BIOELECTRICAL IMPEDANCE ANALYSIS OF HIGH BLOOD PRESSURE PATIENTS

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ABSTRACT

Bioimpedance is a specialized field under constant development. In biomedical engineering, bioimpedance is a term used to describe the response of a living organism to an externally applied electric current. Other than that, bioelectric impedance analysis is one of the famous analyses many clinical applications. It is also considered as a new technique relatively for analyzing body composition. In most of the cases, the reliability and the accuracy that the analyzer carries made it suitable in estimating body composition in human. In this study, about 70 patients were used in which 35 of them are healthy (without high blood pressure or other diseases) and the remaining 35 are high blood pressure patients. Bioelectrical impedance analyzer was used to analyze bioimpedance parameters and biocomposition parameters such as body mass index (BMI), total body water (TBW), intracellular water (ICW), extracellular water (ECW), fat free mass (FFM) and basal metabolic rate (BMR). Comparison was done between the normal subject and the patients. For the most accurate results, the subjects are made sure that they did not eat for 4 hours prior to testing. They also should not have done any exercise for 12 hours prior testing, did not consume alcohol for 24 hours prior testing, did not drink caffeine on the day of the test, and did not wear pantyhose during the test. Positive result of the study will exhibit standard range of value of body composition among high blood pressure patients.

ABSTRAK

Bioimpedan adalah satu bidang khusus di bawah pembangunan berterusan. Dalam kejuruteraan bioperubatan, bioimpedan adalah satu istilah yang digunakan untuk menggambarkan tindak balas organisma hidup kepada arus elektrik kenaan luaran. Selain daripada itu, analisis impedans bioelektrik adalah salah satu daripada analisis yang terkenal dalam banyak aplikasi klinikal. Ia juga dianggap sebagai satu teknik baru untuk menganalisis komposisi badan. Dalam kajian ini, kira-kira 70 pesakit telah digunakan di mana 35 daripada mereka adalah sihat (tanpa tekanan darah tinggi atau penyakit yang lain) dan 35 pesakit merupakan pesakit tekanan darah tinggi. Analisis impedan bioelektrik telah digunakan untuk menganalisis parameter bioimpedan dan juga untuk menganalisis parameter biokomposisi seperti indeks jisim badan (BMI), jumlah air dalam tubuh (TBW), air intrasel (ICW), air luar sel (ECW), berat tanpa lemak (FFM) dan kadar metabolisme basal (BMR). Perbandingan dilakukan di antara subjek normal dan pesakit. Untuk keputusan yang paling tepat, subjek dipastikan bahawa mereka tidak makan selama 4 jam sebelum ujian. Mereka juga tidak sepatutnya melakukan apa-apa senaman selama 12 jam sebelum ujian, tidak mengambil alkohol selama 24 jam sebelum ujian, tidak minum kafein pada hari ujian, dan tidak memakai pakaian ketat semasa ujian. Keputusan positif dari kajian ini akan mempamerkan pelbagai standard nilai komposisi badan di kalangan pesakit tekanan darah tinggi.

TABLE OF CONTENTS

Pages

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS/ NOTATIONS/ SYMBOLS/ GLOSSARY OF TERMS

BMI	Body mass index
BMR	Basal metabolic rate
ECW	Extracellular water
ICW	Intracellular water
TBW	Total body water
FFM	Fat free mass

CHAPTER 1

Introduction

1.1 Bioimpedance

Bioimpedance is a specialized field under constant development (39). In biomedical engineering, bioimpedance is a term used to describe the response of a living organism to an externally applied electric current. Electrical bioimpedance monitoring is an emerging tool for biomedical research and for medical practice. It constitutes one of the diagnostic methods based on the study of the passive electrical properties. It is the measure of the electrical impedance of a biological sample. It can reflect some interesting physiological conditions and events. (41) It is a measure of the opposition to the flow of that electric current through the tissues, the opposite of electrical conductivity (40)

In bioimpedance plethysmography, the measure is sometimes based on pulsatile blood volume changes in the aorta. Bioimpedance is relevant to the development of devices to measure cardiac output and circulating blood volume. Electrical conductivity can vary as a result of breathing. Because of this and other sources of variability, the reliability of bioimpedance for obtaining accurate data has been called into question. Nevertheless, the technique is used in both routine clinical medicine and research.

Bioimpedance is about the electrical properties of your body (or other biomaterials), which means till what extent human body are a good conductor. Bioimpedance is a measure of how well the body impedes electric current flow. Fat has high resistivity, whereas the blood has lower resistivity. Impedance is measured by applying a small electric current via 2 electrodes and picking up the resulting small voltage with another pair of electrodes. The lower the voltage the lower the tissue impedance for a given current. (42)

Tissue consists of cells and membranes, and membranes are thin but have a high resistivity and do electrically behave as small capacitors. By using high measuring frequencies the current passes right through these capacitors, and the result is dependent on tissue and liquids both inside and outside the cells. At low frequencies, however, the membranes impede current flow, and the results are dependent only on liquids outside the cells.(42)

1.2 Bioelectrical impedance analyzer.

In order to determine the nutritional status of either population or any specific individual, human body composition is the vital factor to be considered. (Henry *et al*., 1985). Bioelectric impedance analysis is one of the famous analyses or can be said that it is widely used in many clinical applications (Kyle *et al*., 2004). It is also considered as a new technique relatively for analyzing body composition (Schols *et al*., 1991). In most of the cases, the reliability and the accuracy that the analyzer carries made it suitable in estimating body composition in human.(Houtkooper *et al*., 1989) There are few methods of bioelectrical impedance analysis which includes single frequency BIA, multi frequency BIA, bioelectrical spectroscopy, segmental BIA, localized bioelectric impedance analysis and bioimpedance vector analysis (Segal *et al*., 1985). Basically multi frequency BIA uses empirical linear regression models to evaluate fat free mass (FFM), total body water (TBW), intracellular water (ICW) and extracellular water (ECW) and this multi cellular BIA will be used at the frequency range of 0 to 500 KHz. As for the single frequency BIA, it does measure the fat free mass, but not the intracellular water (Kyle *et al*., 2004). Furthermore appropriate examples have been demonstrated that methodology involved in impedance is meaningful in estimating body composition of the people from the population. It is also regarded as safe and does not bother or burden the patients or the respondents. The advantage over this method is that it is not invasive and will not cause any discomfort. (Jebb and Elia, 1993). It is also relatively easy to be handled because the procedure of using the analyzer is not long as the operator just need to connect the electrodes and proceeds further up with the test. Other advantages include the high reliability, cheap to use and the prediction drawn for the body parts from the impedance analyzer is really valid (Kuczmarski, 1996). Conduction of the applied electric current in the organism's body plays vital role in determining the value of the body impedance (Chumlea and Guo, 1994). Intracellular fluids and extracellular fluids play an important role as the electrical conductor and this basically explains how this machine actually functions. This supported more by the contribution of cell membranes which acts like electrical condensers.((Henry *et al*., 1985).

1.3 Parameters of Bioelectrical Impedance.

1.3.1 Body mass index.

The body mass index (BMI), or Quetelet index, is a heuristic proxy for human body fat based on an individual's weight and height. BMI does not actually measure the percentage of body fat. Body mass index is defined as the individual's body weight divided by the square of his or her height.

1.3.2 Basal metabolic rate.

Basal Metabolic Rate (**BMR**), and the closely related **resting metabolic rate** (**RMR**), is the amount of daily energy expended by humans and animals at rest. Rest is defined as existing in a neutrallytemperate environment while in the post-absorptive state. The release of energy in this state is sufficient only for the functioning of the vital organs.

BMR is measured under very restrictive circumstances when a person is awake. An accurate BMR measurement requires that the person's sympathetic nervous system not be stimulated, a condition which requires complete rest. A more common and closely related measurement, used under less strict conditions, is resting metabolic rate (RMR).

1.3.3 Body water.

In medicine, body water is the water content of the human body. A significant fraction of the human body is water. It can be divided in to two categories which is extracellular water and intracellular water. Extracellular usually denotes all body fluid outside of cells. The remainder is called intracellular fluid. In some animals, including mammals, the extracellular fluid can be divided into two major subcompartments, interstitial fluid and blood plasma.

1.3.4 Total Body Water.

In medicine, total body water is the water content of the human body. A significant fraction of the human body is water. Arthur Guyton 's Textbook of Medical Physiology states that the total amount of water in a man of average weight (70 kilograms) is approximately 40 litres, averaging 57 percent of his total body weight. In a newborn infant, this may be as high as 75 percent of the body weight, but it progressively decreases from birth to old age, most of the decrease occurring during the first 10 years of life. Also, obesity decreases the percentage of water in the body, sometimes to as low as 45 percent. These figures are statistical averages, so are illustrative, and like all biostatistics, will vary with things like type of population, age and number of people sampled, and methodology. So there is not, and cannot be, a figure that is exactly the same for all people, for this or any other physiological measure.

1.3.5 Fat free mass.

Fat-free mass is comprised of the nonfat components of the human body. Skeletal muscle, bone and water are all examples of fat-free mass. Because muscular tissue takes up less space in our body than fat tissue, our body composition, as well as our weight, determines leanness. Two people at the same height and same body weight may look completely different from each other because they have a different body composition.

1.4 High blood pressure.

High blood pressure is a disease for which medical cause is yet to be found (Carretero and Oparil, 2000). According to national heart lung and blood institute, blood pressure is defined or explained as the force of blood which is exerted against the walls of the arteries as the heart pumps out blood. This condition can actually damage the human body if this pressure rises and stays high over time. High blood pressure which is also known as HBP is a condition which can lead to certain diseases such as coronary heart disease, heart failure, stroke, kidney failure, and other health problems. Table 1.1 below shows the categories for blood pressure in adults.

Table 1.1: Categories for Blood Pressure Levels in Adults (in mmHg, or millimeters of mercury)

Category	**Systolic** (top number)		**Diastolic** (bottom number)
Normal	Less than 120	*And*	Less than 80
Prehypertension	120–139	*Or*	80–89
High blood pressure			
Stage 1	140–159	*Or*	90–99
Stage 2	160 or higher	*Or*	100 or higher

In other words, blood pressure is understood as a measure of the force that the circulating blood pushes on the walls of the main arteries. The pressure wave that is transmitted along the arteries can be easily felt as the pulse will indicate the highest pressure which is known as systolic which is created by the heart while contracting and the lowest pressure called diastolic is measured as the heart fills with the blood.(National Heart, Lung and blood Institute, 2008)

According to National Health and Nutrition Examination Survey, it was indicated that 50 million or may be more Americans have high blood pressure (BP). Worldwide statistic estimates the hypertension number can or may be as much as 1 billion individuals, and approximately 7.1 million deaths per year are caused due to the blood pressure or hypertension. Data from World Health Organization (WHO) supports that sub-optimal blood pressure which is 115 mm Hg (also known as standard blood pressure) is accounts for about 62 percent of cerebrovascular disease and about 49 percentage of ischemic heart disease, with little variation influenced by the other parameter such as sex. Other than that, sub-optimal blood pressure is the main cause which accounts major risk for death throughout the world (Green et al., 2003)

Basically, it is regarded as normal when blood pressure in human body increases and fall during the day. The problem rise when the mentioned situation remains elevated over some period of time, in which this situation is regarded as high blood pressure. High blood pressure is really dangerous because it makes the heart to work more hard and the exerted high force of the blood flow causes harm to the arteries and also to the organs such as the heart, kidneys, brain, and eyes. High blood pressure often has no warning signs or symptoms. Once a person is diagnosed and the result is positive for high blood pressure, the disease will last long in him or her for the whole lifetime. As mentioned earlier, if these conditions remain uncontrolled, it can lead to heart and kidney disease, stroke, and even blindness (National Institute of Health, 1998).

