Brandon Bruen
Advisor: Dr. Pamela Bhatti
Team Quadcopter

Body Fat Percentage Calculation via Bioelectrical Impedance Analysis

Introduction

Body composition is linked to many health conditions including heart disease and diabetes. In general, as one's weight increases risks for these and other diseases and conditions increase [1]. Traditionally body composition has been measured by Body Mass Index (BMI). BMI is a relation between a persons weight to height ratio (specifically: (weight in kg)/((height in meters)^2)) as compared to established population metrics [2]. However, concerns have been raised about the validity of this method because it does not take into account the specifics of an individual's body [3]. An alternative that has been suggested is Body Fat Percentage. In this case, a relation is made between lean and total mass. Conceptually, this allows more specific determinations to be made because it allows a distinction between different types of mass, fat mass (FM) versus fat-free mass (FFM)[4].

Body Fat Percentage Methods

While there are many different methods of determining body fat percentage in an individual, some of the most common are skin caliper testing, hydrostatic weighing, Dual-Energy X-Ray Absorptiometry (DEXA), and bioelectrical impedance [5].

Skin caliper testing requires that the subject use a set of calipers to take measurements of the amount of foldable skin on the body at different points including the arms, back, abdominals, and thighs. The measurements taken can then be read into a formula and an estimation of body fat percentage can be calculated. This method is viewed as very low cost, but prone to errors due to the limited amount of testing points.

Hydrostatic weighing requires that the subject be completely submerged in water and weighed. Based on the submerged readings, a calculation can be made for body fat percentage. This is viewed as one of the most accurate methods of obtaining body fat percentage and is viewed as "the gold standard", but it requires specialized equipment, thus is difficult to perform often and at low cost. Additionally, because during the process the person is asked to breath out as much air as possible, it is often described as uncomfortable.

DEXA testing employs X-ray beams of different strengths. The subject is exposed to the different beams and the absorption of the X-rays by the body is used to determine its composition. DEXA is considered to be at least as accurate as hydrostatic weighing, but is less accessible due to the need for high energy X-ray equipment and a subsequent higher cost.

Bioelectrical impedance uses electrical bursts to determine the overall conductance of the subject's body. Based on the delay between the signal being sent and then being received by a sensor at another point on the body, a calculation of how well the body conducts electricity can be calculated. Since lean mass conducts electrical signals well and fatty mass does not, equations can be used to convert the overall conductivity of the body to an estimation of body fat percentage. This method is fast, accessible, and relatively low cost, however a wide array of factors can influence the outcome, making it relatively inaccurate.

Bioelectrical Impedance Analysis

Single Frequency Analysis

When only one frequency is used for the driving signal, bioelectrical impedance analysis (BIA) is conducted using a small electrical current on the order of 1 mA at 50kHz. The signal is sent through the body and is conducted from hand-to-foot, foot-to-foot, or hand-to-hand. The signal relies on conductive material to make its way through the body, most notably water. Because the water in the body is laced with conductive components such as sodium and potassium ions, its ability to conduct an electrical charge is further increased. In general, lean tissue is well hydrated, both inside and outside the cell in order to allow for normal operation. This hydration allows signals to be conducted very easily through these regions. However, fat stores are inherently hydrophobic, causing considerably lower levels of water to be found where fat is stored. Because of this lack of conductive material, signals travel more slowly, causing a longer delay through these regions. By noting the total delay that the signal takes to travel from the source to the receiver, a general proportion of how much lean and fatty mass a subject has can be made [6] [7].

Multiple Frequency Analysis

Alternatively, multiple frequency bioelectrical impedance analysis (MF-BIA) uses several different frequencies of signal to gain a more accurate cross section of the body's water distribution. Because the interior and exterior of cells are separated by the cell membrane, a capacitive element is introduced to the body's resistance to a transmitted signal. At frequencies below 50 kHz, the signal will not penetrate the cell membrane, and the fluid held inside the cells will not be included for transmission. However, as the frequency increases above 50 kHz, the signal is able to pass through the membrane and the intracellular fluid is included [6] [7].

Basic Assumptions

In either case, BIA requires that several assumptions be made about the body, limiting the accuracy of the tests. First, the body is idealized as a group of 5 cylinders with volume determined by height and weight. Second, it is assumed that individual body elements are uniform in composition and evenly distributed. Third, it is assumed that the individual is well hydrated and has not been placed under severe stress recently [8].

References

[1] J. Casey. (2003). *Body Fat Measurement: Percentage Vs. Body Mass* [Online]. Available: http://www.webmd.com/diet/features/body-fat-measurement.

[2] C. Kuzontkoski. "Weight Management." Lecture. HPS 1040. Georgia Institute of Technology. Summer 2011.

[3] A Hohm and BL Heitmann, "The use of bioelectrical impedance analysis for body composition in epidemiological studies," European Journal of Clinical Nutrition, Vol. 67, S79-S85, Jan. 2013.

[4] R Ramsey, E Isenring, LDaniels, "Comparing measures of fat-free mass in overweight older adults using three different bioelectrical impedance devices and three prediction equations," The Journal of Nutrition, Health & Aging, Vol. 16, No. 1, pp. 26-30, Jan. 2012.

[5] J Duval, "5 Best Ways to Measure Body Fat Percentage," Daily Burn, Dec. 2013. Available at: http://dailyburn.com/life/health/how-to-measure-body-fat-percentage/

[6] JR Moon, "Body composition in athletes and sports nutrition: an examination of the bioimpedance analysis technique," European Journal of Clinical Nutrition, Vol. 67, pp.554-559, Jan 2013.

[7] U. Kyle et al., "Bioelectrical impedance analysis-part 1: review of principles and methods," Clinical Nutrition, Vol. 23, pp 1226-1243, Jun. 2004.

[8] Jawon Medical, "Bioelectrical Impedance Analysis (BIA)." [Online]. Available: http://www.jawon.com/reng/res/principles-of-bioelectrical-impedance-analysis.html