# RELATIVE VALIDITY OF THREE BIOELECTRICAL IMPEDANCE ANALYSIS EQUIPMENTS IN MEASURING BODY COMPOSITION OF ADULTS

by

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Thesis submitted in partial fulfillment
of the requirements of the degree of
Bachelor of Health Sciences (Nutrition)

JUNE 2013

**Pengesahan Relatif Tiga Peralatan *Biolectrical Impedance Analysis* dalam Pengukuran Komposisi Badan Golongan Dewasa**

## Abstrak

Tujuan kajian ini adalah untuk menentukan kesahihan relatif peralatan *Biolectrical Impedance analysis* (BIA) untuk mengukur komposisi badan di kalangan orang dewasa. Tiga jenis alat TANITA BIA yang berbeza iaitu SC 330, SC 240 dan BC 545 telah digunakan untuk menentukan komposisi badan peserta dengan SC 330 sebagai kaedah rujukan. Seramai 120 subjek (74 perempuan dan 46 lelaki) berumur 19-30 tahun dari Universiti Sains Malaysia (USM) Kelantan telah mengambil bahagian dalam kajian ini. Dari kajian ini, kedua-dua alat SC 240 dan BC 545 menunjukkan hubungan yang signifikan dengan SC 330 peratusan lemak badan. Khususnya, dalam lelaki korelasi tertinggi dengan SC330 peratusan lemak badan adalah SC 240 ($r = 0.97$, $p < 0.001$). Sementara itu, korelasi tertinggi dengan SC 330 peratusan lemak badan wanita adalah BC545 ($r = 0.97$, $p < 0.001$). Min peratusan lemak badan untuk SC 330 adalah 22.85% (SD 6.08). Min bagi SC 240 iaitu 22.85% (SD 8.59) didapati tidak menunjukkan perbezaan yang ketara dengan SC 330 dalam min peratusan lemak badan. Manakala, terdapat perbezaan yang signifikan bagi BC 545 dengan SC 330 dalam min peratusan lemak badan iaitu 24.32% (SD 8.97). Kesimpulannya, SC240 terbukti mempunyai hubungan yang baik dengan SC 330 dan boleh digunakan sebagai alat yang boleh dipercayai dalam mengukur komposisi badan di kalangan orang dewasa.

**Relative Validity of Three Bioelectrical Impedance Analysis Equipments**

**In Measuring Body Composition of Adults**

## ABSTRACT

The aim of this study is to determine relative validity of bioelectrical impedance analysis (BIA) equipments for the measurement of body composition among adults. Three different Tanita BIA equipments namely SC 330, SC 240 and BC 545 were used to determine body composition of participants with SC330 as the reference method. A total of 120 subjects (74 girls and 46 boys) aged 19-30 years from Universiti Sains Malaysia (USM) Kelantan took part in this study. From the study, both SC 240 and BC 545 showed significant correlation with SC 330 for body fat percentage. Specifically, in male the highest correlation with SC 330 for body fat percentage was SC 240 ($r= 0.97$, $p <0.001$). Meanwhile, the highest correlation with SC 330 for body fat percentage in female was BC 545 ($r= 0.97$, $p <0.001$). Mean body fat percentage for SC 330 was 22.85% (SD 6.08). The mean percent body fat for SC 240 was 22.85% (SD 8.59) showed no significant difference from SC330. There was significant difference of mean body fat percentage by BC 545 to SC 330 which is 24.32% (SD 8.97). In conclusion, SC 240 shown to have good correlation with SC 330 and can be used as a reliable equipment in measuring body composition among adults.

## DECLARATON

I hereby declare that the thesis is my original work except for the quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently submitted for any other degree or purposes in Universiti Sains Malaysia or at any other institutions.

Fatin Huwaina Bt Mohd Ghazali

Date:

I certify that Ms Fatin Huwaina Bt Mohd Ghazali has carried out her study entitled 'Relative Validity of Three Bioelectrical Impedance Analysis Equipments in Measuring Body Composition of Adults' as a final year research project in nutrition under my supervision. She has complied with the ethical standard and regulations in conducting her study and has completed writing her thesis. I am satisfied with her work and have no objection for the thesis to be examined by the appointed examiners by the School of Health Sciences, Universiti Sains Malaysia.