Hypertension is generally detected from the reading of high blood pressure. This shows that hypertension is very much associated with high blood pressure. Technically, the whole process requires three different sphygmomanometer measurements which are measured at least within one week apart. In addition, assessment of the hypertensive or blood pressure patient should include a complete history and physical examination as well. Immediate treatment can be given in some exceptional cases such as when the elevation is very extreme or when there is symptoms showing conditions which can potentially harm vital organs in the body. When the detection of hypertension is done, doctors or the physicians will attempt to identify the cause based on risk factors and other symptoms on the patient, if present. Secondary hypertension is quite often in preadolescent children, in which renal disease causes these conditions for this category of people. Primary or essential hypertension is said to be quite common for adolescents and do carry multiple risks such as obesity and a family history of hypertension (Luma and Spiotta, 2006.)

1.4 Problem Statement

No standard reference values are available for high blood pressure patients from bioelectrical impedance analysis in the research field previously

1.5 Objective of the study

1. To study the body composition of a person who is having high blood pressure.
2. To compare the body composition between normal people and high blood pressure patient.

1.6 Hypothesis

The output of the bioimpedance analyzer will exhibit standard range of value of body composition among high blood pressure patients.

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CHAPTER 2

Literature review

2.1 Bioelectrical impedance.

Bioelectrical impedance analysis which is also known as BIA was analyzed for its accuracy and reliability in estimating body composition in children for the whole body. In this study, it was indicated that percentage of fat and fat free body mass can be accurately predicted by dividing body height with the resistance. In this study, about 94 Caucasian children were used as the sample or subjects. In addition, multicomponent equations were also developed to estimate some of the variables which is fat free body mass and the percentage of fat. Bioimpedance analysis measurements were mentioned to be reliable in this research valuation. Based on the evaluation, it was deduced that resistance together with anthropometry is a reliable and an acceptably accurate method of estimating fat free body mass level and the percentage of fat in children (Houtkooper *et al.*, 1989).

Another study was reviewed in which bioelectrical impedance was also used to study the body composition data which is a vital factor to measure the nutritional status of patients with the disease called chronic obstructive pulmonary which is known as COPD. The scientists have also came out with a regression model to study the bioelectrical impedance by using deuterium dilution as a reference method in the study which used 32 COPD patients as subjects in which all of the subjects were checked if they are stable in pulmonary and cardiac condition. Disturbances in the aspect of nutritional status in these mentioned subjects or patients have been grouped by slow and notable weight loss, a low body weight, and sub-standard values for anthropometric data (McQuillan *et al.*, 1990).

It is also mentioned in one of the review article that bioelectric impedance measurements do consider to provide along a means to estimate body composition which takes into account the differences and changes in fat distribution and in the ratio of fat to fat-free tissue and so it is believed to solve the challenges which is associated with estimates based on measurements of subcutaneous fat which is mostly skinfold thickness or body size which is actually not consideration. Trials to predict fat free mass from total body water and to compare fat free mass predictions from bioelectrical impedance and skinfold thicknesses are one of the hot issue to be discussed and comments are really in need because there is no independent reference standard of fat free mass for these elderly patients is available. To further deduce the mentioned limitations, a new methodology involving age-matched control subjects and patients in which total body weight-prediction equations are independently made and cross validation is actually needed. The researchers have concluded that bioelectric impedance is a handy method of calculations or measurements for the evaluation process of fat free mass in patients with severe chronic obstructive pulmonary disease in stable pulmonary and cardiac condition. The results also support that, when skinfold anthropometry was compared with impedance analysis, impedance measurements are described as more preferable in elderly patients with chronic obstructive pulmonary disease. (Schols *et al*., 1991)

Another study was done before which discussed that bioimpedance analysis appears to be the answer and solution for the demand for a simple, inexpensive, quick, reliable instrument which can be used in population surveys to obtain the body composition. (Harris *et al*., 1989). In another study, which emphasizes more on the variability effect of the sex, race and the disease in the impedance reading, equations for body cell mass (BCM), fat-free mass (FFM), and total body water (TBW) were worked out from the measurements via the use of single-frequency bioelectrical impedance analysis (BIA) using 32 subjects or samples. The subjects used were grouped as white, black, and Hispanic men and women, who were both healthy and acts as control subjects in this study and subjects or patients infected with the human immune deficiency virus (HIV). Research studies have shown more accurate estimation of body cell mass when parallel-transformed values of reactance were used compared to the values reported by the bioelectrical impedance analyzer. (Lohman, 1984)

Modeling equations which were derived after logarithmic transformation of height, reactance, and impedance were shown to be more accurate predictors compare to that of equations using height divide by resistance, while the use of sex-specific equations has actually improved the aspect of accuracy. The effect of adding weight to the modelling equation was less important or less significant compare to that of the bioimpedance measurements. The resulting equations were validated internally, and race and disease (HIV infection) were shown not to affect the predictions or the estimations. The equation for fat free mass was validated externally against results derived from hydrodensitometry by using about 440 healthy individuals as subjects. The outcome of the research study has indicated that body composition can be actually predicted with simple and easily applied methodologies, and that the estimates are sufficiently accurate for the use in clinical research and even for the practical terms (Kotler *et al*., 1996).

Other research study which started in an attempt of an assessment of fat free mass using bioelectrical impedance measurements of the human body, the results have demonstrated a strong relationships between bioelectric impedance measurements and fat free mass, total body water and total body potassium which exhibit that this method can be very wise and as a tool for everyday/routine assessment of human body composition. This fact is even more supported by the advantages of the bioimpedance analyzer which list down it as safe and noninvasive, does not require any special skills from the part of the operator and also the subject. In this aspect, subject cooperation is very minimal and the measurement can be relied on. Other than that, the results are rapid, the instrument is portable and very cheap to use compare to other technologies that we have (Henry *et al*., 1985).

The usage of bioelectrical impedance analysis which is also known as BIA is already widespread for both in healthy subjects and also in patients. The disadvantage in this is it suffers from a lack of standardized procedure and quality control, QC procedures. Bioimpedance analyzer allows the determination of the fat-free mass (FFM) and total body water (TBW) in subjects with no electrolyte abnormalities and significant fluid, when appropriate population, age or pathology-specific BIA equations and established procedures were used. Published bioimpedance analyse equations has been validated against a reference methodology in an about large number of subjects and are presented and ranked according to the standard error of the predictions. The detection of the changes in body cell mass (BCM), extra cellular (ECW) and intra cellular water (ICW) needs more study by using a valid model which can actually guarantee that extracellular water changes do not affect the intracellular water. The use of segmental-BIA, multifrequency BIA, or bioelectrical spectroscopy in altered hydration states also needs further study (Kyle *et al*., 2004). In the effort of studying the validation of tetrapolar bioelectrical impedance method to check human body composition, another research study was conducted. The study was basically carried on to validate the relationship among bioelectric conductance and also the densitometrically available readings. From this studied relation, the scientists were able to check the fat free mass and they have also managed to compare the prediction variability or errors of body fatness which was taken from the tetrapolar impedance method and also the skinfold thickness which is relative to the hydrodensitometry. For this study, about 114 male and female with a wide range of fat free mass were used as their subjects. Regression coefficients between the males and the females were not actually varied. From here the validity and the reliability of the tetrapolar impedance method can be studied. This is alternative to be used in the assessment of body composition from healthy humans (Henry *et al*., 1985).

2.2 Principles of bioelectrical impedance analyzer.

The ECG pads will normally be placed on the patient's wrist and ankle. Bioelectrical impedance analyzer will generate a very low level of electrical current throughout the body and at the same time, it will measure the resistance that the body exerts to this supplied current. The physician will key in some data such as gender, age, height and weight into the biompedance analyzer. All this entered data will be very helpful in determining the percentage of fat, fat weight, lean weight, basal metabolic rate and also the hydration status. When the analyzer completes the analyzing process, it will display the results. The analyzer is actually portable which means that it can be easily transported anywhere, and its single battery charge will long last for the analysis of about 100 patients. Other principles of it includes that no external computer or printer is required because the analyzer is self contained the attachments needed (Biodynamic Corporation, 2010).

2.2.1 Methods of Bioelectrical impedance analysis.

2.2.1.1 Single frequency BIA (SF-BIA)

SF-BIA, uses current generally at 50 kHz, which is passed between surface electrodes which was placed on hand and foot. Some BIA instruments use other locations such as foot-to-foot or hand-to-hand electrodes. At 50 kHz BIA is strictly speaking not measuring TBW but a weighted sum of extra-cellular water (ECW) and intra-cellular water (ICW) resistivities (B25%). SF-BIA permits to estimate fat-free mass (FFM) and TBW. BIA results are based on a mixture theories and empirical equations. The latter have been derived in healthy subjects with tight biological homeostasis. Although SF-BIA is not valid under conditions of significantly altered hydration, this does not negate its use to predict absolute FFM or TBW in normally hydrated subjects. The relative merits of the various equations have to be discussed, when the normal relationships are not met. (35)

2.2.1.2 Multi-frequency BIA (MF-BIA)

As with SF-BIA, MF-BIA uses empirical linear regression models but includes impedances at multiple frequencies. MF-BIA uses different frequencies (0, 1, 5, 50, 100, 200 to 500 kHz) to evaluate FFM, TBW, ICW and ECW. At frequencies below 5 kHz, and above 200 kHz, poor reproducibility have been noted, especially for the reactance at low frequencies. According to studies, MFBIA was more accurate and less biased than SF-BIA for the prediction of ECW, whereas SF-BIA, compared to MF-BIA, was more accurate and less biased for TBW in critically ill subjects. It was also noted that MF-BIA, compared to bioelectrical spectroscopy (BIS), resulted in better prediction of TBW and equal prediction for ECW in surgical patients. It was also determined that MFBIA was unable to detect changes in the distribution or movement of fluid between extracellular and intracellular spaces in elderly patients. (35)

2.2.1.3 Bioelectrical impedance spectroscopy (BIS)

Bioelectrical impedance spectroscopy (BIS) is also said to provide a noninvasive, rapid method for the assessment of total body water (TBW), extracellular water (ECW), and intracellular water (ICW). Few studies, however, have examined the accuracy of BIS in pediatric populations.(51) For the measurement of a subject, one set of electrodes was attached at the subject’s wrist and a second set was placed at the ankle. All measurements were performed on the left side of the body after the subject had been in a supine position for several minutes. All values for the ECW, ICW, and TBW compartments were obtained by using the instrument’s software option for water volume analyses. (51)

BIS models, constants and equations generated in healthy populations have shown to be accurate, with minimal bias in non-physiologically perturbed subjects. However, modeling techniques need further refinement in disease. As studied, body cell mass (BCM), especially muscle mass, constitutes the major current path. These cells are non-spherical, but rather cylindrical, arranged along the current's path.(35)

2.2.1.4 Segmental BIA

Segmental-BIA is performed by either placing two additional electrodes on wrist and foot on the opposite side or by placing sensor electrodes on wrist, shoulder (acromion), upper iliac spine and ankle or by placing electrodes on proximal portion of the forearm and the lower leg and trunk electrode on the shoulder and the upper thigh. The trunk of the body with its large cross sectional area contributes as little as 10% to whole body impedance whereas it represents as much as 50% of whole body mass. This implies three aspects for body composition analysis by the whole body BIA approach the first is about the changes of the impedance are closely related to changes of the FFM (or muscle mass or body cell mass (BCM)) of the limbs. The second approach explains about the changes of the FFM (or muscle mass or BCM) of the trunk are probably not adequately described by whole body impedance measurements, and even large changes in the fluid volume within the abdominal cavity have only minor influence on the measurement of FFM or BCM as could demonstrated in patients with liver cirrhosis and ascites undergoing paracentesis. Segmental-BIA requires prior standardization, particularly when different approaches and different BIA devices are employed. Standardization of the type of electrodes used and their placement is a major concern. Segmental-BIA has been used to determine fluid shifts and fluid distribution in some diseases (ascites, renal failure, surgery), and may be helpful in providing information on fluid accumulation in the pulmonary or abdominal region of the trunk and found high relative errors with segmental-BIA for arms and legs which is 13–17% for arm FFM and 10–13% for leg FFM. Previous studies have also noted that frequencies higher than 50 kHz did not improve the segmental BIA results. Additional research is needed to examine the accuracy of the segmental BIA.

