A Survey on Multifrequency and Multisegment Body Analysis

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Abstract- **Bioimpedance Spectroscopy (BIS) enables the determination of the human body composition (e.g. fat content, water content). From this data, it is possible to draw conclusions about the person's health state. Multi-frequency signals are important for a variety of sensing and instrumentation applications. These include various impedimetric applications inhibiting a time-varying behavior, where a system has to be characterized rapidly across a specific bandwidth. We have studied different multifrequency bioimpedance systems and different body analysis techniques like whole body analysis and segmental analysis in this paper.**

Index Terms-**Bioimpedance, Multifrequency, Multisegment.**

I. INTRODUCTION

Bioimpedance is the response of a living organism to an externally applied electric current. It is a measure of the opposition to the flow of that electric current through the tissues, the opposite of electrical conductivity. The measurement of the bioimpedance (or bioelectrical impedance) of the humans and animals has proved useful as a non-invasive method for measuring such things as blood flow and body composition like Fluid content and fat content. The focus is on bioimpedance body composition models, which have become popular under the term Bioelectrical Impedance Analysis (BIA) and Bioelectrical Impedance Spectroscopy (BIS)[1, 2].

The term bioimpedance measurements refer to all methods based on the characterization of the passive electrical properties of biological tissue. Some biological tissues show active electrical properties, as they are capable of generating electrical potentials, the passive electrical properties of biological tissues relate to their response to the injection of external electrical energy.

Different measurement techniques and various bioelectrical properties form a collection of methods that are now employed for multiple applications.Generally, these methods can be classified according to the following four groups: transimpedance, transmission line, microwave, inductive, and finally a combination of the preceding. Furthermore, all methods can be based on either single- or multiple-channel measurements. While the basic idea of this approach can be generally adopted for cellular measurements, volume changes, tissue classification and tissue monitoring, most research and developments have focused on body composition applications [3].A portable system measuring body impedance in a wide range of frequencies would allow assessing the body water content in a much larger number of applications, including for instance monitoring the hydration state in endurance athletes during sport performances or in elderly subjects during daily activities [4, 5].

The significant impact of this technology can be traced to its main advantages are that it is non-invasive, it is relatively inexpensive, it can be easily operated, it enables continuous (online) monitoring, it is rapid, it is portable.

These benefits are important characteristics in designing new medical instrumentation and are still a major reason for the permanent refinement of existing techniques and the investigation of new applications [2].

Bioelectrical impedance spectroscopy (BIS) provides a fast, noninvasive, cheap, and reliable way to assess the composition of individual segments of the body [1]. The method is based on the measure of the voltage drop across body segments crossed by an injected current and in the calculation of magnitude and phase of the corresponding electrical impedance over a broad range of frequencies. So far, BIS has been applied to study a variety of physiological and clinical conditions.BIS studies, however, have been limited to laboratory or clinical settings. In fact, available instrumentation consists in bulky systems which cannot be used in freely moving subjects for long periods of time. This limit could be overcome by a proper miniaturization of the devices. Actually, small portable systems able to measure the body impedance unobtrusively for several hours would open the use of BIS to many new applications.

Bioimpedance is about the electrical properties of your body (or other biomaterials), e.g. to what extent you are a good conductor. Bioimpedance is a measure of how well the body impedes electric current flow. The elegantly simple technique requires only the application of two or more electrodes, and it has been used successfully for many years to detect a remarkable variety of physiological events. Bioimpedance include applications like Skin water content, Body composition (training, nutrition), Blood volume, Fingerprint sensors and many more.

In body composition the body weight is mainly characterized in two parts, fat mass and fat-free mass. The fat-free mass consists of lean body mass and bone mass. The lean body mass includes skin, water contents of the body. The lean mass has two main categories, body cell mass and extracellular mass.