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## ACKNOWLEDGMENT

First and foremost, thanks God for giving me strength, the divine blessings and His grace throughout the completion of this study. With His blessing, I was able to go through all the hardships and difficulties in preparing the study.

I would like to offer my sincere gratitude to my supervisor Dr Hamid Jan Jan Mohamed for guiding and sharing his time and insight with me on this study. His continuous help and trust enable me to complete the study.

I would like to extend my gratitude to course's coordinator, Prof Wan Manan Muda for providing the guidelines and information that facilitate the completion of the study.

Besides, I would like to thank Ms Loy See Ling and Ms Norliyana Aris for her kindness and enthusiasm in assisting me completing this study, for willingly shared her time and knowledge every time in needed.

I would especially like to give my thanks to all my friends and course mates, whose always give support and encouragement throughout this study. I feel very grateful with the presence of friends, especially when facing the troubles and problems throughout the study.

Last but not least, special thanks to my parents and siblings, for always loving and supporting me all these years.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ADP | - | Air-displacement plethysmography |
| BIA | - | Bioelectrical Impedance Analysis |
| BF | - | Body fat |
| BMR | - | Basal metabolic rate |
| DXA | - | Dual energy x-ray absorptiometry |
| FFM | - | Fat-free mass |
| TBW | - | Total body water |
| UWW | - | Underwater weighing |

## DEFINITION OF KEY TERMS

| | | |
|---|---|---|
| Validation study | - | Validation study is conducted to demonstrate validity of an assessment tool, that provides the evidence to support the validity of the test, tool or equipment or to show that the result from the test is valid and fair. |
| Body composition | - | Body composition often is defined as the ratio of fat to fat-free mass and frequently is expressed as a percentage of body fat. |
| Bioelectrical impedance analysis | - | BIA is widely used method for estimating body composition by measuring the electrical impedance of body, which provides an estimate of total body water. |

# CHAPTER 1 INTRODUCTION

## 1.1 Background of the Study

Measuring body composition in human is usually in response to the need to describe either deficiencies or excesses of a component that is thought or known to be related to health risk (Lee & Gallagher, 2008). The assessment of body fat and fat free-mass provide valuable information about the physical and metabolic statuses of humans. In addition, the ability to accurately measure body fat is important because of the established association between high amounts of body fat and a variety of diseases.

Various methods are available for estimating body composition, and each has its strength and limitations including bioelectrical impedance analysis (BIA), air-displacement plethysmography (ADP), hydro densitometry and anthropometry (Lee & Gallagher, 2008). There are more accurate ways of measuring body fat, such as underwater weighing (UWW) and dual energy x-ray absorptiometry (DXA), but these are much less convenient as they require specialised equipment and expertise.

Bioelectrical impedance analysis (BIA) is widely used method for estimating body composition. This method determines the electrical impedance of body tissues, which provides an estimate of total body water (TBW), and then using this value to estimate fat-free mass (FFM) and body fat (*NIH*, 1994). The analysis of body composition by

bioelectrical impedance produces estimates of total body water (TBW), fat-free mass and fat mass by measuring the resistance of the body as a conductor to a very small alternating electrical current (Duren, et al., 2008).

BIA provides a reliable estimate of TBW under most conditions and it can be useful technique for body composition analysis in healthy individuals. Subsequent estimation of FFM and the percentage of body fat vary in validity depending on the population or individual studied and on the applicability of the prediction equation used to estimate these parameters of body composition (*NIH*, 1994). BIA values are affected by numerous variables including body position, hydration status, consumption of food and beverages, and recent physical activity.

The Tanita Body Composition Analyzer provides estimated values for each measured value of body fat percentage, fat mass, fat-free mass, muscle mass and bone mass, estimated value for the total body water measured value and estimated value for the visceral fat rating by using the BIA method. The Tanita Body Composition Analyzer measures body composition using a constant current source with a high frequency current (50 kHz, 90 μA).

The 8 electrodes are positioned so that electric current is supplied from the electrodes on the tips of the toes of both feet, and voltage is measured on the heel of both feet. The current flows into the upper limbs or lower limbs, depending on the body

parts to be measured. Tanita analyzers have undergone a stringent review by the FDA to ensure that the customers receive the highest quality and most accurate products on the market. The Tanita system measures the voltage drop from foot to foot when a small alternating current is applied through contact with two metal foot plates (Jebb, et al., 2000).

