Bioelectrical Impedance Analysis (BIA)

The body mass index (BMI) can often be misleading. It does not differentiate between fat, muscle, bone or water. An individual may be classified as overweight despite having a high fat free mass (FFM) and a low body fat percentage (BFP). Conversely, an individual may be classified as having a desirable weight despite having a relatively low FFM and high BFP.

According to a study by Smalley et al.,1 BMI is not a sensitive index of obesity. They found in their study that only 44.3% of men were correctly classified as obese using BMI. In comparison to hydrostatic weighing (HW), the gold standard for body fat measurement, the prediction error in estimating BFP using the BMI is ± 5.9% body fat.2

BMI (kg/m²) | Classification
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<18.5 | Underweight
18.5-24.9 | Desirable weight
25-29.9 | Overweight
30 or greater | Obese

It is often important to identify the body composition. Consider the following examples:

1. A new health club member is keen on accurately tracking her workout progress.
2. A nutritionist looks to see if there is a relationship between body fat percentage and the Atkins diet.
3. A pharmaceutical company wishes to analyze the pharmacokinetics of a new drug.
4. A clinician analyzes the effect of different nutritional interventions and their efficacy in countering muscle wasting in AIDS patients.
5. The military requires that its soldiers do not exceed a given BFP.
6. A study wishes to relate BFP to the incidence of hypertension in different populations.

What is BIA and How Does It Work?

BIA is becoming a popular tool in evaluating body composition. It is an inexpensive, non-invasive, quick-and-easy tool that does not require much operator training and does not require active patient cooperation. BIA measures the electrical impedance of body tissues to an alternating current of low magnitude - usually at 50 kHz for single-frequency BIA or at a range of frequencies for multiple-frequency BIA - applied to the body. Impedance, a function of both reactance and resistance, is the total opposition to alternating current provided by a circuit, in this case, the body. This measurement is then used by specific regression equations to estimate TBW (total body water). Consequently, deductions can be made about the FFM, body fat (BF), body cell mass (BCM), and intra- and extracellular water. These regression equations statistically correlate impedance with certain characteristics of a particular population with a similar body type. People differ in size, shape, electrolytes, fluid distribution and body composition. Different body compositions provide different degree of opposition to the flow of current and, in turn, register different values of impedance. Different regression equations are designed for different general body types, which may differ for many reasons: athletic activity, illness, age, race, gender, level of obesity, etc.

Although HW is the gold standard for measuring body composition, there are other proxies other than BIA: skin fold anthropometry, ultrasound methods, dual-energy x-ray absorptiometry (DXA), isotope dilutional method and total body potassium method. The latter three are more accurate than BIA but their drawbacks are numerous. They are expensive, require a lot of time to carry out measurements, and require extensive operator training. These three methods are, therefore, largely limited to research use. Skin fold anthropometry is used to measure local deposition of fat. This is advantageous if one wishes to identify the fat deposition pattern in a subject as this has been shown to relate more strongly to some health risks than does overall level of adiposity.
How BIA is Used

BIA is a very sensitive tool that can give very different results in the same individual under different conditions. Therefore, it is important to standardize the procedures used in BIA. Variables such as electrode position, electrode number, single- versus multiple-frequency measurements, machine specifications, measurement protocols, and algorithms for interpretation may limit the validity of the data obtained using this technology.1

Source electrodes are placed just proximal to the third MCP joint on the dorsal surface of the right hand and just distal to the transverse arch on the anterior surface of the right foot. Sensor electrodes are placed between the distal prominences of the radius and ulna of the right wrist and between the medial and lateral malleoli of the right ankle. A 1-cm displacement of electrodes can result in a 2-percent change in resistance.4

Variability in BIA can be caused by differences in: body position, hydration status, ambient air and skin temperature, recent physical activity, conductance of the examination table and whether the subject is fed or fasting. The length of time the subject is supine before the measurement is taken should be standardized. Patients should be fasting for at least six hours before undergoing BIA. It is also important the subject does not exercise for twelve hours before undergoing BIA. Subjects should urinate within 30 minutes of the test, should refrain from alcohol for 24 hours and diuretics for seven days preceding the test.

