CHAPTER

3

BIOIMPEDANCE IN BIOMEDICAL DEVICE APPLICATIONS

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3.1 INTRODUCTION

Bioimpedance is the response of a living organism to an externally applied electric current. Bioimpedance measures how much a living organism resists the flow of electric current through its tissues, which is the opposite of electrical conductivity. Basically, bioimpedance techniques are measured based on the injection of an alternating electric current into a biological medium with very low intensity. The electric current yields a voltage drop; the higher, the greater the electrical impedance of the tissue. In fact, bioimpedance measurements are based on the biological mediums that behave as conductors, dielectrics, or insulators of electrical current, depending on their composition.

Moreover, one of the most established applications of bioimpedance in healthcare is the estimation of body composition in multiple clinical areas such as obstetrics, postoperative monitoring, critical care, pregnancy and lactation, gastroenterology, nutrition, chronic inflammation, obesity, or sports science. Bioimpedance methods in nephrology have demonstrated their ability to assist in achieving the desired euvolemic state during the dialysis process. Furthermore, advancements in bioimpedance technology continue to enhance its diagnostic accuracy and clinical

applicability, enabling healthcare professionals to obtain real-time, non-invasive insights into patients physiological conditions for more precise and individualised treatment strategies.

3.2 BODY COMPOSITION MEASUREMENTS

Body composition can be examined using a variety of methods, ranging from simple indirect measures to more advanced direct volumetric measurements. Body composition analysis involves modelling the mass and fluid compartments of the body, taking measurements, and performing analyses on the results (Borga et al., 2018). Body composition analysis is utilised in various settings, including prevention, therapy, and research applications, including bioelectrical impedance analysis (BIA), which is a non-invasive clinical approach for determining body composition that examines the electrical properties of the human body by measuring the resistance of the flow of electric current through bodily fluids. Bioimpedance is used for various purposes in health systems, including clinical diagnosis and body vital status monitoring (Price et al., 2019). The examination of body composition by bioelectrical impedance yields estimations of total body water (TBW), lean body mass (LBM), and fat mass (FM) as well as other parameters (Bellafronte et al., 2018).

The water in the human body is divided into two types. The first type is extracellular water (ECW), which refers to the water located outside the cells; it controls the movement of electrolytes, facilitates the supply of oxygen to the cells, and helps dispose of metabolic wastes from cellular metabolism. It can be found in transcellular fluid, interstitial fluid, and blood plasma. The second type is the intracellular water (ICW), which is defined as the water that exists within the body cells. It is composed of 70% of the cytosol, which is made up of water and other dissolved components. The ECW is accountable for around 45% of bodily fluid, whereas ICW is attributed to the other 55%.

FM is a metabolically active tissue in the body. Hence, the variation in LBM between people accounts for most of the variation in resting

energy expenditure. Other factors like age, gender, and physical fitness also influence LBM. The LBM can be accurately measured using several techniques. These include underwater weighing, measuring TBW using stable isotopes of deuterium or oxygen-18, and dual-energy x-ray absorptiometry (DXA) (Beato et al., 2019). Through middle age, body FM rises with age in both men and women; after age 70, it slowly declines. Body fat rises when LBM declines, even in those whose weight does not rise with age.

The BIA is one of the most effective methods for determining body composition. It provides the speed and strength of the electrical signal sent through the body. This approach employs several data points, such as age, height, gender, and weight, to predict basic body composition measurements, such as the amount of fat, TBW, bone mineral mass, and muscle mass (MM) the body contains (Son et al., 2025). In addition, metabolic parameters such as physique rating (body type), basal metabolic rate, and metabolic age are calculated using a bioelectrical impedance analyser. It is very crucial to understand body fat to maintain a physically healthy physique with muscle weights more than fat (Campa et al., 2021).

The data from BIA is instantly available and repeatable, with a 1% error rate on multiple tests. This approach was first commercially accessible in the mid-1980s (Mocini et al., 2023), with a low-cost, portable device, making it a suitable option for determining body composition in epidemiological research.

There are two types of bioimpedance methods: single-frequency devices are also known as BIA, and multiple-frequency devices are usually referred to as bioimpedance spectroscopy (BIS), based on the number of frequencies used in the analysis. The BIA measures the body opposition to an applied electrical current, a property called impedance ($\vec{Z}$). Impedance is made up of two key components: Resistance (R) and reactance (X_c). Resistance reflects the straightforward opposition to the flow of electrical current through the body fluids and tissues. It is primarily influenced by the amount of water and electrolytes, since these conduct electricity easily. In contrast, reactance arises from the body capacitive elements, mainly the cell