2.2.1.5 Localized bioelectrical impedance analysis

Whole body BIA measures various body segments and is influenced by a number of effects such as hydration, fat fraction, geometrical boundary conditions. Hence the validity of simple empirical regression models is population-specific. For these reasons, localized BIA, which focuses on well defined body segments and thus minimizes the interference effects, has been proposed. Studies have been done in patients with neuromuscular disease and shows that phase angle and resistivity of limbs decreased with disease progression and normalized with disease remission and may be useful in the therapeutic evaluation of such diseases.

2.2.1.6 Bioelectrical impedance vector analysis (BIVA or vector BIA)

The ultimate attractiveness of BIA lies in its potential as a stand-alone procedure that permits patient evaluation from the direct measurement of the impedance vector and does not depend on equations or models. The BIVA approach is only affected by the impedance measurement error and the biological variability of subjects. The ellipse varies with age and body size. Clinical validation studies on renal patients, critical care patients and obese subjects have shown that vectors falling outside the 75% tolerance ellipse indicate an abnormal tissue impedance, which can be interpreted by vector displacements parallel to the major axis of tolerance ellipses which indicate progressive changes in tissue hydration (dehydration with long vectors, out of the upper pole, and hyperhydration with short vectors, out of the lower pole and vectors falling above (left) or below (right) the major axis of tolerance ellipses indicate more or less BCM, respectively, contained in lean body tissues. Long-term monitoring of patients has shown combined changes in hydration and soft tissue mass. (35)

2.3 Safety aspects of bioelectrical impedance analyzer.

The currents of 50 KHz is still considered as safe because this level of current will not stimulate any electrically excitable tissues in the body. Current magnitudes that are involved are less than 1mA which is still less than the threshold of perception. Macroshock possibilities are greatly reduced with the usage of low voltage power sources. (National Institutes of Health Technology Assessment Conference Statement,1994))

2.4 Limitations of bioelectrical impedance analysis

Bioelectrical impedance analysis however, does carry certain disadvantages along with it in some aspect. The limitation of bioelectric impedance includes the uncertainties associated with currently available prediction equations. According to the fact, the initial problems in utilizing the bioimpedance analysis methodology in the research has focused on the uncertainties which is associated with the availability and choice of valid equations to predict lean body mass and to calculate fat mass. One of the literatures published in the year of 1985 has indicated about the obese subjects, which says that bioimpedance analysis systematically overestimated lean body mass with increasing obesity (Kuczmarski, 1996).

2.5 Body compartments.

2.5.1 Fat-free mass

FFM is everything that is not body fat. A large number of BIA equations in the studies predict FFM. These equations vary in the parameters included in the multiple regression equations and their applicability in various subjects. Early BIA equations only included height/resistance. Later equations include other parameters, such as weight, age, gender, reactance, and anthropometric measurements of the trunk and extremities to improve the prediction accuracy. FFM can be determined by SF-BIA provided that hydration is normal and BIA equations used are applicable to the study population, with regard to gender, age, and ethnic group.

2.5.2 Total body water (TBW), extracellular (ECW) and intracellular water (ICW)

Data from both hypo- and hyper-hydration studies suggest that electrolyte balance influences BIA measurements independently of fluid changes. Such effects may be difficult to predict, as fluid and electrolyte changes will also affect the ratio of intra- to extracellular water which, in turn, influences resistivity. The ECW:ICW ratio is a factor known to limit the applicability of predictive equations generated by BIA to external populations. Furthermore, BIA does not allow to accurately assess TBW and ECW when body water compartments are undergoing acute changes. In addition, the average body hydration of the FFM varies with age. Studies supports that 50 kHz SF-BIA primarily reflects the ECW space, which represents a constant proportion of TBW in normal condition. An increase in

ECW or in the ECW/TBW ratio may indicate edema and/or malnutrition. MF-BIA appears to be sensitive to such changes, even if there are no significant changes in body weight.

On the other hand, the parallel-transformed, SF-BIA model appears to be sensitive to changes in ICW (or BCM), but not to changes in ECW. Therefore this model may have limited use for estimating FFM or body fat when there is an abnormal hydration state. among the MF-BIA and BIS models, the 0/N parallel (Cole–Cole) model is considered more precise and accurate for the measurement of ECW and ICW than variables obtained by SF-BIA. The potential of BIS can only be exhausted if the data are interpreted with adequate algorithm that include reliable data fitting and a valid fluid distribution model which considers tissue nonhomogeneities. A valid model must guarantee that ECW changes do not corrupt the ICW and vice versa. Standardization of BIS method remains a concern. It was also concluded that SF-BIA and BIS significantly overestimated TBW in healthy individuals, whereas there was no overestimation by MF-BIA. MF-BIA seems to be a more accurate method for determining the TBW compartment for healthy and obese adults and for persons with chronic renal failure.

2.5.3 Body cell mass (BCM)

FFM is everything that is not body fat, there is no consensus on the physiological meaning of measures of ‘‘cellular mass’’, ‘‘BCM’’ or ‘‘metabolically active tissue’’ and ‘‘ICW’’. The BCM is the protein rich compartment which is affected in catabolic states, and loss of BCM is associated with poor clinical outcome. In overhydrated patients, even precise determination of FFM might fail to detect relevant protein malnutrition because of expansion of the ECW. Estimating the size is difficult because it is a complex compartment, comprising all nonadipose cells as well as the aqueous compartment of adipocytes. Future research is needed to define BCM and the role of BIA in its clinical evaluation. In patients with severe fluid overload, such as patients with ascites, inter-individual differences of lean tissue hydration are probably too high to develop uniform equations to assess BCM. In this study, It was also concluded that in patients with large alterations of body geometry or hydration status the application of standard BIA is not appropriate to assess BCM. (35)

2.6 High blood pressure.

According to the statistic drawn by U.S Department of Health and Human Services, National Institute of Health and National Heart, Lung and Blood Institute, high blood pressure affects more than 65 million or 1 in 3 American adults. About 28 percent of American adults ages 18 and older which is stood by 59 million people were diagnosed for prehypertension, which is a condition that also increases the chance of heart disease and stroke. High blood pressure is especially very often among African Americans, and this group tends to develop it even at an earlier age and more often than Whites. It is also said that it is common among older Americans individuals with normal blood pressure at age 55 have a 90 percent lifetime risk for developing high blood pressure (National Institute of Health, 1998). High blood pressure (BP) acts as one of the cause of cardiovascular disease for millions of people worldwide, and there is no strong proof to say that this problem is being solved in anyway but the problem is just getting worse by day (Carretero and Oparil, 2000).

The recognition of elevated blood pressure in both children and adolescents was actually contributed by the national database which was developed throughout childhood which studied the normative blood pressure in them. The epidemic of childhood obesity, the risk of developing left ventricular hypertrophy, and evidence of the early development of atherosclerosis in children would make the detection of and intervention in childhood hypertension important to reduce long-term health risk (Sullivan *et al.*, 1989). Secondary hypertension is more common in preadolescent children, with most cases caused by renal disease. Primary or essential hypertension is more common in adolescents and has multiple risk factors, including obesity and a family history of hypertension. Evaluation in this research study also involves a thorough history and physical examination, laboratory tests, and specialized studies. Management is multifaceted. Recommendations for pharmacologic treatment are based on symptomatic hypertension, evidence of end-organ damage, stage 2 hypertension, stage 1 hypertension unresponsive to lifestyle modifications, and hypertension with diabetes mellitus (Luma and Spiotta, 2006).

Based on National High Blood Pressure Education Program which came out with Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure, for people aged more than 50 years old, systolic blood pressure of more than 140 mm Hg is a more vital cardiovascular disease risk factor if it is compared to diastolic blood pressure which begins at 115/75 mm Hg, cardiovascular disease risk goes double for each increment of 20/10 mm Hg. For those who are normotensive at 55 years of age will have about 90 percentage of lifetime risk of developing hypertension, prehypertensive individuals with systolic blood pressure of 120–

139 mm Hg or diastolic BP 80–89 mm Hg which require modifications of the way of living life to prevent the increasing rise in blood pressure and cardiovascular disease. For simple hypertension, thiazide diuretic should be used in medication for most cases, either alone or combined with drugs from other classes, and this report delineates specific high-risk conditions that are compelling indications for the use of other antihypertensive drug classes. Two or more antihypertensive medications will be needed to achieve goal of blood pressure which carries the reading of 140/90 mm Hg, or 130/80 mm Hg for patients with diabetes and also chronic kidney disease. Patients whose blood pressure is more than 20 mm Hg above the systolic blood pressure goal or more than 10 mm Hg above the diastolic blood pressure goal, initiation of therapy using two agents can be brought to action, one of which usually will be a thiazide diuretic, regardless of therapy or care, hypertension is said able to be controlled only if patients are motivated to stay on their treatment plan. Some other factors like positive experiences such as trust in the clinician, and empathy are beleived to improve patient motivation and satisfaction throughout the process of treatment (Loan and Mayclin, 1987)

CHAPTER 3

Materials and methodology

3.1 Materials

Some of the main materials needed to carry out this research study are:

a. Sphygmomanometer
b. Bioimpedance analyzer
c. Cot
d. Electrolyte gel
e. Alcohol swab
f. ECG sensor pad electrod

3.2 Subject/ Patient Collection.

The subjects in this research study will be 100 male or female high blood pressure patients. All the patients will be approached at University of Malaya Medical Centre. Other hospital such as Tawakkal Hospital will also be approached in the case of inadequate subjects. 100 normal control subjects (disease free individual) will also be referred so that the data between the two types of subjects can be compared. The age range of the subjects will be between 30 to 60 years old. The subjects will be required not to take any meals before the measurements so that no internal factor can affect the reading of the analyzer. The subjects will be informed about the nature and the purpose of the study and they will also be required to give written informed consent. High blood pressure of the patients will be confirmed using the sphygmomanometer. The selected subjects should not have been diagnosed for heart diseases, the female subjects should not be having the menstrual cycle upon measurement of impedance and the subjects are made sure to be free from fever.

3.3 Measurements

3.3.1 Test position.

Subjects lie face up on an examination bench in a supine position.

3.3.2 Sensor pads

Two pairs of sensor electrodes (ecg pads) are placed on the subject's right hand and wrist, and right foot and ankle. This means that 8 electrodes will be used for each subject.

3.3.3 Connecting subjects.

A cable is connected between the analyzer and the sensor electrodes. Each subject will be wearing clothes, but no shoes or socks during the measurement process. The skin contact areas will be cleaned with alcohol at which the electrodes will be placed. The electrodes will be then placed at the dorsal surfaces of the hands, the wrist (at distal metacarpals-phalangeal) and feet, ankle (at the metatarsals-phalangeal). These locations where the electrodes are to be placed must be made sure that it is between the prominences of the radius and ulna and between medial and lateral malleoli of the ankle. Electrolyte gel will be applied on the electrodes before it is connected to the subject's skin of hand and feet.

