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Bioelectrical Impedance Analysis: A Review

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Abstract—The use of bioelectrical impedance analysis (BIA) is common in healthy people as well for patients, but lacks in different consistent mechanism and quality control measures. BIA can be used to measure the fat-free mass (FFM) and total water (TBW) in the matter without considerable fluid and electrolyte abnormalities in the case when appropriate population, age or pathologically specific BIA equations and established procedures are employed. The utilization of basic BIA measurements without relying on the use of regression prediction models and assumptions of the chemical composition of the fat-free body provides a new option for the actual assessment and clinical assessment of nutritional position and prognosis in hospitalized and elderly people. It may help improve patient care and clinical outcomes. Therefore by considering all these points, a survey is provided in this paper. The general description of BIA, types and their application used to determine FFM is demonstrated.

Keywords—Bioelectrical impedance analysis, Single frequency, multiple frequencies, FFM

I. INTRODUCTION

BIA is a non-invasive and comparatively inexpensive mechanism of assessing body composition which does not need high levels of technology. Because of these properties, BIA has become a commonly used assessment method in different clinical and fitness environments. The BIA technique guesses body composition by inserting an electrical signal inside the body while measuring impedance or current resistance [1]. The fat-free mass consists of more water and electrolyte content, making the tissue extremely conductive and has a low resistance to electrical current. Adipose tissue contains a small amount of water and electrolyte, which decrease its conductance [2]. Today's contact electrode BIA analyzers are quite different from conventional BIA systems that need the placement of gel electrodes at exact anatomical locations. When a contact electrode BIA analyzer is used, body composition measurements such as body fat percentage and fat-free mass are automatically computed by utilizing pre-programmed prediction equations [3]. These proprietary equations are used to determine impedance with supplementary information like height, weight, sexual category, age, and body type to guess body composition values [4].

A. Principles of bioelectrical impedance

As we know that the resistance of conductive material is directly proportional to the length of the conductor (L) and inversely proportional to the area of cross section (A) as illustrated in figure 1.

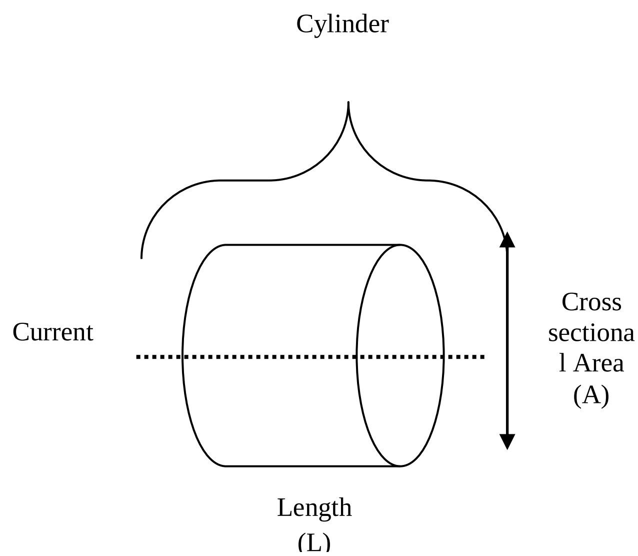

Figure 1. Principles of BIA from physical characteristics to body composition.

Although the human body is not a single cylinder and its permeability is unstable, therefore an empirical connection can exist between the impedance and the volume of the body's electrolyte volume [5]. Practically, it is easier to determine the height, usually greater than the transmitter length from the wrist to the neck. Another difficulty that is observed in BIA is that the body comprises of two different kinds of resistances named as capacitive resistance and resistive resistance [6]. The capacitive resistance has been arising from the cell membrane whereas simple resistance exists due to intra and intercellular fluid. The composition of resistance and capacitive/ reactive resistance is shown in figure 2[7].

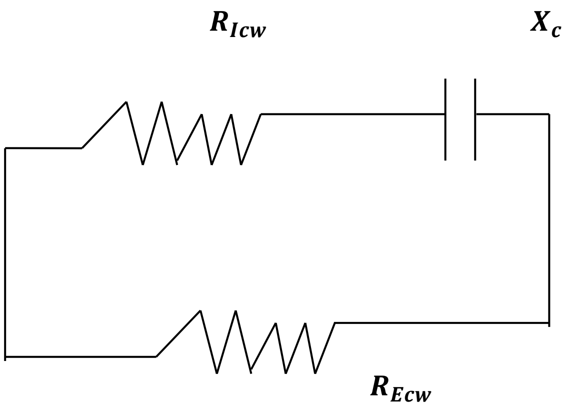

Figure 2. Resistor and capacitor in the human body

B. Method of BIA

BIA analyzer can be categorized into single or multiple frequencies depending upon the electrical current which is used to determine the impedance of the body tissues [8].