Previous studies using earlier Tanita models (TBF-105 and TBF511) assessed the accuracy of using a predictor variable programmed into the Tanita analyzers, to predict TBW, FFM, and FM values. Results from these studies found significant correlations between body composition predicted by the Tanita equipments and that estimated from UWW and DXA.

All high-stakes tests such as assessment of body composition using the new equipments need to be accompanied by a validation study that provides evidence to support the validity of the test or to put it more precisely, evidence to show that the decisions made based on the test results are valid and fair. In order to have good body composition estimates from BIA method, it is necessary to have proper validation based on reference methods of better accuracy and precision (Macias, et al., 2007).

In this study, body composition measurement using three different BIA equipments were compared. In recent years technological improvements have made BIA a more reliable and therefore more acceptable way of measuring body composition. The SC

330 is one of the latest Tanita BIA instruments that is faster, easier and less-intrusive to measure the body composition. This instrument has been clinically proven accuracy with supporting validation for estimation of body composition. Yet the evidence on the validity of the SC 240 and BC 545 were scarce especially in adults population. This study is carried out to determine the validity of these instruments against the Tanita SC 330 as reference method in measuring body composition among adults.

## 1.2 Rationale of Study

The validation study that will be conducted is to determine the validity of TANITA body composition analyzers, SC 240 and BC 545 against SC 330 for estimation of body composition, specifically body fat percentage among adults. As the data and evidence of these equipments on estimation of body composition among adults is still lacking, the research that is going to be conducted will be useful in contributing the evidence and prove that the BIA method using these TANITA devices is valid and good for assessment of body composition in human particularly among adults. The evidence and validation that will be gained from the research later can widely be used in the measurement of body composition for nutritional assessment and intervention for related health risk. Therefore, these BIA instruments can be used as the good equipment in measuring body composition particularly in adults.

## 1.3 Research Objectives

- General objective
  - To determine the relative validity of body composition measurement obtained from Tanita BC 545 and SC 240 compared to SC 330 in adults.
- Specific objectives
  - To determine the body composition of respondents using three different equipments.
  - To compare the estimation of body composition among adults using three different BIA equipments.

## 1.4 Research Questions

- How do the three different devices measure the body composition among adults?
- Do the three different bioelectrical impedance analysis equipments give significant difference on body composition measurement?
- Is this bioelectrical impedance analysis instruments is a good equipment in measuring the body composition?

## 1.5 Research Hypothesis

- **Null hypothesis, $H_0$=** There is no significant different of mean body fat percentage measurement among adults using three different bioelectrical impedance analysis equipments
- **Alternative hypothesis, $H_A$=** There is significant different of mean body fat percentage measurement among adults using three different bioelectrical impedance analysis equipments.

