Body Composition

Body Composition: Assessment and Interpretation
Body composition has great practical and functional significance for many of us: scientists, clinicians and the general population. It can be especially intriguing for divers, as we must evaluate our weighting systems each time we dive to accommodate body composition changes as well as whether we're diving in fresh or salt waters.

An improper body composition balance may affect a person's ability to meet daily job and recreational requirements. Excess body fat has been associated with increased susceptibility to cardiovascular disease, hypertension, stroke, diabetes, orthopedic complications and many other health-related problems.

There are many different methods for estimating body composition. They can vary widely in the accuracy of the estimate delivered and the cost. This article will provide some insight into the merits and shortcomings of several of the wellestablished techniques. Recommendations for interpreting the values will then be provided.

Body Mass Index
Body Mass Index (BMI), less commonly known as the Quetelet Index, is the simplest scale used to predict body composition. The word "predict" is used intentionally, since BMI is not a measure of body composition at all: it is simply a computation based on stature (height) and mass (weight) that is used to assign individuals to categories of body fatness.

BMI predictions are useful for large-scale studies when more sophisticated measures are unavailable, but the predictions are often very poor on an individual basis. The assumption that increasing BMI values indicate increased fatness is often not valid: BMI values will increase whether the extra mass is due to fat or muscle. Individuals with well-developed muscle mass are penalized by this method.

BMI values can be computed easily with a handheld calculator. BMI is reported in units of kilograms per square meter (kg•m-2). It is computed by dividing body weight in kg by the square of height in m:

BMI {in (kg•m-2)} = weight {in kg} ÷ (height)-2 {in m}

Note that metric units are used in the calculation of BMI. The following imperial-metric conversions are required:

weight in lbs. ÷ 2.2 = weight in kg
(height in inches • 2.54) ÷ 100 = height in m

The rest of the methods discussed here are used to develop estimates of body composition, most specifically, the percentage of body fat.

Caliper Anthropometry
Skinfold thickness has long been recognized as an indicator of whole-body fat content. The thickness of the folded skin and underlying fat tissue is simply measured with a handheld caliper (see accompanying photos) . Measures from a number of sites are entered into a regression equation to compute an estimate of body fat. A staggering number of protocols are available in the scientific literature, requiring anywhere from two to 12 site measures to calculate. The estimates are most accurate if the subject is similar in body type and fat deposition to the group used to develop the regression equation. The accuracy of the prediction can vary widely on an individual basis. Simply using an equation that requires a greater number

of measurement sites does not guarantee a more accurate result.

The early, generic equations remain popular for general use. These were developed with large sample sizes and tend to be good predictors for group estimates (remember, not necessarily accurate on an individual basis). The most widely used generalized equations predict the body density specifically for each gender (Jackson and Pollock, 1978; Jackson et al., 1980). The calculated densities are used to compute a two-compartment estimate of body composition – fat-free mass and fat mass (while the two-compartment model is not anatomically accurate it is simple to use and produces reasonably valid results). A measurement known as the Siri equation is commonly used for Caucasian subjects (Siri, 1956). Since the fat-free mass of adult blacks has been documented to be significantly denser than those of a corresponding group of Caucasian subjects (1.113 g•cm-3 vs. 1.100 g•cm-3), a corrected formula – the Schutte equation – is sometimes used for these individuals (Schutte et al., 1984).

Hydrodensitometry

The relationship between body density assessed by buoyancy in water and body composition was developed as a practical technique through the study of U.S. Navy personnel during the Second World War (Behnke et al., 1942) and subsequently refined for easy use (Katch et al., 1967). Divers may appreciate that Dr. Albert Behnke is acknowledged as one of the fathers of modern diving physiology and medicine. He reportedly developed the hydrostatic weighing technique after becoming frustrated with his very fit divers being classified as overweight by the standard evaluations of the time.

Hydrodensitometry also relies on the twocompartment (i.e., fat-free mass and fat mass) model. The percentage of each is again estimated from the mean density of the body. Distilled water is the reference standard for density (described as “specific gravity”, weight per unit mass) with a value of 1.000 g•cm-3.

Fat has a specific gravity of approximately 0.9 g•cm-3 and muscle of approximately 1.1 g•cm-3. The chief difficulty in estimating the mean tissue density of a subject submerged in fresh water is the confounding caused by gas held in the respiratory and digestive tracts. This source of error is typically reduced by having subjects exhale as far as possible prior to relaxing on a scale supporting them underwater. The residual volume of the lung can be computed by an independent test to correct for the buoyant effect of the gas (Wilmore et al., 1980). The volume of gas trapped in the gastrointestinal tract is assumed to be a small volume and corrected for arbitrarily. Variations in water density as a function of temperature are also corrected.

Even with the various limitations and necessary estimations, hydrodensitometry is generally accepted as the reference standard for body composition assessment, particularly useful when evaluating new procedures. The chief limitation of this technique is that subjects must be comfortable enough to stay relaxed with empty lungs while their heads are completely immersed. While alternative techniques have been developed to eliminate the need for exhaling, they are less commonly used.

Air Displacement Plethysmography

A dry method that mimics hydrodensitometry techniques has gained popularity in recent years. Air displacement plethysmography (ADP) is used in a device called the Bod Pod (Life Measurements Instruments, Concord, Calif.) to eliminate the need for immersion and lung evacuation to determine the mean body density.

