# THE EFFECTS OF DIALYSIS ON BODY BIOIMPEDANCE

**NURULNISA NOR AZMAN**

**FACULTY OF ENGINEERING**

**UNIVERSITY OF MALAYA**

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University of Malaya

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**NURULNISA NOR AZMAN**

**RESEARCH REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ENGINEERING (BIOMEDICAL)**

**FACULTY OF ENGINEERING**

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**ABSTRACT**

Recently, hemodialysis has been chosen as a treatment-of-choice for individual which having the kidney problem or kidney impairment. The dialysis machine which works based on the principle of diffusion of solutes (sodium, potassium, urea, etc) and water content through the semipermeable membrane. It removes any wastes in the blood and the excessive water in the body so that body could maintain its fluid and the body composition. The effectiveness of the dialysis treatment to the human body can be determined through the technique known as Bioelectrical Impedance Analysis (BIA) that is inexpensive, non-invasive and promising method. BIA is frequently employed technique to measure the parameter include Resistance and Reactance, mass distribution such as Body Cell Mass, Extracellular Cell Mass, Lean Body Mass, Fat Mass, Body Mass Index (BMI) and Basal Metabolic Rate (BMR). It also can be used to determine the water compartments of the body which includes Intracellular Water, Extracellular Water and Total Body Water (TBW). This technique involved the application of small current through the human body by using four surface electrodes. This measurement was conducted on 50 patients with kidney problem that underwent for the dialysis treatment at the Dialysis Center. The body bioimpedance parameters were measured by using the impedance analyzer before and after the dialysis treatment. The data obtained was analyzed by using the commercial statistical software, Statistical Package for the Social Sciences (SPSS). The ANOVA and paired t-test were conducted to compare the result before and after the dialysis treatment. The result showed that there was an improvement of body bioimpedance parameters after the patient receiving the dialysis treatment. BIA analysis provides an important understanding as a


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measurement tool to study about the body composition and physiology during the dialysis treatment. In addition, this analysis can be used to monitor and evaluate the body bioimpedance directly. It also can contribute to the better planning and strategies to have an effective dialysis treatment so that the patient which receiving the dialysis treatment would have great value of body bioimpedance and healthy lifestyle.

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# ABSTRAK

Baru-baru ini, hemodialisis telah dipilih sebagai rawatan pilihan bagi individu yang mempunyai masalah buah pinggang atau kecacatan buah pinggang. Mesin dialisis ini berfungsi berdasarkan prinsip penyerapan bahan larut (natrium, kalium, urea) dan kandungan air melalui membran separa telap. Ia memindahkan bahan buangan di dalam darah dan air yang berlebihan di dalam badan supaya badan boleh mengekalkan cecair dan komposisi badan. Keberkesanan rawatan dialisis kepada tubuh badan manusia boleh ditentukan melalui teknik yang dikenali sebagai Analisis Impedans Bioelektrik (BIA) yang murah, kaedah yang tidak invasif dan mudah. BIA adalah teknik yang digunakan untuk mengukur parameter termasuk rintangan dan regangan, perataan jisim seperti Jisim Sel Badan, jisim luar sel, jisim tanpa lemak, jisim lemak, Indeks Jisim Badan (BMI) dan Kadar Metabolik Pangkal (BMR). Ia juga boleh digunakan untuk menentukan komposisi cecair dalam tubuh termasuk cecair intraselular, cecair luar sel dan jumlah air dalam badan (TBW). Teknik ini melibatkan penggunaan arus elektrik yang kecil melalui badan manusia dengan menggunakan empat elektrod permukaan. Pengukuran ini telah dijalankan ke atas 50 pesakit dengan masalah buah pinggang yang menjalani rawatan dialisis di Pusat Dialisis. Parameter bioimpedans diukur dengan menggunakan alat analisis impedans sebelum dan selepas rawatan dialisis. Data yang diperolehi telah dianalisis dengan menggunakan perisian komersial statistik, Pakej Statistik untuk Sains Sosial (SPSS). ANOVA dan ujian t-berpasangan telah dijalankan untuk membandingkan keputusan sebelum dan selepas rawatan dialisis. Hasilnya menunjukkan bahawa terdapat peningkatan parameter bioimpedans badan selepas pesakit menerima rawatan dialisis. BIA analisis menyediakan


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satu pemahaman yang penting sebagai alat pengukuran untuk mengkaji tentang komposisi badan dan fisiologi semasa rawatan dialisis. Di samping itu, analisis ini boleh digunakan untuk memantau dan menilai bioimpedans badan secara terus. Ia juga boleh menyumbang kepada perancangan dan strategi yang lebih baik untuk mendapat rawatan dialisis yang berkesan supaya pesakit yang menerima rawatan dialisis akan mempunyai bioimpedans badan yang positif dan gaya hidup yang sihat.

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| BIA | - | Body Impedance Analysis |
| BCM | - | Body Cell Mass |
| BMI | - | Body Mass Index |
| BMR | - | Basal Metabolic Rate |
| ECW | - | Extracellular water |
| ECM | - | Extracellular mass |
| FM | - | Fat mass |
| FFM | - | Free-fat-mass |
| HIV | - | Human Immunodeficiency Virus |
| ICW | - | Intracellular water |
| LBM | - | Lean body mass |
| MF-BIA | - | Multi frequency bioimpedance analysis |
| SF-BIA | - | Single frequency bioimpedance analysis |
| R | - | Resistance |
| TBW | - | Total Body Water |
| WHR | - | Waist-Hip Ratio |
| Xc | - | Reactance |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Kidney is one of the important organs of human body that involved in the excretion system. The main function of the kidney is to filter large amounts of fluid from the bloodstream which eliminate nitrogenous wastes, drugs, and toxins from the body and also to maintain the blood volume by regulating the proper balance in the blood between salts and water (Rizzo, D.C., 2006). Therefore, there is a very important task to take a good care of kidney from being damaged since it plays a major role to maintain a great state of a body health.

Many conditions that interfere with the kidney function can result to the kidney failure. There are many types of disorder related to kidney. By example, glomerulonephritis and kidney stones which affect the effectiveness of the kidney to perform its work. When the kidney failed to perform its function, it will lead to the accumulation of toxic in the body, blood acidosis and if not treated, it can cause death.

Individual who suffered from the kidney failure can be treated by procedure known as dialysis or hemodialysis. In this procedure, the dialysis machine filter substitutes for the excretory functions of the kidney and to remove the excessive water from the body since the damaged kidney cannot excrete urine.

### 1.1.1 Dialysis

Dialysis is a process of removal of certain solutes from a solution through use of a selectively permeable membrane and restoring fluid and electrolyte balance. This is performed to cleanse blood when a person's kidneys impaired due to the disease or injury that limit the kidney to function adequately (Tortora *et.al.,* 2004). There are two

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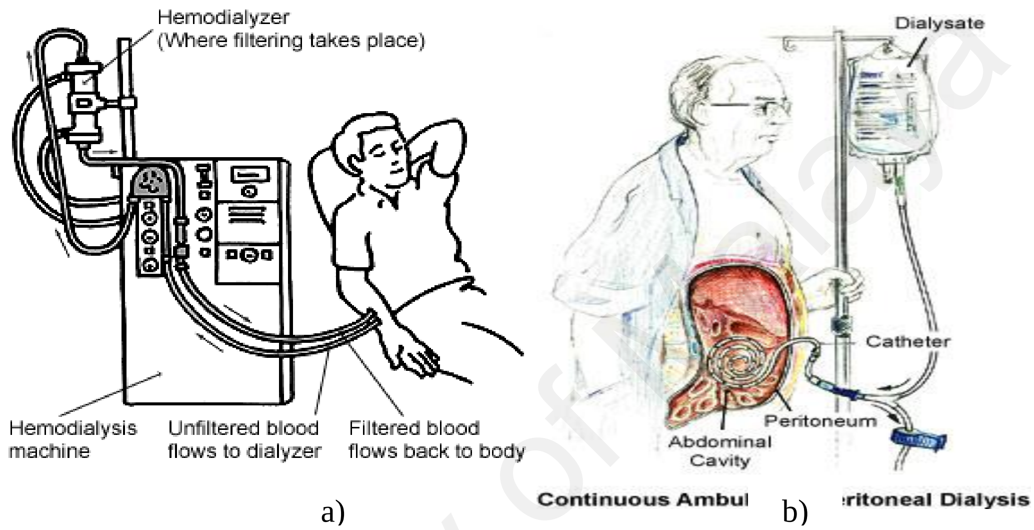
major types of dialysis include hemodialysis and peritoneal dialysis. Hemodialysis directly filters the patient's blood which flows through tubing made of selectively permeable dialysis membrane outside the body. Peritoneal dialysis involved the using of peritoneum surrounding the abdominal cavity and it acts as a dialyzing membrane (Lemone and Burke, 2004).




a) b)

**Figure 1.1:** Differences between a) hemodialysis and b) peritoneal dialysis

Dialysis caused the shifting from intracellular to the extracellular compartment. Due to the kidney impairment, it leads to the loss of lean tissue amd malnutrition which alter the normal body composition (Vine *et.al.,* 2010). Patient with having the dialysis treatment has showed good physiological changes of the body which include the blood flow, body composition and it contributes to the maintaining of the homeostasis in the body. The body composition can be determined by using a technique known as bioimpedance analysis (BIA). Bioimpedance analysis has recently been used since it such a simple and indirect, convenience, and inexpensive method to analyze the body composition and to measure the body fluid volumes.

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### 1.1.2 Bioimpedance

Recently, bioimpedance analysis has been used as a preferred technique to assess the human body compositions which include bioelectrical tissue conductivity, mass distribution and water compartments (Ibrahim *et.al.,* 2005). Bioimpedance refers to the response of living organism with external supplied electrical current and this type is to measure the flow of electric current into the tissues. Bioimpedance plethysmography particularly blood flow and bioelectrical impedance analysis or BIA are useful non-invasive method in measuring the bioimpedance. The electrical activity of body tissues is differ between each other by example tissues rich in water and electrolytes will exhibit high electrical conductivity meanwhile fat tissue does not (McDonald *et.al.,* 1993).

According to Watson (2002), critical cell function normally in the membrane potential of 70 mV. The value of electrical supplied to the tissue affect the general physiological activity of the cells. In the other words, the increasing value of electrical supplied will enhance the activity of the cell. Electrical supplied can be obtained from variety of sources such as electromagnetic wave, electrical or electrophysical or mechanical source. Different types of tissue or cells may need different types of energy sources.

There are two types of mode of delivering of electrical current to the cell (Watson *et.al.,*2002). There are higher energy therapies and low energy therapies. Higher energy therapies seem to be a major mode of delivery of electrical current to stimulate the electrical effects. The flow of electrical current into the tissue will trigger the polarization and depolarization of the nerve membrane. This will create an action potential of the nerve cells. Interferential therapy, transcutaneous electrical nerve stimulation and faradic stimulation are the types of electrical stimulation.

Lower energy therapies are using the much lower energy levels. It includes the low intensity laser therapy, pulsed-short wave therapy and ultrasound that essential in an

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increasing of cell membrane activity which basically affects on the ion gates or channel within the cell membrane. These types of therapies are useful to give the changes in the state of the cell without overheating effects (Watson, 2002). Therapeutic effects by using ultrasound have demonstrated on the clinical applications by example in tendons and range of other musculoskeletal tissue. This showed that significant changes in the tissue level can be achieved by non-thermal effects to give the therapeutic benefits.

The general principle of this BIA analysis is that the very small electrical signal is allowed to be carried by the water and fluid within the body. The greatest impedance is showed by the fat tissue since the water content is between 10% - 20%. Fat free mass which contains 70% – 75% of water shows the lower impedance since the electrical signal can be transmitted easily without any barrier. This impedance measurement can be used to determine the percentage of the body fat and also the hydration level.

### 1.1.3 BIA Parameters

The BIA parameters include the resistance, R and the reactance Xc. BIA determines the body tissue bioimpedance by applying the electrical current which the resistance (R) is the pure opposition of the tissue to the flow of electron and it is correlated to Total Body Water (TBW). Resistance can evaluate the total amount of water in the body. Large amounts of water content can be represented by the low resistance with high conductivity of electricity. The ability of a cell to store energy is known as Reactance (Xc), which produce the capacitance of cell membranes and tissue interfaces (Guida,B. *et.al.*,2000). High reactance tells that the body can store the energy easily. Phase angle is measured as an indicator of cellular health and integrity. This phase angle is depending on total body resistance and reactance regardless body height, weight and body fat. The normal value of phase angle is lying between 6 to 8 degrees. When a phase angle is lower than a 5 degree, it indicates an extremely deficiency of energy. The



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phase angle will decrease as the age increases and it can reach approximately 4 or less when we die. Besides that, phase angle or the angular transformation of Xc/R ratio can be obtained which related to the extent of lean body mass.

The mass distribution include the body cell mass, extracellular mass, lean body mass, fat mass, body mass index (BMI) and Basal Metabolic Rate (BMR). The TBW is related to fat-free-mass (FFM) which contribute average of 73.2% of water in healthy individuals (Jaffrin, M.Y. and Morel, H., 2008). The FFM is the sum of the TBW, minerals, proteins and glycogens. The lean body mass (LBM) composed of the FFM and the essential lipid present in the spinal cord of the brain and also certain organs (Ramos, J. *et.al.*, 2009). The FFM is considered as everything that is not body fat. Single-frequency BIA (SF-BIA) can be used to determine the FFM which shows the hydration is normal.

For the fluid assessment, it tells about the fluid level and its distribution in the body. Extracellular water (ECW) and intracellular water (ICW) is contributing to the TBW. Intracellular water (ICW) is amount of water presence in the cells. Muscle and organs cell contain more water than fat cells. If the ICW value is closer to the ideal, it indicates that more cells will contribute to the metabolism. Extracellular water is the amount of water presence outside of the body cells such as blood plasma and lymphatic fluid. The excessive ECW can cause several conditions by example edema. Edema leads to the reduction of oxygen delivery to the cell thus can cause cell death.

The total body water (TBW) is the summation of amount of water presence in the body. When there is a lot of fluid loss from the body due to the certain conditions such as dehydrated, the TBW will be low. When the fluid is retained in the body due to the renal problem, the TBW will be high. When a constant proportion of TBW is in normal condition, the 50 kHz SF-BIA basically indicates the ECW space. When the

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ECW/TBW ratio is increased, this shows edema and may due to the malnutrition (Kyle *et.al.*, 2004).

The protein rich component of the body is known as the Body Cell Mass (BCM) which involved in the body cell metabolism. All the metabolic processes which include oxygen consumption, synthesis of protein and others are occurred within the body cell mass. The metabolically inactive component of the body is called as Extracellular Mass (ECM) which includes the bone minerals, blood plasma and extracellular water. This extracellular mass is located outside of the cellular compartment or outside the body cell mass. BCM and ECM are used to obtain the ECM/BCM ratio. A low BCM/ECM ratio indicates a high ratio of body cell which is active to extracellular mass. Normal value is almost reached to 1.0 which shows a 50/50 distribution of body cell mass and extracellular mass.

Basal Metabolic Rate (BMR) shows the number of calories consumed and metabolized at a normal resting state over a 24 hours period. The metabolic rate is determined by the cells that are producing the oxidative energy. When many cells are producing the more energy, the metabolic rate will be higher. The lean body mass can detect the BMR since only the lean body mass metabolizes. The greater the lean body mass, therefore the greater the rate of caloric expenditure.

Body Mass Index (BMI) is a measurement of person's weight relative to their height. BMI can be used to estimate the obesity at a risk factor (Guida *et.al.*, 2001) as an indicator of accumulation of fat in the body. High BMI value increased the risk of the developing such diseases by example hypertension, cardiovascular and diabetes.

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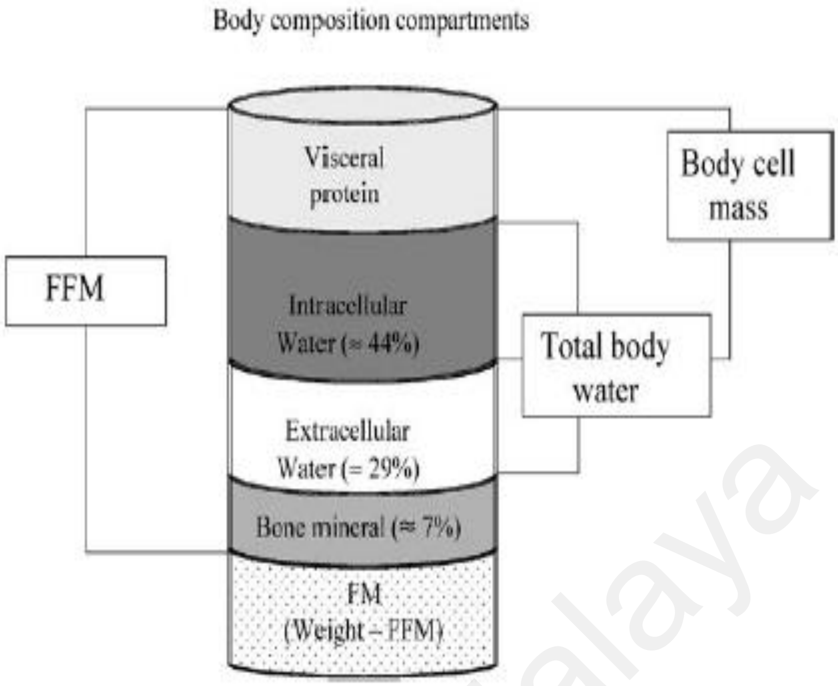


**Figure 1.2** Schematic diagram of fat-free mass (FFM), total body water (TBW, intracellular water (ICW), extracellular water (ECW) and body cell mass (BCM) (Kyle *et.al.*, 2004)

Those parameters that have been discussed above are really important in order to study the effects of dialysis on body bioimpedance. Since the patient's kidney is disabled to perform its function properly, therefore dialysis can help to maintain the physiological changed of the body.

## 1.2 Research Problem

This research was conducted to identify the positive effects of dialysis on body bioimpedance before and after the dialysis treatment. The dialysis may effect the body composition and water compartments since the kidney cannot regulate the body environment.

## 1.3 Problem Statement

The measurement was made on body composition according to the bioimpedance parameters before and after the dialysis treatment by using the impedance analyser BodyStat QuadScan 4000.

## 1.4 Objective of the Study

The objectives of this research are:

a) To study the effects of dialysis on body bioimpedance before and after the dialysis treatment
b) To study the bioimpedance parameters that were used in this study which include the total body water and total body mass.

## 1.5 Hypothesis of the Study

This study suggested that the patient who undergoes the dialysis treatment shows positive effects on body bioimpedance.

## 1.6 Scope of the Study

This study emphasizes on the effects of dialysis on body bioimpedance. Fourty seven patients were selected randomly at two different dialysis centres. The bioimpedance parameters that were measured include the Total Body Water, BMI, Total Body Fat and Basal Metabolic Rate. The results obtained were analyzed by using the SPSS software and the t-test was conducted to compare the bioimpedance parameters before and after the dialysis treatment.

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## 1.7 Significance of the Study

People with kidney impairment can be helped by the dialysis treatment which to maintain the body composition by filtering out the wastes from the blood. Dialysis seems to be a common treatment nowadays since it is convenient and inexpensive especially for older people. In Malaysia, this treatment is going to be a "treatment of choice" rather than kidney transplant due to the lack of donor and in fact receiver's name should be listed in the waiting list for the donor and this will take longer time.

This study also contributes to the knowledge of body bioimpedance parameters which is important in maintaining the nutritional status of body for those having the renal problem. Since BIA is an inexpensive, convenient method, this method can determine the body composition easily and detect the physiological changes of the body before and after the dialysis treatment. These parameters can ensure the great condition of the body and how to maintain good state of health.