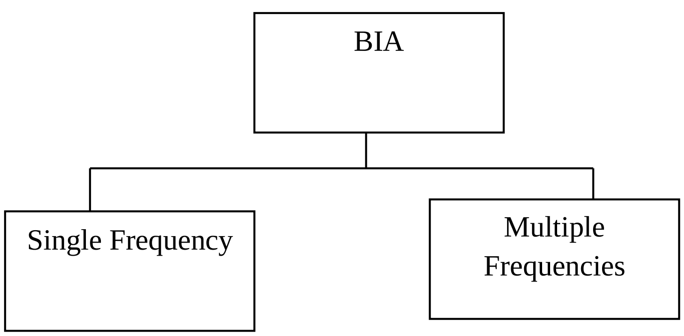

Figure 3.Types of BIA

1) Single-frequency BIA: In Single-frequency analyzers a 50 kHz electric signal is inserted into the body to determine the entire body tissue composition. The electrodes are positioned on hand and foot as depicted in figure 4. It is used to determine the average weighted sum of intra and extracellular water. At 50 kHz, single frequency analyzers, the entire body water has been estimated but it lacks in to distinguish between intracellular and extracellular water measurements. To overcome this problem, multiple frequency analyzers are used [9].

2) Multiple frequency BIA: On the contrary, multiple frequency analyzers send frequencies more than 1MHz in order to achieve body composition measurements. It works with multiple frequencies such as 0 KHz, 1 KHz, 5 KHz, 50 KHz, 100 KHz, 200 KHz up to 500 KHz. The reproducibility above and below 5 KHz and 200 KHz is small [10].

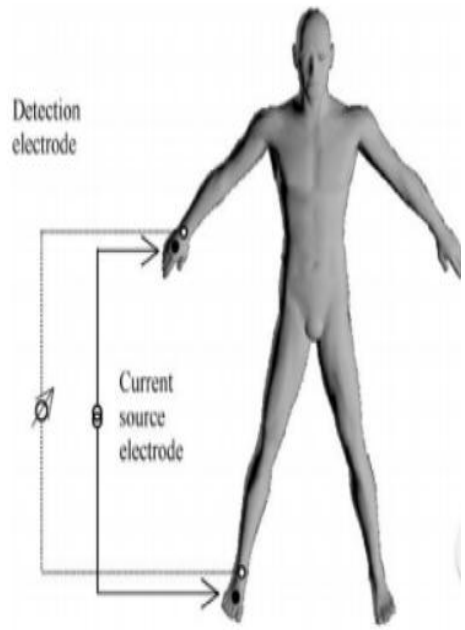

Figure 4.Placement of the electrode for single and multiple frequencies BIA

C. Body compartments

1) Fat-free mass (FFM): It is also known as an oil-free body mass, the non-greasy mass belongs to all body components except fat. It consists of water of body, bone and muscle content However when it comes to weight management and body composition, lean mass is primarily related to the muscle mass. Most Americans are overweight or obese, increase fatless mass and reduce body fat, play an important role in improving your health [11]. Aleman-Mateo et al (12, 2010) have used BIA to measure FFM as well as Total Body Water (TBW). The example is depicted in figure 5.

2) Total Body Water: O'Brien et al. [13] have investigated that the current BIA method is not accurate enough to assess TBW under hydration variations. The equation developed in the hydration population has not proven effective for individuals with altered hydration. Data from low hydration and high hydration studies indicate that electrolyte balance affects BIA measurements, independent of fluid changes. This effect can be difficult to predict because changes in fluids and electrolytes can also affect the ratio of intracellular water to extracellular water, which in turn affects resistivity. ECW: The ICW ratio is a known factor that limits the applicability of the prediction equation generated by the BIA to external populations.