Suggested current of 800 μ A at 50 KHz will be excited into the subject. This electrical current will provide deep homogenous electrical field in the variable conductor of the subject's body. Soon after the current passed into the subject's body, the voltage drop will be detected by the proximal electrodes. Measurement of resistance and reactance will be done by the analyzer which is connected through the electrodes (Henry *et al*., 1985).

3.3.4 Subject data

Since the analyzer is not equipped with the analyzer's keypad, the subject's id, gender, age, height, weights, reading of their blood pressure, duration of their disease are entered manually through a form to collect the information of subjects.

3.3.5 Testing time

About three minutes are required to set up and 20 minutes are required to conduct the test on a subject.

3.3.6 Test accuracy

For the most accurate results, the subjects are made sure that they did not eat for 4 hours prior to testing. They also should not have done any exercise for 12 hours prior testing, did not consume alcohol for 24 hours prior testing, did not drink caffeine on the day of the test did not wear pantyhose during the test. Besides that, the subjects will be given one quart of water one hour before the test.(42) Patients will be excluded if they had any condition known to interfere with the bioimpedance signal such as obesity or pleural effusion. An initial screening or checking the medical history of the subject will be done to exclude patients with significant aortic valve disease, tricuspid incompetence, or pericardial effusion (8)

3.4 Analysis of the data.

All the data received from the analyzer will be converted to Microsoft excel file, updated and will be analyzed thoroughly to study the comparison between the high blood pressure subjects and the normal control subjects using IBM SPSS STATISTIC (V.19) software. Discussion and conclusion will be drawn from the analysis.

CHAPTER 4

Results and discussions

4.1 Subjects' description

Comparison is to be done in various ways including gender, age category and body mass index distribution. Other than that, high blood pressure patients will be also analyzed. To make the process of analysis easier, they were categorized into several groups according to their systolic and diastolic value. Comparison was also done for the test and this includes the significant difference in various points of view which is outlined below. About 70 subjects were used in this study. 35 of them were considered to be the patients who possess high blood pressure in them. These patients chosen were ensured that they do not have any other diseases in them. The remaining 35 subjects are considered to be healthy because they do not possess any diseases in them. These healthy subjects were used as the negative control to compare their readings with the collected patients. Comparisons have been done in various ways using SPSS software. Collected patients were totally random in which the aspect of gender was not limited in anyway. Figure 4.1 shows the number of subjects in terms of male and female.

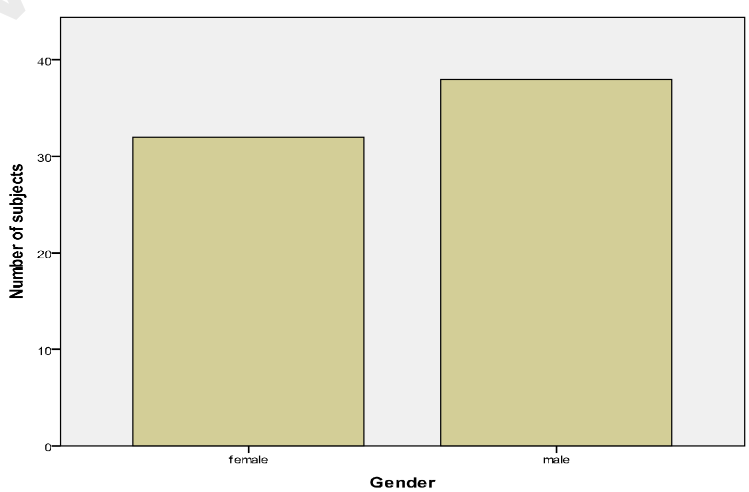


Figure 4.1 Categories of subject in terms of male and female

Based on figure 4.1, 38 males and 32 females were used as the subjects. This accounts for 54.3 % of male and 45.7 % of female. It also was studied that among the male subjects, the distribution of patients and normal subjects are 17 and 21 respectively.

4.1.1 Subjects Age Group

The age group was not specifically limited, but based on the collected subjects, their age group falls between the range of 30-60 years old. For the ease of analysis process, this wide age group was divided into certain category which is 31-40, 41-50 and 51-60 which was designated as 1, 2 and 3 respectively. This is shown in Figure 4.2.

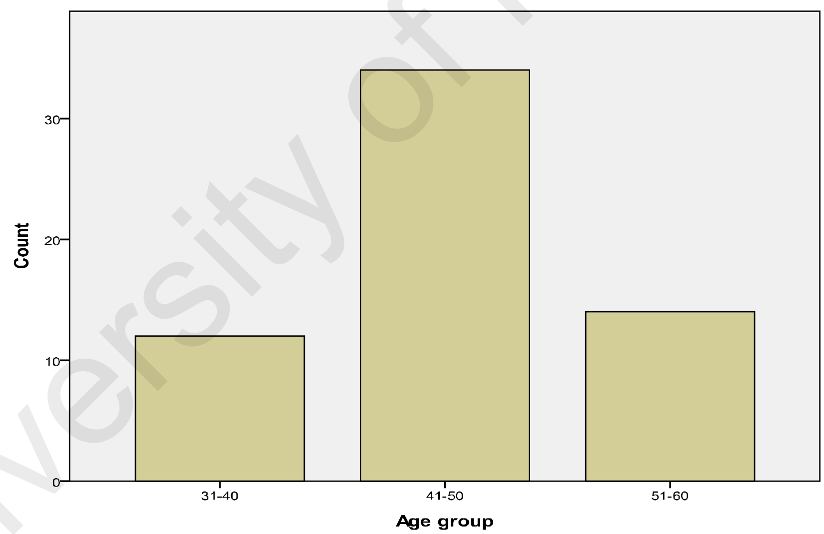


Figure 4.2 Categories of subject in terms of age group

Based on Figure 4.2, group 2 (age between 41 to 50) accounts for the highest peak which stands for 34 subjects followed by group 3 (age group 51 to 60) which stands for 19 and group 1 is the least in terms of the number of subjects which stands for 17 subjects.

4.2 Body Mass Index (BMI) distribution

Calculation for Body mass index (BMI) was performed to all the subjects. This general analysis was performed to understand the distribution clearly before analyzed thoroughly for detailed comparison purposes. Based on the subjects used, it was clear that all the subjects used were not underweight and at the same time, they were not obese as well. Based on the figure below, majority of them fall in the category of "ideal" which accounts for 36 subjects and "overweight" which is 28 subjects. The least category is the "underweight" category which account for only 6 subjects. The evidence is shown in Figure 4.3.

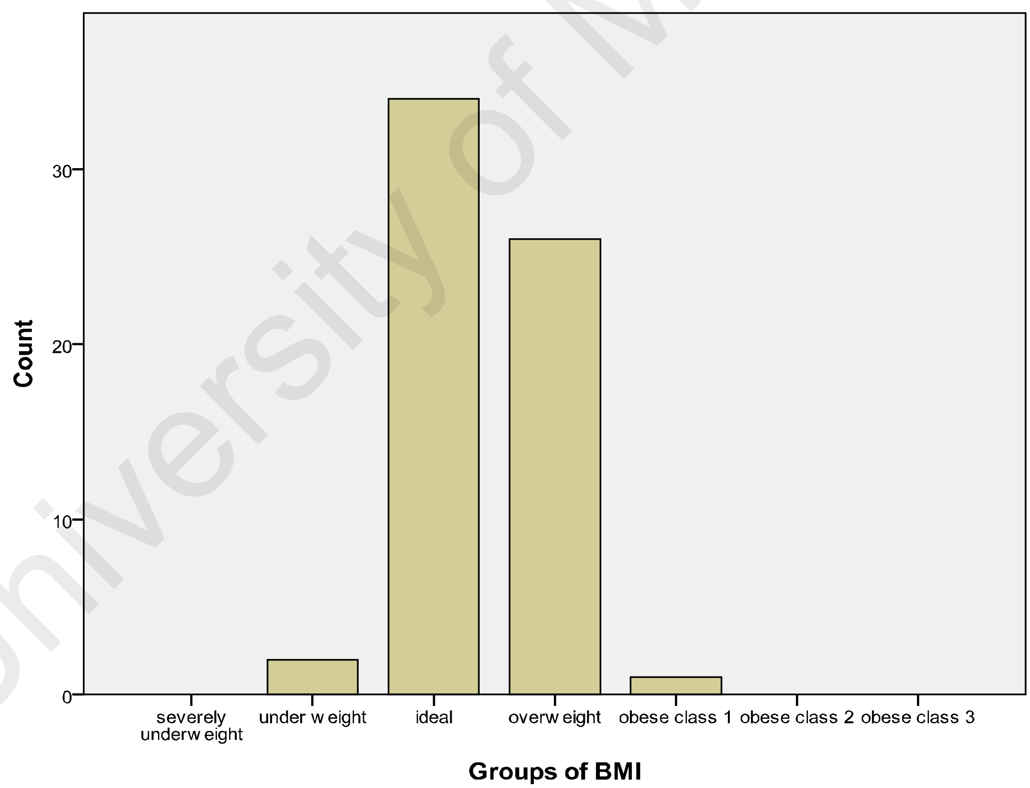


Figure 4.3: Categories of subject in terms of BMI group

4.3 High Blood Pressure Patients.

Subjects used in this study are divided and selected accordingly. This means that only patients with high blood pressure were used in the analysis apart from the normal subjects which were used as a control reference. When taking measurement of blood pressure, it is well known that both systolic and diastolic pressure must be considered. High blood pressure patients who fell in the normal range were 6, prehypertension patients were 28 and patient of hypertension stage 1 was 1. Figure 4.4 shows the frequency against the systolic pressure of high blood pressure patients.

