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Current opinion

A role for bioimpedance analysis (BIA)

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The measurement of body components is central to the study of body composition in animals and humans. The principle underlying the use of bioimpedance analysis (BIA) for assessing body composition is the relationship between body composition and the water content of the body. Resistance and reactance, the two main determinants of impedance, respond differently at any given frequency to intra-cellular and extra-cellular fluids. Estimation of fat and fat-free mass is discussed. Footpad vs lying position is considered in terms of measurement approach as well as accuracy.

BIA can measure water content of the body at population level so that, using appropriate specific equations, we may be able to detect individuals at risk of overweight and obesity.

Introduction

The relationship between body composition components and mortality does not seem to be simple. On the one hand obesity is also associated with increased all-cause mortality rate and even small weight losses can be associated with short-term reduction in risk factors for disease [1,2]. There is strong evidence that weight loss in obese subjects improves risk factors for diabetes and cardiac vascular diseases. On the other hand, the majority of studies show that weight loss is associated with an increased mortality rate [3]. Such inconsistent findings in the literature may be attributable in part to body composition methods that could not disentangle fat from lean body mass. Several studies suggest that better clarity may be achieved by modeling the independent effects of change in fat mass (FM) per se from change in total body mass [4]. The degree of health benefit may be dependent on the degree to which fat mass is lost and lean body mass is preserved [4-6].

For the first time in 1999 Allison and colleagues did a study in order to tease apart the independent effects of weight loss and fat loss on all-cause mortality in two independent samples [4]. The article concluded that it may be reasonable to indicate that FM loss is beneficial, whereas lean body mass loss is deleterious, and that the extent to which weight loss is beneficial or deleterious will depend of the composition of that weight loss. These conclusions underscore the importance of more precise body composition measurements for better understanding of the mechanism involved in the effects of weight loss and fat loss in all-cause mortality. The data also suggest that weight loss may extend longevity if a sufficient proportion of the weight loss is lost as fat.

Several risk factors have been identified as contributors to the development of type 2 diabetes and cardiovascular risk in adult and in children. These factors include increased body fat and abdominal fat, and insulin sensitivity among others (eg ethnicity). Total fat mass is the major contributor to variance in insulin sensitivity in children [7] and adults [8]. More detailed studies have examined whether specific depots of fat such as visceral fat have unique effects on insulin resistance and metabolic risk [9]. Recently Huang et al [10] showed that body fat in general is the predominant factor that influences insulin sensitivity. However, visceral fat displayed additional effects on fasting insulin. Basically there are several potential hypotheses that might explain the link between visceral fat, insulin resistances, type 2 diabetes and cardiovascular risk. However, there is a fundamental need for precise and specific fat measurements in order to detect health risks as early as possible.

How bioimpedance analysis (BIA) works

Accurate assessment of body composition is important in obesity and in many areas of nutrition-related research.

Bioimpedance analysis (BIA) is a potential field and clinical method for evaluating %fat and skeletal muscle mass (SM). It offers the advantages of portability, compactness, economy, and ease of operation.

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Briefly, the BIA technique is based on the principle that the body's electrical resistance is a function of the distribution of water and electrolytes among the various compartments in the body. Total body water in turn can be used to derive fat and fat-free mass [11].

Bioimpedance methods are formulated on a simple concept: tissues rich in water and electrolytes offer considerably less resistance to passage of an electrical current than does lipid-rich adipose tissue. Conceptually, a human devoid of adipose tissue would have minimum impedance, and impedance would increase to a maximum when all lean tissue is replaced by fat/adipose tissue. Impedance (Z) is the frequency-dependent opposition of a conductor to the flow of an alternating current and is composed of two components, resistance (R) and reactance (Xc). Resistance is the pure opposition of the conductor to the flow of the current and is the reciprocal of conductance [11-13]. Reactance is an additional opposition and is defined as the reciprocal of capacitance or the storage of an electrical charge by a condenser for a brief moment of time. The electrical path length also influences impedance, and impedance increases even in the absence of a tissue composition change. Impedance methods include an estimate of weight, to adjust for between-individual differences in electrical path length. Typical measured path length is arm-to-leg, although segmental methods that quantify the impedance of a limb or other body segments are increasing in popularity [11].

The impedance method is typically based on a single frequency, often 50 kHz, although multiple frequency systems are now available [11].

Conducting fluid is found both in the intracellular and extra-cellular compartments. Resistance and reactance at a given electrical frequency respond differently to intracellular and extra-cellular fluid, and this phenomenon provides an opportunity to 'predict' fluid. Some BIA systems therefore are calibrated to provide separate estimates of intracellular and extracellular fluid volume. Body cell mass and intracellular fluids are similar compartments, and some BIA systems also give a body cell mass estimate [12].

An important issue emerging from the NIH Technology Assessment Conference is that subject measurement conditions must be rigorously standardized to obtain accurate body composition estimates. Subject and room temperature, body position, electrode placement, and a multitude of controllable factors such as eating or drinking and proximity of exercise to time of evaluation, should be standardized where possible [11].

