides information on the magnitude of fat in the body. BIA uses a weak 50 kHz electrical current run through the body to identify resistance to the electrical flow referred to as impedance. Numerous instruments, techniques, and population specific equations exist for BIA. Clinical assessments using BIA have been shown to be the most accurate (SEE 4%) (88). The protocol requires the subject to lie in a supine position with electrodes placed on the top of the right hand and foot. Using this technique, outcomes compare favorably to the standard error of estimation for skinfold measurement. Other techniques of BIA have not shown the same level of accuracy, particularly in obese persons (32; 43; 49; 73). Hand-held devices and scales show pronounced differences in accuracy and measurement consistency. Even similar equipment has shown variations among manufacturers (42).

Numerous factors affect the accuracy and precision of BIA (41). Equipment, environmental factors, client factors, and equation appropriateness are all factors influencing error. Because of the variations in equipment prediction, the same measurement instrument should be used each time in order to maximize reliability. Even if the measurement is incorrect when compared to more accurate protocols, it should still reliably show change between pre- and post-tests on the same subject. To maintain reliability and enhance accuracy of the assessment, certain client factors should be considered. Client hydration state needs to be regulated because an increase or decrease in water volume creates variation in the measure. Likewise, the environment needs to be controlled because cold skin temperatures cause underestimation of fat mass. Additionally, the skin thickness at the point of the electrodes influences the assessment. Measurements performed in the original clinical trials are accurate because the electrodes are placed on the back of the hand and top of the foot, where the skin is not conditioned from friction and consequently more permeable to the current. The bottom of the feet and palms of the hands are the most frictionally conditioned parts of the body, and therefore, are not the best sites for electrode placement. Ironically, almost all devices manufactured for BIA use these undesirable locations for electrode placement.

BIA certainly has its share of shortcomings, but it can be used to track changes effectively outside of clinical environments (40). The assessments are non-threatening and pinpoint accuracy is not completely necessary. When used in conjunction with girth measures, BIA is a viable solution for certain populations. Taking the steps to enhance accuracy is important if the data is to be used effectively. Closely observing the testing protocols and using the correct equation reduces error. Adding client specific data, including age, gender, height, weight, and activity status can also improve accuracy (29). Some devices, including the Omron hand-held BIA analyzer have a computer that adjusts for client specific data.

### Testing Guidelines for BIA

1. No eating or drinking within 4 hours of test
2. No exercise or strenuous work within 12 hours of the test.
3. No alcohol consumption for more than 24 hours.
4. Void the bowel and bladder before assessment if possible.
5. Avoid testing during female menstruation.
6. Diuretic medications will invalidate the test.
Near Infrared Light Interactance

Near-infrared (NIR) light interactance was originally used by the USDA to identify food compositions. It has been employed as an easy method to analyze the fat and protein mass of cattle. NIR indirectly measures tissue composition through light absorption and reflection, called optical density (25). Typically performed at the site of the bicep, the NIR emits light into the tissue and measures the amount reflected back. Body fat absorbs the light, while lean mass reflects it. Therefore, the more light emitted back, the leaner the mass. Currently one company, Futrex, makes several commercial instruments with costs in the thousands (69). Claims of accuracy from the manufacturer differ significantly from those found in clinical trials using the NIR device when compared to hydrostatic weighing (44). Standard estimation of error may be as high as 5-8% (26; 33; 48; 68). New equations may improve the prediction accuracy, but more research is needed (50). When the standard estimation of error is added to the cost of the equipment, NIR is not the most practical choice for body composition analysis.