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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Researches regarding bioimpedance analysis have been a topic of discussion for the recent years since its greatest contribution for human health in estimation of body composition.Diseases can change the body composition and due to this, it is good to monitor these changes for early diagnosis and treatment. This technique is an objective, non invasive and promising tool to detect early change in hydration status and nutritional deficiency such as in renal disease (Saxena, A. and Sharma, R.K., 2005).

Bioimpedance technique relies upon the using of the bioimpedance analyzer which assesses the changes of body parameters such as body impedance (Z), phase angle (α), resistance (R) and reactance (Xc). These parameters are been used to estimate the body compositions such as total body water, total body fat, body mass index and basal metabolic rate.

Many research topics have been focused on bioimpedance in various types of body condition and clinical situations. Body composition by example Total Body Water is estimated by the opposition to the flow of electrical current through body tissue which is this value will be used to estimate the fat free mass.

Bioimpedance parameters can predict the clinical condition of the human body. According to Jaffrin and Morel, (2008), healthy individuals exhibit an average of 73.2% of total body water. Independent measurements of FFM and TBW can estimate dehydration especially in elderly person and athletes after vigorous training.

Evaluation of diuretic therapy can be done by measuring the TBW. Patient which undergo the treatment of dialysis will accumulate fluid between treatments. Excessive

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fluid can determine the amount of fluid they should loose by ultrafiltration and how this fluid loss is distributed between ECW and ICW. Besides that, BCM measurement is proposed to check the morbidity of patients infected by HIV.

In the body bioimpedance analysis, it used the device known as bioimpedance analyzer (QuadScan 4000) and the surface long electrodes which stick onto the body of the subjects. The bioimpedance analyzer will record the value of each trial and gives the direct measurement of the body composition with its proprietary equations discussed in this chapter.

## 2.2 Principles of Bioimpedance

Body tissues basically have a unique property which it can conduct electricity. The resistance (R) is proportional to its length (L) and inversely proportional to its cross sectional area (A) as shown in the Figure 2.1 (Kyle *et.al.*, 2004 and Massalska *et.al.*, 2010.). Assumptions has been made showed that the body can be represented by a single cylinder and the volume is a function of resistivity (*p*) x length$^2$/impedance (Z) (Kushner *et.al.*, 1996).

Impedance (Z) of the body involved the two components, Resistance (R) and the capacitive reactance (Xc) of the conducting substance (Saxena, A. And Sharma, R.K., 2005). The low resistance of electrical pathway is showed by the conductive tissue with large amount of water while other tissue by example fat and bone showed very high resistance. Capacitive reactance is the direct measurement of the intracellular volume and it is produced by the tissue interface and the cell membrane.



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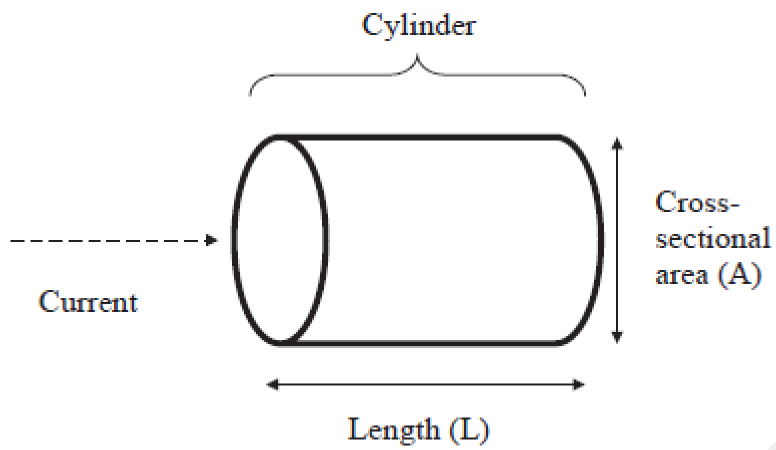


**Figure 2.1** Principles of BIA from physical characteristics to body composition (Kyle *et.al.*, 2004)

Based on the Figure 2.1, assumed the human body as a cylinder, therefore the following impedance value can be obtained:

$$\mathbf{Z = pL/A\ (1)}$$

Where p = specific resistivity of the conductor

L = length of the conductor

A = cross section area of the conductor

The Z value is depending on the fluid volume of the body compartment and also the resistivity of the body, include the presence of the hemotocrit, sodium, potassium chloride and also bicarbonate ions (Kushner *et.al*., 1996). The high value of Z indicates that there is barrier that resists the flow of the electricity in the human body cell by example impedance value is high in fat cell due to the high resistance by the fat cells. The low value of Z shows low resistance, hence the flow of electricity is smooth such as in the cell containing more water which induce the fast flow of electricity in the human body cell.

In the case of dialysis, the value of Z is increased due to the increasing in hematocrit, changes in intracellular and extracellular water distribution and also decreasing amount of total body water. A study has been conducted by Kushner *et.al.*, (1996) to compare

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the body composition between dialysis patient and normal people. The study showed that the ICW of all dialysis patients relatively lower than normal caused by the depletion of FFM.

Relationship can be obtained between the impedance and the volume of water which can be measured by conducting the electrical current due to the electrolytes present in the body. Hence the following equation can be obtained:

**Resistance (R) = pL/A = $pL^2$/V (2)**

and

**volume (V) = $pL^2$/R (3)**

where p is the resistivity of the conducting material and V equals AL (Reijven-Cox, P.L. and Soeters, P.B., 2000, Kyle *et.al.*, 2004, Ibrahim *et.al.*, 2005, Mager *et.al.*, 2008 ). From equation (2), it noticed that the resistance is inversely proportional to the volume of the container.

This means that when the volume of the container is high, the resistance will be low since more space for the current to move without barriers that limit their flow.

Some of the electrical circuits have been designed to represent the biologically electrical circuit in the human body which arrange in series or parallel as shown in the Figure 2.2. The commonly used circuit is which the arrangement R of the extracellular fluid is in the parallel circuit to the second arm of the circuit. This circuit consists of capacitance and R of the intracellular fluid in series. These two parameters, resistance and capacitive reactance can be used to determine the body composition as shown below:

$$Z = \frac{XcR}{\sqrt[2]{Xc^2 + R^2}}$$

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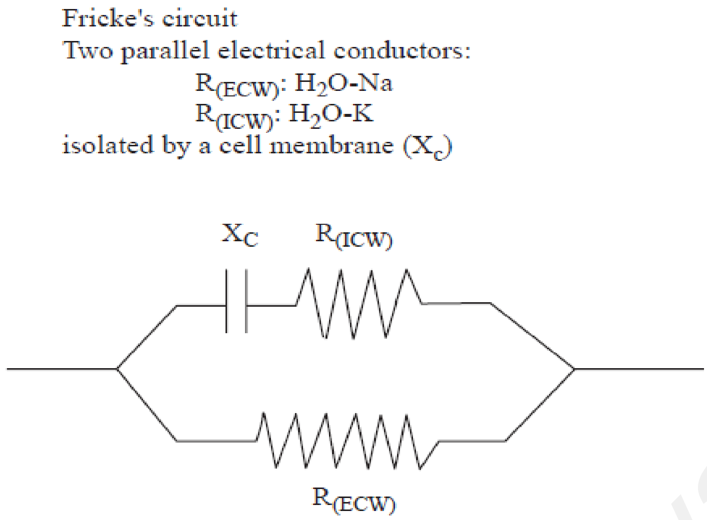


**Figure 2.2** The common circuit in human body that arranged in parallel or series circuit (Kyle *et.al.*, 2004 and Talluri.A., and Maggia, G., 1995)

Both capacitance and R give very vital information since they reflect different electrical properties of tissues due to the certain diseases, nutritional and hydration status.

Phase angle occurred due to the capacitance which create a phase shift and this can be represented as the following:

$$\textbf{Phase angle } (\alpha) = Xc/R$$

Normal value of phase angle is ranged between 6˚ to 10˚ (Ibrahim *et.al.*, 2005). Low phase angle is depending on the low X*c* which due to the inability of cells to store energy and this represents the cell breakdown in selective permeability of cell membranes.

The most common model used in the bioimpedance analyzer is the Cole-Cole model (Reijven and Soeters, 2000, De Lorenzo *et.al.*, 1997, Andersen *et.al.*, 2010). The combination of resistor and capacitor were used to calculate the resistance of the ICW as the following:

$$R_{TBW} = (R_{ICW} \times R_{ECW})/(R_{ICW} + R_{ECW})$$

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The Hanai theory stated that the effect of a concentration of nonconductive material on the apparatus resistivity (p) of the surrounding conductive fluid (Reijven and Soeters, 2000, De Lorenzo *et.al.,* 1997) which is represented by:

$$\boldsymbol{p = p0/((1 - C)^{3/2})}$$

where $p0$ = actual resistivity of a conductive material and C = volumetric concentration of the nonconductive material.

The volumetric concentration of the nonconductive elements at low frequencies can be determined by the following equations:

$$\mathbf{1 - (V_{ECW}/V_{TOT})}$$

where the $V_{TOT}$ = the total body volume

For the high frequencies, the equation as below:

$$\mathbf{1 - (V_{ECW} + V_{ICW})/V_{TOT}}$$

The derivation of the set of equation from the Hanai equation was proposed as below:

$$V_{ECW} = k_{ECW} (L^2Wt^{1/2}/R_e)^{2/3} \quad (4)$$

$$k_{ECW} = (1/1000)(K_b^2P_{ECW}^2)D_b)^{1/3} \quad (5)$$

$$K_b = (1/Ll^2)(((L_i/C_l^2) + (L_t/C_t^2) + (L_a/C_a^2))(2L_aC_a^2 + 2L_lC_l^2 + L_tC_t^2)) \quad (6)$$

$$(1 + V_{ICW}/V_{ECW})^{5/2} = ((r_e + r_i)/r_i)(1 + (Kp V_{ICW}/V_{ECW})) \quad (7)$$

Where,

$Kp$ = $P_{ICW}/P_{ECW}$

$V_{ECW}$ = the predicted ECW (4)

Wt = weight (kg)

L = Length (cm)

$R_e$ = resistance of extracellular water (Ω) from model fitting

$D_b$ = body density (kg/cm3);

= $L_a$, $L_l$ and $L_t$ are the length respectively of arm, leg and trunk (cm)

= $C_a$, $C_l$ and $C_t$ are the circumference respectively of an arm, leg and trunk (cm)



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$K_{ECW}$ is considered as constant

ECW and ICW can be calculated by using the equation (4) and (7) and the $R_e$and $R_i$can be estimated by inserting the data into the Cole – Cole model (Reijven and Soeters, 2000).

BIA analysis involved the use of electrodes and the bioimpedance analyzer which connected the data to the computer for recording by using the Bluetooth connection. Before the analysis, the weight and the height of the patient were recorded since these two values will be inserted into the calculation. Basically four electrodes are used which the two external electrode excite the current and the two internal voltage electrodes are used for scanning as shown in the Figure 2.3.

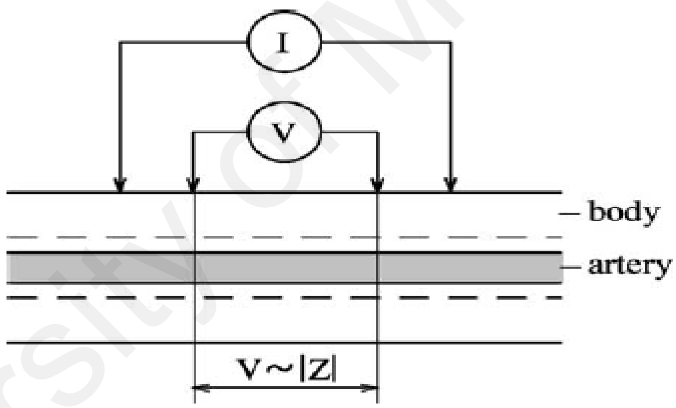


**Figure 2.3** Four-electrode method for measuring bioimpedance (Papezova, S., 2003)

Four electrodes are placed on the dorsal surfaces of the right hand and foot, distal (current) which respectively proximal to metacarpal and metatarsal phalangeal joints which follows the standard tetra polar electrode placement as shown in the Figure 2.4 (Ibrahim *et.al.*, 2005).



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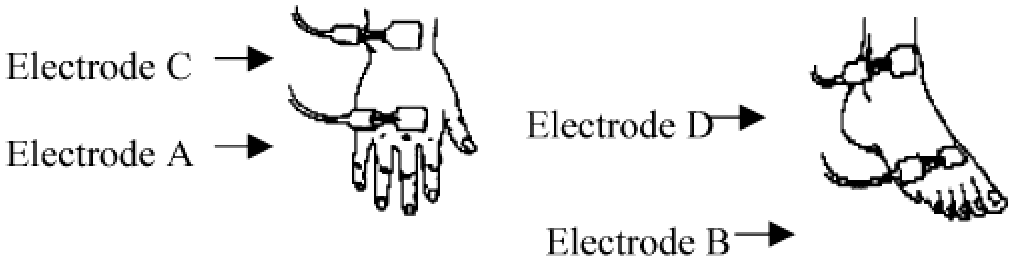


**Figure 2.4** Electrode placement at the wrist and ankle. Electrode A and B are the source of the current and electrode C and D as the pickup current (Source: Ibrahim *et.al.*, 2005)

The proximal (voltage) electrodes were separated 5 cm from the distal electrodes (Jaffrin and Morel, 2008).A standard application of bioimpedance has been mentioned in the study conducted by Cornish *et.al.*(1998) by using a tetra-polar electrode arrangement. Surface ECG type electrode has been used which by the outer electrodes delivering a constant current and the inner electrodes measuring the impedance. This arrangement can remove the skin impedance. The bipolar arrangement by using the surface electrode, the value of the skin impedance involved the measurement of impedance of underlying body tissues plus twice that of the skin and skin-electrode contact which it can increase the skin impedance (Refer to Figure 2.5).

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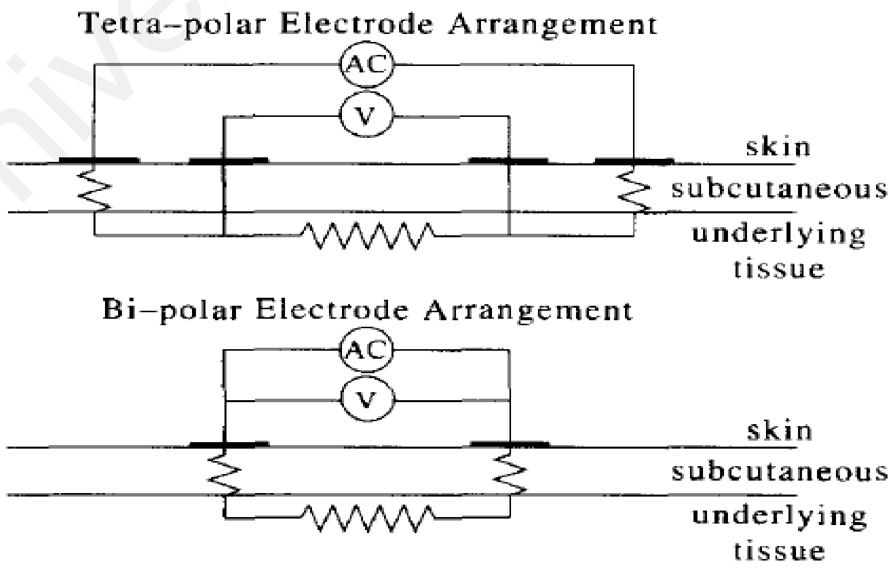


**Figure 2.5** Electrode arrangements used in bioelectrical impedance analysis (Cornish *et.al.*, 1998)

The measurement of the body composition of the patient has been done in supine position within 5 to 10 minutes so that the body fluid can reach equilibrium and the accuracy of the reading can be obtained (Moreno, M.V., Djeddi, D.D., and Jaffrin, M.Y., 2008).

### 2.2.1 Understanding the Bioimpedance Analysis

There are several bioimpedance devices that have been used to measure the body composition. These impedance analyzers may be vary form the simplest which only measure resistance at only two frequencies to the more complex which can measure resistance and reactance at a wide range of frequencies and this requires computer to perform the data analysis (Hannan *et.al.,* 1995). There are two types of biompedance analyzer i) Single Frequency Bioimpedace Analyzer and 2) Multiple Frequency Bioimpedance Analyzer.

Single Frequency Bioimpedance Analysis (SF-BIA) is using generally 50 kHz which passed between the surface electrodes placed on hand and foot (Kyle *et.al.,* 2004). This type of BIA only measures the body impedance at 50 kHz. SF-BIA allows the measurement of fat-free mass and total body water but it cannot estimate the differences in intracellular water since the 50 kHz frequency is not sufficient to penetrate the cell membrane. Table 2.1 shows some of the single frequency bioimpedance analyzer commonly used in research.

**Table 2.1:** List of the Single Frequency Bioimpedance Analyzer

| **Single Frequency Bioimpedance Analyzer** | **Source** |
|---|---|
| Biodynamics Model 450 (BIA-450) | Ibrahim, *et.al.,* (2005) |
| Biodynamics 310 (USA) at 50 kHz | Locsey *et.al.,* (1999) |

Multi-frequency Bioimpedance Analysis (MF-BIA) involved the measurement of body impedances at multiple frequencies at 0, 1, 5, 50, 100, 200 and 500 kHz to calculate fat-free mass, total body water, intracellular water and extracellular water. According to Kyle *et.al.,* (2004), poor reproducibility has been obtained at frequencies below 5 kHz and above 200 kHz. MF-BIA seems to give accurate measurement of the TBW composition in healthy and chronic patients. Table 2.2 shows some of the multi-frequency bioimpedance analyzer commonly used in researches.

**Table 2.2:** List of the Multifrequency Bioimpedance Analyzer

| **Multi-Frequency Bioimpedance Analyzer** | **Source** |
|---|---|
| 4000B | Mager *et.al.,* (2008) |
| Xitron Hydra 4200 | Jaffrin, M.Y. and Morel, H. (2008) |
| QuadScan 4000 | Mager *et.al.* (2008), Sun et.al. (2005) |
| SEAC SFB3 | Cornish *et.al.* (1998) |
| Model 101 A, RJL Systems. | Arpadi *et.al.,* (1996) |

One of the devices that were used in this study was known as BodyStat QuadScan 4000 which used long electrodes attached on the patient's hand and feet. In this analysis, the device applied several different frequencies. By example, low frequency at 1 or 5 kHz was used to quantify extracellular water (ECW) since the water can penetrate easily without any barriers and the high frequency is used to estimate the ICW since it needs greater electrical current to penetrate the cell membrane.

The BodyStat QuadScan analyzer is programmed with its proprietary equations as shown in the Table 2.3. It also most probably applied the Cole-Cole modelling and the Hanai theory-derived equations as been mentioned in the equation (4) to (7) (Mager *et.al.*, 2008).



