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Limits of body composition assessment by bioelectrical impedance analysis (BIA)

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Abstract

Bioelectrical impedance analysis (BIA) is a safe, non-invasive and repeatable method of body composition assessment, based on diversified electrical conduction through the aqueous and fat compartment of the body. The popularity and availability of the BIA study has increased in recent years. The aim of the work is to discuss its limitations, which can be divided into factors affecting the measurement of parameters and contraindications for measurements. The first group includes body structure, obesity and malnutrition, body temperature, intake of fluids and foods, changes in hydration and water and electrolyte balance, physical activity, long-term staying in a supine position, examination procedure and method of placing measuring electrodes. Contraindications include implanted cardiac devices (cardiac pacemaker, implantable cardioverter-defibrillator, resynchronization therapy), metal implants and pregnancy. There is no unambiguous confirmation of the validity of the mentioned contraindications in literature. Knowing the limitations of BIA is important because parts of potential errors can be avoided by properly preparing for the examination and following appropriate procedures during the measurements.

Keywords: bioelectrical impedance analysis; BIA

Introduction

The bioelectric impedance analysis (BIA) is a safe method used to assess body composition. Its physical basis is the diversified conduction of electric current through the aqueous and fat compartment of the human body. [1] [2] The BIA test is based on the measurement of impedance, i.e. the total resultant electrical resistance of the body to the alternating current. Impedance is a derivative of two parameters, resistance (R) and reactance (Xc). Resistance is measured in ohms, active electrical resistance - resistance of the conductor through which the alternating current flows. The conductor is water with the electrolytes dissolved in it, and the resistance value is inversely proportional to its content in the body. Reactance, also measured in ohms, is so-called electric resistance - passive - the resistance exerted on alternating current by the condenser, which is the effect of capacitor properties of cells (connected with the presence of protein-lipid membranes). The value of reactance allows to determine the body cell mass. [2] [3] The BIA measurement is based on the assumption that the human body is composed of five segments (upper right and left limb, torso, lower right and left limb) connected in series. Due to the different proportions of these segments depending on gender, age, weight and ethnicity, it is necessary to use different BIA equations in different populations [2] [4]

The BIA method allows to obtain results in the form of direct parameters and to calculate indirect parameters based on them. The first group includes: membrane potential and the aforementioned impedance, resistance and reactance. On their basis, using the appropriate equations for the population, the following can be calculated: fat mass (FM), fat-free mass (FFM), body cell mass (BCM), total body water (TBW), extracellular water (ECW), intracellular water (ICW) and phase angle (PA). [2] [4] Available devices for assessing the body composition by BIA method work using one (usually 50 kHz) or several frequencies. It is possible to measure the bioelectrical impedance of the whole body or its parts (segmental BIA method). [5]

Due to many undoubted advantages the BIA method is being widely used in clinical practice. The measurement is quick and non-invasive, highly qualified personnel nor patient's active participation is not needed. [1] Nevertheless the repeatability is crucial - it allows to observe changes in patient's body composition. [6]

There are publications discussing the value of BIA selected body composition indexes in many fields of medicine: as a prognostic indicator for cancer sufferers [7] [8] [9], haemodialyzed patients[10], HIV-infected patients [11], patients with cirrhosis [12] and in the wound healing supervising [13]. The

BIA method, allowing the assessment of body composition, is also an important tool in diagnosing and monitoring the treatment of overweight and obesity. The last one makes the BIA measurement devices often used by dieticians and trainers, which significantly increases their availability. Due to the growing popularity of this method and many reports highlighting its advantages, it is worth considering the limitations of BIA.

Factors influencing the measurement of parameters of the bioelectrical impedance analysis

Among the factors affecting the measurement parameters are body structure, obesity and malnutrition, body temperature, intake of fluids and foods, changes in hydration and water and electrolyte balance, physical activity, long-term staying in a supine position, examination procedure and method of placing measuring electrodes.

Anthropometric parameters In majority of measuring devices patient's height accurate within 0,5 cm and weight accurate within 0,1 kg are entered manually by the examiner. 2.5 cm incorrection in height may disrupt TBW measurement by 1 litre. In case of body weight, an incorrection of 1 kg may distort the TBW measurement by 0.2 litre. [1] Due to the variability in the body proportions associated with sex, age and ethnicity, it is not possible to apply the same equations in all populations. To obtain a reliable result, it is necessary to configure the measuring device taking into account the above variables [2] For example, the Nigerians showed a higher total body impedance compared to Caucasian population, this may be due to the increase in impedance with the increase in the length of the guide (in this case, the limbs). [14] The limitation of the BIA method is the difficulty in examining patients with abnormal body structure (very low or very high height, deformations, amputations, advanced scoliosis). In this group, the results of measurements obtained using general equations should be interpreted with caution, whereas the segmental analysis of the body composition with the BIA method seems to allow for more accurate measurements. [15]