Body Composition Continuum

Body composition values fall along the continuum of health and physical fitness. As a health-related component of fitness, various body compositions associate with a range of positive and negative health outcomes. There does appear to be a threshold where, beyond a certain point, the amount of fat mass on the body begins to negatively affect the biological function of other tissues. Although identifying the exact body fat that is ideal for all men and women has been somewhat elusive for researchers, there seems to be a reasonable cut off value for each gender. Values above 20% for men and above 30% for women are more associated with negative health outcomes than values below these body fat percentages (2). This, of course, considers body fat as an independent variable for health risk. When physical activity, diet, and smoking are factored in, the ideal values may fluctuate based on the additional information. A 35-year-old male who smokes and has a body fat of 17% is at much greater risk for disease than a 35-year-old male with 20% body fat who does not smoke. Likewise, a female who has 29% body fat, but routinely eats a healthy diet and performs aerobic exercise most days of the week will likely have a lower risk than a sedentary female with a body fat of 25%. Body fat can be viewed the same way as aerobic fitness, only the relevant numbers are inverted. In aerobic fitness, very low numbers increase risk for disease; with fat the high numbers associate with negative health consequences. Maintaining values that are moderate, in conjunction with appropriate health and fitness behaviors will dramatically reduce risk for possible health problems.

Body fat values can be used for more than predicting health risk. When the values are accurately assessed they can be used in the development and evaluation of the exercise prescription. This is accomplished by converting the weight of fat into caloric value. The Target Body Weight Formula identifies fat weight changes associated with changes in body fat. If the desired body fat is placed in the formula, the end value reflects the new appropriate weight for a client at that particular body fat percentage. This calculation can determine the number of calories that need to be expended and can help clients to realize weight loss goals.

The formula can assist in setting short- and long-term weight loss goals for a client, as well as aid in tracking program effectiveness and identifying errors in balance between diet and energy expenditure. Using the predicted value, correct adjustments can be determined for caloric intake and expenditure recommendations.

Target Body Weight Formula

\[
\text{Fat mass} = \text{current body weight} \times (\% \text{ body fat} \div 100) \\
\text{Fat-free mass (FFM)} = \text{current body weight} - \text{fat mass} \\
\text{Target body weight} = \frac{\text{FFM}}{1 - (\text{Desired } \% \text{ BF})} \\
\]

Example

A 30-year-old male weighs 185 lbs. and has a body fat percentage of 20%. His goal is to reach 15% body fat. What is his target bodyweight at 15% body fat?

\[
\text{Fat mass} = 185 \times .20 = 37 \text{ lbs} \\
\text{FFM} = 185 \text{ lbs.} - 37 \text{ lbs.} = 148 \text{ lbs} \\
\text{Target body weight} = \frac{148}{1 - (15)} = 174 \text{ lbs}
\]
Using the previous example for a 155 lb. person, to change from 20% body fat to 15% he would have to lose approximately 9 lbs. Taking into account that 3,500 calories equals one pound of fat energy, this individual must create a negative caloric balance of 31,500 kcal to lose the 9 lbs. If the goal is one pound of weight loss per week, the client would have to create a negative caloric balance of 500 kcal everyday for nine weeks. Five hundred calories equates to about five miles of running, probably an unrealistic goal for a client to accomplish every day. Instead, diet and exercise management can be used together to make sure each day ends with a 500 kcal negative balance. Realistic goals are the foundation of exercise adherence. This and other weight loss strategies will be covered in Chapter 11.

### Key Terms

**Skinfold Measurements** - The most widely used body composition testing method to assess body fat percentage. This body composition technique involves the use of calipers to determine levels of subcutaneous fat.

**Cellulite** - A fatty deposit causing a dimpled or uneven surface.

**Bioelectrical Impedance Analysis (BIA)** - A body composition technique using the electrical impedance of body tissues, which provides an estimate of total body water (TBW). TBW can be used to estimate fat-free body mass and body fat.

**Near-infrared (NIR) Light Interactance** - A relatively new method in assessing body fat in which infrared light is emitted into a tissue and the amount reflected back is measured as fat absorbs, and lean mass reflects, the infrared light in determining overall percentage.

**Target Body Weight Formula** - A formula used to assist in setting short- and long-term weight loss goals.

### Chapter Ten References


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**Body Composition**


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Body Composition