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**Table 2.3** Equations for calculation of total body water, extracellular water and intracellular water from bioimpedance data (Mager *et.al.*, 2008)

Table 1 Equations for calculation of total body water, extracellular water, and intracellular water from bioimpedance data

| Method | Label | Equation calculation | Subject population | Criterion method |
|---|---|---|---|---|
| *Total body water* | | | | |
| De Lorenzo et al.[25] | A. $TBW_{100Z}$ | $0.069 * [ht * C^2/(4\pi * Z_{100})] + 19.671$ | Overweight to obese F | $^2H_2O$ dilution |
| De Lorenzo et al.[24] | B. $TBW_{5Z\&100Z}$ | $0.0242 * (V/Z_5) + 0.3048\ \{V/[(Z_5 * Z_{100})/(Z_5 - Z_{100})]\} + 22.0319$, where $V$ (body volume, $cm^3$) = (hip $C^2$) * $(Ht/4\pi)$ | Overweight to obese F | $^2H_2O$ dilution |
| Deurenberg et al.[27] | C. $TBW_{100Z}$ | $0.51303 * (Ht^2/Z_{100}) + 6.29$ | Relatively lean (M and F) | $^2H_2O$ dilution |
| QuadScan MFBIA device | D. $TBW_{200Z}$ | Unpublished equation/proprietary | NA | NA |
| Hydra BIS device | E. $TBW_{\infty}$ | Cole–Cole modeling/Hanai mixture theory-derived equations | NA | NA |
| *Extracellular water* | | | | |
| Deurenberg et al.[27] | A. $ECW_{5Z}$ | $0.23413 * (Ht^2/Z_5) + 4.2$ | Relatively Lean (M and F) | Br dilution |
| QuadScan MFBIA device | B. $ECW_{5Z}$ | Unpublished equation/proprietary | NA | NA |
| Hydra BIS device | C. $ECW_0$ | Cole–Cole, Hanai Mixture Theory | NA | NA |
| *Intracellular water* | | | | |
| Deurenberg et al.[27] | A. $TBW_{100Z} - ECW_{5Z}$ | $\{0.51303 * (Ht^2/Z_{100}) + 6.29\} - \{0.23413 * (Ht^2/Z_5) + 4.2\}$ | Relatively lean (M and F) | NA |
| QuadScan MFBIA device | B. $ICW_{BS}$ | Unpublished equation/proprietary | NA | NA |
| Hydra BIS device | C. $ICW_{\infty-0}$ | Cole–Cole modeling/Hanai mixture theory-derived equations | NA | NA |

*Abbreviations:* C, Hip circumference; ECW, extracellular water; F, Female; Ht, Height; ICW, Intracellular water; M, Male; R, Reactance; TBW, Total body water; Wt, Weight; and Z, Impedance.

At high frequency such as 100, 200 or 500 kHz was applied to measure the total body water. Value at 50 kHz of SF-BIA represents the ECW space which means the constant proportion of TBW in the normal condition. . According to the Kyle *et.al.*, (2004) as been mentioned by Scharfetter *et.al.*, at the end of dialysis, the value of volume change is larger which is less than 15% for ECW and less than 20% for ICW. Therefore, in order to more reliable ICW data, it is necessary to build up the fluid distribution model for resistivity changes.

The impedance obtained from the measurement is used to estimate the total body water (TBW) and to calculate the lean body mass (LBM) and body fat by using the regression equations (Esposito *et.al.* 2008). The subtraction between TBW and ECW resulted in intracellular water (ICW).

**ICW = TBW – ECW (8)**

Intracellular water value will be useful because it can estimate the body cell mass (BCM) and the lean tissue compartment represents the metabolic activity of the body

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and energy consuming tissue. Table 2.4 shows a range of parameters measured by this device.

**Table 2.4** The parameters measured by the QuadScan 4000 (Source: QuadScan Brochure)

| BODY COMPOSITION | HYDRATION STATUS | ILLNESS & SEGMENTAL MONITORING |
|---|---|---|
| Fat % and Mass* | Total Body Water – TBW* | Illness Marker™ |
| Lean % and Mass* | Intra-cellular Water – ICW* | Phase Angle at 50 kHz |
| Dry Lean Mass* | Extra-cellular Water – ECW* | Resistance at 50 kHz |
| Body Mass Index - BMI | Third Space Water* | Reactance at 50 kHz |
| Fat Free Mass Index – FFMI*<br>Body Fat Mass Index- BFMI* | Body Cell Mass* | Impedance Values at<br>5, 50,100 and 200 kHz |
| | **OTHER MEASUREMENTS** | |
| Waist / Hip Ratio | Average Daily Calorie Requirement* | Basal Metabolic Rate* |
| *Estimated | | |

The subtraction of lean body mass (LBM) from the total body water (TBW) resulted in fat mass (FM).

**Fat mass (FM) = TBW – LBM (9)**

The body fat percentage was obtained by dividing fat mass by body weight and multiplies with 100.

**Body fat (%) = (Fat mass/Body weight) x 100 (10)**

Figure 2.6 showed the mass and water distribution of the body. The fat mass is closely related to the total of the body water. By the measurement of the TBW, the composition of fat mass and the ICW within the body can be estimated by using the equation (8) to (9).

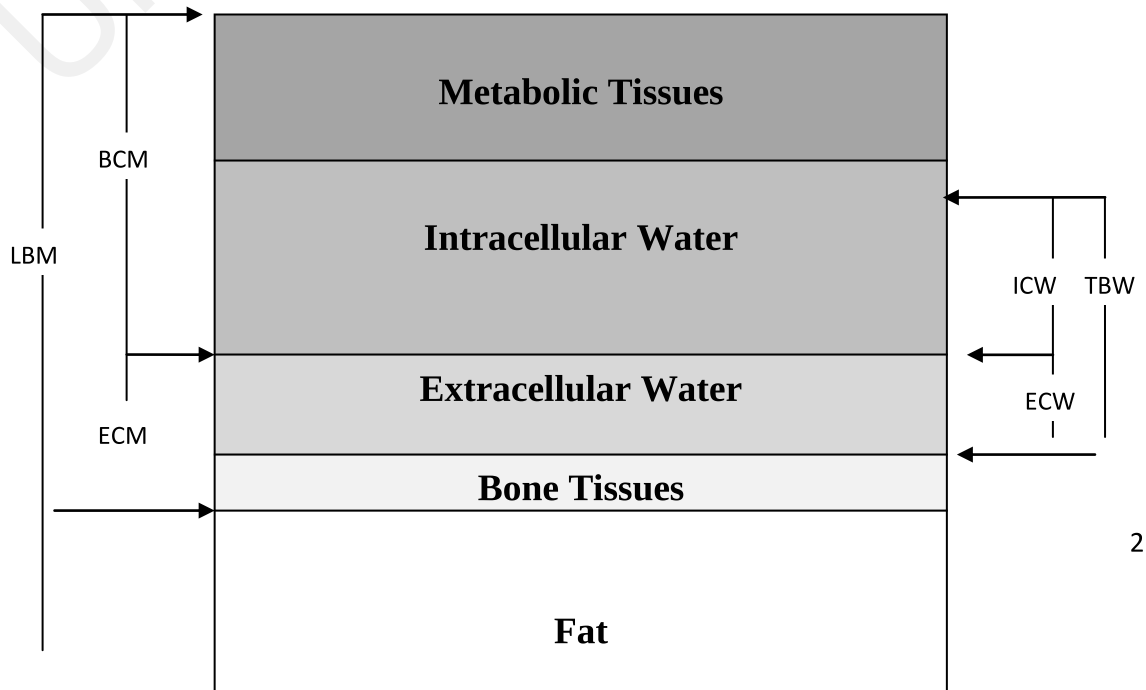




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**Figure 2.6** Mass and water distribution of the body

The impedance (Z) values at 5 kHz were used to assess the ECW and 100 or 200 kHz for TBW. Low frequency is not able to penetrate the cell wall and pass through the extracellular space. Higher frequency is able to penetrate the cellular membrane and pass through the intracellular and extracellular spaces.

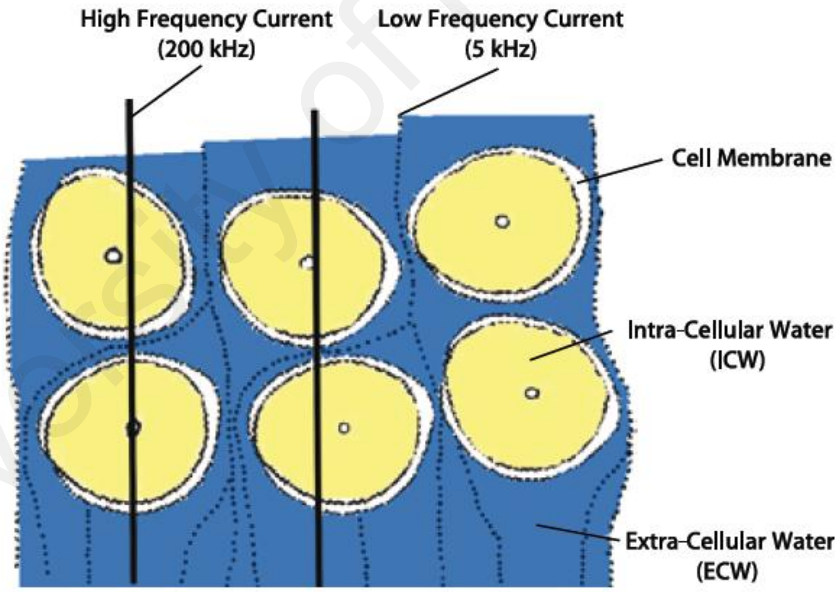


**Figure 2.7** The movement of different frequencies of current within the body

This device is already programmed with its equation accompanied with the software provided. There are some variables involve in the equation which include height, weight, hip and waist. By example, assessment of BCM and ECW by BIA without the height measurement showed that significance differences in mean values.

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The Body Mass Index is used as indicator to classify the weight of the patient according to their height. This can be used to check the healthy level of the patient. It can be calculated by using the formula below:

$$\textbf{BMI = Weight (kg)/height (m}^2\textbf{).}$$

The BMI of the patient was classified into the BMI categories as shown in the Table 2.6

**Table 2.6** The BMI Category

| **BMI Value** | **Category** |
|---|---|
| Below 20 | Underweight |
| 20 - 25 | Ideal weight |
| 26 – 30 | Overweight |
| 30 - 40 | Obese |
| Over 40 | Very obese |

The waist-hip ratio (WHR) is obtained by dividing the waist circumference by the hip circumference. When the WHR value is greater than 0.85, it shows the accumulation of the abdominal fat. The waist circumference greater than 80 cm indicates that the increased risk of cardiovascular disease (Esposito *et.al.*, 2008).

The phase angle obtained acts an indicator to measure the overall body health. Higher phase angle indicates the body is in a good health and nutrition. Normal phase angle it seems to be between 5 and 6. Phase angle will decrease as our age increases. By example, adolescence will have phase angle greater than 10.  Low phase angle due to



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the less cell integrity and always consistent with certain conditions such as malnutrition, infection, chronic diseases by example kidney problem and also old age.

Impedance index is used to measure the general health after the phase angle. The impedance is the resistance to the flow of the current in a body. High impedance is showed by the lower frequency at 5 kHz since the current cannot penetrate the cell membrane and this can only measure the extracellular water. However, at 200 kHz, the impedance is lower since the current can penetrate the cell membrane and this measure both inside and outside of the cell, thus the total body water.

These two values of impedance will result in a variance which is the greater the variance between these two values, the healthier the body cell. Normal value is greater than 1273 and it shows the health level is in good condition. But, when the value is below 1273, it shows bad condition of health level.

Illness marker is another parameter that has to take into an account since it also provides good information of body health. Patient with good cellular nutritional status, the value will show the value is around 0.75 while for very unfit patient, this value it seems to be increased around 0.88 and higher.

It is totally confirmed that the estimation of the body composition by the direct measurement of the bioimpedance analysis can tell us the quality and condition of the body. Hence, this analysis can give the medical practioner chances to improve their medical and diagnostic assessment to their patients so that the patient would have a better treatment of particular disease.

## 2.3 Effects of Dialysis in Bioimpedance

The changes of body composition of the patient due to the dialysis treatment can be improved by the BIA analysis. BIA provides clinical applications for dialysis patients (Kushner *et.al.*, 1996) which include the assessment of volume status that is important

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to maintain the euvolemic state or dry weight. Kidney impairment caused the insufficient removal of fluid and this may lead to hypertension, dyspnea, and pulmonary congestion while excessive fluid removal can lead to hypotension, muscle cramping and vomiting (Kushner *et.al.,* 1996 and Kyle *et.al.,* 2004). Besides that, BIA measurement can help to give the understanding about the physiologic mechanism and hemodynamic changes during dialysis. Thus it can help to revise and design the better strategies to achieve effective dialysis. The total body water (TBW) measured by the BIA can be used to estimate the clearance of small molecules from the blood by example urea. Urea can be calculated by using the urea kinetic modelling *Kt/V*so where *K* is the dialyzer clearance (mL/min) of urea, *t* is time (min) and *V* is the volume of distribution of urea (Kushner *et.al.,* 1996 and Chumlea, W.C., 2004). This can be used to measure the dialytic efficiency (Donadio *et.al.,* 2005). Urea has been assumed to be distributed in the body water, thus V=TBW and it is important to have accurate measurement of TBW. The electrical resistance of the body decreases by the increasing volume of normal saline during the dialysis treatment. Nutritional status of dialysis patient can be predicted since the BIA measures the fat-free mass (FFM) and this can be used to detect malnourished patient. The mortality rate in dialysis patient increased when the FFM is depleted. The malnutrition of FFM due to the several conditions such as anorexia or nausea, loss of amino acids with hemodialysis and may also from infections.

Two mechanisms occurred during dialysis which resulted in physiologic changes. There are diffusion and ultrafiltration which use to reduce the uremic toxins, to regulate the electrolytes in blood and also to remove the excess water.  Kidney disease which is classified as chronic is seem to reduce the lean body mass. There are some conditions that can lead to reduction of the lean body mass which include the high level of urea, metabolic acidosis that can cause proteolysis and stimulation of amino acid catabolism by parathormone levels (Rigalleau *et.al.,* 2005).



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Bases on Chumlea, W.C., 2004, diabetic patient which went through the dialysis patient resulted in greater BMI and weight which indicates that the accumulation of body fat. The fat free mass is estimated from the TBW which average is between the ranges of 67% to 80% but this value may be vary due to the renal disease. Renal insufficiency can affect the TBW and it reflects the urea distribution.

Dialysis treatment seem to alter the body water composition as been studied by Locsey *et,al.* (1999). The extracellular water should be reduced after the dialysis treatment since the kidney cannot remove the excess water. The value of resistance and reactance is showed by the dialysis patient is higher compare to the healthy people. The reason may be due to the reduction of various water compartments in the body and the ions shifting which can lead to the alteration of membrane potential and electrical activity of the body cells.

## 2.4 Role of Bioimpedance Analysis

Generally, BIA helps to determine the body composition. The changes occurred on body composition indicates the health status of the body. By example, BIA is valuable diagnostic test in renal disease. According to the Saxena and Sharma (2005), this technique can check the nutritional status of body between healthy patient and malnourished patient. Patient with renal disease usually exhibits the relative increase in ECW which results in increase in TBW. Research conducted by Saxena and Sharma (2005) showed that the impedance plethysmography was been applied which underlying the principle of BIA. The measurement of body compartments is based on the principal that various types of biological tissues act as conductors, semiconductors or insulators (McDonald *et.al.*, 1993).

Besides that, McDonald *et.al.*, (1993) have conducted a research in monitoring the rehydration status in cholera by using bioimpedance. Symptoms of cholera by example diarrhoea can cause hypovolaemia which after a few hours can be fatal. Therefore, bioimpedance is a fast and reliable method to assess fluid changes and has potential to be used in the management of trauma patient and sepsis and also to monitor the dehydration due to the cholera.

Bioimpedance also has been used in detection or screening of tongue cancer (Sun *et.al.,* 2010) since this method is non invasive and low cost to detect cancer. The objective of this study was to check the electrical properties of the cancerous tongue tissue and normal tongue tissue. They found that the cancerous tongue tissue has the lower impedance compare to the normal tongue tissue due to the abnormality of the tissue.

Measurement of muscle function has been done by using the bioimpedance analysis (Norman *et.al.,* 2009). Previously, hand grip strength was a common method used to determine the muscle function. Even though this is easy-to-use method, however it still needs patient's cooperation in terms of compliance and ability. Thus, bioimpedance analysis was been preferred since it is reliable and independent of patient cooperation.

Body composition has also been measured in prepubertal children which infected by HIV (Arpadi *et.al.,* 1996). Objective of this study was to measure the total body water and fat free mass by using the bioimpedance. Tetrapolar bioelectrical impedance analyzer has been used to determine the total body resistance and reactance. The equations for TBW and FFM were derived from the regression techniques. The result showed that prediction of body composition from BIA measurement was not valid for application to children with HIV infection but this method is useful to determine the body compartments in children in range moderate to severe symptoms HIV.

Thoracic bioimpedance technology has been used to study the effect of obesity on bioimpedance cardiac index in order to measure the cardiac output (Brown, C.V.R. *et.al.,* 2005).By inserting the invasive catheter into the obese patient's body, it may not feasible due to the certain reasons such as cannot find the landmark and increased the distance to reach the central vein. So, in this technology, 8 electrodes were been used which two electrodes were placed on the patient's neck and another two on the thorax. This study showed that the thoracic bioimpedance technology can be applied either for obese or non obese patient with less pain and it is reliable and safer method to determine the cardiac output.

Besides that, the assessment of the body composition on the obese patients has been done by Mager*et.al.* (2008). In this study, there were assessed the body composition through several bioimpedance techniques which include multifrequency bioelectrical impedance analysis device (MFBIA: QuadScan 4000), bioimpedance spectroscopy device (Hydra 4200) and multiple dilution. They found that both MFBIA and BIS were practically convenient method to assess fluid compartments but not for most extremely obese patient and more researches need to be done in order to minimize the errors. The Bodystat Quadscan also has been used to study the changes of body composition on female subjects which went through the highly active antiretroviral therapy (Esposito *et.al.*, 2008). The study showed that the body compositions such as fat mass, body fat percentages and BMI were significantly increased since the therapy improve the overall performance of the body.

It is suggested that the BIA analysis provides major contribution to the human needs especially to improve their quality of life and health. BIA analysis is an easiest and promising way in early detection of changes in body compositions. Thus, more researches should be done in order to improve the accuracy of the bioimpedance analysis.

## 2.5. Statistical Analysis



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Statistics is the science that deals with the collection, classification, analysis, and interpretation of information or data (Daud, Z.M. *et.al.,* 2005). Statistical analysis has been performed to determine the comparison between the two groups of data or multiple groups of data. This research involved two mean groups and this requires a hypothesis testing to compare the two variables, before and after the treatment of dialysis.

Hypothesis test is a process to decide whether accept or reject the hypothesis statement about the parameters in the study. The process of statistical analysis involves the prediction of the two types of hypothesis:

a) Null hypothesis, Ho is generally a statement that a population parameter has a specific value and this usually assumed to be true. Therefore, this is the hypothesis that needs to be tested. In this research, assumptions of the null hypothesis has been made as the following:

   $H_0$ = Patients who received the dialysis treatment shows the positive effects on the body bioimpedance.

b) Alternative hypothesis, $H_1$ is the statement about the same population parameter that is used in the null hypothesis and this statement generally specifies the population parameter has a value different in some way from the value given in the null hypothesis. The rejection of the null hypothesis will lead to the acceptance of this alternative hypothesis. The H1 has been decided in this research as stated below:

   $H_1$ = Patients who received the dialysis treatment shows negative effects on the body bioimpedance.

A t-test for dependent data is performed to determine the critical value and the rejection region. The significance level value (α) and the inequality used in the alternative hypothesis are used to establish the test criterion. The P value $< 0.05$ is considered to be significant. If the test of the significant resulted in P value less than 0.05, the null hypothesis will be rejected.