In conclusion, all BIA body composition methods are based on 'descriptive' prediction models. The importance of this observation cannot be overstated: all descriptive methods are, by definition, population-specific. For example, BIA prediction equations developed in normal-weight adults may not be valid in obese subjects. It is important that prediction formulas are applied to populations for whom the regression equations were developed [14].

BIA measurements of central/visceral fat

Quantification of internal adipose tissue such as visceral adipose tissue currently relies on expensive, cross-sectional imaging modalities. Recently He and colleagues [15] tested the hypothesis that surface impedance, determined by bioimpedance analysis, might be used to predict regional internal fat content change in a phantom model. They concluded that surface impedance measured by bioimpedance analysis can detect variations in fat content in the interior of a cylindrical phantom.

On the other hand abdominal fat is of major importance in terms of body fat distribution, but is poorly reflected in conventional body impedance measurements. Scharfetter and colleagues [16] developed a new technique for assessing the abdominal subcutaneous fat layer thickness with single-frequency determination of the electrical impedance across the waist. They showed that this technique provided an excellent tool for the assessment of central obesity.

Changes in skeletal muscle mass are involved in several important clinical disorders including sarcopenia and obesity. Pietrobelli and colleagues [17] tested the hypothesis that cell mass in the arm is highly correlated with electrical impedance after adjusting for the arm's length. These results demonstrate the feasibility of calibrating BIA-measured electrical properties of the arm against estimates of arm cell mass, mainly of skeletal muscle, obtained by regional 40-K counting. This simple and practical approach should facilitate the development of BIA-based regional cell-mass prediction formulas.

Footpad vs lying supine

For the first time in 1997 Heymsfield's group [18] tested the validity of the pressure contact electrode approach in 231 healthy adults (age 18-79 years) and examined correlation between stature-adjusted impedance derived by this system and two body compartments, total body water and fat-free mass, using tritium dilution volume, underwater weighing and DXA as gold standards. Similar correlation was also examined using a 'conventional' arm-to-leg gel electrode BIA system with subject in a lying supine position.

The leg-to-leg pressure contact BIA approach has the potential of simplifying measurements by first eliminating the need for gel electrodes. There is not the concern with the accuracy of electrode placement with the pressure contact electrodes as there is with gel electrodes. The leg-to-leg approach may be valuable in screening programs, in medical offices, or in setting where time and/or technician experience is at a premium.

Heymsfield's group [18] found that leg-to-leg impedance gave body composition correlations of overall magnitude similar to conventional arm-to-leg-gel-electrode BIA system.

Jebb and colleagues [19] tested the Tanita BIA ana-

lyzer in 104 men and 101 women (16-78 years) and compared the results with conventional tetra-polar BIA for which the four-compartment model is defined as the 'gold standard'. A foot-to-foot analyzer is a valid alternative method to conventional BIA techniques for the estimation of body fat. Later on the same group investigated changes in body composition and the validity of the leg-to-leg BIA method to measure body fat during weight loss and weight regain against conventional tetra-polar BIA and the multi-compartment model [20]. The authors found that the leg-to-leg BIA method performed better than the other prediction methods and had a comparable performance in measuring FM changes during weight loss and weight regain. In particular the authors underlined the superiority of the leg-to-leg BIA system relative to the supine tetra-polar BIA system explained by a more robust prediction equation or technical advantages of measurements biased towards the lower body.

Spencer and colleagues compared estimation of %FM by a foot-to-foot Tanita BIA and a conventional tetra-polar model in healthy young male students [21]. The authors found that both measures of %FM were highly correlated, showing the possibility of using the foot-to-foot BIA measurement in this population.

Ritchie and colleagues determined the validity of a foot-to-foot BIA system for body composition assessment in older adults [22]. Percent FM in 50 healthy subjects 55 years of age and older was measured using a foot-to-foot BIA system and compared to traditional BIA measurement. Results showed that foot-to-foot BIA provided a valid measure of %FM in older adults and could be a convenient and practical approach for assessment in public health setting.

Pateyjohns and colleagues tested the accuracy of tetra-polar BIA against foot-to-foot Tanita BIA in assessing body composition in a group of overweight and obese men using DXA as a reference [23]. This study showed a great agreement between the two BIA methods and DXA %FM measurement with foot-to-foot Tanita BIA producing less bias than tetrapolar BIA for the absolute differences. In particular, Tanita BIA overestimated %FM by 1.2% while tetra-polar BIA underestimated %FM by 1.7%.

Conclusions

Looking at the literature we can conclude:

1. An increased use of body fatness measurements and decreased reliance on BMI will promote better understanding of the U- or J-shaped obesity-mortality rate.

2. Weight change and fat change tend to be positively associated such that when individuals lose weight they also lose fat and vice versa.
3. Fat gain is associated with increased mortality rate.