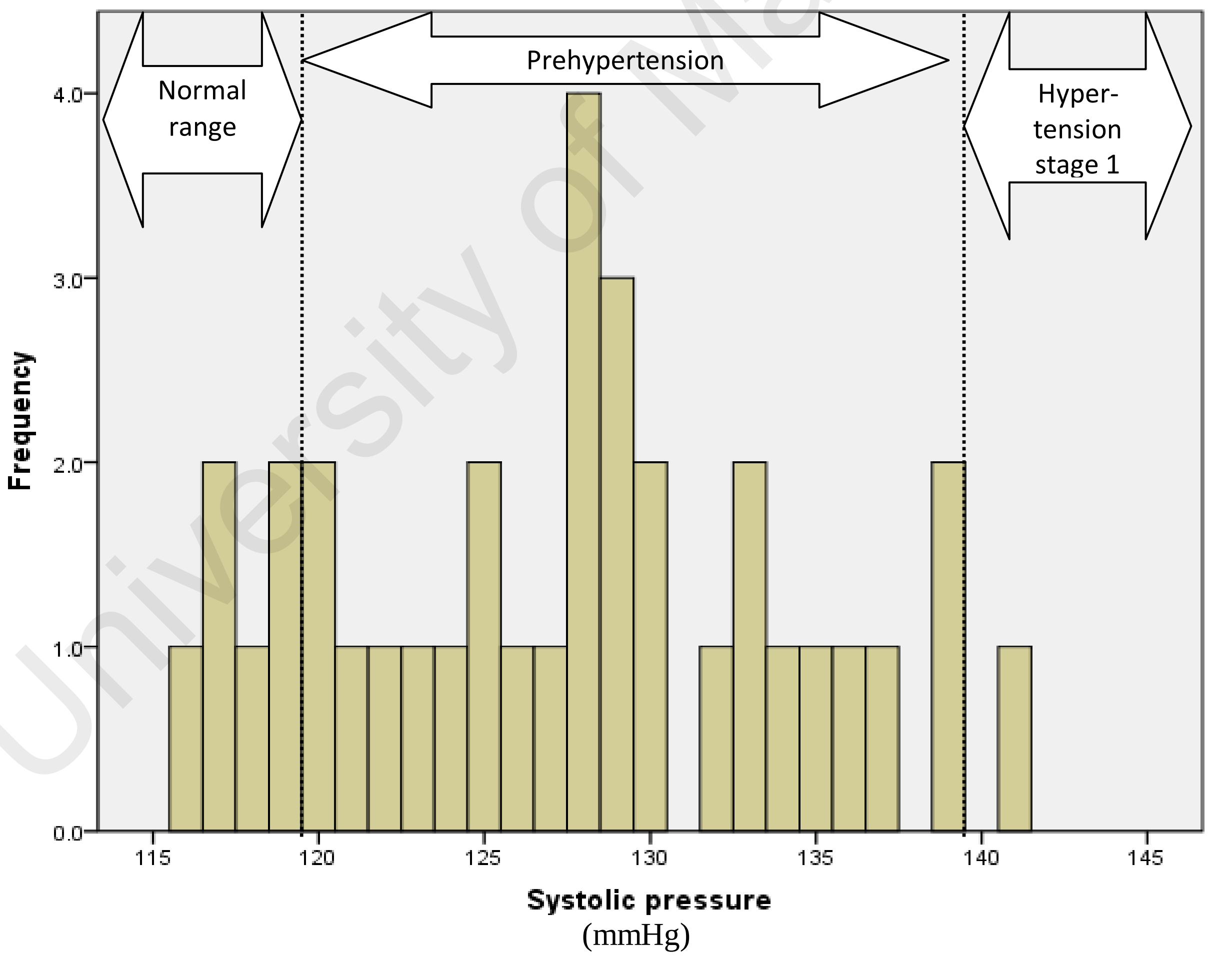
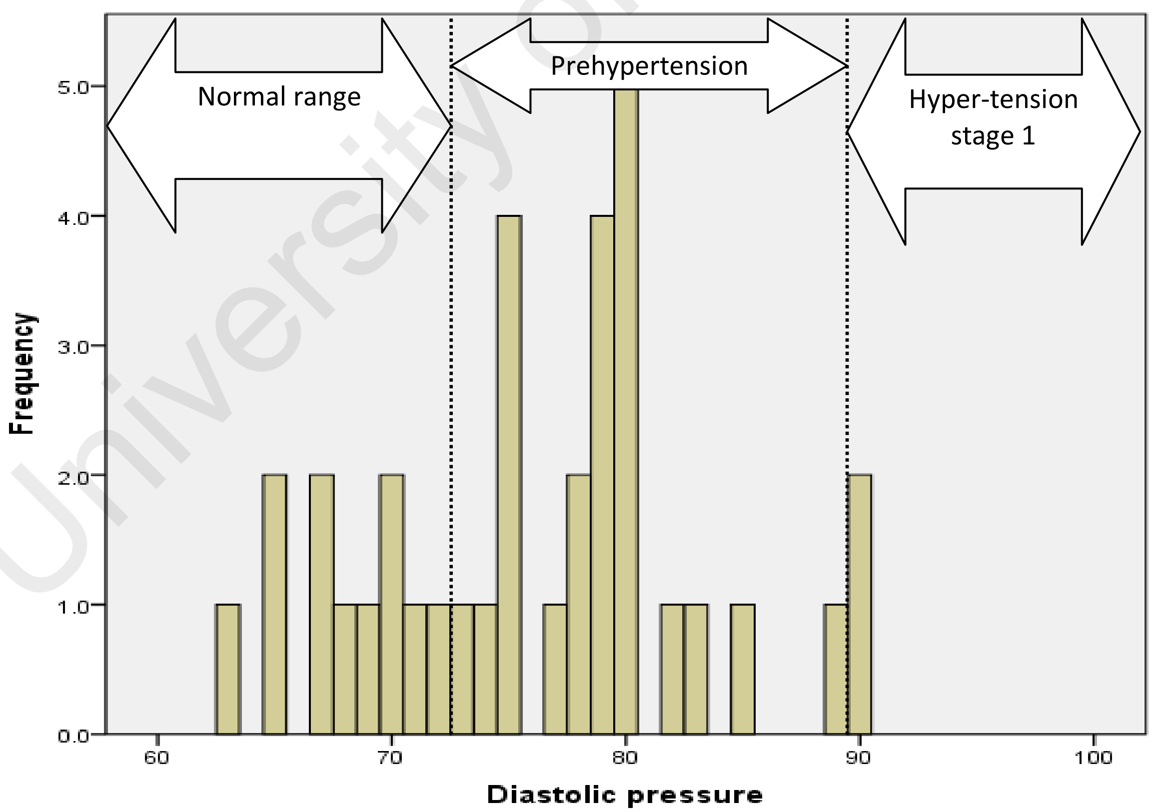


Figure 4.4: Frequency against the systolic pressure of high blood pressure patients

Two dotted lines were directed from x-axis to differentiate between the types of blood pressure. Readings which fall in between the first dotted line and second dotted line indicate the occurrence pre-hypertension where as values after the second dotted line accounts for hypertension stage 1. It is noted that readings before the first dotted line fall in to the category of normal subject. It is also necessary to know that the chart above was built for patients only and the systolic reading shown in the graph was noted during the measurement of high blood pressure during the period of subject collection. So, it is normal and possible to have normal range readings in the results shown. The value for N (number of subjects) for normal range based on the diastolic pressure was 11, prehypertension was 22 and hypertension stage 1 is 2. Figure 4.5 shows the frequency against the diastolic pressure of high blood pressure patients.



(mmHg)

Figure 4.5: Frequency against the diastolic pressure of high blood pressure patients.

Diastolic pressure value which falls before the first dotted line does not account for high blood pressure although the graph is drawn only for patients of high blood pressure. Values which fall within first dotted line and second dotted line accounts for prehypertension. It is also to be noted that values which fall after the second dotted line are representing hypertension stage 1.

Figure 4.6 shows the summary of both Figure 4.4 and 4.5 for systolic and diastolic pressure which was drawn earlier in terms of percentage.

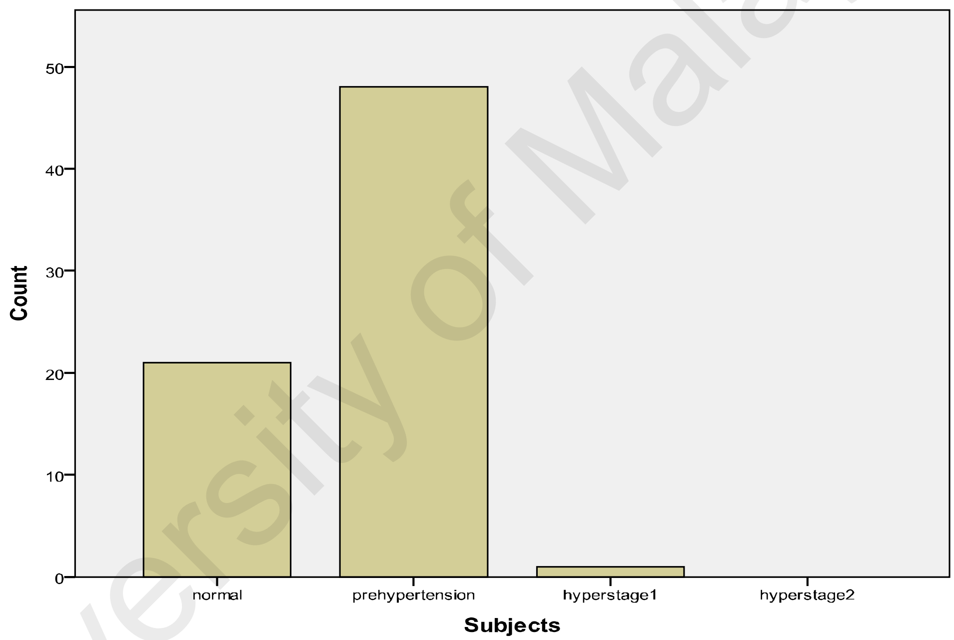


Figure 4.6: Summary of percentage of systolic and diastolic pressure

4.4 Bioimpedance parameter analysis

Bioimpedance parameters are reactance, resistance, impedance, phase angle, capacitance and quality factor. All of these details were taken at frequency of 50 Hz, 5 kHz, 50 kHz, 100 kHz, 200 kHz and 500 kHz.

4.4.1 Analysis of Variance of Normal and Patient Subjects tested with different modes of electrodes.

All the tests were compared among the different modes of measurement. Modes in this context are representing the position of electrodes. All the tables from Table 1 to 19 used which have been described in this section are presented in Appendix. Basically, 4 modes were used in the study. For this analysis, analysis of variance was used to compare the significant of position of electrodes among normal subject and patients. The reason to perform this test is to compare which mode is contributing the best significance so that a standard or measurement mode can be known.

Based on Table 1, when significant values of reactance were studied, significant values cannot be seen at 50 Hz and 50 kHz for patients. For normal subject, significant values cannot be seen at 5 kHz and 200 kHz. Mode 1 and mode 2 have shown significance among them meaning that they have do not have much differences in terms of value. Based on the post hoc results for normal subjects, which was presented in Table 2, it can be seen that mode 3 and 4 exhibit significant differences from mode 1 which means that mode 1 is the best to study the values. Meanwhile, for the post hoc results for patients in Table 3 for the same category proves the same, meaning that mode 1 again exhibits significant differences compared to mode 2,3 and 4.

According to Table 4, for the analysis for resistance, in normal subjects, the values were not significant at 50 Hz, 5 kHz, 50 kHz and at 100 kHz meaning that the significance can only be seen at 200 kHz and 500 kHz. It can be clearly seen that lower frequencies up to 100 kHz did not give significance in this category. In patients, the value was not significant at 50 Hz of resistance according to table 4. The same conclusion is to be drawn because insignificant value was again seen in 50 Hz which is the lowest frequency. In terms of post hoc test for normal subject (Table 5), it is difficult to decide the effective mode because all 4 modes exhibit mixture of values between significant and insignificant values. The same conclusion is to be drawn for post hoc test in patients and the results are presented in Table 6.

When the data for the impedance (Table 7) were studied, it was noticed that the values for normal subject were not significant at 5 kHz, 50 kHz and also at 100 kHz. This means that significant values can be noted at only high frequencies. Meanwhile, for patients, the value was not significant at 50 Hz. This is because 50 Hz is considered too low compared to other frequencies used in this study. Post hoc results from Table 8 have suggested that more significant values were obtained at frequency of 200 kHz compared to 500 kHz and there was a significant difference between mode 1 and other 3 modes. Table 9 has shown good inter relationship between mode 1 and 2 because significant values were noted among them at the frequencies of 5 kHz, 50 kHz, 100 kHz, 200 kHz and 500 kHz. No relationships can be seen when mode 1 is compared to mode 3 and mode 4.

Next, based on the Table 10, it was found that there are no significant values in phase angle values for normal subject at 5 kHz, 200 kHz and also at 500 kHz. For patients, the phase angle values were not significant at 50 kHz, 5 kHz, 200 kHz and 500 kHz. Since only few frequencies exhibited significant values, post hoc test again was carried out to see the relationships among the position of electrode. Table 11 says that all the modes were effective in exhibiting significant results but only at 50 Hz in normal subjects whereas for patients, based on Table 12, mode 1 again exhibits significant values and it was not having same means with other modes especially at the frequency of 100 kHz.