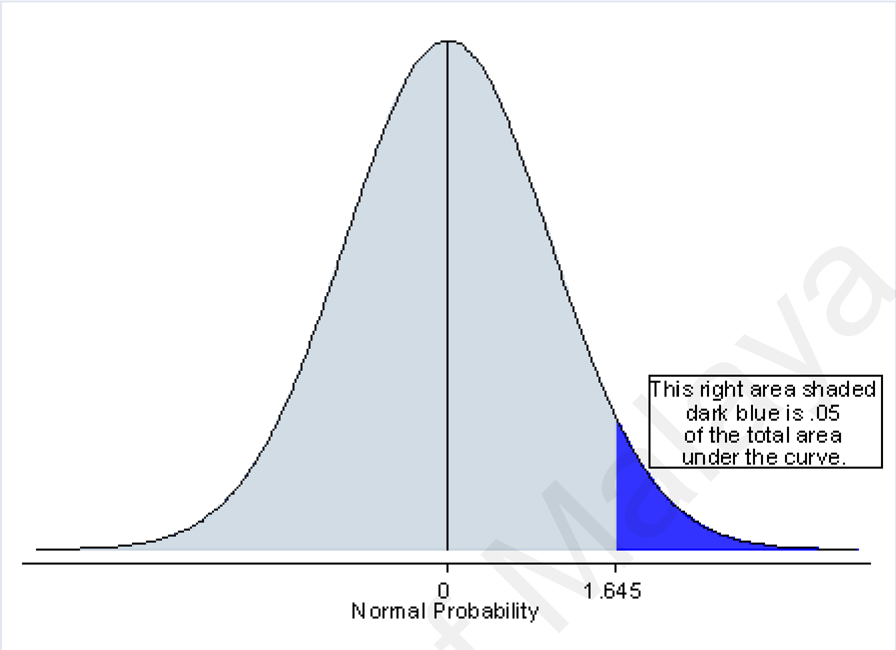


**Figure 2.8** The one tailed t-test when $Z_{test} > Z_{\alpha}$, $H_0$ accepted.

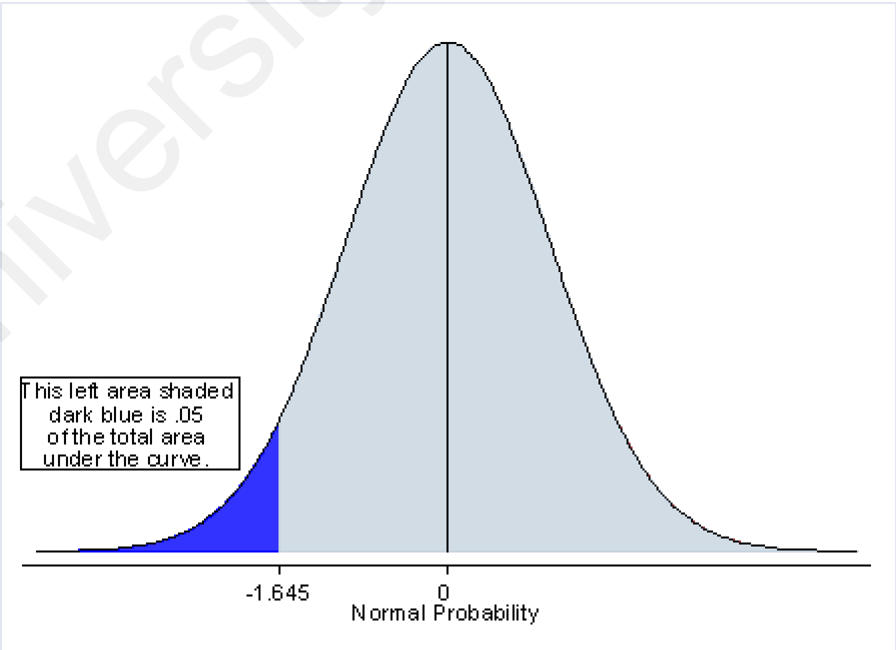


**Figure 2.9** The one-tailed t-test when Ztest < Zα, H0 rejected.

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ANOVA or Analysis of Variance is another statistical analysis performed to compare more than two population means. Two types of ANOVA include one-way ANOVA and two-way ANOVA. Two-way ANOVA emphasizes on the interaction of factors that involve in the case of study. In this study, only one factor is involved, that is bioimpedance, it is referred as one-way ANOVA. One-way ANOVA is the extension of the t-test more than two groups of sample. Hence, the null hypothesis can be written as:

$H0: \mu 1 = \mu 2 = \mu 3 = .... = \mu k$ versus the alternative hypothesis $H1 : \mu 1 \neq \mu j$.

The statistical analysis gives very good advantages to determine the reliability of the hypothesis of the study. Thus, the objectives of this study could be achieved.

The statistical analysis was conducted by using the software IBM SPSS Statistics. The comparison was made between the parameters before and after the dialysis treatment. The expected result will show that there is a positive effect on the body bioimpedance after received the dialysis treatment.

Dialysis has shown to help people with the kidney impairment to regulate the body compositions so that they can maintain the balance condition of the body. Bioimpedance analysis seems to contribute important advantages in clinical field as it helps in early and immediate diagnosis of chronic diseases.

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CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

The research has been done at two different centres of haemodialysis, located at Subang Bistari and Wisma FELDA, Kuala Lumpur. These two centres were using different types of dialysis machine. There are Fresenius, Gambro and Nikkiso dialysis machine. The dialysis treatment took four hours to complete the one treatment. The reading has been taken before and after the dialysis treatment by using the Bodystat QuadScan Analyzer. The result obtained was been analysed by using the SPSS software to determine the comparison of the body bioimpedance before and after the treatment.

## 3.2 Materials and Method

This research required the bioimpedance analyser machine, BodyStat Quadscan 4000 as shown in the Figure 3.1 to measure the body bioimpedance of the dialysis patient. The type of electrode used is known as disposable long electrode which placed on the patient's hand and feet (Refer to Figure 3.2). A questionnaire provided was to record the patient's personnel info (Refer to Appendix A).


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Figure 3.1 Bioimpedance analyser machine, BodyStat QuadScan 4000

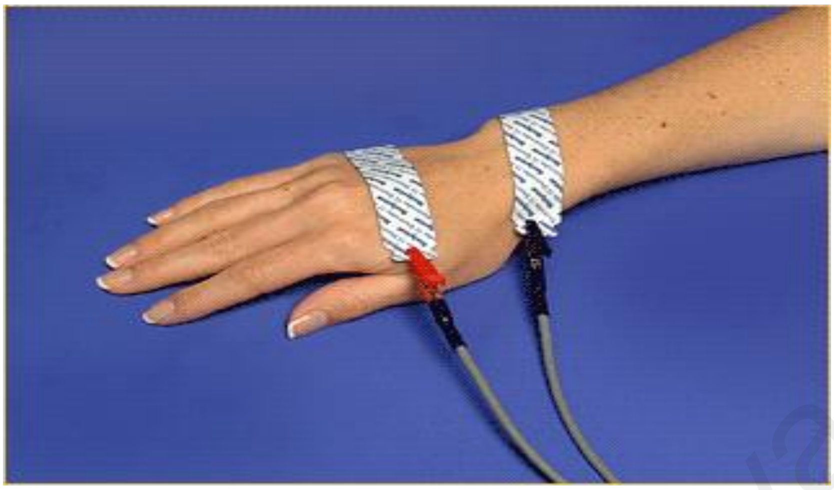

**Figure 3.2** Disposable long electrode

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This research has been conducted at the dialysis centre to obtain 47 patients that underwent the dialysis treatment. Before the start of the dialysis treatment, the patient's weight, height, waist and hip circumference have been taken to be recorded in the analyser. The electrodes were placed on the right hand and right feet of the patients and the measurement was performed. For each patient, the measurement was conducted five times. After the end of the dialysis treatment, the same steps before the treatment were repeated. The data obtained was transferred into the computer and analysed in the SPSS software to check the differences of the body bioimpedance before and after the dialysis treatment.

## 3.3 Sampling

A sample of 47 patients that went through the dialysis treatment was collected at the haemodialysis centre. This centre provides the dialysis machine to the patient who needs the dialysis treatment. Sampling of the 47 patients was conducted randomly.

## 3.3 Instrumentation

A questionnaire (Refer to Appendix A) was provided to the patient in the dialysis centre to record some of their personnel info. The questionnaire includes the personnel info such as patient's id, age, gender, weight, height, address, job and disease.

Bioimpedance analyser, BodyStat QuadScan 4000 was used to record the body bioimpedance include resistance, reactance, body cell mass, extracellular mass, lean body mass, fat mass, body mass index, basal metabolic rate, intracellular water, extracellular water and total body water. The data obtained from the analyser was transferred to the computer by using the Bluetooth connection. The software provided by the analyser manufacturer was used to download and open the data. The result of the bioimpedance parameters obtained was analysed by using the SPSS software. Statistic analysis was conducted which involved the ANOVA and paired t-test and the comparison was made between the reading before and after the dialysis treatment

## 3.4 Procedures

Before the measurement taken, the weight, height, waist and hip circumference of the patient has been taken and recorded. The patient was laid on the bed in the supine position as shown in the Figure 3.3. Four electrodes have been used in which two electrodes were placed on the right hand and another two on the right feet as shown in the Figure 3.4. The electrodes were connected to the bioimpedance analyser by using wires.

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**Figure 3.3** Supine position

**Figure 3.4** Placement of electrodes

### 3.3.1 Measurement of Electrical Body Impedance

Four electrodes were used for one patient and it was placed on the right hand and right foot in the supine position (Donadio *et.al.*, 2005, Guida *et.al.*, 2000, Jaffrin and Morel, 2008, Toso *et.al.*, 2000). According to the Papezova, S, (2003), the two external electrodes excite the current and the two internal voltage electrodes used for scanning as shown in Figure 3.4. Determination of impedance is based on the voltage difference of the voltage electrodes at a given moment. The electrodes were connected to the bioimpedance anaylzer. The measurement was conducted immediately before the start and after the end of dialysis treatment.

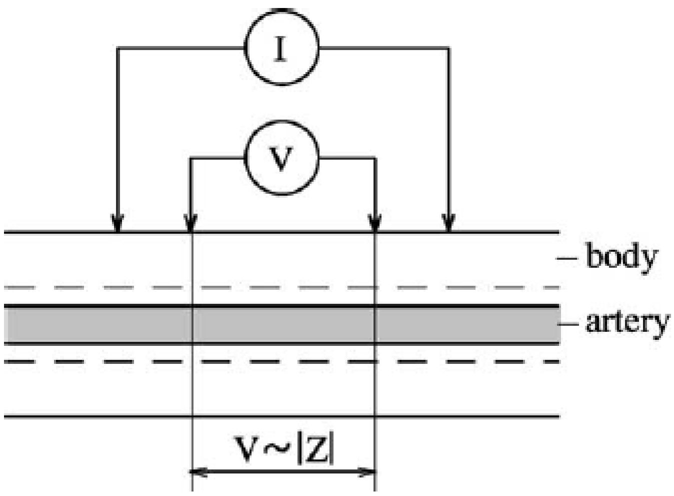


**Figure 3.5** Four electrodes method for measuring bioimpedance (Papezova, S., 2008).

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### 3.3.2 Statistical Analysis

The linear correlation of the measurement was performed by using SPSS software. The paired t-test was performed to compare the two variables before and after the dialysis treatment and to evaluate the statistical significance of the differences between the mean value of different groups of data (Donadio *et.al.,* 2005). The one way analysis of variance (ANOVA) was carried out to determine the significance value of multiple groups of data. The data has been analysed by using the Post Hoc Test to determine the significance value at 0.05 between each of the data for comparing the comparisons of the bioimpedance parameters before and after the dialysis.

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## CHAPTER 4

## RESULTS

### 4.1 Introduction

Interpretation of all the data obtained from the measurements was analyzed by using the software Statistical Package for the Social Sciences (SPSS), IBM SPSS Statistics 19. The statistical analysis have been conducted which involved independent t-test, paired t-test and ONEWAY Anova. In this study, the results have been grouped into three category a) Independent or demographic variable such as gender, age, additional disease, body mass index, and weight height ratio, b) Comparison of the body bioimpedance parameters before and after the dialysis treatment and c) Interaction of body bioimpedance parameters with the independent variables.

### 4.2 Statistical Analysis of Demographic Variable

Demographic or independent variable analysis was been conducted to determine the number or frequency of the variables such as gender between male and female, patient's age, types of additional diseases, body mass index and weight height ratio.

#### 4.2.1 Subject's Analysis

Table 4.1 shows the total frequency of male and female dialysis patient. Based on the analysis that have been done, the total number of patients went to the dialysis treatment was 48. Table 4.1 showed the detail of the number of patients.

**Table 4.1** The frequency of male and female dialysis patients.



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| Gender | Frequency | Percent |
|---|---|---|
| Female | 80 | 34.0 |
| Male | 155 | 66.0 |
| Total | 235 | 100.0 |

Based on the Table 4.1, it seems the numbers of male patients are higher than female patients that went through the dialysis treatment.

Figure 4.1 shows the percentage of the male and female patients that underwent the dialysis treatment. Sixty six percents of male patients and thirty four percents of female patients received the dialysis treatment.


**Figure 4.1** The percentages of male and female patients that went through the dialysis treatment.

### 4.2.2 Analysis of Subject's Age

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Table 4.2 shows the frequency based on the patient's age. The percentage of dialysis patients is demonstrated by Figure 4.2.

**Table 4.2** The frequency of the patients based on age group.

| Age Group | Frequency | Percent |
|---|---|---|
| **Less than 35** | 30 | 12.8 |
| **35 to 50** | 45 | 19.1 |
| **51 to 60** | 85 | 36.2 |
| **61 to 70** | 60 | 25.5 |
| **More than 70** | 15 | 6.4 |
| **Total** | 235 | 100.0 |

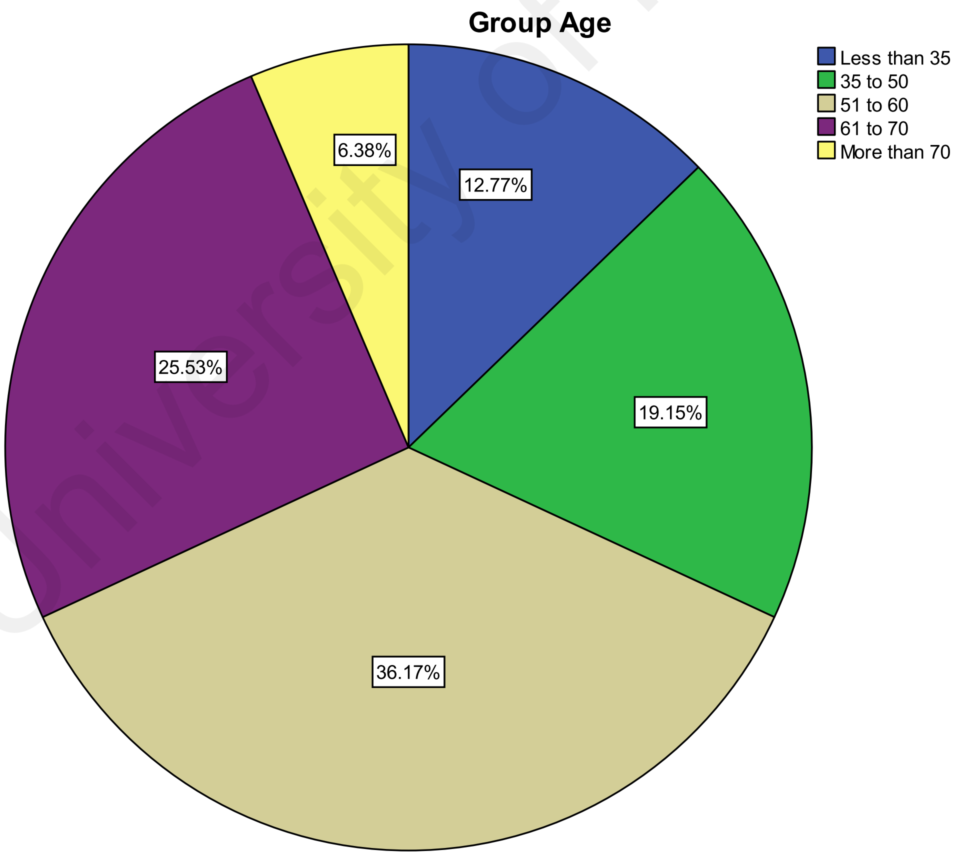


**Figure 4.2** The percentages of dialysis patients based on age group

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Based on the both figures, the highest percentage was demonstrated by patients aged between 51 to 60 years, which almost 36.2% of them. The lowest percentage was shown by patients having age more than 70 years, only 6.4%. There were 12.8% of patients aged less than 35 years, 19.1% of patients aged between 35 to 60 years and 25.5% of patients aged between 61 to 70 years old.

### 4.2.3 Analysis on Subject's Additional Diseases

Additional diseases suffered from the patients also have been analyzed which may affect their life activity. There were four common diseases besides kidney impairment that have been indentified in this study; diabetes, heart disease, obesity and high blood pressure. One or two patients may have more than one disease. For example, a patient besides kidney problem, he or she may also have obesity and high blood pressure. Table 4.3 shows the frequencies and percentages of patients which having additional disease.

**Table 4.3** The frequency and percentages of patient's additional diseases.

| Additional Diseases | Frequency | Percent |
|---|---|---|
| Kidney Problem | 140 | 59.6 |
| Kidney and Diabetes | 25 | 10.6 |
| Kidney and High Blood Pressure | 30 | 12.8 |
| Kidney and Heart Disease | 15 | 6.4 |
| Kidney and Obesity | 5 | 2.1 |
| Kidney, Diabetes and High Blood Pressure | 5 | 2.1 |
| Kidney, High Blood Pressure and Obesity | 15 | 6.4 |
| Total | 235 | 100.0 |

According to the Table 4.3, 59.6% of patients having only kidney problem, this is the largest frequency since kidney problem is the main disease. The lowest percentages



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have been showed by patients having kidney problem with obesity and also kidney problem with diabetes and high blood pressure, which only 2.1%, respectively. There were 10.6% of patients with kidney and diabetes and the total of 12.8% of total patients with diabetes. There were only 6.4% of patients having kidney and heart disease and also kidney problem with high blood pressure and obesity. The disease group which is less than 2% will be excluded in future analysis because of the very small sample size. Those diseases somehow may be related to the body bioimpedance that would be discussed in the next chapter.

### 4.2.4 Analysis on Body Mass Index of the Subjects

One of the independent variables that have been studied was Body Mass Index (BMI). Based on the literature review, the BMI can be grouped into five different categories as shown in the Figure 4.3. Table 4.4 shows the BMI value for each category.