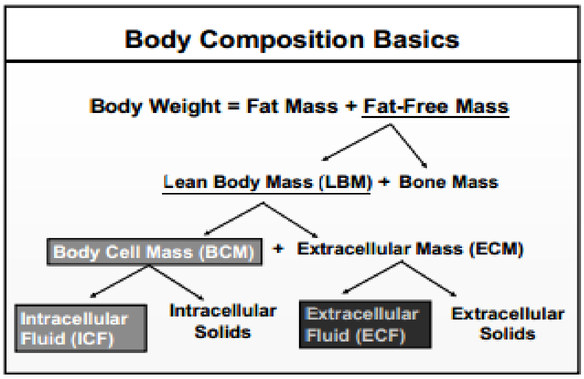

Figure 1 Classification of fats

Body composition analysis can be classified according to several models, depending on the purpose or analysis methods and devices available. These include mainly atomic model, molecular model, cellular model and tissue-system model and of course the whole body model as well. The atomic level usually includes 11 main elements: oxygen (O), carbon (C), hydrogen (H), nitrogen (N), calcium (Ca), phosphorus (P), potassium (K), sulphur (S), sodium (Na), chlorine (Cl) and magnesium (Mg). It is possible to reconstruct the molecular level model from human body by this model. The molecular model is the most studied model in the field of body composition research. The classical two-compartment (2-C) model consisting of fat (FM) and fat-free mass (FFM) is a molecular level model. The human body cellular model consists from three main components including cells, extracellular fluids and extracellular solids. Cellular model has been found to be important in physiological evaluations since cells constitute the functional biological element of human body. The main components of tissue-system model are adipose tissue, skeleton muscle, bone, visceral organs and brain.

II. MULTIFREQUENCY

Bioimpedance spectroscopy is based on the measure of the voltage drop across body segments crossed by an injected current. The voltage drop is due to the internal resistance of the body cells. When a certain amount of frequency is passed through a body segment it takes the least resistive path. For low frequency signal the current avoids the intracellular cells and passes from the extracellular fluids because fluids provide less resistance as compared to the cells. In case of high frequency signals the current passes directly through the intracellular water cells. The concept of flow of frequency current is explained in figure 2.

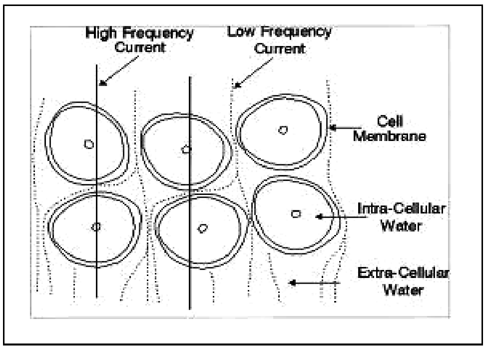

Figure 2 The movement of current through cells at both low and high frequencies.

Multiple frequency bioelectrical impedance analysis (MBIA) is an interesting method for the assessment of body composition because, in comparison with most other methods, it is safe and non-invasive. The technique consists of measurement of the impedance of the body to the flow of an alternating current. The use of bioelectrical impedance is based upon the higher electrolyte content and greater conductibility of fat free mass than of adipose tissue or bone and upon the geometrical relationship between impedance and the conductor volume.[6] Body composition assessment of young tennis players by multi-frequency impedance measurements were studied by E. Gualdi-Russo et al.,[7] Body composition was estimated in 169 young tennis players using the multi-frequency impedance method to predict their fat-free-mass, fat, extra-cellular water, and total body water. Bio-electrical impedances at 1, 5, 10, 50 and 100 kHz were determined. Although the multi-frequency impedance method is thought to be very useful in the assessment of body water compartments, there is some doubt about the validity of body composition estimates in athletes, because dehydration associated with exercise can cause variability in impedance values. The multi-frequency impedance method (under controlled conditions) presents good prospects for the future, especially that of ECW. A direct measurement of ECW is also possible by isotope dilution, but this method is expensive, difficult and not practicable for repeated assessments in patients and for TBW assessing. Toshiro Sakai et al.,[8] studied the relationship between body composition and BMI in preschool children. Childhood obesity is one of the most serious public health challenges of the 21st century. Obesity is a state in which body fat accumulates to an abnormal degree, and detailed information about body composition is necessary to investigate the problems of obesity in children. The measurement procedure required the subject to stand bare-foot on the analyzer and to hold a pair of hand-grips, one in each hand. The device used Multifrequency (5, 50, 250 and 500 kHz) Bio-impedance analysis technology, and had eight electrodes: two in contact with the palm and thumb of each hand, and two in contact with the front and back part of the sole of each foot. With a database stated that for all age groups of boys, no correlations were found between height and BMI, height and %Fat, and height and muscle percentage. In addition, the %Fat in girls was higher than in boys, and the muscle percentage was the opposite. Multifrequency Impedance Plethysmograph was analyzed by Jerzy Wtorek et al.[9]Multifrequency Impedance Plethysmograph is achieved by sequentially changing the drive current and measuring the resultant voltages at each frequency. The change in frequency is made so fast that physiological events are considered steady. The measured voltage is demodulated digitally. Jerzy Wtorek suggested that for higher operating range of frequencies can be obtained by using faster A/C converter.