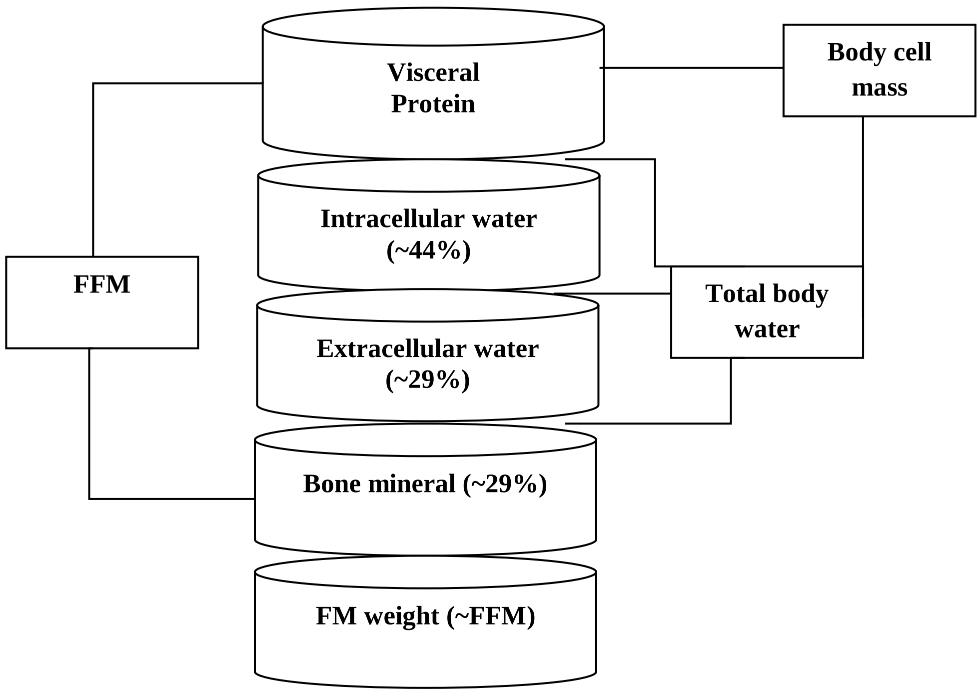

Figure 5.Schematic diagram of fat-free mass (FFM), total body water (TBW), intracellular water (ICW), extracellular water (ECW) and body cell mass (BCM).

According to Ellis et al.,[14] 50 kHz SF-BIA mainly reflects the ECW gap that provided a constant ratio of TBW under normal conditions. An increase in the ECW or ECW / TBW ratio might be indicated edema and/or malnutrition. MF-BIA seems to be sensitive to these variations, even if the body weight has not changed significantly. On the other hand, the parallel transformed SF-BIA model 58 appears to be sensitive to changes in ICW (or BCM) but is not sensitive to changes in ECW. Therefore, when there is an abnormal hydration state, the model may be limited to estimating FFM or body fat.

The paper is organized as follows: in section-1, the introduction about bioelectrical impedance along with their principle, methods and types is introduced. In section –II, the work performed by a number of authors in the field of bioelectrical engineering specifically, using bioelectrical impedance followed by conclusion in section-II is discussed. The main contribution of this paper is to provide the general idea of the bioelectrical impedance analysis tool. This tool is used to measure human body fat of patient that helps the doctor to know the physical condition of the human body.

II. RELATED WORK

Lukaski et al. (15, 2017) have found a correlation between phase angle and different nutritional status. It has been determined that if the phase angle is small it does not reflect impaired nutritional status. The BIA has been used to defined phase and determined that it is a simple, easy-to-use test to assess the risk of angular illness and to evaluate the prognosis. It is important that the measurements are implemented in strict protocols with a phase-sensitive tool, which has been confirmed with a periodic sensitivity. Patient results were given by BIA analysis (RXc graph). Operators of BIA instruments should be trained and certified to comply with the standardized protocols and should ask questions about non-intermittent or clinically improper results.

Genton et al. (16, 2018) have used the BIA device to measure phase angle in older people. This research covers all people having age 65 years and older who have a phase angle between 1990 and 2011 in RJL-101® (RJL Systems), Xitron 4000B® (Xitron Technologies), Eugedia® (Eugédia-Spengler), Geneva University Hospitals. During the phase angle measurement, the disease has been reported as cumulative disease Measurement Scale. Death date has been received by December 2012. The phase angle values have been separated into quartile categorical genres and devices, where quartile represents the lowest quartile and reference value of 1. Cox regressions have been made to evaluate the relationship between phase angle quartiles and mortality. From the tests, it has been measured that the utilization of

RJL-101® or Bio-Z, phase-angled quartiles cause ≥ 65 years of people's death.

Sowers et al. (17, 2007) have investigated the chronological age and ovarian period, and to consider how this midlife can affect the size and composition of the body in women. 543 premenopausal/early perimenopausal African-American and Caucasian women have taken part. From the experiment, it has been concluded that both time (chronological ageing), as well as ovulation, led to significant changes in the ageing, body composition (fat and skeletal muscle mass) and waist circumference. These changes have a significant impact on the formation of a metabolic environment that can be healthy or unhealthy.

Shafer et al. (18, 2009) have used eight numbers of electrodes using multiple frequencies BIA devices to determine percentage BF in adult. The classification has been performed on the three categories named as normal, overweight and obese.

Hulens et al. (19, 2001) have evaluated the nature and size of differences in submaximal as well as maximal exercise potential parameters among lean and obese women. Overall, 225 healthy obese women have been selected for 18-65 years (BMI> = 30 kg / m2) and 81 non-Athletic women (BMI <or = 26 kg / m2). Anthropometric measurements (weight and altitude), body composition evaluation (bioelectric impedance method) and bicycle ergometry tests have been performed for maximum manoeuvre testing.

III. Conclusion

BIA is a repetitive, easy and efficient method for evaluating FFM in physiological and pathological conditions. Many conditions may affect the BIA method, it is advisable to use scientifically-certified analyzers to ensure reliable measurements, to place correct electrodes and respect standard procedures. In addition, in order to reach acceptable predictions, all the equations available in the literature have to be selected, taking into account the nutritional, ethnic or age-related characteristics of the regulatory setting, the most appropriate one must be selected.

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