**Table 4.4** The BMI Value

| BMI Value | Category |
|---|---|
| Below 20 | Underweight |
| 20 - 25 | Ideal weight |
| 26 – 30 | Overweight |
| 30 - 40 | Obese |
| Over 40 | Very obese |

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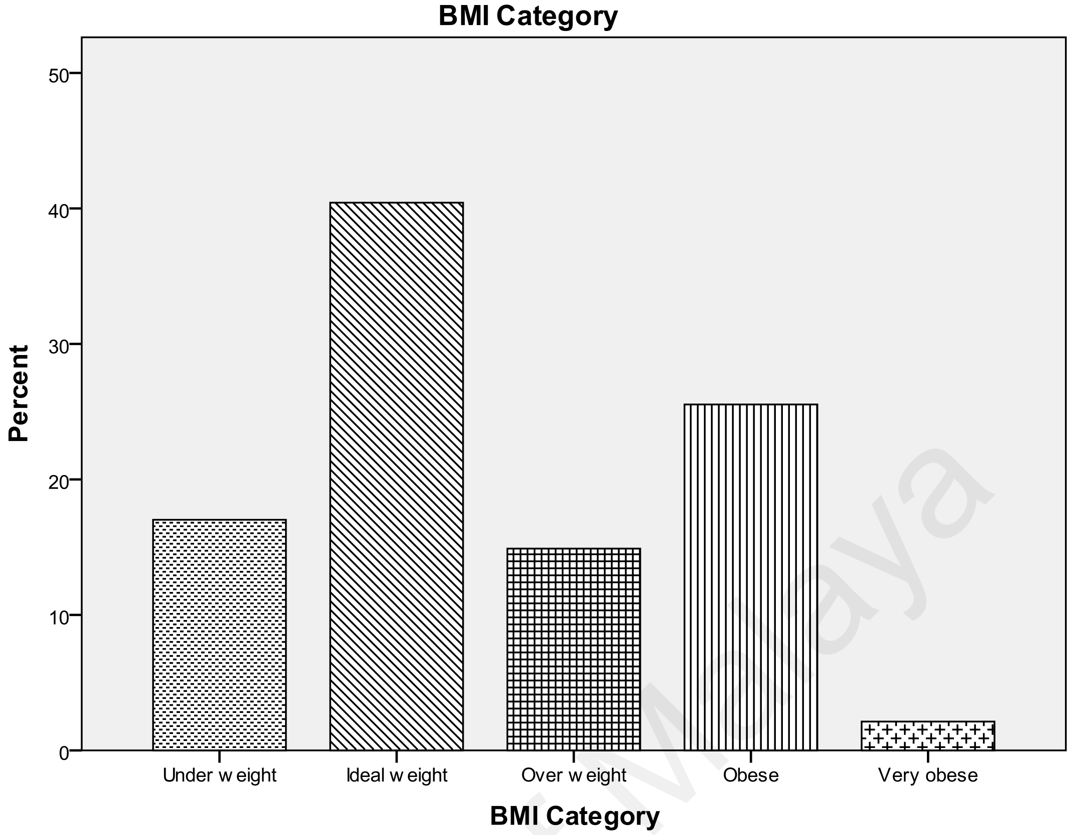


**Figure 4.3** The BMI category of the dialysis patients.

Based on the bar chart in Figure 4.3, it was noticed that, most of the patients showed an ideal BMI value which comprises of 40.4% from the total patients followed by obese and underweight patients, which 25.5% and 17.0%, respectively. Patients with overweight BMI category showed the percentage of 14.9%. It is only about 2.1% of the patients categorised under very obese group.

### 4.1.5 Analysis on Waist-Hip Ratio of the Subjects

Besides the BMI value of the patient, another demographic variable that need to take into an account is the Waist-Hip Ratio (WHR). Figure 4.4 shows the graph of the total number of the WHR group. Based on the figure, the largest WHR value is ranged about 0.91 to 1.00, contribute to the 69.8% out of the total patients. Then, it is followed WHR group 0.81 to 0.90 about 25.5%. It is clearly showed that only 2.6% of the patients lied within a range of 1.01 to 1.0 and only 2.1% of patients were identified less than 0.80.

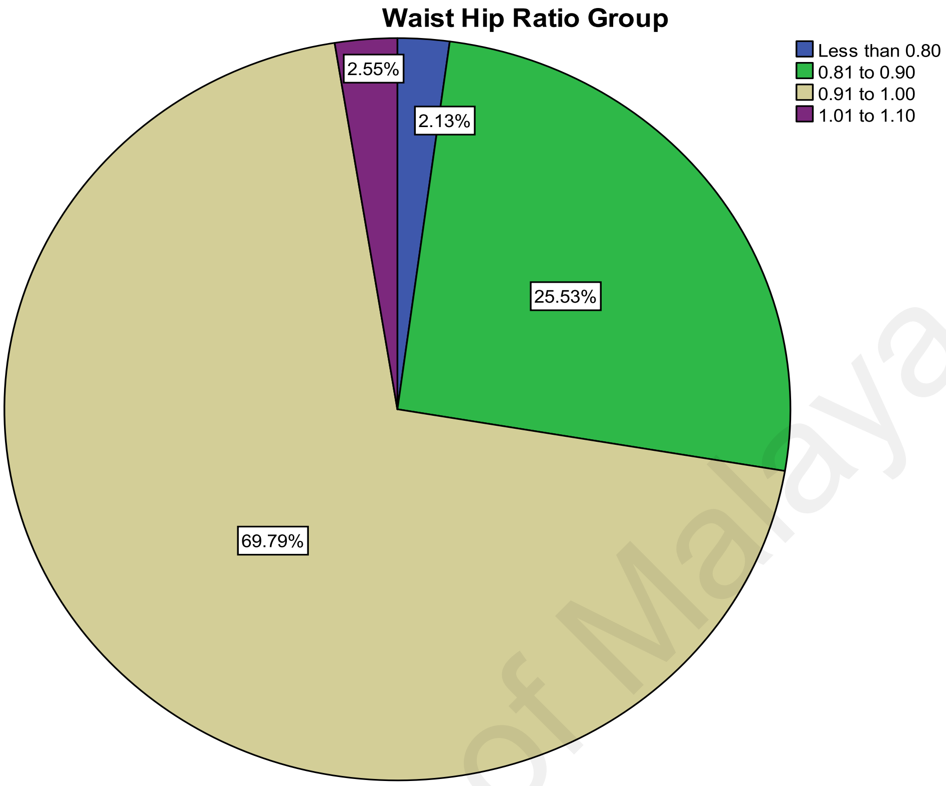


**Figure 4.4: The percentages of Waist-Hip Ratio group**

These demographic variables obtained from the result above may affect the body bioimpedance. There will be an interaction between independent and dependent variable before and after the dialysis treatment. Further analysis has been carried out to identify the comparison between those body bioimpedance variables before and after the dialysis treatment.

## 4.3 Body Bioimpedance Analysis

The analysis of the body bioimpedance analysis has been done to identify the comparisons of the body bioimpedance parameters before and after dialysis treatment. Besides that, the interactions between the bioimpedance parameters and independent variables also have been performed to identify their relationships and the significance difference between them.

## 4.4 Comparison of the Body Bioimpedance Parameters Before and After the Dialysis Treatment

Statistical analysis for comparing the dependent variables before and after the dialysis treatment has been conducted by using the Paired t-Test. The purpose of this test was to determine the mean before and after the dialysis treatment and also significance level at 0.05 to find out the differences between the two mean values. Table 4.5 shows the results obtained from the paired t-test for all body bioimpedance parameters before and after dialysis treatment.

Based on the Table 4.5, most of the parameters showed the significance level value less than 0.05. This means that the difference between the two means is significant at 0.05. However, there also some parameters showed higher significance value which is greater than 0.05. By example, dry weight showed significance level value is 0.203 and also the percentage of intracellular water and the total of intracellular water is 0.411 and 0.738, respectively. Body cell mass showed the greater significance level value which is 0.727.

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**Table 4.5** Overall comparison between body bioimpedance parameters before and after the dialysis treatment from paired t-test.

| Bioimpedance Parameter | Mean | | Significance Level at 0.05 |
|---|---|---|---|
| | Before | After | |
| Fat (%) | 28.5664 | 32.4043 | 0.000 |
| Total Fat | 19.6051 | 22.0838 | 0.000 |
| Lean (%) | 71.0081 | 67.1702 | 0.000 |
| Total Lean | 46.6587 | 44.0132 | 0.000 |
| Water (%) | 58.4979 | 55.4345 | 0.000 |
| Total Water | 37.6817 | 35.3991 | 0.000 |
| Dry Weight | 9.1034 | 8.9515 | 0.203 |
| BMR | 1460.7617 | 1392.9021 | 0.000 |
| Est.Average Req. | 2045.1149 | 1950.0553 | 0.000 |
| Impedance 5 kHz | 524.1915 | 628.5064 | 0.000 |
| Impedance 50 kHz | 501.4468 | 568.4426 | 0.000 |
| Impedance100 kHz | 482.2000 | 541.8085 | 0.000 |
| Impedance 200 kHz | 466.2426 | 521.2681 | 0.000 |
| Resistance 50 kHz | 499.8383 | 566.1362 | 0.000 |
| Reactance50 kHz | 37.5698 | 49.0481 | 0.000 |
| Phase Angle50 kHz | 4.3668 | 4.9272 | 0.000 |
| ICW (%) | 29.2451 | 29.6217 | 0.411 |
| ECW (%) | 26.3157 | 24.8281 | 0.000 |
| TBW (%) | 58.4979 | 55.4345 | 0.000 |
| Total ICW (%) | 19.2332 | 19.3247 | 0.738 |
| Total ECW | 16.7434 | 15.7430 | 0.000 |
| TBW | 37.6817 | 35.3991 | 0.000 |
| BCM | 27.4723 | 27.6085 | 0.727 |
| Third Space Water | 1.0085 | 0.2485 | 0.000 |
| Body Impedance | 1.1165 | 0.8363 | 0.016 |

Note: BMR = Basal Metabolic Rate. ICW = Intracellular Water. ECW = Extracellular Water. TBW = Total Body Water. BCM = Body Cell Mass.

## 4.5 The Effects of Independent Variables on the Bioimpedance Parameters Before and After the Dialysis Treatment.

Independent variable such as gender, age group, additional diseases and BMI group perhaps can be one of the factors that may affect the body bioimpedance. In this section, another type of statistical analysis was performed to identify the difference or comparison of the bioimpedance parameters with the independent variables.

### 4.5.1 Statistics Comparisons of Body Bioimpedance Parameters with Gender



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Table 4.6 showed the results obtained from the paired t-test for all body bioimpedance parameters before and after dialysis treatment for female and male group.

**Table 4.6** The comparison between body bioimpedance parameters before and after the dialysis treatment from paired t-test for gender.

| Bioimpedance Parameter | Significance Level at 0.05 | |
|---|---|---|
| | Female | Male |
| Fat (%) | 0.000 | 0.000 |
| Total Fat | 0.000 | 0.000 |
| Lean (%) | 0.000 | 0.000 |
| Total Lean | 0.000 | 0.000 |
| Water (%) | 0.000 | 0.000 |
| Total Water | 0.000 | 0.000 |
| Dry Lean Weight | 0.000 | 0.000 |
| BMR | 0.000 | 0.691 |
| Est.Average Req. | 0.000 | 0.000 |
| Impedance 5 kHz | 0.000 | 0.000 |
| Impedance 50 kHz | 0.000 | 0.000 |
| Impedance100 kHz | 0.000 | 0.000 |
| Impedance 200 kHz | 0.000 | 0.000 |
| Resistance 50 kHz | 0.000 | 0.000 |
| Reactance50 kHz | 0.000 | 0.000 |
| Phase Angle50 kHz | 0.000 | 0.044 |
| ICW (%) | 0.435 | 0.515 |
| ECW (%) | 0.005 | 0.005 |
| TBW (%) | 0.000 | 0.000 |
| Total ICW | 0.000 | 0.706 |
| Total ECW | 0.871 | 0.003 |
| TBW | 0.000 | 0.000 |
| BCM | 0.873 | 0.696 |
| Third Space Water | 0.000 | 0.000 |
| Body Impedance | 0.028 | 0.022 |

Note: BMR = Basal Metabolic Rate. ICW = Intracellular Water. ECW = Extracellular Water. TBW = Total Body Water. BCM = Body Cell Mass.

The comparisons of body bioimpedance parameters before and after dialysis treatment were conducted by using the paired t-test. The purpose of this test was to determine the mean before and after the dialysis treatment and also significance level at 0.05 to find out the differences between the two mean values. Based on the Table 4.6, most of the comparisons show the significance value p less than 0.05 except for BMR, phase angle at 50 kHz, ICW (%), total ICW and BCM.

### 4.5.2 Statistics Comparisons of Body Bioimpedance Parameters with Age Group



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Based on the demographic analysis, the patients which went to the dialysis treatment aged between 20 to 70 years. The age of the patients have been analysed and grouped into five age groups. The paired t-test was conducted for comparing dependent variables before and after the dialysis treatment. The purpose of this test was to determine the mean before and after the dialysis treatment and also significance level at 0.05 to find out the differences between the two mean values for age group variable. Table 4.7 shows the results obtained from the paired t-test for all body bioimpedance parameters before and after dialysis treatment for each age group.

Oneway ANOVA was performed to compare and find out the significance value at 0.05 of the body bioimpedance parameters before and after the dialysis treatment between and within age group. Multiple comparisons by using the Post Hoc Tests also have been conducted for all the bioimpedance parameters before and after dialysis treatment to determine the significance value between each age group. The overall results of the ANOVA tests for all the bioimpedance analysis before and after the treatment are shown in Table 4.8.

**Table 4.7** The comparison between body bioimpedance parameters before and after the dialysis treatment from paired t-test for age groups

| Bioimpedance Parameter | Age Group 1 | Age Group 2 | Age Group 3 | Age Group 4 | Age Group 5 |
|---|---|---|---|---|---|
| Fat (%) | 0.006 | 0.000 | 0.000 | 0.000 | 0.000 |
| Total Fat | 0.002 | 0.000 | 0.000 | 0.000 | 0.879 |
| Lean (%) | 0.080 | 0.212 | 0.000 | 0.000 | 0.000 |
| Total Lean | 0.052 | 0.182 | 0.000 | 0.000 | 0.000 |
| Water (%) | 0.431 | 0.039 | 0.000 | 0.000 | 0.000 |
| Total Water | 0.104 | 0.024 | 0.000 | 0.000 | 0.000 |



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| | | | | | |
|---|---|---|---|---|---|
| Dry Weight | 0.002 | 0.236 | 0.226 | 0.919 | 0.004 |
| BMR | 0.022 | 0.355 | 0.000 | 0.000 | 0.000 |
| Est.Average Req. | 0.022 | 0.353 | 0.000 | 0.000 | 0.000 |
| Impedance 5 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.539 |
| Impedance 50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Impedance100 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Impedance 200 kHz | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| Resistance 50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Reactance50 kHz | 0.000 | 0.001 | 0.000 | 0.000 | 0.012 |
| Phase Angle50 kHz | 0.000 | 0.800 | 0.000 | 0.118 | 0.102 |
| ICW (%) | 0.001 | 0.052 | 0.002 | 0.011 | 0.049 |
| ECW (%) | 0.000 | 0.538 | 0.000 | 0.000 | 0.141 |
| TBW (%) | 0.431 | 0.039 | 0.000 | 0.000 | 0.000 |
| Total ICW | 0.006 | 0.068 | 0.000 | 0.006 | 0.003 |
| Total ECW | 0.000 | 0.762 | 0.000 | 0.000 | 0.737 |
| TBW | 0.104 | 0.024 | 0.000 | 0.000 | 0.000 |
| BCM | 0.006 | 0.069 | 0.002 | 0.007 | 0.002 |
| Third Space Water | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| Body Impedance | 0.000 | 0.027 | 0.000 | 0.004 | 0.072 |

Note 1: BMR = Basal Metabolic Rate. ICW = Intracellular Water. ECW = Extracellular Water. TBW = Total Body Water. BCM = Body Cell Mass

Note 2: Age Group 1 = Less than 35. Age Group 2 = 35 to 50. Age Group 3 = 51 to 60. Age Group 4 = 61 to 70. Age Group 5 = More than 70

It can be seen from the Table 4.7, most of the age groups produced significance value p less than 0.05 for all the bioimpedance parameters before and after dialysis treatment. However, there are also some values which is greater than 0.05. For example, the highest significance value was shown by age group 5 for the comparison of total fat, total ECW and body impedance before and after dialysis treatment with its p values is 0.879, 0.737 and 0.072, respectively.

Table 4.8 shows the overall comparisons of all the bioimpedance parameters obtained from ANOVA test before and after dialysis treatment for age group.

**Table 4.8** The overall results from ANOVA test for comparisons of all the bioimpedance parameters before and after dialysis treatment for age group

| Bioimpedance Parameters | Significance Value at 0.05 | |
|---|---|---|
| | Before | After |
| Fat (%) | 0.000 | 0.000 |
| Total Fat | 0.001 | 0.007 |
| Lean (%) | 0.000 | 0.000 |
| Total Lean | 0.000 | 0.000 |
| Water (%) | 0.327 | 0.094 |
| Total Water | 0.000 | 0.002 |



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| | | |
|---|---|---|
| Dry Weight | 0.000 | 0.000 |
| BMR | 0.000 | 0.000 |
| Est.Average Req. | 0.000 | 0.000 |
| Impedance 5 kHz | 0.007 | 0.306 |
| Impedance 50 kHz | 0.117 | 0.942 |
| Impedance100 kHz | 0.084 | 0.734 |
| Impedance 200 kHz | 0.059 | 0.565 |
| Resistance 50 kHz | 0.108 | 0.929 |
| Reactance50 kHz | 0.000 | 0.000 |
| Phase Angle50 kHz | 0.000 | 0.000 |
| ICW (%) | 0.004 | 0.000 |
| ECW (%) | 0.552 | 0.001 |
| TBW (%) | 0.327 | 0.094 |
| Total ICW | 0.000 | 0.000 |
| Total ECW | 0.052 | 0.102 |
| TBW | 0.000 | 0.002 |
| BCM | 0.000 | 0.000 |
| Third Space Water | 0.008 | 0.040 |
| Body Impedance | 0.001 | 0.000 |

Note 1: BMR = Basal Metabolic Rate. ICW = Intracellular Water. ECW = Extracellular Water. TBW = Total Body Water. BCM = Body Cell Mass

The comparisons of the bioimpedance parameters before and after dialysis treatment between each of the age group can be clearly viewed by using the Post Hoc Test. Table 4.9 shows the effects of age group on the total fat and percentage before and after dialysis treatment. Table 4.10 shows the results from Post Hoc Test on the comparisons of the lean (%) and total lean before and after dialysis treatment.

**Table 4.9** The effects of age group from Post Hoc Test on comparisons of the fat (%) and total fat before and after dialysis treatment**.**

| **Body Bioimpedance Parameter** | **Fat (%)** | | **Total Fat** | |
|---|---|---|---|---|
| **Age Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 1 and 3 | - | 0.037 | - | - |
| 1 and 4 | 0.001 | 0.000 | 0.007 | 0.008 |
| 1 and 5 | 0.000 | 0.000 | - | - |
| 2 and 5 | 0.000 | 0.001 | - | - |
| 3 and 4 | 0.027 | - | - | - |
| 3 and 5 | 0.000 | 0.002 | - | - |
| 4 and 5 | 0.018 | - | - | - |

Note: 1 = Less than 35 years. 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years

**Table 4.10** The effects of age group from Post Hoc Test on comparisons of the lean (%) and total lean before and after dialysis treatment.



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| Body Bioimpedance Parameter | Lean (%) | | Total Lean | |
|---|---|---|---|---|
| Age Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 4 | 0.003 | - | - | - |
| 1 and 5 | 0.000 | 0.001 | 0.033 | - |
| 2 and 5 | 0.001 | 0.004 | 0.000 | 0.000 |
| 3 and 5 | 0.000 | 0.006 | 0.000 | 0.000 |
| 4 and 5 | 0.040 | - | 0.002 | 0.003 |

Note: 1 = Less than 35 years. 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years

**Table 4.11** The effects of age group from Post Hoc Test on comparisons of dry weight and basal metabolic rate before and after dialysis treatment.

| Body Bioimpedance Parameter | Dry Weight | | Basal Metabolic Rate | |
|---|---|---|---|---|
| Age Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 5 | 0.000 | 0.008 | 0.008 | - |
| 2 and 5 | 0.002 | 0.001 | 0.003 | 0.002 |
| 3 and 5 | 0.000 | 0.000 | 0.000 | 0.002 |
| 4 and 5 | 0.010 | 0.013 | 0.016 | 0.022 |

Note: 1 = Less than 35 years. 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years.
5 = More than 70 years

Table 4.11 shows the comparisons of the dry weight and BMR from Post Hoc Test before and after the treatment between each of the age group.

