Comparison between Dual-X-ray Absorptiometry and Bioelectrical Impedance Analyses in dietary practice

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Abstract

Body composition assessment is an essential part of assessing overall health, training progress, nutritional status, and monitoring the level of body fat and lean tissue content. This article is a review made to compare body composition analysis methods with the help of BIA and DXA as a dieticians' working tool. The practical advantages of the bioimpedance method enable the wide application of this method in dietary practice. BIA can be a safe and helpful method for monitoring patient progression in terms of changes in body composition. Although DXA is currently the gold standard for measuring body composition in clinical trials, the use of this method is associated with numerous limitations resulting from the high cost of the technique, limited availability of this type of equipment and time consumption.

Introduction

Body composition assessment is an essential element for assessing general health, training progress, nutritional status and monitoring the level of adipose tissue and lean tissue content [1]. Particular attention in the case of body composition analysis focuses on the body fat content. This is related to the common opinion on the existence of a correlation related to the increased content of adipose tissue and the increased incidence of cardiovascular diseases and mortality [2]. Cardiovascular diseases pose serious threats to healthcare, especially in highly developed countries [3]. It is well known that the risk of disease development is related to the distribution of adipose tissue. A high level of visceral adipose tissue predisposes to an increased risk of developing cardiovascular diseases, type II diabetes and neoplastic changes [2]. According to Zborowski and Mikulec [4], an access to a wide range of food products and an increase in nutritional awareness encourage consumers to reflect and make nutritional choices that have a beneficial effect on health. Body mass index (BMI) is the basic screening tool to identify overweight or obese patients [5]. BMI assessment, being a basic, simple and inexpensive method, should not constitute a diagnostic basis due to the change in body fat content with age, and the rate of this change varies depending on gender, ethnicity and individual differences. Although BMI correlates with fat accumulation and metabolic health in large populations, it is insensitive to the actual distribution of adipose tissue. Another parameter that is a simple tool to identify metabolic risk are anthropometric measurements such as waist circumference and waist-to-hip ratio, which correlate more strongly with the predisposition to the development of civilization diseases. In the light of the current scientific knowledge and the development of technology, it is known that the above-mentioned methods of metabolic risk assessment are predictors that need to be supported by more reliable and accessible methods [2, 6, 7].

Another important parameter of interest to scientists, used in the assessment of health in clinical practice, is the content of skeletal muscle. Cachexia and involuntary loss of muscle tissue are life-threatening and often will be directly correlated with disease progression (e.g. cancer) and increase the risk of rehospitalisation [8].

Aim

The aim of the article is to compare the methods of body composition analysis with the help of BIA and DXA as a dieticians' working tool. In clinical and epidemiological practice, the method of measuring electrical bioimpedance is the main form of controlling parameters related to body recomposition during dietary intervention.

Material and methods

This article is a review to compare body composition analysis methods with BIA and DXA as a dieticians' tool.

Analysis of the literature

Human body weight is a sensitive indicator susceptible to changes resulting mainly from the energy balance, i.e. the difference between the energy supplied to the body with food and the energy expenditure necessary for the functioning of the body and additional physical activity. A positive energy balance leads to excessive accumulation of adipose tissue in the body, which in turn leads to overweight or obesity. Assessing body tissue parameters, such as lean body mass and body fat, as well as body water, is important for a number of reasons. The most common research is to establish an appropriate diet, examine the effects of exercise, select the appropriate training (including physiotherapy) and establish developmental norms [9].

Body composition (BC) measurement is now an important tool for assessing nutritional status in health and disease. The most commonly used tools for analyzing body composition in clinical practice are based on two-compartment models and measure, directly or indirectly, fat mass (FM) and fat-free mass (FFM). Bioelectric impedance analysis (BIA) and dual energy X-ray absorptiometry (DXA) are widely used in epidemiological (mainly BIA) and clinical (mainly DXA) conditions to assess the body composition of patients [10].

Electrical Bioimpedance Analysis (BIA)

Bioelectric Impedance Analysis is an indirect body composition estimation technique that determines the electrical impedance of a tissue in relation to an alternating current of very low intensity and specified frequency. Electrical impedance (Z) consists of two elements: resistance (R) and reactance (Xc). Resistance is defined as the opposition to the flow of alternating current through intra- and extracellular ionic solutions. In the model, the

diaphragm behaves like a capacitor that charges and discharges as current flows. Reactance (reciprocal of capacitance) is defined as the lag in conduction of the current produced by cell membranes and tissue contact surfaces. In this way, a delay is generated during the flow of current, which is expressed as a phase shift called the phase angle (AF) [11, 12].

BIA body volume and compartment estimation is based on Ohm's law. In customary BIA practice, the most common analysis is a constant alternating current of low 50kHz flowing through the body. The human body (or body segments: torso, arms and legs) is considered as a cylindrical conductor of variable length, uniform cross section and uniform composition. Converting these electrical properties into body composition variables requires a two-compartment model. Total body water (TBW) is the largest component of fat-free mass (FFM) and the best conductor of electrical current in the human body. Total water includes the water inside the cells (intracellular water) and outside the cells (extracellular water). Both are perfect current conductors and are separated by cell membranes that act as capacitors. The obtained water content measurements are the starting values   for the estimation of other parameters of the body composition analysis [12]. The technology of using bioimpedance (BIA) is a willingly used tool for the routine assessment of the composition of the human body, because it is safe, characterized by low application costs, mobility, speed of analysis and high repeatability. In addition, bioimpedance measurements can be performed by dieticians and do not require the involvement of specialists, such as in the case of computed tomography (CT) or magnetic resonance imaging (RMI). The technique usually uses four contact electrodes placed on the hands and feet. Bioimpedance offers the possibility of improving the prognosis of patients due to its ability to non-invasively assess the structure and function of the cell membrane using the phase angle, which is an excellent predictor of morbidity and mortality in many types of chronic diseases. Age, gender, body mass index, nutritional status and physical activity influence the phase angle values. Thus, larger values of the phase angle can be proportionally considered an indicator of vitality, while smaller ranges indicate a decrease in vitality and be a tool for assessing the deterioration of health and the prognosis of patients, e.g. in the case of neoplastic diseases. Moreover, studies indicate the possibility of using bioimpedance in diseases of skeletal muscles [11, 13, 14].