When comparing using capacitance from Table 13, for normal subject, it was found that there was no significant value at 50 Hz and 100 kHz whereas for patients, no significant values were found at any frequency. Post hoc test for normal subject in this category (Table 14) has shown that mode 1 possessed some significant values when compared to other 3 modes especially at frequency of 200 kHz. It is also to be noticed that mode 2 also exhibited significance when compared to modes 1,3 and 4 at 500 kHz.

In the aspect of quality factor (Table 16), no significant values were noticed at 100 kHz and at 200 kHz for normal subjects, whereas no significant values were noticed at any frequency for patients except at 200 kHz. Post hoc test (Table 17) for normal subjects has suggested that mode 1 exhibited good significance when compared to other modes at the frequency of 5 kHz. Based on post hoc test for patients (Table 18), the interaction among the modes was not clear to be understood. When the biocomposition parameters were analyzed (Table 19), patients' data did not at all exhibit any significant value ($p > 0.05$) indicating that the means are the same while normal subjects did show significant values for basal metabolic rate, total body water and also for fat free mass. This shows that there are differences in terms of mean for basal metabolic rate, total body water and fat free mass which means that these parameters can be used to study the differences between normal subjects and patients. According to the results, some significant values fall below 0.05 ($p < 0.05$) indicating that the null hypothesis (H_o) can be rejected because the means are not the same. This shows that the electrode position affects the data obtained. Thus determining which mode (electrode position) is the best for measurement is necessary. For this, post hoc test is necessary. Through post hoc test, similar means can be detected and conclusion on which mode is giving significant values can be also known. Based on the data and discussion so far, mode 1 exhibited the best significance for the study.

Based on data obtained, the change in reactance did not show significant difference between patients and normal. This is because there is an increase and decrease in the value without any pattern to be understood between patient and normal. The significance seemed to be completely jumbled thus no obvious comparison can be done in the aspect of differences in the position of electrodes between patients and normal.

4.4.2 Independent T- test of Normal and Patient Subjects tested with different modes of electrodes.

All the tests were compared among the different modes of measurement. Modes in this context are representing the position of electrodes and are presented from Table 20 to Table 26. Basically, 4 modes were used in the study. Mode 1 stands for the position of electrodes at left hand and left leg, mode 2 represents position of electrode at left hand and at right leg, mode 3 is representing position of electrode right hand and at right leg and mode 4 stands for position of electrode at right hand and at left leg. Independent T test has been done to compare the significant values at each frequency generally among patients and normal subjects for all the modes, and also between the modes separately.

According to Table 20, significant results can be seen at all values for all modes at 50 Hz. While at 5 kHz, significant readings were obtained at mode 1, mode 2 and mode 3. At 50 kHz, only mode 2 has shown significant value and the same goes to the frequency of 100 kHz. Mode 1 has shown significant value at reactance at 200 kHz. Meanwhile, at 500 kHz, all the modes have exhibited significant values. This proves that mode 1 exhibits good significant differences compare to other modes. This means that the means are not the same, thus we can know the difference range of values compared to other modes.

When comparing the results for resistance from Table 21, significant values were obtained at all modes at 50 Hz, mode 2 at 5 kHz, mode 1 at 50 kHz, mode 1,2 and 4 at 100 kHz, mode 1,2 and 3 at 200 kHz and again in all modes at 500 kHz. This proves that mode 1 again exhibits good significant differences compare to other modes. This means that the means are not the same, thus we can know the difference range of values compared to other modes. Studies of impedance (Table 22) have shown zero values at all modes at 50 Hz, significant values at mode 1,2 and 3 at 5 kHz. No significant values were observed for impedance at 50 kHz. Meanwhile, it can be noticed that there were significant values at all modes for impedance at 200 kHz and 500 kHz. Overall results of significance of impedance have shown that 5 and 50 kHz did not exhibit significance. This might be due to the low amount of frequency provided. Readings from Table 23 for phase angle have shown that significant values can be seen at mode 1,2 and 4 for phase angle of 50 Hz. Significant values also can be seen at 5kHz and 50 kHz for modes of 2,3 and 4. For phase angle of 100 and 200 kHz, significant values were obtained at all 4 modes. At 500 kHz, significant values were noticed at modes 2, 3 and 4. It is to be noted that at 100 and 200 kHz, all the modes have shown significance due to the high current level. Nothing much can be concluded here because all other modes also did exhibit significance so their means are all not the same. Readings of capacitance from the Table 24 has performed significant values at all modes at 50 Hz. This suggested that mode 1 possessed different modes than other modes thus the null hypothesis can be rejected. Modes 1,2 and 4 possessed significant values at 5 kHz, only mode 3 possessed significant values at 50 kHz and 100 kHz. At 200 kHz, mode 2 and mode 4 have exhibited significant values. Consequently, mode 2,3 and 4 have included significant values at 500 kHz. Studies for quality factor from Table 25 have shown significant values at mode 4 for 50 Hz, all modes at 5 kHz and 50 kHz, mode 3 and 4 at 100 kHz, mode 1, 3 and 4 at 200 kHz and mode 1 and 3 at quality factor of 500 kHz. Since 5 and 50 kHz exhibited significance as mentioned, this is considered to be the good frequency level to test the parameters but 5 kHz seemed to be better because it exhibited better overall value.

For this mentioned category (Table 26), the BMI was 0.27, BMR was 0.006, ECW was 0.008, ICW was 0.008, TBW was 0.004 and FFM was 0.006. Based on data obtained, it can be studied 50 Hz there are consistent reading between the analysis of reactance, resistance, impedance, phase angle and capacitance in which the mentioned analysis exhibited significant value. The consistency is almost the same at 500 kHz. It is also to be noted that biocomposition parameter, except for BMI, other such as BMR, ECW, ICW, TBW and FFM all exhibited significant values meaning that compared to frequency readings, biocomposition parameters are easily compared in terms of significance and the effectiveness of the modes.

4.4.3 Comparison of modes of measurements for normal subject, subjects with prehypertension and subjects with hypertension.

To further up with the research, ANNOVA test has been used to do comparison among the position of electrode (modes used for the measurement) for normal subjects, subjects with prehypertension and subjects with hypertension. No test was performed for patients in hypertension stage 1 and hypertension stage 2 due to few data. This section refers to the Tables from 27 to Table 40.

According to Table 27, when the comparison of reactance among the position of electrode for normal subjects were studied, it was noticed that the results are all 0 for all modes at 50 Hz while at 5 kHz, mode 1 shown not significant value ($p > 0.05$), mode 2 at this frequency has shown 0 value, significant value at mode 3 and again 0 value in mode 4. For reactance at 50 kHz, 100 kHz, 200 kHz and 500 kHz, all 4 modes possessed 0 values. About the same results were obtained for resistance readings for this category based on the Table 28. In this reading of 5 kHz at mode 3 possessed significant values of 0.01 and at mode one of the same frequencies has shown no significant value. Other than that, all the obtained value were 0 for all modes at frequency of 50 Hz, 50 kHz, 100 kHz, 200kHz and 500 kHz. Mode 2 and mode 4 at 5 kHz for resistance also have shown 0 values.

Based on Table 29, comparisons of impedance among the position of electrode for normal subjects were analyzed, it was noticed that impedance at mode 1 for 5 kHz has shown not significant value while all other readings are 0 for frequency and modes. Comparison of phase angle (Table 30) among the position of electrode has shown all significant for all modes 1, 2, 3 and 4 for all frequencies 50 Hz, 5 kHz, 50 kHz, 100 kHz, 200 kHz and 500 kHz. According to Table 31, the studies for capacitance were done on the same category and it was noticed that mode 2, 3 and 4 did not show significant value while all others possessed significant values for all the tested frequencies. Studies on the quality factor from Table 32, among the position of electrode for normal subjects have shown 0 value in mode 1 at 50 Hz, significant value in mode 2 at the same frequency, not significant value at mode 3 and mode 4 while 0 value for other frequencies at 5 kHz, 50 kHz, 100 kHz, 200 kHz and 500 kHz for all modes. Since the results did not exhibit consistency, the null hypothesis (H_o) cannot be rejected meaning the means are the same.

Comparisons of reactance among the position of electrode for prehypertension patients from Table 34 have shown significant values at all except for mode 2, mode 3 and mode 4 for 50 Hz, 5 kHz and 5 kHz respectively. This means that 50 Hz gave the best significance compared to other frequencies which gave only 0 values at most. For resistance from Table 35, not significant value was obtained at mode 4 (50 Hz). In 5 kHz, mode 1 and 2 exhibited significant values. Again 50 Hz has shown good significance meaning that the null hypothesis can be rejected for all modes except for mode 4. In the case of impedance in Table 36, mode 1 of 50 Hz has shown significant value whereas 5 kHz of the same mode didn't reveal significant value. Other than that, all the other values of all the modes and frequencies have shown 0 values. Comparison of phase angle among the position of electrode for prehypertension patients from Table 37 has shown 0 values at 50 Hz for mode 1,2 and 3. Mode 4 has shown not significant value. Mode 1 in 5 kHz has shown significant values, mode 2 and 4 has shown 0 values whereas mode 3 has shown not significant value. Mode 1 and 4 have shown not significant values but modes 2 and 3 have shown significant value at the ode of 50 kHz. Only mode 1 of 100 kHz shown significant values and other modes did not. Mode 3 in 200 kHz revealed 0 value and mode 4 in the same frequency has shown significant value. This is a proof to say mode 1 is effective enough to do the measurements process at the frequency of 50 Hz. Comparison of capacitance in Table 38 among the position of electrode for prehypertension patients revealed that significant values fell in the category of mode 2 at 5o Hz, mode 1 and 4 at 5 kHz, mode 3 in 50 kHz, mode 1 in 100 kHz, mode 2 and 3 at 200 kHz and mode 3 at 500 kHz. All other non mentioned area has shown non-significant values. Comparison of quality factor among the position of electrode for prehypertension patients form Table 39 has shown 0 values for all the modes in 50 Hz, significant values in mode 2 and 3 in 5 kHz, mode 1 and 3 in 50 kHz, all modes in 100 kHz, mode 1,2 and 3 at 200 kHz and 500 kHz. Mode 1 at all the frequency has shown good significant except at 5 kHz. That may be because of low frequency level. As Table 40 is showing, biocomposition parameters mostly have shown non consistency in terms of significance. So it is difficult to compare efficiency of the modes. Based on data obtained, starting from reactance to quality factor, most of the value was 0 for almost all the frequencies. Consistency of the values in terms of significance can be noted meaning that they possessed more significant values than not significant values other than just 0. Since the majority of the readings exhibit 0 values, it is not valid to compare the efficiency of the position of electrodes for both patients and normal subject. It is also to be noted that for the aspect of biocomposition parameter, BMI exhibits 0 values for all 4 modes because the calculation of BMI has nothing to do with the influence of impedance analyzer other than detecting the difference. For the case of BMR, ECW, ICW, TBW and FFM all exhibited not significant values meaning that compared to frequency readings, biocomposition parameters are not worth of having relationship among each other between patients and normal subjects.

4.5 Comparison of Bioimpedance Parameters Among Subjects.

This test is done to compare the bioimpedance parameter among subjects. These entire tests were analyzed in detail using different frequency such as 50 Hz, 5 kHz, 50 kHz, 100 kHz, 200 kHz and 500 kHz.