## 1.6 Conceptual Framework

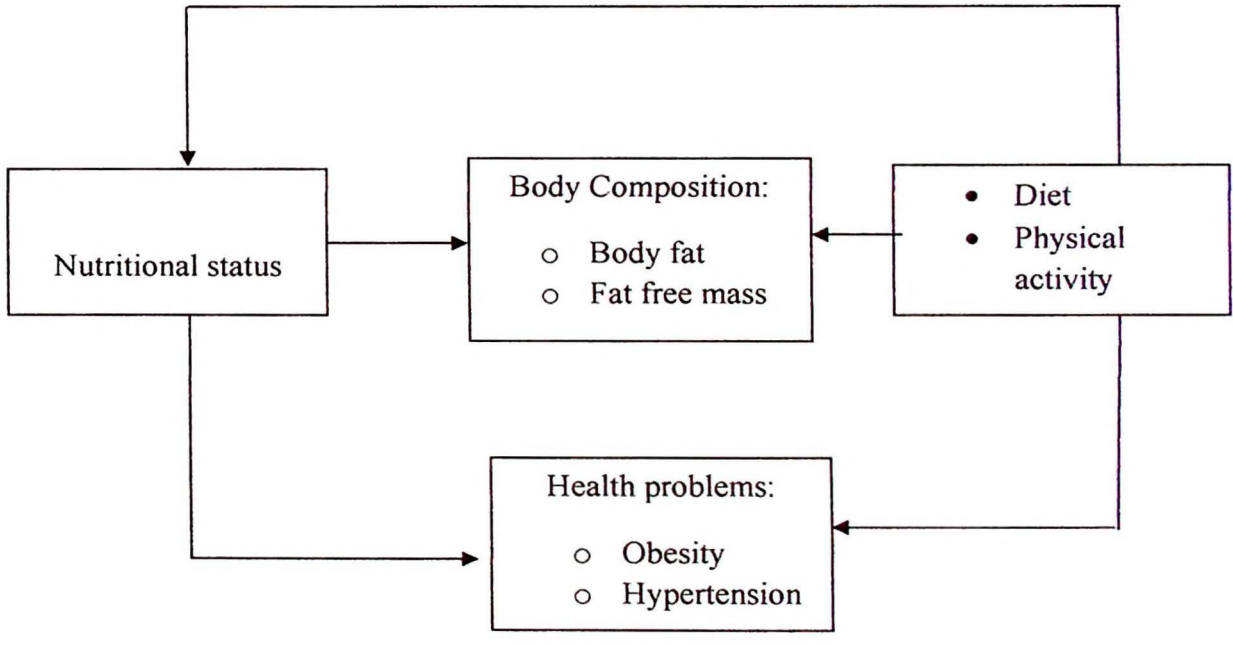


**Figure 1.0 Conceptual Framework**

# CHAPTER 2 LITERATURE REVIEW

## Body composition

Body composition often defined as the ratio of fat to fat-free mass and frequently is expressed as a percentage of body fat (R. D. Lee & Nieman, 2010). Body composition varies among individuals as a result of differences in body density and degree of obesity. Those with a higher proportion of fat-free mass to a lower proportion of body fat have a healthy body composition.

Body composition assessment can be used in the evaluation of malnourished and thin people as well. Body composition measurements may be useful for identifying person who do not have an increase in overall body fat, but who have an increase in visceral fat (Ayvaz & Cimen, 2011).

Body composition assessments vary in precision and in the target tissue of interest (Duren, et al., 2008). It is important to recognize that there is no single measurement method that allows for the measurement of all tissue and no method is error free. The available measurement methods range from simple to complex with all methods having limitations and some degree of measurement error (Lee & Gallagher, 2008).

The accurate measurement of body composition is crucial for the assessment of nutritional status and physical fitness in various clinical circumstances (C. H. Y. L. Ling & J.M., 2011). In order to have good body composition estimates from bioelectrical impedance techniques, it is necessary to have proper validation based on reference methods of better accuracy and precision (Macias, et al., 2007).

**Bioelectrical impedance analysis**

BIA offers advantages in terms of its simplicity and portability, hence making it an appealing and frequently used tool in estimating body composition in the wide population (C. H. Y. Ling, et al., 2011). BIA is a method that is easy to use, inexpensive and readily available. BIA has gained acceptance as an accurate method of estimation body fat percentage in clinics, laboratories and field setting. A large number of studies has compared results obtained using this technique with those obtained by other methods (Maughan, 1993).

This BIA method is based on the assumption that the body is a cylindrical-shaped ionic conductor in which extracellular and intracellular non-adipose tissue compartments act as resistors and capacitors, respectively (Kotler, et al., 1996). Assessment of body composition by BIA is based on the determination of total body water content from body resistance and reactance measurements (Lukaski, 1996).

BIA measures the impedance to an applied small electric current as it passes through the body's water pool. In practice, impedance is a drop in voltage when a small current with a fixed frequency passes between electrodes spanning the body.

From an established equation that uses the measured impedance value and height, total body water is estimated. It is assumed that the total conductive volume of the body is equivalent to that of total body water (TBW), most of which is contained in muscle tissue, and that the hydration of adipose tissue is minimal. BIA method is based on the principle that the conductivity of body varies in different body compartments (Ayvaz & Cimen, 2011).

The analysis of body composition by BIA produces estimates of total body water (TBW), fat-free mass (FFM), and fat mass by measuring the resistance of the body as a conductor to a very small alternating electrical current (Duren, et al., 2008). Most BIA research to date has utilized instrumentation capable of measurement at a single frequency, commonly 50 kHz (Hills & Byrne, 1998).

The study on accuracy and validity of BIA technique in measurement body composition in various populations has been widely argued and discussed. Lukaski et al indicated that the bioelectrical impedance technique was a valid and reliable approach for estimation of body composition in healthy adult population (Lukaski, et al., 1985).