Obesity. In obese patients, highly developed adipose tissue affects the resultant electrical resistance, which requires the use of higher frequency currents than the standard 50 kHz. [3] [16] In addition, in obese people, the hydration status exerts a relatively greater influence on the measurement result compared to lean people. [6] From the literature it can be assumed that the BIA method is useful in patients whose BMI index is below 34 kg/m^2. At higher values, there are difficulties with a reliable analysis of body composition and obtaining repeatable results. [2]

Malnutrition. The results of body composition measurements with BIA method should also be treated with caution in malnourished patients, whose BMI is below 16 kg/m^2. Research in this area also showed a lower accuracy of the BIA method, which may be related to changes in hydration status. [15]
Consumption of food. It is recommended to take measurements on an empty stomach or 4 hours after the last meal. It has been shown that food and drink intake may cause an impedance decrease of 5 to 15 within 2-4 hours of food intake (which may cause a measurement error of up to 3%). [15] [17] [18]

Changes in hydration and disturbances of water and electrolyte balance. The conditions that cause changes in hydration and disturbances of water and electrolyte balance belong under the factors influencing the measurement of bioelectrical impedance parameters. These include, among others, edema diseases such as heart failure, liver failure, kidney failure, edema resulting from venous or lymphatic vessel insufficiency. This group also comprises therapeutic methods, such as the use of drugs affecting the water and electrolyte balance (diuretics, glucocorticoids, growth hormone), dialysis (haemodialysis, peritoneal dialysis), intravenous fluid infusion and therapeutic paracentesis. There are no properly adjusted equations, allowing reliable calculation of parameters. Furthermore, in addition to changes in impedance resulting from changes in body composition, there may be fluctuations in electrolyte concentrations, changes in diameter of swollen limbs and skin temperature, which is another obstacle to reliable measurement. [15] An additional complication is the uneven influence of individual body segments on its impedance. For example, the torso, although it is about half the body weight, it only accounts for between 5 and 12% of the total impedance, and thus, changes in hydration within the torso will have less impact on impedance than analogous changes in the limbs. Also, the distribution of fluid between the vascular, interstitial and intracellular compartments is characterized by high variability depending on the patient's condition, in addition, it is also dependent on body temperature, body position and physical activity. Several studies have been conducted to evaluate the effect of intravenous fluid delivery on resistance measured using the BIA method. It has been shown that intravenous saline and hypertonic solutions cause a decrease in resistance, and the actions leading to a decrease in the concentration of sodium ions in the plasma (hypotonic solution, mannitol) cause an increase in resistance or do not significantly affect it. [19]

Body temperature. Body temperature may influence the measurement of BIA parameters. It has been shown that a decline of skin temperature causes an increase in impedance; a skin temperature growth - a decrease in impedance. [20] It has been proven by the study in which a bioelectrical impedance was measured after warming up skin to 35.8 ± 0.6 ° C, then after cooling it to 26.9 ± 1.3 ° C. The BIA measurement was performed with the multifrequency bioelectrical impedance analysis (MF-BIA), in

the distal (traditional) and proximal position of the electrodes. Regardless of the location of the electrodes and the frequency used (from 5 to 500 kHz), the impedance change was inversely proportional to skin temperature. At 50 kHz, an impedance change caused TBW increment by 2.6 ± 0.9 litres and FM reduction by 3.3 ± 1.3 kg, while the ECW / TBW ratio did not change significantly. In the ambient temperature range of 22.3-27.7°C, the error in the TBW is less than 1%. In order to obtain reliable and reproducible results of the BIA test, the ambient and skin temperature should be controlled. [20] It should also be remembered that skin temperature may be influenced by factors such as circadian rhythm, cardiovascular fitness, physical activity, meal intake, emotional state, individual variability and some diseases. [21] The parameters may also be affected by skin changes (they should not be on the surface of the skin to which the electrode is applied). [15]

Physical activity. The interval between exercises and measurement is recommended (depending on the source - minimum 8-12 hours). In one of the studies, it was shown that the exercises caused a decrease in resistance by about 3% and reactance by about 8% in the measurement immediately after the exercises (compared to the initial state), one hour after the end of exercise, these parameters reached the baseline values. [22] [15]

Prolonged recumbency. Also, a long-lasting lying position can affect the measurement of parameters. One of the studies showed an increase in resistance by 3% (17 □) after spending an hour in a lying position. [23] It is estimated that errors of the order of 1.0-1.5 liters in the TBW measurement may occur in patients lying, using standard equations, created for patients whose measurement is performed after a rest period of several minutes in a supine position. Bigger changes can be expected at EBW, because this range shows greater sensitivity to displacement under the influence of gravity. [15]