Table 4.12 shows the multiple comparisons from Post Hoc Test on the Est. Average Req before and after the dialysis treatment.

**Table 4.12** The effects of age group from Post Hoc Test on the comparisons of the Est.Average Req. before and after dialysis treatment.

| Body Bioimpedance Parameter | Est. Average Req. | |
|---|---|---|
| Age Group | Sig. Before | Sig. After |
| 1 and 5 | 0.008 | - |
| 2 and 5 | 0.003 | 0.002 |
| 3 and 5 | 0.000 | 0.002 |
| 4 and 5 | 0.016 | 0.021 |

Note:
1 = Less than 35 years. 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years

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Table 4.13 represents the effects of age group on the comparisons of impedance value at different frequencies before and after the dialysis treatment between each age group by using the Post Hoc Test.

**Table 4.13** The effects of age group from Post Hoc Test on the comparisons of impedance value at different frequencies before and after dialysis treatment.

| **Body Bioimpedance Parameter** | **Impedance at 5 kHz** | | **Impedance at 50 kHz** | | **Impedance at 100 kHz** | | **Impedance at 200 kHz** | |
|---|---|---|---|---|---|---|---|---|
| **Age Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 1 and 2 | 0.040 | - | - | - | - | - | - | - |

Note: 1 = Less than 35 years. 2 = 35 to 50 years.

Table 4.14 shows the multiple comparisons between each age group on the resistance, reactance and phase angle at 50 kHz before and after dialysis treatment.

**Table 4.14** The effects of age group from Post Hoc Test on the comparisons of the resistance, reactance and phase angle at 50 kHz before and after dialysis treatment.

| **Body Bioimpedance Parameter** | **Resistance at 50 kHz** | | **Reactance at 50 kHz** | | **Phase Angle at 50 kHz** | |
|---|---|---|---|---|---|---|
| **Age Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 1 and 3 | - | - | - | - | - | 0.000 |
| 1 and 4 | - | - | - | - | | 0.000 |
| 1 and 5 | - | - | 0.004 | 0.000 | 0.044 | 0.000 |
| 2 and 3 | - | - | 0.012 | 0.044 | 0.001 | 0.010 |
| 2 and 4 | - | - | - | - | - | 0.022 |
| 2 and 5 | - | - | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 and 5 | - | - | - | - | - | 0.001 |
| 4 and 5 | - | - | 0.012 | 0.015 | - | 0.001 |

Note:1 = Less than 35 years. 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years

Table 4.15 shows the significance value of the multiple comparisons between each age group on the water percentage and total water before and after dialysis treatment.



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**Table 4.15** The effects of age group from Post Hoc Test on comparisons of water (%) and total water before and after dialysis treatment.

| **Body Bioimpedance Parameter** | **Water (%)** | | **Total Water** | |
|---|---|---|---|---|
| **Age Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 2 and 5 | - | - | 0.011 | 0.011 |
| 3 and 5 | - | - | 0.005 | 0.016 |
| 4 and 5 | - | - | 0.036 | 0.041 |

Note:
2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years

Table 4.16 shows the multiple comparisons between each age group on the ICW (%), total ICW, ECW (%) and total ECW before and after dialysis treatment. Table 4.17 represents the multiple comparisons between each age group on the TBW (%) and TBW before and after dialysis treatment.

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**Table 4.16** The effects of age group from Post Hoc Test on comparisons of ICW (%), total ICW, ECW (%) and total ECW before and after dialysis treatment

| Body Bioimpedance Parameter | ICW (%) | | Total ICW | | ECW (%) | | Total ECW | |
|---|---|---|---|---|---|---|---|---|
| Age Group | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 5 | - | 0.000 | - | 0.037 | - | - | - | - |
| 2 and 3 | 0.012 | - | - | - | - | - | - | - |
| 2 and 5 | - | 0.015 | - | 0.000 | - | - | - | - |
| 3 and 5 | - | 0.031 | 0.013 | 0.000 | - | 0.013 | - | - |
| 4 and 5 | - | - | 0.024 | 0.000 | - | 0.005 | - | - |

Note 1: 1 = Less than 35 years. 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years
Note 2: ICW = Intracellular water. ECW = Extracellular water

**Table 4.17** The effects of age group from Post Hoc Test in comparisons of TBW (%) and TBW before and after dialysis treatment.

| Body Bioimpedance Parameter | TBW (%) | | TBW | |
|---|---|---|---|---|
| Age Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 2 and 5 | - | - | 0.011 | 0.011 |
| 3 and 5 | - | - | 0.005 | 0.016 |
| 4 and 5 | - | - | 0.036 | 0.041 |

Note 1: 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years
Note 2: TBW = Total Body Water

**Table 4.18** The effects of age group from Post Hoc Test on comparisons of body cell mass, third space water and body impedance before and after dialysis treatment.

| Body Bioimpedance Parameter | BCM | | Third Space Water | | Body Impedance | |
|---|---|---|---|---|---|---|
| Age Group | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 2 | - | - | - | - | 0.047 | - |
| 1 and 5 | - | 0.000 | - | - | - | 0.000 |
| 2 and 3 | - | - | - | - | 0.005 | - |
| 2 and 4 | - | - | 0.043 | - | 0.011 | - |
| 2 and 5 | 0.472 | 0.000 | - | - | - | 0.000 |
| 3 and 4 | - | - | 0.041 | 0.463 | - | - |
| 3 and 5 | 0.013 | 0.000 | - | 0.408 | - | 0.000 |
| 4 and 5 | 0.023 | 0.000 | - | - | - | 0.000 |

Note 1: 1 = Less than 35 years. 2 = 35 to 50 years. 3 = 51 to 60 years. 4 = 61 to 70 years. 5 = More than 70 years
Note 2: BCM = Body Cell Mass

Table 4.18 represents the multiple comparisons between each age group on the body cell mass, third space water and body impedance before and after dialysis treatment.



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Age group seems to be one of the factors that can affect the body bioimpedance parameters. It is noticed that most of the interactions between the age groups and the dependent variables produce significance value which p is less than 0.05.

### 4.4.3 Statistics Comparisons of the Body Bioimpedance Parameters with BMI Group

Body bioimpedance parameters can be affected by the BMI of the patient. As been discussed earlier, the BMI of the patients has been categorized into different group. The comparison of the body bioimpedance parametes before and after dialysis treatment for each age group has been analyzed by using the Paired t-Test as shown in the Table 4.19 The analysis of the comparison between those BMI groups with the body bioimpedance parameters has been conducted by using the ANOVA test to determine the significance value on the comparisons of the bioimpedance parameters before and after dialysis treatment. Table 4.20 shows the overall results from ANOVA test on the comparisons of the bioimpedance parameters for the BMI group.

Post Hoc Test was performed to determine the significance value between each of the BMI group and to identify the relationship between one BMI groups with another BMI group. The analysis of the Post Hoc test for the comparisons of the bioimpedance parameter for BMI group are shown in Table 4.21 to Table 4.31. First, Table 4.21 shows the multiple comparisons of the fat (%) and fat total before and after dialysis treatment for BMI group.

**Table 4.19** Overall comparisons from the Paired t-test of the body bioimpedance parameters before and after dialysis treatment for each age group.

| Bioimpedance Parameter | BMI Group 1 | BMI Group 2 | BMI Group 3 | BMI Group 4 | BMI Group 5 |
|---|---|---|---|---|---|
| Fat (%) | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Total Fat | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 |



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| | | | | | |
|---|---|---|---|---|---|
| Lean (%) | 0.000 | 0.043 | 0.001 | 0.000 | 0.000 |
| Total Lean | 0.000 | 0.049 | 0.001 | 0.000 | 0.000 |
| Water (%) | 0.000 | 0.013 | 0.000 | 0.002 | 0.000 |
| Total Water | 0.000 | 0.010 | 0.000 | 0.000 | 0.000 |
| Dry Weight | 0.084 | 0.326 | 0.030 | 0.264 | 0.000 |
| BMR | 0.000 | 0.106 | 0.000 | 0.000 | 0.000 |
| Est.Average Req. | 0.000 | 0.106 | 0.000 | 0.000 | 0.000 |
| Impedance 5 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Impedance 50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Impedance100 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Impedance 200 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Resistance 50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Reactance50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Phase Angle50 kHz | 0.003 | 0.407 | 0.000 | 0.000 | 0.003 |
| ICW (%) | 0.392 | 0.208 | 0.035 | 0.499 | 0.000 |
| ECW (%) | 0.040 | 0.796 | 0.000 | 0.009 | 0.000 |
| TBW (%) | 0.000 | 0.013 | 0.000 | 0.002 | 0.000 |
| Total ICW | 0.343 | 0.181 | 0.000 | 0.051 | 0.000 |
| Total ECW | 0.027 | 0.951 | 0.012 | 0.000 | 0.000 |
| TBW | 0.000 | 0.010 | 0.000 | 0.000 | 0.000 |
| BCM | 0.339 | 0.178 | 0.012 | 0.055 | 0.000 |
| Third Space Water | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Body Impedance | 0.345 | 0.033 | 0.000 | 0.000 | 0.001 |

Note 1 : BMR = Basal Metabolic Rate. ICW = Intracellular Water. ECW = Extracellular Water. TBW = Total Body Water. BCM = Body Cell Mass.

Note 2 : BMI Group 1 = .Under weight. BMI Group 2 = Ideal weight. BMI Group 3 = Over weight. BMI Group 4 = Obese. BMI Group 5 = Very obese

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**4.20** The overall results from ANOVA based on the effect of the BMI group on the statistics comparisons of the bioimpedance parameters before and after the dialysis treatment.

| Bioimpedance Parameters | Significance Value at 0.05 | |
|---|---|---|
| | Before | After |
| Fat (%) | 0.000 | 0.000 |
| Total Fat | 0.000 | 0.000 |
| Lean (%) | 0.000 | 0.000 |
| Total Lean | 0.000 | 0.000 |
| Water (%) | 0.000 | 0.000 |
| Total Water | 0.000 | 0.000 |
| Dry Weight | 0.000 | 0.000 |
| BMR | 0.000 | 0.000 |
| Est.Average Req. | 0.000 | 0.000 |
| Impedance 5 kHz | 0.001 | 0.000 |
| Impedance 50 kHz | 0.000 | 0.000 |
| Impedance100 kHz | 0.000 | 0.000 |
| Impedance 200 kHz | 0.000 | 0.000 |
| Resistance 50 kHz | 0.000 | 0.000 |
| Reactance50 kHz | 0.000 | 0.003 |
| Phase Angle50 kHz | 0.000 | 0.000 |
| ICW (%) | 0.001 | 0.000 |
| ECW (%) | 0.000 | 0.000 |
| TBW (%) | 0.000 | 0.000 |
| Total ICW | 0.000 | 0.000 |
| Total ECW | 0.000 | 0.000 |
| TBW | 0.000 | 0.000 |
| BCM | 0.000 | 0.000 |
| Third Space Water | 0.000 | 0.000 |
| Body Impedance | 0.308 | 0.000 |

Note 1: BMR = Basal Metabolic Rate. ICW = Intracellular Water. ECW = Extracellular Water. TBW = Total Body Water. BCM = Body Cell Mass.

Post Hoc Test was performed to determine the significance value between each of the BMI group and to identify the relationship between one BMI groups with another BMI group. Table 4.21 shows the multiple comparisons of the fat (%) and fat total before and after dialysis treatment for BMI group.

**Table 4.21** The effects of BMI group from Post Hoc Test on comparisons of fat (%) and total fat before and after dialysis treatment

| Body Bioimpedance Parameter | Fat (%) | | Total Fat | |
|---|---|---|---|---|
| BMI Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 3 | - | 0.000 | 0.000 | 0.000 |
| 1 and 4 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 and 5 | - | - | 0.000 | 0.000 |
| 2 and 3 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 and 4 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 and 5 | 0.013 | 0.003 | 0.000 | 0.000 |
| 3 and 4 | - | - | 0.000 | 0.000 |
| 3 and 5 | - | - | 0.000 | 0.000 |
| 4 and 5 | - | - | 0.000 | 0.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese

Table 4.22 shows the multiple comparisons of the lean (%) and total lean before and after dialysis treatment between interactions of each BMI group.

**Table 4.22** The effects of BMI group from Post Hoc Test on comparisons of the lean (%) and total lean before and after dialysis treatment for BMI group.

| Body Bioimpedance Parameter | Lean (%) | | Total Lean | |
|---|---|---|---|---|
| BMI Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 2 | - | - | 0.000 | 0.000 |
| 1 and 3 | - | 0.001 | 0.000 | 0.000 |
| 1 and 4 | 0.000 | 0.001 | 0.000 | 0.000 |
| 1 and 5 | - | - | 0.000 | 0.000 |
| 2 and 3 | 0.009 | 0.000 | - | - |
| 2 and 4 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 and 5 | - | 0.023 | 0.000 | 0.000 |
| 3 and 4 | - | - | 0.002 | 0.000 |
| 3 and 5 | - | - | 0.000 | 0.000 |
| 4 and 5 | - | - | 0.000 | 0.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese

Table 4.23 represents the multiple comparisons from Post Hoc Test between each of the BMI group on the water (%) and total water before and after dialysis treatment.

**Table 4.23** The effects of BMI group from Post Hoc Test on comparisons of the water (%) and total water before and after dialysis treatment.

| Body Bioimpedance Parameter | Water (%) | Total Water |
|---|---|---|



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| BMI Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
|---|---|---|---|---|
| 1 and 2 | 0.000 | 0.006 | 0.000 | 0.000 |
| 1 and 3 | 0.000 | 0.000 | 0.003 | - |
| 1 and 4 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 and 5 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 and 3 | 0.001 | 0.000 | - | 0.010 |
| 2 and 4 | 0.000 | 0.000 | 0.002 | 0.001 |
| 2 and 5 | 0.012 | 0.001 | 0.000 | 0.000 |
| 3 and 4 | 0.025 | - | 0.013 | 0.000 |
| 3 and 5 | - | - | 0.000 | 0.000 |
| 4 and 5 | - | - | 0.000 | 0.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese

Table 4.24 represents the multiple comparisons between each of the BMI group on the dry weight and basal metabolic rate before and after dialysis treatment.

**Table 4.24** The effects of BMI group from Post Hoc Test on the comparisons of dry lean and BMR before and after dialysis treatment.

| Body Bioimpedance Parameter | Dry Weight | | BMR | |
|---|---|---|---|---|
| **BMI Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 1 and 2 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 and 3 | 0.000 | 0.000 | 0.000 | 0.001 |
| 1 and 4 | 0.000 | 0.002 | 0.000 | 0.000 |
| 1 and 5 | 0.000 | - | 0.000 | 0.000 |
| 2 and 3 | - | 0.000 | - | - |
| 2 and 4 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 and 5 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 and 4 | 0.001 | 0.000 | 0.001 | 0.000 |
| 3 and 5 | 0.002 | 0.000 | 0.000 | 0.000 |
| 4 and 5 | - | - | 0.000 | 0.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese
Note 2: BMR = Basal Metabolic Rate

Table 4.25 represents the multiple comparisons between each of the BMI group on the Est. Average Req. before and after dialysis treatment.

**Table 4.25** The effects of BMI group from Post Hoc Test on comparisons of Est. Average Req. before and after dialysis treatment

| Body Bioimpedance Parameter | Est. Average Req. | |
|---|---|---|
| **BMI Group** | **Sig. Before** | **Sig. After** |
| 1 and 2 | 0.000 | 0.000 |

| | | |
|---|---|---|
| 1 and 3 | 0.000 | 0.001 |
| 1 and 4 | 0.000 | 0.000 |
| 1 and 5 | 0.000 | 0.000 |
| 2 and 4 | 0.000 | 0.000 |
| 2 and 5 | 0.000 | 0.000 |
| 3 and 4 | 0.001 | 0.000 |
| 3 and 5 | 0.000 | 0.000 |
| 4 and 5 | 0.000 | 0.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese

Table 4.26 represents the multiple comparisons between each of the BMI group on the impedance at different frequencies before and after dialysis treatment.

**Table 4.26** The effects of BMI group from Post Hoc Test on comparisons of impedance at various frequencies before and after dialysis treatment

| Body Bioimpedance Parameter | Impedance 5 kHz | | Impedance 50 kHz | | Impedance 100 kHz | | Impedance 200 kHz | |
|---|---|---|---|---|---|---|---|---|
| BMI Group | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 2 | - | - | - | - | - | 0.030 | 0.038 | 0.023 |
| 1 and 4 | - | - | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 and 5 | 0.005 | 0.009 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 and 5 | 0.041 | 0.018 | 0.000 | 0.011 | 0.000 | 0.021 | 0.000 | 0.026 |
| 3 and 4 | - | 0.001 | - | 0.001 | - | 0.003 | - | 0.004 |
| 3 and 5 | 0.042 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 |
| 4 and 5 | - | - | 0.012 | - | 0.015 | - | 0.015 | - |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese

Table 4.27 represents the multiple comparisons from the Post Hoc Test between each of the BMI group on the resistance, reactance and phase angle at 50 kHz before and after dialysis treatment.

**Table 4.27** The effects of BMI group from Post Hoc Test on the comparisons of resistance, reactance and phase angle at 50 kHz before and after dialysis treatment.

| Body Bioimpedance Parameter | Resistance 50 kHz | | Reactance 50 kHz | | Phase Angle 50 kHz | |
|---|---|---|---|---|---|---|
| BMI Group | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 1 and 2 | - | - | 0.023 | - | 0.001 | 0.001 |
| 1 and 3 | - | - | - | - | - | 0.009 |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 1 and 4 | 0.000 | 0.001 | - | - | - | 0.011 |
| 1 and 5 | 0.000 | 0.000 | - | - | - | - |
| 2 and 4 | - | - | 0.047 | - | - | - |
| 2 and 5 | 0.000 | 0.011 | - | - | - | - |
| 3 and 4 | - | 0.002 | - | - | - | - |
| 3 and 5 | 0.000 | 0.000 | - | - | - | - |
| 4 and 5 | 0.012 | - | - | - | - | - |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese

Table 4.28 shows the multiple comparisons between each BMI group on the ICW (%), total ICW, ECW (%) and total ECW before and after dialysis treatment.

**Table 4.28** The effects of BMI group from the Post Hoc Test on the comparisons of ICW (%), total ICW, ECW (%) and total ECW before and after the dialysis treatment.

| Body Bioimpedance Parameter | ICW (%) | | Total ICW | | ECW (%) | | Total ECW | |
|---|---|---|---|---|---|---|---|---|
| **BMI Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 1 and 2 | - | - | 0.000 | 0.000 | 0.000 | 0.000 | - | 0.000 |
| 1 and 3 | - | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | - | - |
| 1 and 4 | - | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 and 5 | - | - | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| 2 and 3 | - | 0.000 | - | - | - | 0.000 | - | - |
| 2 and 4 | 0.002 | 0.000 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 |
| 2 and 5 | - | - | 0.000 | 0.000 | - | 0.002 | 0.000 | 0.000 |
| 3 and 4 | - | - | 0.004 | 0.000 | - | - | - | 0.000 |
| 3 and 5 | - | - | 0.000 | 0.000 | - | - | 0.000 | 0.000 |
| 4 and 5 | - | - | 0.000 | 0.000 | - | - | 0.001 | 0.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese
Nore : ICW = Intracellular water. ECW = Extracellular water

Table 4.29 represents the multiple comparisons between each of the BMI group on the TBW (%) and TBW before and after dialysis treatment.