III. MULTISEGMENT

The impedance measurement consists of applying a current and measure the voltage (or the opposite), and there are two methods to do it in a body by using electrodes. First one uses the same electrodes to inject the current and measure the voltage, and in the second one, a different pair of electrodes pumps the current and measures the potential. First method is easier however it is not a good choice when electrodes are used, because the electrodes impedance is also added to the measure, which means that all the motion artifacts affecting the electrodes shall change the measure. A better option is the second well-called tetrapolar configuration.

The sinusoidal current source generated by signal generating circuit is imposed on the corresponding parts of the body as the system excitation signal. The system applies eight electrodes (4 pairs) measurement system, and each pair includes an incentive electrode and a detection electrode, where a, b, c, d are the current incentive electrodes, and A, B, C, D are voltage detection electrodes. All the electrodes the same reference plane [9]. A loop can be formed by imposing AC current with frequency of 5 kHz, 50 kHz, 100 kHz, 250 kHz and 500 kHz between different incentive electrodes. Bioelectrical impedance of each section can be obtained by measuring between different detection electrodes. For example, after imposing incentive current between a and c, the electrical impedance of the left lower limb can be obtained by the measurement between A and B; the electrical impedance of the left upper limb can be obtained by the measurement between C and D; electrical impedance of trunk can be obtained by the measurement between B and D.

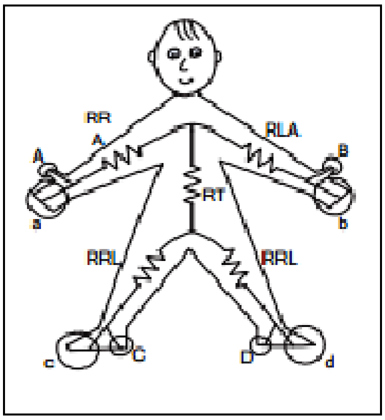

Figure 3 Electrodes Distribution.

There are different ways of electrode placement; it depends on which part of the body is under study. Multisegment means testing of multiple segments separately for accuracy in measurement.

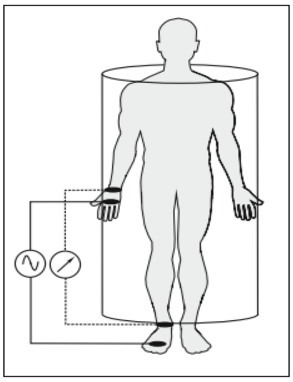

Figure 4 Whole-body bioimpedance measurement modeling the body as a single cylinder.

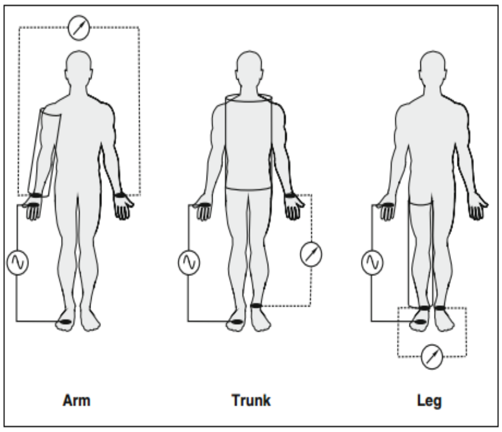

Figure 5 Segmental analysis.

J. Nystrom studied a group of 34 diabetic men, with different degrees of diabetes complications, including skin changes by near-infrared (NIR) spectroscopy and total body multi-frequency bio-impedance analyses (MFBIA-body). Skin reflectance spectra were measured with a fibre-optic probe in four locations (sites): hand, arm, leg and foot.NIR uses the wavelength range of 780-2500 nm. In this region, overtones of the different vibrations of C-H, C-O, O-H and N-H bonds cause absorption of NIR radiation. This makes the technique ideal for use on organic and biological materials. Another attractive property of NIR is that the radiation can penetrate deep into organic materials and does not only interact with the surface of solid samples. Near-infrared radiation can be used in transmission, reflection etc. for samples in sample holders, but it can also be used in different modes with fibre optics. The frequency range was 5 kHz-1 MHz, with the 50 frequencies equally spaced on a logarithmic scale. A variable current between 50 µA and 700 µA was used, depending upon frequency output and load. The current injector was connected to the foot and the hand, and the voltage detector was connected on the wrist and ankle. The distance between the current injector and the voltage detector was 5 cm.

IV. Conclusion

We have analyzed that the principle of the multi-frequency and multi-segment bioelectrical impedance measurement method and designed bioelectrical impedance measurement systems high precision, excellent repeatability and wide practical value and application prospects. Multifrequency gives accuracy in the measurement with a wide range of frequencies and smaller the segment of analysis higher is the accuracy in the measurement of bioelectrical impedance.

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