Using BIA we can measure body composition at population level, using specific appropriate equations, with the ensuing ability to identify subjects at risk of overweight and obesity.

References

1. Goldstein DJ. Beneficial effects of modest weight loss. Int J Obes 1992; 16: 397-415.
2. Pi-Sunyer FX. A review of long term studies evaluating the efficacy of weight loss in ameliorating disorders associated with obesity. Clin Ther 1996; 18: 1006-35.
3. Andres R, Muller DC, Sorkin JD. Long-term effects of change in body weight on all cause mortality: a review. Ann Intern Med 1993; 119: 737-43.
4. Allison DB, Zannolli R, Faith MS, Heo M, Pietrobelli A, Van Itallie TB, Pi-Sunyer FX, Heymsfield SB. Weight loss increases and fat loss decreases all-cause mortality rate: results from two independent cohort studies. Int J Obes 1999; 23: 603-11.
5. Williamson DF, Pamuk E, Thun M, Flanders D, Byers T, Heath C. Prospective study of intentional weight loss and mortality in never-smoking overweight US white women aged 40-64 years. Am J Epidemiol 1995; 141: 1128-41.
6. Williamson DF, Pamuk E, Thun M, Flanders D, Heath C, Byers T. Prospective study of intentional weight loss and mortality in overweight men aged 40-64 years. Obes Res 1997: 5(S1): S94.
7. Gower BA, Nagy TR, Goran MI. Visceral fat, insulin sensitivity and lipids in prepubertal children. Diabetes 1999; 48: 1515-21.
8. Yanovski SZ, Yanovski JA. Obesity. N Engl J Med 2002; 346: 591-602.
9. Goran MI, Bergman RN, Gower BA. Influence of total vs. visceral fat on insulin action and secretion in African American and white children. Obes Res 2001; 9: 423-31.
10. Huang TK, Johnson MS, Gower BA, Goran MI. Effect on changes in fat distribution on the rates of change of insulin response in children. Obes Res, 2002; 10: 978-84.
11. Yanovski SZ, Heymsfield SB, Lukaski HC. Bioelectrical impedance analysis. Am J Clin Nutr 1996; 64(S3): 387-532.
12. Baumgartner RN. Electrical impedance and total body electrical conductivity. In Roche AF, Heymsfield SB, Lohman TG (Eds). Human body composition. Human Kinetics, Champaign IL, (USA), 1996, 79-107.
13. Pietrobelli A, Morini P, Battistini NC, Chiumello G, Nunez C, Heymsfield SB. Appendicular skeletal muscle mass: prediction from multiple frequency segmental bioimpedance analysis. Eur J Clin Nutr; 1998; 52: 507-11.
14. Pietrobelli A, Heymsfield SB. Establishing body composition in obesity. J Endocrinol Invest 2002; 25: 884-92.
15. He Q, Wang J, Engelson ES, Kotler DP. Detection of segmental internal fat by bioelectrical impedance analysis in a biological phantom. Nutrition 2003; 19: 541-4.
16. Scharfetter H, Schlager T, Stollberger R, Felsberger R, Hutten H, Hinghofer-Szalkay H. Assessing abdominal fatness with local bioimpedance analysis: basics and experimental findings. Int J Obes 2001; 25(4):502-11.
17. Pietrobelli A, Nunez C, Zingaretti G, Battistini N, Morini P, Wang ZM, Yasumura S, Heymsfield SB. Assessment by bioimpedance of forearm cell mass: a new approach to calibration. Eur J Clin Nutr 2002; 56: 723-8.

18. Nunez C, Gallagher D, Visser M, Pi-Sunyer FX, Wang ZM, Heymsfield SB. Bioimpedance analysis: evaluation of leg-to-leg system based on pressure contact footpad electrodes. Med Sci Sports Exerc 1997; 29: 524-31.
19. Jebb SA, Cole TJ, Doman D, Murgatroyd PR, Prentice AM. Evaluation of the novel Tanita body-fat analyzer to measure body composition by comparison with a four-compartment model. Br J Nutr 2000; 83: 115-22.
20. Jebb SA, Siervo M, Murgatroyd PR, Evans S, Fruhbeck G, Prentice AM. Validity of the leg-to-leg bioimpedance to estimate changes in body fat during weight loss and regain in overweight women: a comparison with multi-compartment models. Int J Obes 2007; 31: 756-62.
21. Spencer CE, Lingard JM, Bermingham MA. Comparison of a footpad analyzer with a tetra-polar model for the determination of percent body fat in young men. J Sci Med Sport 2003; 6: 455-60.
22. Ritchie JD, Miller CK, Smiciklas-Wright H. Tanita foot-to-foot bioelectrical impedance analysis system validated in older adults. J Am Diet Assoc 2005; 105: 1617-19.
23. Peteyjohns IR, Brinkworth GD, Buckley JD, Noakes M, Clifton PM. Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. Obesity 2006; 14: 2064-70.