4.5.1 Overall comparison of Bioimpedance Parameters

Comparisons of bioimpedance parameters have been done among the high blood pressure patients along with the normal subjects and the results are presented in Table 41. In this analysis, only the data for mode 3 (right leg right hand) is used. Comparison for hypertension stage 1 and 2 was excluded because there is few and no data available for that category mentioned respectively. In term of bioimpedance parameters, 50 kHz has shown very good significance because it exerts more significant values compared to other modes. Means taken from 50 kHz are not the same thus the null hypothesis can be rejected meaning that the position of electrodes did give effect on the values obtained from the analyzer for patients and normal subjects especially at 50 kHz but the values obtained from the aspect of biocomposition parameters were not satisfying because none exhibits significant values.

4.5.2 Comparison of Bioimpedance Parameters between normal subjects and Prehypertension patients at different frequencies.

Independent t test has been used in this study to compare the bioimpedance parameter of the systolic pressure between normal subjects with prehypertension subjects at different frequencies. In the first aspect, comparisons of bioimpedance parameters of the systolic pressure between normal subjects with prehypertension patients were done at different frequencies. According to Table 44, for reactance, reading for 50 kHz and 100 kHz exhibited not significant values. For the category of resistance, value for the frequency of 200 kHz did not show significant value. The same goes to the category of impedance. For the aspect of phase angle, value at 50 Hz did not show significant value. In capacitance studies, readings at 50 Hz, 100 kHz and 500 kHz exhibited significant values. In quality factor, only value for 200 kHz did not show significance. For this mentioned category, the BMI was 0, BMR was 0.006, ECW and ICW was 0.18, TBW was 0 and FFM was 0.006. Based on the analysis done, it was noticed that there are some consistency between resistance and impedance meaning that it is having significant readings. This also means that there are differences between patients' reading and normal subjects' reading which makes it to be efficient to compare these two parameters, resistance and impedance should be considered for further studies. As mentioned before, not promising results were obtained for the biocomposition parameters as there is no significance of reading for both normal and patient subjects.

For the aspect of the comparisons of bioimpedance parameters of the diastolic pressure between normal subjects with prehypertension at different frequencies derived from Table 45, it was noticed for reactance, values at 5 kHz, 100 kHz and 500 kHz did not show significant values. All the tested frequencies exhibited significant values for resistance and impedance. Only frequencies of 50 Hz and 500 kHz have shown significant value in phase angle. Capacitance has shown significant value in 50 Hz and again 0 values at 500 kHz in quality factor. For this mentioned category, the BMI was 0.003, BMR was 0.583, ECW and ICW was 0.294, TBW was 0.353 and FFM was 0.583. The noticeable aspect of this table is that most of the results exhibits 0 values which is not promising good significance among the patients and normal subjects in terms of diastolic pressure. So it is concluded that there is no relationship between the diastolic pressure in terms of bioimpedance and also the biocomposition parameters because of not significant values obtained. This is because the means are the same thus the null hypothesis cannot be rejected.

4.6 The Effect of Demographic Variables on the Bioimpedance Parameters

In this topic, important variables will be analyzed and these parts of results are also important for the comparison study. The aspects that are going to be presented here is going to be about, the effect of gender, age group, BMI group and the duration of disease.

4.6.1 The effect of gender on the Bioimpedance Parameters

Comparisons of bioimpedance parameters have been done among the high blood pressure patients along with the normal subjects. In this analysis, only the data for mode 3 (right leg right hand) is used. Comparison for hypertension stage 2 was excluded because there is no data available for that category mentioned.

Overall effects of the gender on the bioimpedance parameters of systolic pressure between prehypertension patients and normal subjects at different frequencies have been studied. According to the Table 46, reactance at 50 kHz and 500 kHz did not show significant value. For resistance, only value at 5 kHz has shown significance. In impedance, reading at the frequency of 50 Hz, 5 kHz and 50 kHz have shown significant value while in phase angle value at 50 Hz, 50 kHz and 100 kHz did not show significant value. In the case of capacitance, value at 5 kHz and 200 kHz did not show significant value. In quality factor, value at the frequency of 100 and 200 kHz did not show significant value. It is to be noted that 5 kHz has reported good significance compared to other frequencies which has jumbled values of significance. In comparing the effect of gender on bioimpedance parameters, 5 kHz seemed to be helpful for the comparison. BMI also has shown significance in this section meaning that the BMI of the gender (male and female) did exhibit differences in terms of their means which is not the same with others. For this mentioned category, the BMI was 0.004, BMR was 0.164, ECW was 0.254, ICW was 0.263, TBW was 0.000 and FFM was 0.164. For the study of diastolic pressure from Table 47, reactance at 50 kHz and 500 kHz did not show significance. Resistance at 200 kHz and 500 kHz did not reveal significant value. The results for impedance has shown that value at the frequency of 5 kHz and 500 kHz did not exhibit significant value. This time 50 Hz seemed to be helpful when diastolic pressure was used to compare the values between the genders. For phase angle, value at the frequency of 50 Hz has shown significant value. Capacitance has shown significance at 5 kHz and 50 kHz whereas in quality factor, values at the frequency of 50 kHz, 100 kHz and 200 kHz did not show significance. For this mentioned category, the BMI was 0.137, BMR was 0.399, ECW was 0.001, ICW was 0.001, TBW was 0.123 and FFM was 0.399.

From this not much interrelationship can be seen due to inconsistency of the results obtained. No relationship was noticed among the bioimpedance parameters and so for the biocomposition parameters. It is to be noted that only extracellular water and intracellular water exhibited significance for the aspect of gender using diastolic pressure. For the two parameters, their mean are not the same with others so comparison of gender can be done in terms of intracellular water and extracellular water.

4.6.2 The effect of age groups on the Bioimpedance Parameters

The effect of age group on the bioimpedance paremeters was studied in detail based on the Table 52 and Table 53. Overall effect of age group on the bioimpedance parameters of the systolic pressure between prehypertension patients and normal subjects at different frequencies. For reactance, value at 5 kHz, 100 kHz and 200 kHz exhibited significant values, while for resistance, all the column came out with significant values except for 200 kHz. For the case of impedance, all the frequencies have significant values. For phase angle, 100 kHz and 200 kHz exhibited no significance. In capacitance, 100 and 500 kHz exhibited no significance. 50 kHz and 100 kHz have shown no significant value. For this mentioned category, the BMI was 0.016, BMR was 0.000, ECW was 0.024, ICW was 0.025, TBW was 0.000 and FFM was 0.000. based on the description, it can be concluded that frequency of 5 kHz and 50 kHz have shown tremendous significance meaning that their means are not the same compared to other values from other frequencies. So it can be said that these two frequencies for both systolic and diastolic pressure are having different range of values that makes them acceptable for the comparison process in future study.

Since age group is not a factor that is depending on the criteria of subject being patients or normal, overall effects have been discussed and more significant values were noted in this area. For the case of reactance in Table 52, it is difficult to conclude whether it is exhibiting the changes, but for other parameters such as resistance, impedance, phase angle, capacitance and quality factor the results were more optimistical. The same conclusion is to be drawn for table 53 which is representing the relationship between age group and diastolic pressure but for this time the problematic row fell in the category of capacitance which did not show much significance as mentioned at any frequency. It is also to be noted that frequency of 50 kHz is the best to refer because it is the column where almost all the frequency values have shown significant values. This is also applicable for body biocomposition parameters in which body mass index, basal metabolic rate, extracellular water, intracellular water, total body water and fat free mass did exhibit significant value in both Table 52 and 53. This is an obvious result showing that bioimpedance analysis is showing significant values to distinguish the age group.

4.6.3 The effect of BMI groups on the Bioimpedance Parameters

Another analysis has been studied study the effect of BMI readings on the bioimpedance parameters based on Table 60. Overall effect of BMI group 3 on the bioimpedance parameters have been tested between prehypertension patients and normal subject at different frequencies. In this category, all the values have exhibited significant value at all frequencies for reactance but for resistance and impedance, all frequencies exhibited significant values except for 200 kHz. In the case of phase angle, value for 50 Hz did not show significance. For capacitance, 50 kHz did not show significant value. For the aspect of quality factor, all the frequencies have shown that there are significant values for all the frequencies. Based on the description on the Table 60, it was noted that Body Mass Index did successfully exhibit significance on the bioimpedance parameters and biocomposition parameters. This is because, as mentioned before, only little insignificance has been noted which can be due to minor errors during measurement process. This is discussed in detail in next chapter. So it can be concluded that overall effect of BMI exhibited significance on bioimpedance parameters in terms of systolic pressure which was studied on both normal subjects and patients because their means are not the same especially at the frequency of 5 kHz and 50 kHz. Meanwhile, for the aspect of diastolic pressure (Table 62), not much satisfying results were obtained due to the random results with a mixture of significance and insignificance. Nothing much can be concluded from here because the pattern of the results cannot be understood due to the jumbled significances.

4.6.4 The effect of duration of disease on the Bioimpedance Parameters

Comparisons of bioimpedance parameters have been done among the high blood pressure patients along with the normal subjects in terms of duration based on Table 64. The duration was grouped into 4 main groups with designation of 0 for normal patient, 1 for patients possessing the disease for 1 to 4 years, number 2 for patients possessing the disease for 5 to 8 years, number 3 for patients possessing the disease for 9 to 12 years and number 4 for patients possessing the disease for about 13 to 16 years. Data from mode 3 (right leg right hand) was used. Only comparison for prehypertension was done due to data availability. Other than that analysis can only be done for patients who possess the disease for 1 to 4 years (number 1) due to data availability. Based on Table 64, for reactance, frequency of 5 kHz and 50 kHz show no significance whereas for resistance, frequencies of 5 kHz and 500 kHz have shown no significance as well. In the case of impedance, frequency of 5 kHz exhibited no significance. For the aspect of phase angle, all the frequencies have exhibited significant value. In capacitance, values at the frequencies of 5 kHz and 200 kHz exhibited no significance. In terms of quality factor, at 5 kHz and 500 kHz exhibited no significance. For this mentioned category, the BMI was 0.078, BMR was 0.061, ECW was 0.095, ICW was 0.095, TBW was 0.053 and FFM was 0.061. based on the description it is clear that some frequencies such as 50 Hz, 100 kHz and 200 kHz exhibited significance meaning that it is not very promising to say that BMI is showing an effect on bioimpedance parameters based on the systolic pressure. It is also to be noted that none of the biocomposition parameters exhibited significance which is indicating no relationship among the effect of BMI on bioimpedance parameters in terms of systolic pressure. Again, based on Table 65, more insignificance was noted than significant values. In the case of biocomposition parameters none of the values were significant. So diastolic pressure have no relationship between BMI and bioimpedance parameters. So as a discussion, using systolic pressure, it is to be noted that this time 50 Hz and 100 kHz have shown good significance compared to other frequencies. This means that patients who were having high blood pressure for 4 years or below can use the frequency of 50 Hz and 100 kHz for their comparison purposes of bioimpedance parameters but not for the biocomposition analysis. Unfortunately, results were not supporting enough for the diastolic pressure analysis among the patients due to insignificance obtained. This means that, compared to systolic pressure, dystolic pressure has more common means with other readings because their results are all having value of p less than 0.05.

CHAPTER 5

Conclusions and Suggestions

5.0 Introduction

The data presented is very much numerical and statistical which emphasizes on the value of significance. There are some differences that can be noticed between patients and the normal subject, so the Null hypothesis, *Ho* is rejected. Most of the results which consist of bioimpedance and body composition parameters show significant difference between patients and also the normal subject. This is much more optimistically delighting because when there are significant differences, the Bioimpedance Analyzer can be used for the detection of high blood pressure in humans.