**Table 4.29** The effects of BMI group on the comparisons of the TBW (%) and TBW before and after dialysis treatment.

| Body Bioimpedance Parameter | TBW (%) | | TBW | |
|---|---|---|---|---|
| **BMI Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 1 and 2 | 0.000 | 0.006 | 0.000 | 0.000 |
| 1 and 3 | 0.000 | 0.000 | 0.003 | - |
| 1 and 4 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 and 5 | 0.000 | 0.000 | 0.000 | 0.000 |

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| | | | | |
|---|---|---|---|---|
| 2 and 3 | 0.001 | 0.000 | - | 0.010 |
| 2 and 4 | 0.000 | 0.000 | 0.002 | 0.001 |
| 2 and 5 | 0.012 | 0.001 | 0.000 | 0.000 |
| 3 and 4 | 0.025 | - | 0.013 | 0.000 |
| 3 and 5 | - | - | 0.000 | 0.000 |
| 4 and 5 | - | - | 0.000 | 0.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese
Nore : TBW = Total Body Water

Table 4.30 represents the multiple comparisons between each of the BMI group on the body cell mass, third space water and body impedance before and after dialysis treatment.

**Table 4.30** The effects of BMI group from Post Hoc Test on the comparisons of BCM, third space water and body impedance before and after dialysis treatment

| **Body Bioimpedance Parameter** | **BCM Before** | | **Third Space Water** | | **Body Impedance** | |
|---|---|---|---|---|---|---|
| **BMI Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 1 and 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.784 | 0.000 |
| 1 and 3 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.005 |
| 1 and 4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.999 | 0.007 |
| 1 and 5 | 0.000 | 0.000 | 0.020 | 0.000 | 1.000 | 0.598 |
| 2 and 3 | 0.992 | 0.352 | 0.159 | 0.000 | 0.696 | 1.000 |
| 2 and 4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.476 | 0.925 |
| 2 and 5 | 0.000 | 0.000 | 0.597 | 0.003 | 0.971 | 0.999 |
| 3 and 4 | 0.004 | 0.000 | 0.002 | 0.883 | 1.000 | 0.988 |
| 3 and 5 | 0.000 | 0.000 | 0.991 | 0.769 | 1.000 | 1.000 |
| 4 and 5 | 0.000 | 0.000 | 0.770 | 0.939 | 1.000 | 1.000 |

Note: 1 = Under weight. 2 = Ideal weight. 3 = Over weight. 4 = Obese. 5 = Very obese
Note 2 : BCM = Body Cell Mass

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### 4.5.4 Statistics Comparisons of the Body Bioimpedance Parameters for Additional Diseases

There are four common diseases that have been identified in dialysis patients which include diabetes, high blood pressure, obesity and heart disease. Statistical analysis for comparing the dependent variables before and after the dialysis treatment has been conducted by using the Paired t-Test. The purpose of this test was to determine the mean before and after the dialysis treatment and also significance level at 0.05 to find out the differences between the two mean values. Table 4.31 shows the results obtained from the paired t-test for all body bioimpedance parameters before and after dialysis treatment for disease group.

Further analysis has been conducted which involved the ANOVA test. The purpose of this test was to determine the significance value of the two means, before and after for all the bioimpedance parameters. Table 4.32 shows the comparisons obtained from ANOVA test to compare the bioimpedance parameters before and after dialysis treatment for disease group.

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**Table 4.31** The comparison between body bioimpedance parameters before and after the dialysis treatment from paired t-test for additional disease groups.

| Bioimpedance Parameter | Disease Group 0 | Disease Group 1 | Disease Group 2 | Disease Group 3 | Disease Group 4 | Disease Group 5 | Disease Group 6 |
|---|---|---|---|---|---|---|---|
| Fat (%) | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Total Fat | 0.000 | 0.446 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Lean (%) | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Total Lean | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Water (%) | 0.000 | 0.277 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Total Water | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Dry Weight | 0.145 | 0.144 | 0.556 | 0.000 | 0.016 | 0.000 | 0.000 |
| BMR | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Est.Average Req. | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Impedance 5 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Impedance 50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Impedance100 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 |
| Impedance 200 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.028 | 0.000 | 0.000 |
| Resistance 50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Reactance50 kHz | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Phase Angle50 kHz | 0.017 | 0.003 | 0.045 | 0.000 | 0.000 | 0.000 | 0.016 |
| ICW (%) | 0.177 | 0.577 | 0.097 | 0.000 | 0.002 | 0.000 | 0.001 |
| ECW (%) | 0.052 | 0.266 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| TBW (%) | 0.000 | 0.277 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Total ICW | 0.199 | 0.350 | 0.018 | 0.000 | 0.000 | 0.000 | 0.001 |
| Total ECW | 0.073 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| TBW | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| BCM | 0.197 | 0.360 | 0.018 | 0.000 | 0.000 | 0.000 | 0.001 |
| Third Space Water | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Body Impedance | 0.024 | 0.039 | 0.013 | 0.000 | 0.000 | 0.000 | 0.000 |

Note 1: BMR = Basal Metabolic Rate. ICW = Intracellular Water. ECW = Extracellular Water. TBW = Total Body Water. BCM = Body Cell Mass.
Note 2: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity.

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**Table 4.32** The overall results from ANOVA test for comparisons of all the bioimpedance parameters before and after dialysis treatment for disease group

| Bioimpedance Parameters | Significance Value at 0.05 | |
|---|---|---|
| | Before | After |
| Fat (%) | 0.000 | 0.000 |
| Total Fat | 0.000 | 0.000 |
| Lean (%) | 0.000 | 0.000 |
| Total Lean | 0.000 | 0.000 |
| Water (%) | 0.000 | 0.000 |
| Total Water | 0.000 | 0.000 |
| Dry Weight | 0.000 | 0.000 |
| BMR | 0.000 | 0.000 |
| Est.Average Req. | 0.000 | 0.000 |
| Impedance 5 kHz | 0.001 | 0.000 |
| Impedance 50 kHz | 0.000 | 0.000 |
| Impedance100 kHz | 0.000 | 0.000 |
| Impedance 200 kHz | 0.000 | 0.000 |
| Resistance 50 kHz | 0.000 | 0.000 |
| Reactance50 kHz | 0.003 | 0.003 |
| Phase Angle50 kHz | 0.242 | 0.230 |
| ICW (%) | 0.063 | 0.004 |
| ECW (%) | 0.018 | 0.000 |
| TBW (%) | 0.000 | 0.000 |
| Total ICW | 0.000 | 0.000 |
| Total ECW | 0.000 | 0.000 |
| TBW | 0.000 | 0.000 |
| BCM | 0.000 | 0.000 |
| Third Space Water | 0.000 | 0.000 |
| Body Impedance | 0.824 | 0.776 |

For clearly view of the comparisons, the Post Hoc Test was performed to determine the significance value between each of the disease groups. The analysis of the Post Hoc test of the bioimpedance parameters are shown in Table 4.33 to Table 4.42.

Table 4.33 represents the multiple comparisons between each of the disease group on the fat (%) and total fat before and after dialysis treatment.

**Table 4.33** The effects of disease group from Post Hoc Test on the comparisons of fat (%) and total fat before and after dialysis treatment.



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| Body Bioimpedance Parameter | Fat (%) | | Total Fat | |
|---|---|---|---|---|
| **Disease Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 0 and 1 | - | - | 0.000 | 0.003 |
| 0 and 4 | 0.000 | 0.004 | 0.000 | 0.000 |
| 0 and 5 | 0.050 | - | 0.000 | 0.000 |
| 1 and 1 | - | - | 0.002 | - |
| 1 and 4 | - | - | 0.002 | 0.007 |
| 1 and 6 | - | - | 0.000 | 0.000 |
| 2 and 4 | 0.001 | 0.016 | 0.000 | 0.000 |
| 2 and 6 | - | - | 0.000 | 0.000 |
| 3 and 4 | 0.007 | - | 0.000 | - |
| 3 and 5 | - | - | - | 0.000 |
| 3 and 6 | - | - | 0.000 | 1.000 |
| 4 and 5 | 0.022 | 0.034 | 0.000 | 0.000 |
| 4 and 6 | - | - | - | 0.001 |
| 5 and 6 | - | - | 0.000 | 0.000 |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity.

Table 4.34 represents the multiple comparisons between each of the disease group on the lean (%) and total lean before and after dialysis treatment.

**Table 4.34** The results from Post Hoc Test based on the effect of the disease group on the comparisons of the lean (%) and total lean before and after the dialysis treatment.

| Body Bioimpedance Parameter | Lean (%) | | Total Lean | |
|---|---|---|---|---|
| **Disease Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 0 and 4 | 0.002 | 0.016 | - | - |
| 0 and 5 | - | - | 0.000 | 0.000 |
| 1 and 6 | - | - | 0.000 | 0.000 |
| 2 and 4 | 0.003 | 0.035 | - | - |
| 2 and 6 | - | - | 0.000 | 0.000 |
| 3 and 4 | 0.021 | - | - | - |
| 3 and 6 | - | - | 0.000 | 0.000 |
| 4 and 6 | - | - | 0.000 | 0.000 |
| 5 and 6 | - | - | 0.038 | - |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity.

Table 4.35 shows the multiple comparisons from Post Hoc Test of the water (%) and total water before and after dialysis treatment.

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**Table 4.35** The effects of disease group from Post Hoc Test on comparisons of the water (%) and total water before and after dialysis treatment.

| Body Bioimpedance Parameter | Water (%) | | Total Water | |
|---|---|---|---|---|
| Disease Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 0 and 1 | 0.035 | - | - | - |
| 0 and 4 | 0.021 | - | - | - |
| 0 and 6 | 0.006 | 0.005 | 0.000 | 0.000 |
| 1 and 6 | - | - | 0.000 | 0.000 |
| 2 and 4 | 0.028 | - | - | - |
| 2 and 6 | 0.022 | - | 0.000 | 0.000 |
| 3 and 6 | - | - | 0.000 | - |
| 4 and 5 | - | - | 0.000 | 0.001 |
| 5 and 6 | - | - | 0.014 | 0.031 |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity.

Table 4.38 represents the multiple comparisons between each of the disease group on the dry weight and Basal Metabolic Rate before and after dialysis treatment.

**Table 4.36** The effects of disease group from Post Hoc Test on comparisons of the dry weight and BMR before and after dialysis treatment.

| Body Bioimpedance Parameter | Dry Weight | | BMR | |
|---|---|---|---|---|
| Disease Group | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 0 and 1 | - | - | - | 0.044 |
| 0 and 6 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 and 6 | 0.015 | 0.007 | 0.000 | 0.000 |
| 2 and 6 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 and 6 | - | 0.000 | 0.000 | 0.000 |
| 4 and 5 | 0.002 | - | - | - |
| 4 and 6 | - | 0.002 | 0.000 | 0.000 |
| 5 and 6 | - | - | 0.021 | 0.043 |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity
Note 2: BMR=Basal Metabolic Rate

Table 4.37 represents the multiple comparisons between each of the disease group on the Est. Average Req. before and after dialysis treatment.

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**Table 4.37** The effects of disease group from Post Hoc Test on comparisons of the Est. Average Req. before and after dialysis treatment.

| Body Bioimpedance Parameter | Est. Average Req | |
|---|---|---|
| Disease Group | Sig. Before | Sig. After |
| 0 and 1 | - | 0.044 |
| 0 and 6 | 0.000 | 0.000 |
| 1 and 6 | 0.000 | 0.000 |
| 2 and 6 | 0.000 | 0.000 |
| 3 and 6 | 0.000 | 0.000 |
| 4 and 6 | 0.000 | 0.000 |
| 5 and 6 | 0.021 | 0.043 |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity

Table 4.38 represents the multiple comparisons between each of the disease group on the impedance value at different frequencies before and after dialysis treatment..

**Table 4.38** The effects of disease group from Post Hoc Test on comparisons of the impedance value at different frequencies before and after dialysis treatment.

| Body Bioimpedance Parameter | Impedance 5 kHz | | Impedance 50 kHz | | Impedance 100 kHz | | Impedance 200 kHz | |
|---|---|---|---|---|---|---|---|---|
| Disease Group | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After |
| 0 and 6 | 0.027 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 2 and 6 | - | 0.009 | 0.009 | 0.000 | 0.018 | 0.019 | 0.000 | 0.031 |
| 3 and 6 | 0.006 | 0.000 | - | - | 0.000 | 0.000 | - | 0.000 |
| 4 and 5 | - | - | 0.000 | - | - | - | - | - |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity

Table 4.39 represents the multiple comparisons between each of the disease group on the resistance, reactance and phase angle at 50 kHz before and after dialysis treatment

**Table 4.39** The effects of disease group from Post Hoc Test on comparisons of the resistance, reactance and phase angle before and after dialysis treatment.

| Body Bioimpedance Parameter | Resistance 50 kHz | Reactance 50 kHz | Phase angle 50 kHz |
|---|---|---|---|

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| Disease Group | Sig. Before | Sig. After | Sig. Before | Sig. After | Sig. Before | Sig. After |
|---|---|---|---|---|---|---|
| 0 and 6 | 0.000 | 0.000 | - | - | - | - |
| 2 and 6 | 0.010 | 0.010 | - | 0.025 | - | - |
| 3 and 6 | 0.000 | 0.000 | - | - | - | - |

Note 1: Disease Group 0=Kidney Problem. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 6=Kidney, High Blood Pressure and Obesity

Table 4.40 represents the multiple comparisons between each of the disease group on the ICW (%), total ICW, ECW (%) and total ECW before and after dialysis treatment.

**Table 4.40** The effects of disease group from Post Hoc Test on comparisons of the resistance, reactance and phase angle before and after dialysis treatment.

| Body Bioimpedance Parameter | ICW (%) | | Total ICW | | ECW (%) | | Total ECW | |
|---|---|---|---|---|---|---|---|---|
| **Disease Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. After** | **Sig. Before** |
| 0 and 1 | - | - | - | - | - | - | - | 0.001 |
| 0 and 6 | - | - | 0.000 | 0.000 | - | 0.001 | 0.000 | 0.000 |
| 1 and 3 | - | - | - | - | - | - | - | 0.036 |
| 1 and 6 | - | - | 0.000 | 0.000 | - | - | 0.019 | 0.000 |
| 2 and 6 | - | - | 0.000 | 0.000 | - | - | 0.000 | 0.000 |
| 3 and 5 | - | - | - | - | - | - | 0.000 | - |
| 3 and 6 | - | - | 0.000 | 0.000 | - | - | 0.000 | 0.000 |
| 4 and 6 | - | - | 0.013 | 0.004 | - | - | - | 0.005 |
| 5 and 6 | - | - | - | 0.050 | - | - | - | 0.001 |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity

Table 4.41 represents the multiple comparisons between each of the disease group on the TBW (%) and TBW before and after dialysis treatment.

**Table 4.41** The effects of disease group from Post Hoc Test on comparisons of the TBW (%) and TBW before and after dialysis treatment.

| Body Bioimpedance Parameter | TBW (%) | | TBW | |
|---|---|---|---|---|
| **Disease Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 0 and 1 | 0.035 | - | - | - |



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| | | | | |
|---|---|---|---|---|
| 0 and 4 | 0.021 | - | - | - |
| 0 and 6 | 0.006 | 0.005 | 0.000 | 0.000 |
| 1 and 6 | - | - | 0.000 | 0.000 |
| 2 and 4 | 0.028 | - | - | - |
| 2 and 6 | 0.022 | - | 0.000 | 0.000 |
| 3 and 6 | - | - | 0.000 | 0.000 |
| 4 and 6 | - | - | 0.000 | 0.001 |
| 5 and 6 | - | - | 0.014 | 0.031 |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity
Note 2: TBW=Total Body Water

Table 4.43 represents the multiple comparisons between each of the disease group on the body cell mass, third space water and body impedance before and after dialysis treatment.

**Table 4.42** The effects of disease group from Post Hoc Test on comparisons of the body cell mass, third space water and body impedance before and after dialysis treatment.

| **Body Bioimpedance Parameter** | **Body Cell Mass** | | **Third Space Water** | | **Body Impedance** | |
|---|---|---|---|---|---|---|
| **Disease Group** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** | **Sig. Before** | **Sig. After** |
| 0 and 4 | - | - | 0.005 | 0.026 | - | - |
| 0 and 6 | 0.000 | 0.000 | - | 0.025 | - | - |
| 1 and 6 | 0.000 | 0.000 | - | - | - | - |
| 2 and 4 | - | | 0.015 | 0.046 | - | - |
| 2 and 6 | 0.000 | 0.000 | - | 0.091 | - | - |
| 3 and 6 | 0.013 | 0.000 | - | - | - | - |
| 4 and 6 | - | 0.004 | - | - | - | - |
| 5 and 6 | - | 0.051 | - | - | - | - |

Note 1: Disease Group 0=Kidney Problem. Disease Group 1=Kidney and Diabetes. Disease Group 2=Kidney and High Blood Pressure. Disease Group 3=Kidney and Heart Disease. Disease Group 4=Kidney and Obesity. Disease Group 5=Kidney, Diabetes and High Blood Pressure. Disease Group 6=Kidney, High Blood Pressure and Obesity

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# CHAPTER 5

# DISCUSSION

## 5.1 Introduction

This study was focused on the effects of the dialysis on the body bioimpedance parameters. The main purpose of the dialysis treatment is to remove all the excessive water and to filter blood from any wastes or materials out of the body since the kidney is not able to function properly. This process was performed by using the dialysis machine which acts as an artificial kidney. Forty-eight patients have been selected randomly from two centres of heamodialysis. A bioimpedance analyzer device, the BodyStat QuadScan 4000 was used to check the bioimpedance parameters of the patients before and after the dialysis treatment. The data obtained from the experiment has been analyzed by using the SPSS software to find the significance value of the bioimpedance parameters before and after dialysis treatment.

## 5.2 Measurement Techniques of Body Bioimpedance

Before the measurement of the body bioimpedance was taken, the weight and height of the patients were recorded as the values will be used in the calculation especially to calculate BMI and WHR. The patient was lying on the bed and this was to ensure that the blood flow smoothly so that the body equilibrium can be achieved. This is important to obtain the accurate and precise reading of the body bioimpedance. Small electrical current that injected into the body can travel easily when the body in supine position because more surface area of the blood vessels. The patients have been asked do not to take in food or drink during the treatment because this can affect the biompedance reading. Two long electrodes have been used and these electrodes were placed on the

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right hand and feet. The measurement was repeated for five times to ensure the accuracy of the reading.

## 5.3 Demographic Analysis

There were four demographic factors that involved in this research. The types of gender, age group, BMI category and WHR are the factors that may affect the body bioimpedance parameters before and after the dialysis treatment.

The analysis of the frequencies for gender variable has been performed. Based on the Table 4.1, it noticed that the percentage of male patients was higher than female. It can be concluded that male gender has potential to have the kidney problem. This can be occurred due to the unhealthy lifestyle such as smoking, drinking or uncontrolled eating habit which leads to the damaging of the kidney (Hills and Byme, 1998). However, there are several other causes of kidney problem. For example, it may be due to an accident that damages the kidney, infections of pathogens and also the patients already suffered the kidney problem since birth.

According to the Table 4.2, the ages of the patients have been grouped into five. Basically, many of the older people receive the dialysis treatment. Figure 4.2 shows the percentage of dialysis patients based on the age group. It is clearly viewed that patients aged between 51 to 60 years showed the highest percentage compare to the other age groups. As a human being, as the age increases, the ability of the body to maintain the healthiness will be decreased. So, for older people, the tendency to obtain chronic disease is much easier since their body is very weak in terms of the body activity. The lowest frequencies showed by the patients aged more than 70 since this group of age are very few.