Dual X-ray Absorptiometry (DXA)

Dual X-ray Absorptiometry (DXA) is currently the gold standard for measuring body composition in clinical trials. The use of this method is, however, associated with numerous limitations resulting from the high costs of applying the technique, limited availability of this

type of equipment, time-consuming and patient exposure to ionizing radiation [15]. Among the various methods of measuring body composition, DXA allows you to estimate the whole body and region of three major components: fat mass (FM), lean body mass (LBM), and bone mineral content (BMC). Several options are available in clinical practice, such as magnetic resonance imaging (MRI) or computed tomography (CT). However, significant limitations are cost, technical staff and expertise, contraindications and the availability of these methods. Therefore, DXA is also used to test visceral fat [10].

DXA uses an X-ray generator, a detector, and an interface with a computer system to image scanned areas of interest. The effective doses of radiation used are small (range 1-7 µSv), which makes this technique widely applicable. Due to the advantages of DXA in terms of accuracy, simplicity, availability and relatively low cost compared to procedures such as MRI or CT and low radiation exposure, DXA measurement is gaining more and more popularity in terms of application, becoming the reference evaluation technique also for mass muscle. DXA systems are practical, require no active involvement of the subject, and involve minimal risk. Radiation exposure from a whole body DXA scan is equivalent to 1 to 10% of a chest X-ray [10].

It can therefore be concluded that there are no contraindications to the use of this technique in clinical practice - the exception are pregnant women [16]. According to Kendler et al. [17], body composition analysis using DXA is a radiological procedure and should not be performed more than twice a year, which may be comparable to the radiation equivalent to which a human is exposed during an intercontinental flight, and therefore does not require close monitoring in certain patient groups. Importantly, unlike most other body composition methods that are designed to quantify a single component of the whole body, DXA can quantify multiple components of the whole body. As a result, DXA is gaining international acceptance as the reference method for body composition, especially in the case of severe malnutrition, overweight or obesity [10]. DXA can be routinely used in clinical practice to measure bone mineral, enabling the diagnosis and monitoring of sarcopenia, osteoporosis, a potentially high-risk condition characterized by malabsorption, malnutrition, and long-term corticosteroid therapies commonly observed in the perimenopausal age [10]. Another area of application of dual x-ray absorptiometry may be used in HIV patients to assess the distribution of adipose tissue in antiretroviral users at risk of lipoatrophy [18]. DXA can be used in obese patients undergoing bariatric surgery to control changes in lean and fat mass. According to the authors, this tool may be beneficial in order to work on the recomposition of the figure and to individualize clinical and dietary recommendations in working with the

patient. The fact is that in the case of severely obese patients, the use of the technique is associated with numerous limitations [17, 19, 20].

Comparison of the results obtained with the use of BIA and DXA

Bioelectric impedance measurement instruments are inexpensive, portable and relatively easy to use compared to more expensive invasive DXA methods. It is worth noting that the pattern of differences differed between lean mass and fat mass. The authors' conduct was to test the initial validity of the segmental body composition estimation measured with BIA compared to DXA. The results show differences between lean mass and fat mass. Both the overestimation of lean body mass and the underestimation of adipose tissue mass were significant for total body and arm measurements [8]. Also Raymond et al. [21] indicate that the current literature in the general population shows a contradictory underestimation and overestimation of BIA total body composition measurements compared to various DXA models. Achamrah et al. [22] indicate that their studies also showed a lack of compliance of BIA and DXA methods at the individual level. One explanation for the discrepancy in the analysis could be the difference in how DXA and BIA define segments. A potential explanation for the discrepancies observed in these segmental measures is that the BIA uses regression methods to estimate each component individually, rather than using an additive or deductive methodology for explicitly measured body regions to calculate composition. This leads to a potential discrepancy between the total segment weight and the sum of the segment tissue components [8].

Both accuracy and precision are important when comparing different technologies. Accuracy, however, can be quite difficult to compare between technologies for several reasons, although there is increasing consensus that CT methods are the gold standard that can be used to judge the accuracy of other methods, they differ and are difficult to compare in terms of accuracy. Importantly, depending on the tool used, we observe a different measurement method, so even if the two technologies strongly correlate with each other, there may be a significant deviation if they measure different physical units [2]. The correlation found between BIA and DXA indicates that they measure similar body compartments, but a significant difference in many segments indicates that further refinements may be needed for use in a clinical care setting [8]. Despite the high accuracy of tomographic methods in clinical practice, BIA can be used to detect low muscle mass in clinical practice. Since these tools are easy to implement by dietitians, they may be suitable for routine muscle mass assessment in clinical practice [14].

Conclusion

The practical advantages of the bioimpedance method enable the wide application of this method in dietary practice. BIA can be a safe and helpful method for monitoring patient progression in terms of changes in body composition. Although DXA is currently the gold standard for measuring body composition in clinical trials, the use of this method is associated with numerous limitations resulting from the high cost of the technique, limited availability of this type of equipment and time consumption.

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