However, due to large degree of heterogeneity in body composition of different population, the use of BIA may provide limitation in the measurement. Differences in body fluid distribution across body compartment, variability in tissue hydration both within and among individuals, and differences in age, degree physical fitness and adiposity can affect bio-impedance measures (Hills & Byrne, 1998). It is generally agreed that the accuracy of BIA depends on the variables included in the prediction equation of BIA equipments (Kyle, et al., 2001).

As body impedance is not only determined by the amount of body water but also by other factors like body water distribution, body build, body temperature and osmolarity, prediction formulas developed in healthy populations may not be valid under clinical conditions when usual used assumptions are violated (*NIH,* 1994). Regardless of the factors that may affect the body composition measurement, some of the previous studies indicated that FFM and TBW can be accurately estimated with BIA even when these factors existed in the study (Kotler, et al., 1996).

In general, because the current is greater in those paths with lower resistance, the paths will differ from person to person because of differences in body size, shape, electrolytes, fluid distribution, or other aspects of body composition, and will vary in the same person from time to time as these characteristics change. Almost any change in body size, shape, or composition will have at least a small effect on impedance (*NIH*, 1994).

Two types of impedance measurement methods were developed. The first one is the medical impedance measurements or known as traditional hand-to-foot BIA. Medical impedance meters are used in supine position with four gel-type electrodes, two voltage and two current ones, pasted on the right foot and wrist. The second one is classified as body fat analyzers. Body fat analyzers are commonly used for both health care professionals and the general public and are also called leg-to-leg or foot-to-foot impedance meters (FF-BIA) (Ayvaz & Cimen, 2011).

The Tanita body fat analyser is a novel system to estimate body fat based on principle of BIA method (Nunez, et al., 1997). Tanita equipments are designed for the majority of the population leading healthy lives with a regular lifestyle. Currently there are various BIA machines available on the market but little research has been published about their validity or reliability (Peterson, et al., 2011).

The Tanita BIA system provides a valid measure of percent body fat in older adults, and could be a convenient and practical approach for assessment in public health setting (Ritchie, Miller, et al., 2005). It is generally agreed that the accuracy BIA depends on the variables included in the prediction equation and on using a specific prediction equation validated for specific population (Kyle, et al., 2001).

For the Tanita system, the prediction equation used is usually unknown. Most impedance software is confidential because of its commercial sensitive nature, therefore

the equation used cannot be presented (Parker, et al., 2003). This makes it difficult to determine the appropriate population to use with each machine (Peterson, et al., 2011).

In this study, three different models of Tanita BIA equipments were used to measure body composition in adults. The study was conducted to determine the relative validity of Tanita equipments namely SC240 and BC545 against SC330. The SC330 was used as reference to determine the accuracy of the other two equipments in the study. According to research conducted by manufacturer, SC330 was proven as a valid and reliable tool in measuring body composition.

SC 330 is one of the Tanita equipments that had proven accuracy of body composition measurement. The validation researches by Tanita Medical Advisor Board are based on comparison with gold standard technique DXA; ensure this Tanita product scientifically accurate.

In addition, a study conducted to examine the accuracy of several BIA models compared with ADP concluded that Tanita 300 was the most reliable in measuring body composition among adults. As the Tanita SC330 used in this study is the latest and upgraded model from the same manufacturer, it has many features similar to the Tanita 300 model. Hence, the SC330 was relatively a valid and reliable tool to use as reference.

Apparently, there appear to have been fewer studies comparing different equipments of BIA for estimates of body composition. In the most previous validation studies, Tanita BIA equipments were commonly compared with other reference method such as DXA, ADP, and underwater weighing. Many studies considered these methods as reliable and valid technique in a wide range of subjects (Macias, et al., 2007).

To the best of my knowledge, there was no previous study had been carried out to validate the same three BIA equipments as used in this study. There were limited study had been done to determine the validity of BIA method using different equipments. Nevertheless, several studies have compared data of foot-to-foot impedance (FFI) built by Tanita with DXA and showed that they were reliable for a healthy population (Jaffrin, 2009).

It is important to note that various BIA equipments are supplied with proprietary prediction equations for the estimation of different body composition parameters. The details of these equations, as well as the measurement values generated by the BIA machine are generally unavailable to the users (C. H. Y. Ling, et al., 2011). As these equations are formulated on population-specific data, they may contribute to error in body composition measurements in different populations study. Nevertheless, the BIA equipments that were used in the study was from the same manufacturer may limit or reduce the differences of prediction formula used. It also has been recommended by the manufacturer that these equipments were suitable for adults.