5.1 Conclusions

Few conclusions have been drawn based on the discussions mentioned in previous chapters. All the conclusions are based on the study done in this research.

5.1.1 Analysis of variance of Normal and Patients subjects tested with different modes of electrodes

Analysis of variance was used to compare the significant of position of electrodes among normal subject and patients. The reason to perform this test is to compare which mode is contributing the best significance so that a standard or measurement mode can be known. According to the results, some significant values fall below 0.05 ($p < 0.05$) indicating that the null hypothesis (H_o) can be rejected because the means are not the same. This shows that the electrode position affects the data obtained. Thus determining which mode (electrode position) is the best for measurement is necessary. For this, post hoc test is necessary. Through post hoc test, similar means can be detected and conclusion on which mode is giving significant values can be also known. Based on the data and discussion so far, mode 1 exhibited the best significance for the study.

5.1.2 Independent T-test of Normal and Patient subjects tested with different modes of electrodes

Independent T test has been done to compare the significant values at each frequency generally among patients and normal subjects for all the modes, and also between the modes separately. All the frequencies prove that mode 1 exhibit good significant differences compare to other modes. This means that the means are not the same, thus we can know the difference range of values compared to other modes. This suggested that mode 1 possessed different modes than other modes thus the null hypothesis can be rejected. It is also to be noted that biocomposition parameter, except for BMI, other such as BMR, ECW, ICW, TBW and FFM all exhibited significant values meaning that compared to frequency readings, biocomposition parameters are easily compared in terms of significance using mode 1 at mostly at the frequency of 50 kHz.

5.1.3 Comparison of modes of measurements for normal subject, subjects with Prehypertension and subjects with hypertension

ANNOVA test has been used to do comparison among the position of electrode (modes used for the measurement) for normal subjects, subjects with prehypertension and subjects with hypertension. No test was performed for patients in hypertension stage 1 and hypertension stage 2 due to few data. Generally, mode 1 shown not significant value ($p > 0.05$), mode 2 at this frequency has shown 0 value, significant value at mode 3 and again 0 value in mode 4. Since the results for normal patients did not exhibit consistency, the null hypothesis (H_o) cannot be rejected meaning the means are the same. For Prehypertension patients, 50 Hz at mode 1 gave the best significance compared to other frequencies which gave only 0 values at most meaning that the null hypothesis can be rejected for all modes except for mode 4. This is a proof to say mode 1 is effective enough to do the measurements process at the frequency of 50 Hz. Mode 1 at all the frequency has shown good significant except at 5 kHz. That may be because of low frequency level. Biocomposition parameters mostly have shown non consistency in terms of significance. So it is difficult to compare efficiency of the modes. Based on data obtained, starting from reactance to quality factor, most of the value was 0 for almost all the frequencies. Consistency of the values in terms of significance can be noted meaning that they possessed more significant values than not significant values other than just 0. Since the majority of the readings exhibit 0 values, it is not valid to compare the efficiency of the position of electrodes for both patients and normal subject. For the case of BMR, ECW, ICW, TBW and FFM all exhibited not significant values meaning that compared to frequency readings, biocomposition parameters are not worth of having relationship among each other between patients and normal subjects.

5.1.4 Comparison of Bioimpedance Parameters between normal subjects and Prehypertension patients at different frequencies.

Independent t test has been used in this study to compare the bioimpedance parameter of the systolic pressure between normal subjects with prehypertension subjects at different frequencies. In the first aspect, comparisons of bioimpedance parameters of the systolic pressure between normal subjects with prehypertension patients were done at different frequencies. For this mentioned category, the BMI was 0, BMR was 0.006, ECW and ICW was 0.18, TBW was 0 and FFM was 0.006. Based on the analysis done, it was noticed that there are some consistency between resistance and impedance meaning that it is having significant readings. This also means that there are differences between patients' reading and normal subjects' reading which makes it to be efficient to compare these two parameters, resistance and impedance should be considered for further studies. As mentioned before, not promising results were obtained for the biocomposition parameters as there is no significance of reading for both normal and patient subjects. For the aspect of the comparisons of bioimpedance parameters of the diastolic pressure between normal subjects with prehypertension at different frequencies, all the tested frequencies exhibited significant values for resistance and impedance. Only frequencies of 50 Hz and 500 kHz have shown significant value in phase angle. For this mentioned category, the BMI was 0.003, BMR was 0.583, ECW and ICW was 0.294, TBW was 0.353 and FFM was 0.583. The noticeable aspect of this table is that most of the results exhibits 0 values which is not promising good significance among the patients and normal subjects in terms of diastolic pressure. So it is concluded that there is no relationship between the diastolic pressure in terms of bioimpedance and also the biocomposition parameters because of not significant values obtained. This is because the means are the same thus the null hypothesis cannot be rejected.

5.1.5 The effect of gender on the on the Bioimpedance parameters

Comparisons of bioimpedance parameters have been done among the high blood pressure patients along with the normal subjects. In this analysis, only the data for mode 1 (right leg right hand) is used. Comparison for hypertension stage 2 was excluded because there is no data available for that category mentioned. Overall effects of the gender on the bioimpedance parameters of systolic pressure between prehypertension patients and normal subjects at different frequencies have been studied. It is to be noted that in general, 5 kHz has reported good significance compared to other frequencies which has jumbled values of significance. In comparing the effect of gender on bioimpedance parameters, 5 kHz seemed to be helpful for the comparison. BMI also has shown significance in this section meaning that the BMI of the gender (male and female) did exhibit differences in terms of their means which is not the same with others. For this mentioned category, the BMI was 0.004, BMR was 0.164, ECW was 0.254, ICW was 0.263, TBW was 0.000 and FFM was 0.164. For the study of diastolic pressure, the results for impedance have shown that value at the frequency of 5 kHz and 500 kHz did not exhibit significant value and 50 Hz seemed to be helpful when diastolic pressure was used to compare the values between the genders. For this mentioned category, the BMI was 0.137, BMR was 0.399, ECW was 0.001, ICW was 0.001, TBW was 0.123 and FFM was 0.399. From this not much interrelationship can be seen due to inconsistency of the results obtained. No relationship was noticed among the bioimpedance parameters and so for the biocomposition parameters. It is to be noted that only extracellular water and intracellular water exhibited significance for the aspect of gender using diastolic pressure. For the two parameters, their mean are not the same with others so comparison of gender can be done in terms of intracellular water and extracellular water.

5.1.6 The effect of age groups on the Bioimpedance parameters

Overall effect of age group on the bioimpedance parameters of the systolic pressure between prehypertension patients and normal subjects at different frequencies have been studied in detail. For this mentioned category, the BMI was 0.016, BMR was 0.000, ECW was 0.024, ICW was 0.025, TBW was 0.000 and FFM was 0.000. Based on the description, it can be concluded that frequency of 5 kHz and 50 kHz have shown tremendous significance meaning that their means are not the same compared to other values from other frequencies. So it can be said that these two frequencies for both systolic and diastolic pressure are having different range of values that makes them acceptable for the comparison process in future study. Since age group is not a factor that is depending on the criteria of subject being patients or normal, overall effects have been discussed and more significant values were noted. For the case of comparison of systolic pressure, it is difficult to conclude whether it is exhibiting the changes for reactance, but for other parameters such as resistance, impedance, phase angle, capacitance and quality factor the results were more optimistic. The same conclusion is to be drawn the relationship between age group and diastolic pressure but for this time the problematic row fell in the category of capacitance which did not show much significance as mentioned at any frequency. It is also to be noted that frequency of 50 kHz is the best to refer because it is the column where almost all the frequency values have shown significant values. This is also applicable for body biocomposition parameters in which body mass index, basal metabolic rate, extracellular water, intracellular water, total body water and fat free mass did exhibit significant value. This is an obvious result showing that bioimpedance analysis is showing significant values to distinguish the age group thus the null hypothesis is rejected.

5.1.7 The effect of BMI groups on the Bioimpedance parameters

It was noted that Body Mass Index did successfully exhibit significance on the bioimpedance parameters and biocomposition parameters. This is because, as mentioned before, only little insignificance has been noted which can be due to minor errors during measurement process. So it can be concluded that overall effect of BMI exhibited significance on bioimpedance parameters in terms of systolic pressure which was studied on both normal subjects and patients because their means are not the same especially at the frequency of 5 kHz and 50 kHz. Meanwhile, for the aspect of diastolic pressure, not much satisfying results were obtained due to the random results with a mixture of significance and insignificance. Nothing much can be concluded from here because the pattern of the results cannot be understood due to the jumbled significances.

5.1.8 The effect of duration of disease on the Bioimpedance parameters

Data from mode 1 (right leg right hand) was used. Only comparison for prehypertension was done due to data availability. Other than that analysis can only be done for patients who possess the disease for 1 to 4 years (number 1) due to data availability. For this mentioned category, the BMI was 0.078, BMR was 0.061, ECW was 0.095, ICW was 0.095, TBW was 0.053 and FFM was 0.061. Based on the description it is clear that some frequencies such as 50 Hz, 100 kHz and 200 kHz exhibited significance meaning that it is not very promising to say that BMI is showing an effect on bioimpedance parameters based on the systolic pressure. It is also to be noted that none of the biocomposition parameters exhibited significance which is indicating no relationship among the effect of BMI on bioimpedance parameters in terms of systolic pressure. In the case of biocomposition parameters none of the values were significant. So again, diastolic pressure have no relationship between BMI and bioimpedance parameters. So as a discussion, using systolic pressure, it is to be noted that this time 50 Hz and 100 kHz have shown good significance compared to other frequencies for patients with high blood pressure below 4 years. This means that patients who were having high blood pressure for 4 years or below can use the frequency of 50 Hz and 100 kHz for their comparison purposes of bioimpedance parameters but not for the biocomposition analysis. Unfortunately, results were not supporting enough for the diastolic pressure analysis among the patients due to insignificance obtained. This means that, compared to systolic pressure, dystolic pressure has more common means with other readings because their results are all having value of P more than 0.05.

5.2 Limitations

Subject collection was very challenging because the task was to find patients who possesses only high blood pressure and without any other diseases in them. Other than that, getting approval from some hospitals was more challenging too. The number of subjects for both normal and patients in this study was 70. This amount is not good enough for drawing concrete conclusions. However, conclusions were still made using the data available. Consistency of the subjects may be the other limitation. Basically subjects were required to be in empty stomach before the testing was done. But this was made sure only by verbal conversation. In addition, the measurement processes for this study have to be taken outside the university which limits the use of equipment and the availability of the equipment also was one of the factors. Reluctance of some patients to cooperate for the study is also something to be considered as one of the limitation for this study. This was aided with the testing period which is considered to be long (25-30 minutes). Subjects also tend to make movements while the measurement was being done. That can affect the reading. It is also important to emphasize on all this limitations which can potentially affect the overall outcome of the study.

5.3 Recommendations and Future works

Increasing the subjects for this kind of study will be a good idea for future researches so that we can have wide age range of subject and more precise data can be obtained. The findings of this study show that there are changes noticed in bioimpedance and body composition parameters between normal subjects and patients. After the analysis, it was noticed that overall reactance has increased from patient to normal. In the case of impedance, normal subjects have shown an increased value compared to the patients while for phase angle, patients again have shown increased value. In the case of capacitance, patients have shown increased value than the normal subjects. For quality factor, normal subjects have shown decreased value when compared to patients. About the body composition parameters, for Body mass index, normal subjects and patients have shown no significant difference. For basal metabolic rate, normal subjects exhibited lesser value compared to the patients, increased value for normal subjects in extracellular water and intracellular water. Total body water and fat free mass have shown decreased value for normal subjects.

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