Examination procedure. The result of the BIA measurement is also influenced by the body position during the examination. It is also advisable to have an appropriate environment during the examination (no contact with metal objects, for example bed elements or current-carrying medical devices, for example an electrocardiograph). Depending on the device used, the test is performed in a standing or lying position. In the most commonly described four-electrode system, the patient is examined in a supine position. Before taking the measurement, the patient should remain in a lying position for about 10 minutes (it was shown that within 10 minutes from the moment of taking the supine position, the impedance increases rapidly, and for the next 4 hours slower). Upper limbs should form with the trunk angle 30°-45° lower limbs should not touch each other (it was shown that crossing the limbs results in lower impedance). [1] [15]

Placement of electrodes. In the most commonly described measuring system, the patient is lying, and the electrodes are placed on an alcohol-cleaned surface of the dorsal skin of the hand and foot. Displacement of electrodes by 1 cm can cause a change in resistance by approximately 2%. The designation of a permanent electrode placement site avoids this disturbance. [1] The measurement of bioelectrical impedance is also influenced by alcohol washing of the skin surface at the electrode application site. It has been shown that this procedure can increase the impedance by 1.5%. [24]

Contraindications for bioelectrical impedance analysis

Contraindications to the measurement of bioelectrical impedance analysis result from the potential impact of measuring equipment with other devices emitting an electromagnetic field. The most frequently mentioned contraindications are implanted cardiac devices, metal implants and pregnancy.

Implanted cardiac devices. BIA is routinely contraindicated in people who have an implanted cardiac device – a pacemaker (PM), implantable cardiac defibrillator (ICD), cardiac resynchronization therapy (CRT). [25] There are publications suggesting that the BIA method is safe for people with implanted cardiac devices - those studies have not found any negative impact of devices measuring bioelectrical impedance on PM, ICD and CRT activity. [25] [26] The effect of the implanted cardiac device on the BIA measurement result was also examined, the study assessed the body composition of patients before and after implantation. After the procedure, compared to measurements made before the procedure, the resistance and FM values decreased, while the BCM and FFM values increased. The authors note that this may be the effect of hydration changes, independent of the presence of the implanted device. [25]

Implants. Among the contraindications for the bioelectrical impedance analysis, metal implants are mentioned. [1] It is sometimes recommended to measure on the side without an implant. [15] However, according to the website of one of the leading producers of BIA analysers, people with non-electrical implants can safely use the device, but the presence of the implant may disturb the result, underestimating the measurement of body fat. This does not interfere with the body composition monitoring in people with implants, because the metal will have the same effect on the reading for each measurement. [27] The influence of having silicone breast implants on the result of body composition measurement by the BIA method was also evaluated. The analyser recognized silicone as adipose tissue (FM difference in the results of pre- and post-operative body composition analysis correlated with the mass of the implanted implant). [28]

Pregnancy. Some sources among contraindications to perform bioelectrical impedance analysis give a pregnancy, but without substantiation. [1] There are numerous publications describing research on pregnant women using BIA [29] [30] [31] [32], which indicates the possibility of using this method in pregnant women. However, there is no doubt that changes in the body of a pregnant woman have a significant impact on the result of the examination and the reliability of the results obtained. Research results are available to establish reference ranges and equations adapted to pregnant women. [33] Some sources also provide the benefit of taking measurements at a fixed time of the day. Further research is needed regarding this issue. [34]

Conclusions

Assessment of the body composition by bioelectrical impedance analysis allows measurement of, among others, fat mass, fat-free mass, body cell mass, total body water and phase angle. This method is constantly gaining popularity The main advantages of the BIA method are non-invasive, shortness of durance, lack of necessity for highly-qualified personnel and patient's active participation. Nevertheless the repeatability of BIA test is crucial to observe changes in patient's body composition. Body composition analysis using the BIA method is useful in science, medicine, dietetics and sport. Due to the growing popularity of this method, it is necessary to know its limitations. They can be divided into factors disturbing the measurement of parameters during BIA analysis and contraindications for conducting the examination (resulting from the emission of the electromagnetic field by the analyzer). The first group includes body structure, obesity and malnutrition, body temperature, intake of fluids and foods, changes in hydration and water and electrolyte balance, physical activity, long-term staying in a supine position, examination procedure and method of placing measuring electrodes. Some potential errors can be avoided by proper preparation for the examination and compliance with procedures during the measurement. The available sources do not agree on contraindications for the BIA. The most frequently mentioned contraindications are implanted cardiac devices (pacemaker, implantable cardiac defibrillator, cardiac resynchronization therapy), metal implants and pregnancy. However, there are publications suggesting that these states do not increase the risk when analyzing bioelectrical impedance, but only may affect its outcome. This issue requires further research.

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