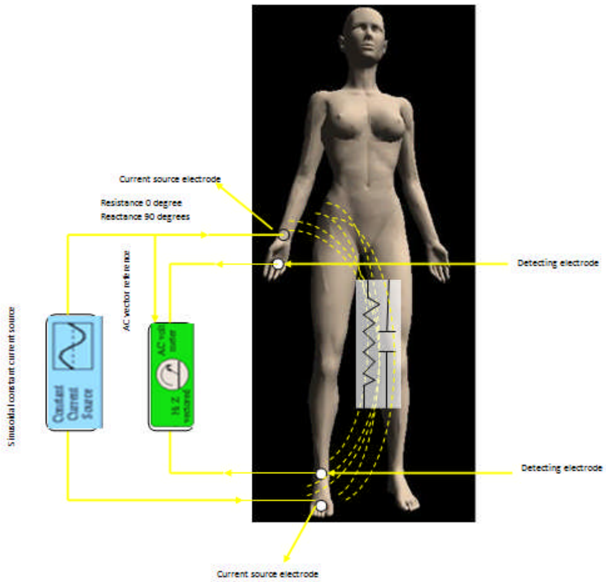
Bioelectrical impedance: General principles

Bioelectric impedance measurements (BIM) represents a wide range of old and new non-invasive technologies and methods where a very small electric current is applied to the body via one or more surface electrode and the resultant electricity pulse passing through the body is detected at other surface electrodes placed elsewhere on the body.
A drop in voltage occurs as the current encounters impedance or resistance inherent in the fluids and tissues it passes through as it courses through the various physiological “compartments” of the body. (1) (3). These compartments include the bloodstream, the intracellular space, the lymphatic system, the interstitial space, and others. (4) (5) this drop in voltage provides indirect information about the physical properties of the compartment(s) that the current passed through.

Alternating Current Bioelectric Impedance Analysis (BIA) :

The most familiar form of BIA uses alternating current (A.C.). There are dozens of readily available commercial and custom-built A.C. BIA(Bioelectrical Impedance Analysis) systems differing widely in design and complexity.(6) Most systems are used to indirectly estimate the fat content of the body and measuring total body water.*(7) (8) (38)These systems typically employ A.C. electricity with a wide range of currents, frequencies, and intensities. The amount of electricity delivered to the body is usually imperceptible and far below the level that would cause cellular or tissue damage.(9) (10) Studies of A.C. BIA systems operating at 50 KHz or higher, have revealed that these frequency A.C. electric currents flow *non-selectively* through both intracellular and extra cellular spaces (10) (see Fig. below).

Following the sending of intensity at the frequency 50 KHz (to active tactile electrodes, the system make the measurement of the resistance and reactance between 2 other passive tactile electrodes (tetra-polar mode).



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Impedance
So far, only the term impedance Z has been used. The impedance is the total resistance of a biological conductor to alternating current. The impedance is made up of two components:
1. The resistance R, which is a pure (ohms) resistance of the electrolyte-containing total body water, and
2. The reactance Xc, the capacitive resistance, which arises due to the condenser-like properties of the body cells.
Differentiation and determination of both of these components of impedance is possible by measuring the phase angle.

Phase angle
In order to be able to differentiate between the two components resistance and reactance from the measured total resistance, modern BIA devices have phase sensitive electronics.
The principle of measurement is based upon themfact that the condensers in the alternating current circuit lead to a time delay Δt: the current maximum is in advance of the voltage maximum. Every metabolically active cell of the body has an electrical potential difference at the cell membrane of about 50-100 mV. This membrane potential allows the cell to act in an alternating electrical field like a spherical condenser. As alternating current has a sinus wave, this shift is measured in ° (degrees) and is described as a phase angle ϕ (phi) or α (alpha).
Expressed figuratively, well nourished, "plump"cells with stabile membrane potentials have a large phase angle, whereas poorly nourished, you could say "withering" cells with low membrane potentials have correspondingly small phase angles.

The phase angle is most meaningful at a frequency of 50 kHz. A pure cell membrane mass would have a phase angle of 90 degrees, pure electrolyte water has a phase angle of 0 degrees. The phase angle is thus directly proportional to the body cell mass BCM. In contrast to cells of the body cell mass, fat cells, which are purely storage cells, have hardly any metabolic activity, only possess a minimal membrane potential and cannot be detected by phase sensitive measurements.

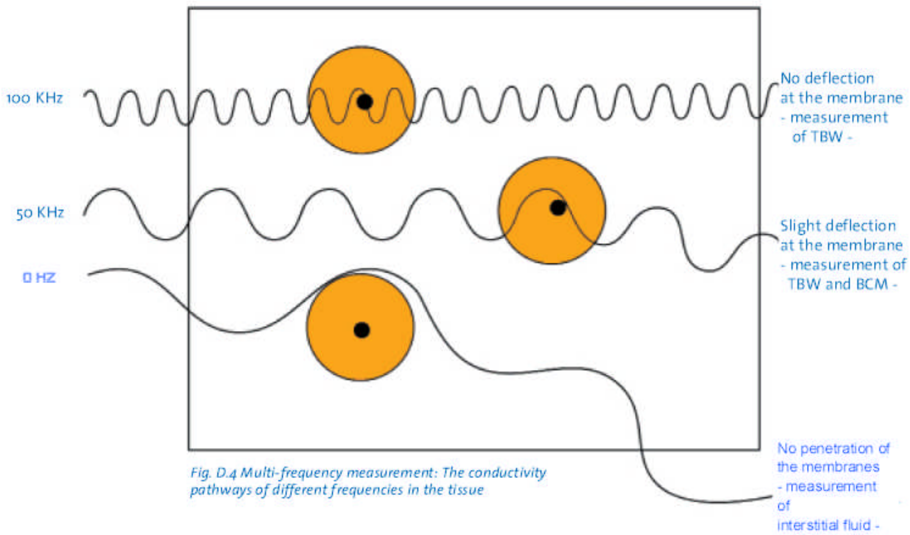

Fig. D.4 Multi-frequency measurement: The conductivity pathways of different frequencies in the tissue

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Predictive equations from peer reviewed journal articles, generated by correlating impedance measures against an independent estimate of Total Body Water (TBW) or Fat Free mass (FFM) with a common coefficient Ht2/R (where He is the Height and R the resistance)

BC Module Predictive equation used:

- **Total Body Water :TWB**
  5-19 yr Davies et al 1988
  20-80 yr Heitmann 1990

  Adult obese subjects: Segal et al 1988
  Fat free fat mass:
  7-15 yr Deurenberg et al
  16-83 yr Deurenberg et al 19910Extra cellular water volume :
  EWC
  Sergi G, et al 1994

Intracellular water: TWB- EWC

Actual Impedance = $\sqrt{\text{resistance } 2 + \text{reactance } 2}$

Actual Phase Angle (PA) = arctan $\left\{ \frac{\text{reactance}}{\text{Resistance}} \right\}$

Estimated Basal Metabolic Rate (BMR)
Harris-Benedict BMR formulas:
BMR (female) =651.1+ (9.6X Weight (Kg)) + (1.8X Height (cm)) – (4.7 X age (years))
BMR (male) =66.5+ (11.8 X Weight (Kg)) + (5 X Height (cm)) – (6.8 X age (years))

Actual Body Mass Index (BMI) = Weight (Kg)/ Height2 (meters)

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