The prediction equations used in the FF-BIA analysers used in the present study are also unknown. However, the prediction equations of FFM from BIA measurements have generally been validated against densitometry (Lazzer, et al., 2003). In actual use, BIA calculations of an individual's body fat may vary by as much as 10 percent of body weight because of differences in machines and methodology used (*NIH*, 1994).

Traditional hand-to-foot BIA is shown to be valid for assessing body composition of adults and older adults compared to gold standard of underwater weighing. Study by Ritchie et. al to determine the validity of Tanita FF- BIA with traditional BIA for body composition assessment of older adults found that Tanita FF-BIA provide valid measure of percent body fat. Utter et. al (1999) assessed the accuracy of the Tanita system in women in a cross-sectional study found no significant difference between underwater weighing and Tanita analyzer (Jebb, et al., 2000).

Furthermore, previous study that measure the validity of Tanita TBF 310 against four-compartment model, indicates that this FFI BIA device able to provide accurate measurements of group mean values but not of individual body composition assessments in overweight or obese children (Radley, et al., 2009).

To date, numerous previous validation studies on BIA technique in measuring body composition have shown inconsistency results. The discordance between results may be due to methodological differences such as various BIA devices and reference

method used, as well as heterogeneity in the study population (C. H. Y. Ling, et al., 2011). This may be due to various BIA devices used which have different equations used in estimate body composition. Hence, ccomparison of the present results with other validation studies is difficult due to different BIA devices used.

Selection of the technique and equipments for body composition measurement in this study also depends on the availability of measuring devices, the setting where the measurement is performed, and the applicability of body composition analysis results for to the study hypothesis.

Previously, the BIA is shown to be valid for assessing body compostition of adults and older adults compared to gold standard of underwater weighing. When impedance measurements are compared with estimates of total body water obtained by dilution methods, the correlations between the two methods are generally good (Maughan, 1993)

In addition, body impedance found to varies among different ethnic groups and may influences the accuracy of BIA. In this study, the effect of race was not analyzed as the distribution of subjects within each ethnic group is not equally distributed. Most of the subjects are Malay which is 85 subjects and the rest is Chinese.

An earlier study by Deurenberg et al., (2001) indicated that different body composition and body build among ethnic population may also influence the impedance. As impedance is related to the length of the conductor and inversely related to its cross-sectional area, it can be argued that instruments measuring impedance give relatively high impedance values in subjects with long and thin extremities and consequently body fat percent is likely to be overestimated.

As there are marked differences between ethnic groups in body build, for example Chinese and Malays having relatively shorter legs and arms than Indians, the use of those instruments in comparing body composition between ethnic groups may lead to systematic biases. As the incorporated formulas in those instruments may have been developed in populations with different body composition and body build, systematic biases in applying it to local populations may occur (Deurenberg-Yap & Deurenberg, 2001). Thus, it is possible that the Tanita is not appropriate for all races.

A previous validation study on the effect of race and sex in prediction of body composition with BIA indicated that both factors influence the normal ranges of body composition. However, these factors do not necessarily affect the ability of BIA to estimate the body composition in the study (Kotler, et al., 1996).

# CHAPTER 3 METHODOLOGY

## 3.1 Study Design

This cross-sectional study was designed to test the relative validity of body composition measurement obtained from the Tanita SC240 and BC545 devices using Tanita SC330 as the reference. Person who met the inclusion criteria were eligible to participate in the study. All measurements were completed on the same day, during one visit at the laboratory and each subjects was measured using all three devices. Anthropometric measurement including height and waist-hip circumferences of the participants were taken along on the same day.

### 3.1.1 Participants

After obtaining approval from the Ethics Committee, a sample comprising seventy-four women and fourty-six men aged 19-30 years were recruited voluntarily from Universiti Sains Malaysia (USM) students for the study. The sample of participants which consist of university students was representative of adult population.

### 3.1.2 Sample Size

Sample size calculation was determined by using single mean formula;

$$n = (1.96(SD)/ \Delta)^2$$

$(\alpha) = 0.05$

SD= standard deviation for % BF

$\Delta$= detectable mean difference

Refer to the Parker et al., SD for % BF is 7.8, and the $\Delta$ is set to 1.46

$$n = [1.96\ (7.8) / 1.46]^2$$

$$= \underline{109.6}$$

With the addition of 10% of non response rate, the total sample size proposed was 120. Thus, there were 74 women and 46 men participate in this study.