Patients which underwent the dialysis treatment might have other types of diseases besides kidney impairment. In this research, there were four types of disease commonly suffered by patients; diabetes, obesity, high blood pressure and heart disease. These

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diseases may affect their body bioimpedance and body health. Based on the Table 4.3, most of the patients had kidney problem and high blood pressure followed by diabetes. High blood pressure may be due to the physiological activity of the blood vessels. When kidney does not able to filter the blood wastes, these wastes will accumulate in the blood vessels and consequently increases the viscosity of the blood ( Scharfetter *et.al*., 1997). This situation will increase the resistance and the body impedance.

Patients with chronic dialysis tend to have high mortality which related to cardiovascular disease or heart disease (Voroneanu *et.al.*, 2010). Heart disease may be due to the high blood pressure created in the bloodstream.

Obesity is the excessive accumulation of body fat. In this study, only 2.1% of the patients are having kidney problem with obesity. Accumulation of fat is very dangerous because whenever fat deposited within the blood vessels, it will narrow the blood vessels and can cause hypertension.

The interaction of these demographic factors can be seen by analyze the comparisons using the Paired t-test. Next section will be discusses on the effects of these factors on the bioimpedance parameters before and after the dialysis treatment.

## 5.4 Interpretation of Body Bioimpedance Analysis

The analysis of the body bioimpedance was done by comparing the parameters before and after the dialysis treatment. The paired t-test was performed to determine the significance value between the mean before and mean after the dialysis treatment in order to identify the differences between the two mean values.

Table 4.5 shows the overall comparisons of the body bioimpedance parameters before and after the dialysis treatment. It can be seen that most of the parameters produced p less than 0.05. This can explain that the body bioimpedance parameters changed after the dialysis treatment consequently accepts the hypothesis that the dialysis treatment

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gives effects to the body bioimpedance. However, bioimpedance parameters such as dry weight, ICW (%), total ICW and BCM seems to have p more than 0.005. It tells that in these parameters, there was no changes occurred after dialysis treatment. For example, dry weight is an amount of the body mass without the extracellular water. The fluid removal out of the body can be assessed by the changes of the dry weight (Charra, B., 2007). After dialysis treatment, the reduction of the ECW should be achieved as an indicator for the removal of the excessive water from the body and this can be assessed by the dry weight. The decreasing of the ICW can be explained that the ultrafiltration process removes the ECW directly while the behaviour of ICW is more complex (Al-Surkhi *et.al.,* 2007)

In this research, no difference identified between dry weight before and after the dialysis treatment. This because during dialysis, the patients did not control the intake of water and fluid still accumulates inside the body even after dialysis treatment. The same reasons can be applied to the ICW (%) which also contribute to the assessment of the dry weight after dialysis. Another bioimpedance parameter which produced significance difference value less than 0.05 is the body cell mass. Body cell mass is the metabolically active cell which is most of the body metabolism will occur here. During dialysis treatment, the body cell mass is decreased since the energy stored was used to normalize the altered body composition.

However, based on the Lukaski, H.C., (1997), the decreasing value of BCM not really rised from the dialysis treatment, somehow it can be caused to the uremia. From the table, it can be concluded that the dialysis affects mostly the bioimpedance parameters. The bioimpedance parameters value were changed after dialysis treatment and this indicates that the alteration of body composition.

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## 5.5 The Effects of the Independent Variables on the Bioimpedance Parameters of Dialysis Treatment

This section will discuss on the effects of the independent variables such as gender, age group, additional diseases and BMI group on the body bioimpedance parameters before and after the dialysis treatment. This was done by comparing the mean before and after the treatment.

### 5.5.1 The Effects of Gender on the Comparisons of the Body Bioimpedance Parameters Before and After the Dialysis Treatment

Paired t-test have been performed to identify the mean difference at significance level 0.05 between body bioimpedance parameters before and after for female and male. Based on Table 4.6, it shows the significance level value at 0.05 in comparisons of all bioimpedance parameters before and after the treatment for female and male.

Both female and male show the significance level value greater than 0.05 for body bioimpedance parameters such as ICW (%) and BCM. This means that no significance difference between these parameters before and after the dialysis treatment. For example, ICW (%) shows no difference before and after dialysis treatment because during the dialysis treatment, the patients did not control their water intake and led to the accumulation of body water. So, the dialysis treatment seems not to be efficient to remove the excessive water out from the patient's body.

BCM as been discussed earlier, no significance difference can be found between the parameters before and after dialysis for female and male. Significance value is higher for the BMR of male means that there is no difference between BMR before and after the treatment. BMR is the energy expenditure to carry out the body activities such as respiration, heart beating, metabolism and other body activities to ensure the continuity of the life. Male generally will have higher BMR compare to female based on their lifestyles which is active. Female shows greater significance value for total ECW while male shows the p more than 0.05 for total ICW which is no difference between before and after the dialysis treatment for both parameters. Total ICW and total ECW gives the amount of TBW. Dialysis removed all the excessive water from the body since the kidney failed to do this function. So, efficient dialysis process will reduce the amount of TBW. However, in this research, most of the patients still keep drink water during the treatment and maybe due to this, there was no difference between total ICW and ECW before and after dialysis treatment. Phase angle at 50 kHz was higher in male. Phase angle is an indicator for measuring overall body health. Kidney problem seems to lower the body phase angle due to the less cell integrity.

### 5.5.2 The Effects of Age Group on the Comparisons of the Body Bioimpedance Parameters Before and After the Dialysis Treatment

Age group is another factor that can be related to the bioimpedance parameters. In this research, most of the patients aged between 51 to 60 years. The Paired t-test has been performed to compare the mean before and after the dialysis treatment and to find out the significance value at 0.05 for each age group. Table 4.7 shows the comparisons of the bioimpedance parameters before and after the dialysis treatment for each of the age group.

The significance value which is p less than 0.05 indicates that there is a difference of the parameters between before and after the dialysis treatment. Meanwhile, significance value which is greater than 0.05 indicates that there is no difference found between the comparison of the bioimpedance parameters before and after dialysis treatment.

The comparisons of the parameters before and after the dialysis treatment between the age group also have been performed by using the ANOVA test. Table 4.8 shows the overall comparisons from ANOVA test for all the bioimpedance parameters before and



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after the dialysis treatment. All the bioimpedance parameters before the treatment showed significance value less than 0.05 except for water (%), impedance at 50 kHz, 100 kHz, and 200 kHz, resistance 50 kHz, ECW (%), TBW (%), and total ECW. To clearly view the comparisons between the age group, the Post Hoc Test was performed to identify the significance value of the bioimpedance parameters before and after the dialysis treatment between each of the age group. In the Post Hoc Test, the comparisons have been made between one age group with another age group. This test can reveal the significance value between two groups of age. By example, Table 4.9 shows the significance value for comparisons of fat (%) and total fat before and after dialysis treatment. It can be seen from the table, interaction between age group 1 and 3 produced significance value which less than 0.05 for fat (%) after the dialysis treatment. This means that there is a difference value of the fat (%) after dialysis treatment between Age Group 1 and 3. Meanwhile, the interaction between age group 1 and 5 produced significance value less than 0.05 for fat (%) and total fat before and after the treatment. This indicates that the value for fat (%) and total fat before dialysis treatment is difference after dialysis between Age Group 1 and 4.

Different age groups give different values of bioimpedance parameters between before and after dialysis treatment. This research mostly involved patients aged between 51 to 60 years. This type of age is very common since during this age, people tend to suffer from several chronic diseases especially kidney problem. This can be related to another type of body bioimpedance parameters that is phase angle. The value of phase angle will decrease as our age increases. The phase angle is depending on the value of the reactance. Low reactance leads to the low phase angle due to the cell breakdown and unable to store energy to perform the body functions (Ibrahim *et.al,* 2005). Basically, young people will have greater phase angle compared to old people since young people can maintain their cell integrity. Based on the Table 4.14, there is a difference of phase



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angle at 50 kHz after the dialysis treatment between the interactions of different age group. Only interactions between Age Group 1 and 5, Age Group 2 and 3 and Age Group 2 and 5 produced significance level which is p=0.044, p=0.001 and p=0.000 for the comparisons of the phase angle before the dialysis treatment.

BMR seems to be higher for the young people since young people need to spend more energy to carry out their life activities compared to the old people. Table 4.11 shows the comparisons of the BMR before and after the dialysis treatment for interaction of difference age group. The significance difference which is less than 0.05 can be seen by the interactions between Age Group 1, 2, 3 and 4 with Age Group 6. This means that the difference is significance between this age group. This can be explained that the BMR is needed during the dialysis because it is important to maintain and stabilize the altered body compositions.

Impedance at 5 kHz showed the only significance value p less than 0.05 for interaction between Age Group 1 and 2 (Refer to Table 4.13). Impedance, Z is the total resistance and reactance of the body by conducting the electrical current. This maybe because of the less fat content in the patients within Age Group 1 and 2 which is can induced the lower resistance. High fat content in the dialysis patient may resist the flow of the electrical current and lead to the high value of impedance.

The water content also can affect the impedance value. Table 4.15 to Table 4.17 represent the significance difference value of the water content in the body for the interaction between difference group of age which include the ICW, ECW and TBW. The water content should be reduced after the dialysis treatment which indicates the effectiveness of the dialysis treatment. However, not all the age group produced significance difference value less than 0.05. It may be because the patients did not control the intake of the water. High water content lead to the low value of impedance since water acts as a good electric conductor. Low water content increases the

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impedance value by example the presence of hematocrit in the blood vessels and any other blood materials which act as barrier of electrical conductivity.

The body bioimpedance parameters which have been discussed above are the one which affected by the age group. The next section will discuss the effects of the BMI group and disease group on the body bioimpedance.

### 5.5.3 The Effects of BMI on the Comparisons of the Bioimpedance Parameters Before and After the Dialysis Treatment.

The Body Mass Index can be a good indicator to predict body's health. BMI helps to predict the body condition either underweight, ideal weight or obese. BMI is calculated by using the formula weight (kg)/height ($m^2$). The patient's BMI has been categorized into five different groups as shown in the Table 4.4. BMI can affect the body bioimpedance parameters before and after the dialysis treatment. The Paired t-test has been conducted to identify the significance value before and after the dialysis treatment. Table 4.19 shows the overall comparisons between the parameters before and after for each age group.

For BMI group 1 which is the BMI value is below 20, produced significance value p less than 0.05 for all the bioimpedance parameters except for dry weight, ICW (%), BCM, and body impedance. This means that there is no difference found in this BMI group before and after the dialysis treatment.

For BMI group 2 which the value range between an ideal weight, all the bioimpedance parameters produced the significance level p less than 0.05 which means that there is a difference of the body bioimpedance before and after the dialysis treatment. However, parameters such as dry weight, BMR, Est. Average Req, phase angle 50 kHz, ICW (%), ECW (%), total ICW, total ECW and BCM produced the significance level value p greater than 0.05.

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BMI group 3 which is overweight patients produced the p less than 0.05 for all the body bioimpedance parameters before and after the dialysis treatment. This indicates that the body bioimpedance parameters were changed after the dialysis treatment.

BMI group 4 is considered as obese patient which is the range of the BMI lies within 30 to 40. In this group, it can be seen that the significance value which is less than 0.05 produced mostly by the comparisons before and after the dialysis treatment for all the parameters except the dry weight, ICW (%), total ICW and BCM.

Very obese patients have been categorised under the BMI group 5. The comparisons of all the body bioimpedance parameters before and after the dialysis treatment for this BMI group produced the significance level value p less than 0.05. This means that the difference is significance between each other for BMI group 5.

The interactions between the BMI groups were identified by using the ANOVA test. Table 4.20 shows the overall comparisons of all the bioimpedance parameters before and after the dialysis treatment with difference BMI groups. The Post Hoc test was been carried out for the bioimpedance parameters which produced the significance level value p less than 0.05 to identify the difference between the two BMI groups. This was showed by the Table 4.21 until Table 4.31 which summarized all the BMI groups interactions with the significance value p before and after dialysis treatment. When the interaction of two BMI groups produced the significance level value which is less than 0.05, this means that there is a difference of the bioimpedance parameters before and after dialysis for these two types of BMI groups.

BMI value seems to give effects to the body bioimpedance parameters before and after the dialysis treatment. For example, fat content can be a factor contributes to the ineffectiveness of the dialysis treatment. Patients which have higher BMI accumulate the fat within the body. As we know, fat acts as a barrier of electricity. High fat content

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will reduced the penetration of the electricity within the body cell. This will increase the body resistance and led to the high body impedance.

Low BMI seems to have less fat content. This can induce the flow of electrical current within the body and lower the resistance. This condition will produced low impedance value.

The body bioimpedance parameters can be related to each other. By example, high fat content may be less water inside the body. Water acts as good conductor of the electricity. So when the body contains more fat but in dehydrate conditions, this also can lead to the higher resistance and impedance value.

### 5.5.4 The Effects of the Additional Diseases on the Comparisons of the Body Bioimpedance Parameters Before and After Dialysis Treatment.

In this research, four common diseases have been identified in the dialysis patients instead of kidney problem. These diseases include the diabetes, high blood pressure, obesity and heart disease. These types of additional diseases have been grouped into different groups based on the Table 5.1 below.

**Table 5.1** The additional disease group of the dialysis patients

| Disease Group | Types of Diseases |
|---|---|
| 0 | Kidney Problem |
| 1 | Kidney and Diabetes |
| 2 | Kidney and High Blood Pressure |
| 3 | Kidney and Heart Disease. |
| 4 | Kidney and Obesity |
| 5 | Kidney, Diabetes and High Blood Pressure |
| 6 | Kidney, High Blood Pressure and Obesity. |

Table 4.32 shows the overall comparisons of the Paired t-test for all the disease groups before and after the dialysis treatment. This test was conducted to find out the significance level value before and after the dialysis treatment.

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For disease group 0 which involved only the patients with kidney, all the bioimpedance parameters produced the significance level value which is p less than 0.05 except for dry weight, ICW (%), ECW (%), total ICW, and BCM.

Disease group 1 produced the comparisons of all the bioimpedance parameters with significance level value which less than 0.05. However, the parameters such as total fat, water (%), dry weight, ICW (%), ECW (%), TBW (%), total ICW and BCM produced the significance difference p greater than 0.05. This showed that the difference is not significance between the parameters before and after the dialysis treatment.

Paired t-test for disease group 2 showed the significance value less than 0.05 for all the body bioimpedance parameters except for dry weight and ICW (%).

Comparison of the body bioimpedance parameters before and after the dialysis treatment from Paired t-test showed the significance difference less than 0.05 for all the body bioimpedance parameters for disease group 3 to disease group 6. This means that the difference is significance between each other and indicates that the dialysis can affect the body bioimpedance parameters.

The interaction of the bioimpedance parameters with the additional disease group can be seen in the Table 4.32. Table 4.32 shows the overall results from ANOVA for comparing of all the bioimpedance parameters before and after the dialysis treatment. The comparisons produced the significance value p less than 0.05 for all the bioimpedance parameters except for phase angle 50 kHz, ICW (%) and body impedance.

Interaction of the disease group and the bioimpedance parameters can be clearly shown in the Table 4.32 until Table 4.42. These tables showed the multiple comparisons from Post Hoc Test of the bioimpedance parameters before and after the dialysis treatment between each of the disease group. These comparisons is to determine which of the disease group produced the significance value p less than 0.05, which means that the difference between these two groups is significance between each other.

Kidney problem was the major disease studied in this research. Patients who received the dialysis treatment basically due to the kidney which do not able to filter and remove the body wastes and excess water. This condition leads to the accumulation of the body wastes and excessive water in the body. Accumulation of body wastes such as urea and ammonia can increase the viscosity of the body fluid, thus increase the resistance. The increasing of the resistance will limit the flow of the current within the body. Thus, it will increase the body impedance.

Besides kidney problem, one of the additional diseases that have been identified was the diabetes. Diabetes is caused by the increasing amount of glucose in the body. When the glucose is too high in the blood vessels, this also can increase the blood viscosity. Lack of water in the body also can lead to the diabetes. The inability of the body to produced insulin is the major factor of diabetes. People with diabetes seem to have higher body impedance and resistance.

High blood pressure always related to the diabetes. The high viscosity of the blood leads to the slow movement of the blood flow. To prevent this situation, the heart needs to pump stronger to make sure the blood delivered frequently to the entire body. Stronger pumping actions from the heart will cause the high blood pressure.

Obesity is the excessive accumulation of fat. Obese people always have high BMI value and greater WHR. Fat which accumulates in the body acts as barrier and this will increase the body resistance and impedance.

These are some of the effects of the demographic factor on the body bioimpedance parameters before and after dialysis treatment. It can be concluded that most of the interactions produced significance value less than 0.05 and this indicates the difference



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is significance between each other. Thus, dialysis can affect the body bioimpedance parameters.

Bioimpedance analysis gives major advantages to monitor the body compositions through out the dialysis treatment. This can help the doctors and the patients to improve the quality of life. Besides that, the effectiveness of the dialysis treatment can be achieved to ensure that the patients would have a greater body quality.

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# CHAPTER 6

# CONCLUSION

## 6.1 Introduction

The data that has been analyzed showed the significance result. The measurements taken before and after the dialysis treatment showed the significance difference. This will reject the Null hypothesis, Ho. So, it can be concluded that the most of the results produced the significance difference before and after the dialysis treatment. Besides that, this study also proved that the dialysis treatment gives positive effects on the body bioimpedance.

## 6.2 Limitations

This study was conducted at the dialysis center which located outside the faculty which leads to the limitations of using the equipment. There was only one bioimpedance analyzer available in the faculty during that time and due to this, time needed to conduct the experiment was very short since other students also need to use the same equipment. The recruitment of the subjects also limits the objective of this study. Most of the subjects aged between fifty years and above and this reduced the subject's populations. Besides that, some of the subjects did not give full commitment during the experiment especially after the treatment because they felt very tired and weak after four hours treatment and they did not want to wait for the measurement.

Besides that, during the measurement, some of the patients did not stay in the supine position and this problem may affect the body bioimpedance reading. The long electrodes that have been used in the study were too sticky on their hands and feet and some of the subjects refused to involve in this measurement.

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## 6.3 Conclusion

The bioimpedance technique is non invasive, quick and reliable method in order to assess the body composition.

The comparisons between before and after dialysis showed that the dialysis treatment can give a good effect of bioimpedance parameters for kidney patients. This study concluded that bioimpedance parameters of the subjects before and after the dialysis treatment are significantly different. Most of the parameters showed positive effects for the body health especially to improve the quality of life for kidney patients.

## 6.4 Future Works

This study only focuses on the effects of dialysis on body bioimpedance. Future works that can be implemented to achieve good and precise result may include the using of latest bioimpedance analyzer that is more convenient not only for dialysis patient but also for other chronic patients. Besides that, this study can be upgraded by analyze the type of dialysis machine that is used in the dialysis center, so that the effectiveness of the dialysis treatment can be identified.

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## APPENDIX A
## A sample of questionnaire

**Questionnaire**
**The Effects of Dialysis on Body Bioimpedance**

..........................................................................................................................................

**No. :**

Name :..........................................................................................................

Gender : ( ) Male ( ) Female

Age : ( ) Less than 20 years ( ) 20 – 30 years
( ) 30 – 39 years ( ) 40 -50 years
( ) 50 – 60 years ( ) 61 years and above

Weight :............................kg Height :.................................cm

Address:...............................................................................................................

Disease (Other than kidney impairment):.........................................................................

**Questionnaire**
**The Effects of Dialysis on Body Bioimpedance**

..........................................................................................................................................

**No. :**
Name :....................................................................................................
Gender : ( ) Male ( ) Female
Age : ( ) Less than 20 years ( ) 20 – 30 years
( ) 30 – 39 years ( ) 40 -50 years
( ) 50 – 60 years ( ) 61 years and aove

Weight :............................kg Height :.................................cm

Address :.........................................................................................................

Disease (Other than kidney impairment):.........................................................................

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