Fluid imbalances are the most significant limitation to obtaining accurate BIA measurements. Although single-frequency BIA is not valid under conditions of significantly altered hydration, new studies are showing multiple-frequency BIA may still be accurate in such situations.5 Both single- and multiple-frequency BIA equations become inaccurate when the extra- to intracellular ratio is altered as a result of disease and treatment (e.g. diuretics, dialysis, etc.).5 In the patient with a variable TBW-to-FFM ratio, variable body impedance measurements are achieved. Thus, BIA is not useful in conditions like ascites, anasarca, severe peripheral edema, massive overhydration as well as any clinical condition with disturbances in water distribution.7 Finally, it is important to choose the correct regression equation for the patient and to input accurate data into the regression equations like accurate height and weight.

If BIA is used in a standardized fashion, it is an accurate and reliable measure of body composition for most people. There are some limitations, however, that are keeping it from more widespread use in medicine. BIA has not been shown to be accurate in the setting of acute changes in body composition, such as rapid weight loss due to dieting in obese patients, rapid weight loss due to protein/calorie malnutrition, and acute weight gain by infusion. Many critically ill patients suffer from injuries and inflammation, characteristically accompanied by changes in TBW and the ratio of intracellular-to-extracellular water. In turn, BIA cannot accurately assess their FFM.3

Clinical Applications of BIA

Clinical applications of BIA are increasing as its use becomes more standardized and new regression equations are developed. Generally, it is used in any situation where an accurate determination of body composition could be helpful in planning or monitoring treatment regimens. Knowledge of TBW could serve as a reference for nutritional support and pharmacologic dosage.3,89

One common use is in identifying those who are not overtly obese by inspection but nonetheless have excessive BFP. Early identification of obese individuals could lead to early treatment and, in turn, avoid many of the complications associated with prolonged obesity.4

Another common use of BIA can be found in the geriatric population. Fluid imbalance, both dehydration and overhydration, is common among elderly patients. Dehydration is the most common fluid disorder responsible for increased morbidity and mortality and for substantial hospital expenditure.9 Its prevalence increases with age, from about 1% of hospital admissions in 65-year-old patients to above 5% in patients older than 85 years.10 Early diagnosis is sometimes difficult because the classical signs may be absent or misleading in an older patient.9 Overhydration - which can be caused by heart, kidney or liver failure - can also be hard to diagnose early and can also be a source of serious complications. Weinberg et al. found in their study of elderly patients that BIA with specific equations for elderly subjects could be used as a bed-side tool for discriminative diagnosis and for monitoring changes in fluid balance in geriatric patients. This was found to apply to TBW across the range of hydration disorders.9

There are certain uses for BIA in patients undergoing hemodialysis. It can be used in the prescription and monitoring of the adequacy of dialysis, for which urea kinetic modeling (UKM) has become the common standard. UKM requires an accurate assessment of TBW. BIA can be used to assess the volume status in the dialysis patient in order to minimize common problems related to inaccurate volume determination.9

Another population in which BIA use is common is in the HIV/AIDS population. Wasting and protein malnutrition is relatively common in this population. Those on active antiretroviral therapy have also been documented to acquire peripheral lipodystrophy, a syndrome of abnormal fat redistri-
Clonon in the population must ensure that nutritional interventions are adequate in order to reduce wasting. Thus, it is necessary to closely monitor changes in body composition to assess the efficacy of nutritional interventions. BIA can accurately measure fat-free mass in people with HIV/AIDS in a clinical setting, with the use of an appropriate prediction equation (eg, that of Kotler or Heitmann).12

BIA continues to be a valuable research tool in studies hoping to elucidate a relationship between phenomena of interest and body composition. It has shown solid incorporation into clinical situations, and it seems as though that trend will continue as BIA techniques are improved. For example, BIA is currently being investigated as an accurate substitute for the Subjective Global Assessment (SGA), a preoperative nutritional assessment. Body cell mass (BCM) has been shown to be an indicator of nutrition, and BIA is capable of detecting changes in impedance caused by changes in BCM and functional defects of the cellular membrane. BIA may therefore impart some objectivity to the SGA, quantify the magnitude of malnutrition, and monitor nutritional interventions.

**References**