### 3.1.3 Inclusion and Exclusion Criteria

Upon the approval from the Universiti Sains Malaysia Human Research Ethics Committee (USMKK/PPP/JEPeM [260.4.(3.7)] ) (Appendix 4), the study has recruited the respondents based on the following criteria:

The inclusion criteria were:

1. Adults aged 19-30 at the time of study.
2. Physically and mentally healthy adults.

The exclusion criteria were:

1. Pregnant and lactating woman
2. Adult with chronic diseases such as heart disease.
3. Adult with a pacemaker or other internal medical devices
4. Take medication that would produce abnormalities in body composition.

## 3.2 Instrumentation

Before the assessment of body composition, all subjects were asked to fill out a brief questionnaire about their basic data such as age, sex, and race.

### 3.2.1 Body Composition Instruments

In this study, the body composition was measured by using bioelectrical impedance analysis method. Three different Tanita Body Composition Analyser equipments namely SC 330, SC 240 and BC 545 were used to determine body composition of the participants.

Measurement of body composition using each different devices were conducted according to standard procedures provided by manufacturer. Gender, age and height were input manually into the system, and the subject's body composition was measured. The analysers were placed on a flat, hard surface that allow them to used securely without rocking or shaking. The scale's digital reading was always checked every time before first weighing to make sure the equipments functioning well.

### 3.2.1.1 Tanita SC 330

Subjects were measured standing erect with bare feet on the analyzer footpads. The body composition analyser directly measures weight, body fat percentage, fat free mass, total body water and BMR. The data such as age, sex, and height were input into the device after the subject step on the electrode plate for measurement This analyser provides a print-out of measured impedance and calculated body composition. The equipment is shown in Figure 3.1.

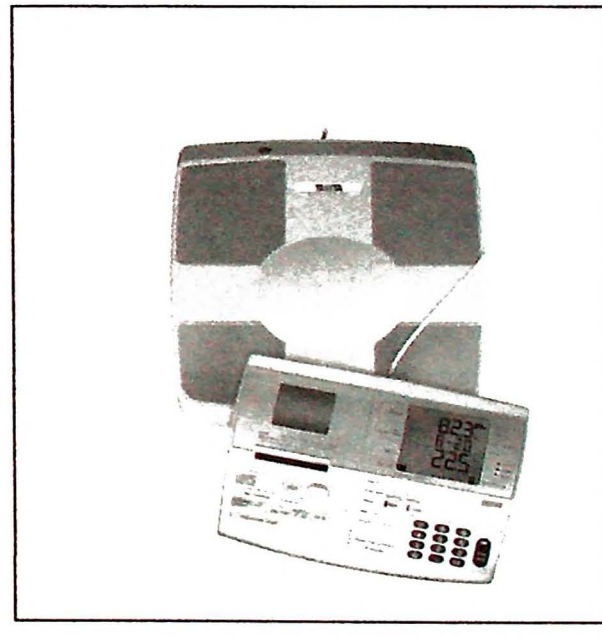

**Figure 3.1 Tanita SC 330 (Source: Tanita.com)**

### 3.2.1.2 Tanita SC 240

The SC 240 is a body composition analyzer medically approved scale to provide measurements including body weight, percentage of body fat and body water. The data such as age, sex, and height were input into the device before the subject step on for the measurement. The equipment is shown as in Figure 3.2.