Here is how it works: the subject sits at rest in a small, dry computerized chamber that accurately measures his or her mass and volume. The whole-body density is computed and the fat-free mass and fat mass estimated as with hydrostatic measures. The differences between hydrostatic and ADP measures vary for different groups, and individual results can be highly variable (Collins et al., 2004), but ADP does have the advantage in ease of testing. This is particularly important for subjects who have difficulty relaxing underwater after completely exhaling. Those with claustrophobia, however, may still feel challenged.

Bioelectric Impedance

Bioelectric impedance analysis (BIA) is undoubtedly the most convenient method for estimating body composition. The measurement device can resemble a bathroom scale or a small box with two hand grips. The operating principle is simple in concept. The human body conducts electrical current. BIA assumes that the overall conductivity is increased by lean mass and inhibited by fat mass. The device requires two contact points on the body at some distance from each other (typically the two feet or two hands). An extremely low-energy, high-frequency electrical signal (unfelt by the person) is sent between the two contact points. The speed at which the current flows through the body is used to estimate the relative percentages of fat-free mass and fat mass.

While the devices can provide reasonable estimates under controlled conditions, the results can be affected substantially by state of hydration, electrolyte shifts or even a recent meal. The electrolyte shift effect will be evident if measurements are taken immediately before and after a 30-minute run. Some researchers have sharply criticized the validity of BIA measures (Gelbrich et al., 2005). While they have a potential for inaccuracy, these devices, which are inexpensive and simple to use, may have a place. Readily available for home use, regular measures made after first waking may provide reasonable trend information.

Ultrasound

Ultrasound can be used to measure body composition at sample sites. More involved and less comprehensively tested than the other techniques described here, this approach may be most useful with obese subjects for which other alternatives may not be practical. Such techniques may also be used to estimate visceral fat content as an indicator of cardiovascular disease risk (Kim et al., 2004).

Dual-Energy X-Ray Absorptiometry

Dual-energy X-ray Absorptiometry (DEXA) instruments employ two X-ray energies to measure fat, muscle and bone contents through whole or partial body scans. DEXA has the advantage over the traditional methods of skinfold thickness and hydrodensitometry; it can take bone density into consideration when estimating fat-free mass and fat mass (reducing the error of the two-compartment model). While the technique may provide accurate estimates of body density (Prior et al., 1997), the expense has kept it from becoming the new standard outside the research setting.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) employs a magnetic field to excite select nuclei in the body to produce high-resolution images of body tissues without exposure to ionizing radiation. The amount and distribution of fat can be accurately determined (Ross et al., 2000). The technique is safe but limited in use due to the high cost of equipment and computer-intensive analysis.

Interpreting Body Composition Assessment Results

BMI information must be applied with a great deal of common sense. The best way to use the measure on an individual basis is as a simple check to repeat over time. Individuals with BMI values outside of the desirable range or with values that creep up through adulthood (without a significant addition of muscle mass) may benefit from a reevaluation of dietary and exercise habits.

The classification of BMI is arbitrary and subject to the evolution of medical sensitivity. The scale recognized by the U.S. National Heart, Lung and Blood Institute (NHLB) and the World Health Organization

(WHO) in 1998 is currently the most widely used international standard (see Table 1).

The NHLB/WHO categorization is not necessarily the only valid interpretation. The definition of “normal” is a point of contention. Others have recommended that the lower end of the “overweight” category might be more appropriately represented by higher BMI values. It is difficult to establish a single valid classification system to accommodate a diverse population with such a simplistic and potentially misleading measure as BMI.

Body fat results must also be interpreted rationally. The potential for error with each technique must be considered. Estimates obtained through skinfold measures or BIA are the most likely to be erroneous. Estimates obtained through hydrodensitometry or the other high-tech methods are likely to be more definitive. Regardless of the tool used, it is important to maintain a healthy perspective. Our human nature is evident when, regardless of the number, almost everyone wishes for a smaller one. Remember that a certain amount of body fat is essential to maintain health.

A range of categorization systems based on body fat percentages can be found. A scale promoted by the American Council on Exercise provides reasonable reference ranges (see Table 2). Others provide additional leeway with increasing age.

Fat Loss Recommendations

If required, the best way to reduce excess body fat is to combine diet and exercise programs. Dieting alone will cause the loss of both fat and muscle tissue.

The subsequent reduction in metabolic rate that follows a loss of muscle mass will ultimately make excess weight come back faster. The loss of weight per se should generally not be the primary goal: the goal is to improve the ratio of lean tissue to fat tissue.

Those participating in serious weight loss programs should reassess body composition at regular intervals to monitor progress. The absolute numbers are less important than the change over time. Even if the absolute numbers are not accurate, repeated measures can be used effectively to compare change over time, as long as the same procedures and computations are employed.

Any program should be designed for the long term: modest improvement targets supported by many frequent short-term goals with a healthy long-term destination. Setbacks should not be allowed to derail a long-term effort.

Table 1: Classification of Overweight and Obesity by Body Mass Index

Classification	**BMI (kg • m-2)**
Underweight	<18.5
Normal weight	18.5 – <25.0
Overweight	25.0 – <30.0
Grade 1 Obesity	30.0 – <35.0
Grade 2 Obesity	35.0 – 40.0
Extreme Obesity	>40.0

(US NHLB, 1998; WHO, 1998)

Table 2: Classification of Overweight and Obesity by Percent Body Fat

Classification	Classification Women (% fat)	Men (% fat)
Essential Fat	10-12	2-4
Athletes	14-20	6-13
Fitness	21-24	14-17
Acceptable	25-31	18-25
Obese	32+	25+