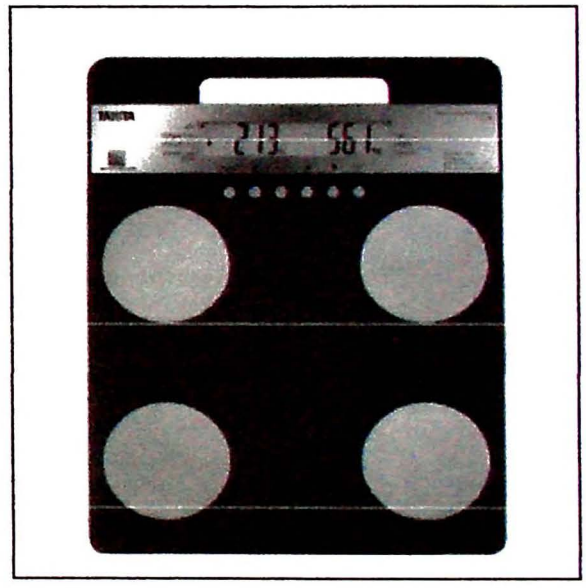

**Figure 3.2 Tanita SC 240 (Source: Tanita.com)**

### 3.2.1.3 Tanita BC 545

This equipment is segmental innerscan scales to measure body composition. The subject stands on four footplates on the platform of the scale and gently pulls the hand electrodes that are conveniently housed in the base using retractable connecting cables. The monitor will then send a safe low signal from the 8 hand and footplate electrodes through the body. The retractable hand-grips allow full body composition to be taken quickly and with increased accuracy. The equipment is shown in Figure 3.3.

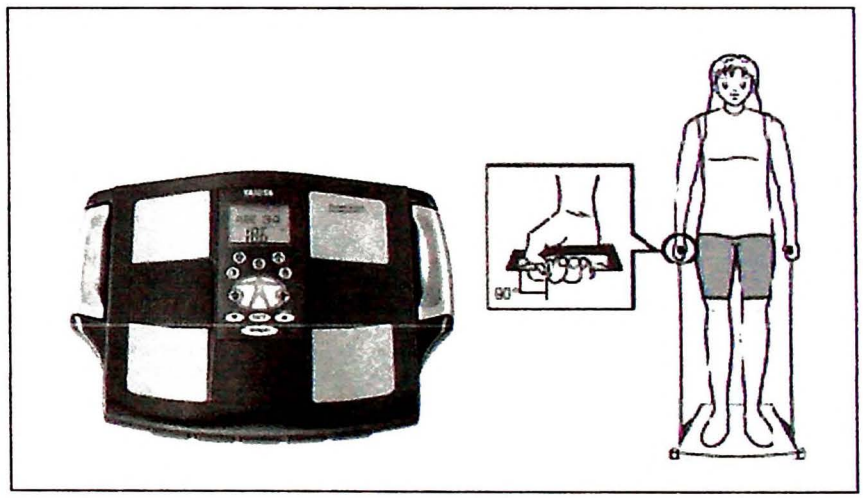

**Figure 3.3 Tanita BC 545 (Source: Tanita.com)**

### 3.2.2 Anthropometric Measurement

In this study, the anthropometric measurement such as height, waist and hip circumference was taken prior to body composition assessment.

#### 3.2.2.1 Body Height

Height measurement is necessary to be taken prior to body composition assessment as the need to input the data into the system for measurement. Height was measured to the nearest 0.5 cm using SECA Stadiometer as shown in Figure 3.4 The participant stood straight in correct position barefoot with heels together, arms to the side, shoulder relaxed and head look straight ahead.

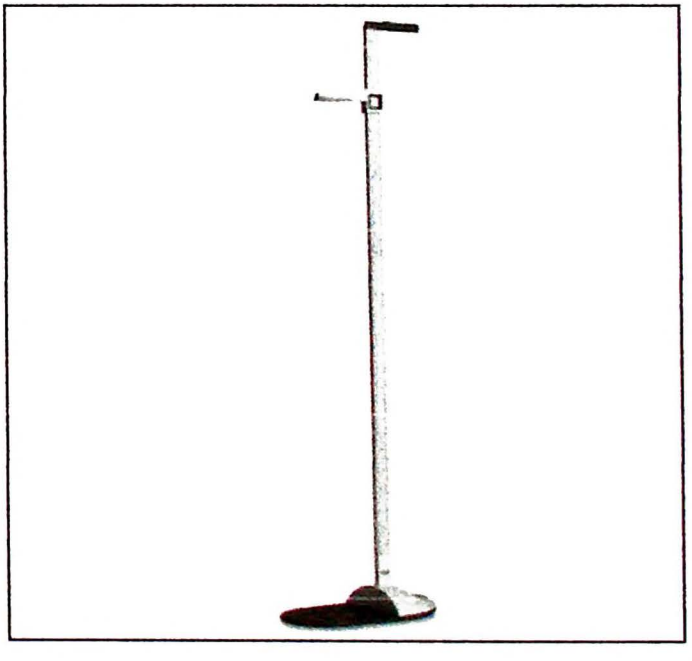

**Figure 3.4 Seca Stadiometer (Source: SECA.com)**