ASSESSMENT OF BODY FAT CONTENT USING BIOELECTRICAL IMPEDANCE ANALYSIS IN RELATION TO BODY MASS INDEX AMONG ADULTS AGED 18-55 YEARS IN TERTIARY INSTITUTIONS IN LUSAKA

BY

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A dissertation submitted to the University of Zambia in partial fulfillment for the requirements of the Master`s Degree in Human Nutrition

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DECLARATION

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APPROVAL

This dissertation of Augustine Chiba Kaunda has been approved as fulfilling the requirements for award of Master`s Degree in Human Nutrition by the University of Zambia.

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Supervisor ………………………………… Signature……………. Date……………

DEDICATION

I dedicate this work to my first born granddaughter, Jacqueline Lucia Chanda, whom I named in memory of my late sister, Jacqueline Malama and may her soul rest in eternal peace.

ABSTRACT

Accurate measurement of body fat mass (BFM) is critical in assessing overweight and obesity that pause health implications of other non-communicable diseases (NCDs). The traditional commonly used method, body mass index (BMI) is not adequate to measure BFM because it does not account for body composition. Hence the study measured BFM and free fat mass (FFM) using bioelectrical impedance analysis (BIA) in relation to BMI. This allowed for better estimation of human nutritional status and determination of misclassification when BMI method is used alone.

A total of 247 participants, comprising 54% females and 46%males aged 18-55 years were selected from University of Zambia (UNZA), Chalimbana University (CHAU), Natural Resources Development College (NRDC) and Chongwe College of Education (CCE). Participants were further categorized into young adults aged 18-39 years (77%) and old adults aged 40-55 years (23%). Both measurements of BMI and BIA were taken in the morning following overnight fasting Statistical package for social sciences (SPSS) was used to analyze data. Descriptive statistics were used to characterize participants while inferential statistics applied a 95% confidence interval (CI). Results showed Pearson correlation BMI and BFM ($r=0.660$), age BMI ($r=0.372$) and BFM ($r=0.273$), sex BMI ($r= -0.273$), and BFM ($r=-676$). The ANOVA and t-test associations for all parameters gave $p<0.001$. Age regression (coefficient =0.372 BMI; 0.273 BFM, $p< 0.001$) and sex effect (coefficient= -0.273 BMI; -0.676 BFM, $p< 0.001$) .Cross tabulation of World Health Organization (WHO) cut offs for BMI against BFM reviewed a difference of 82.2%.

In all categories BFM values were higher than BMI and differences were significant ($p<0.001$), though correlated positively ($r=0.660$). As BMI increased BFM also increased. Both age and sex indicated significant influence on BMI and BFM whilst the correlation reflected positive for age and negative for sex.

This study showed that BMI in relation to BIA underestimates BFM if used as a proxy which leads to misclassification of nutritional status. Increase in age translated into increased BMI and BFM. Lower BMI and BFM values were observed in men in relation to females and increased BMI and BFM in old adults in comparison with young adults. Thus BIA can be used to supplement BMI in diagnosis and management of problems associated with overweight and obesity.

Key words: Body Fat Mass (BFM), Free Fat Mass (FFM), Body Mass Index (BMI), Bioelectrical Impedance Analysis (BIA) and Non Communicable Diseases (NCDs).

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ABBREVIATIONS

BF:	Body Fat
BFM:	Body Fat Mass
BIA:	Bioelectrical Impedance
BMI:	Body Mass Index
CCE:	Chongwe Collage of Education
CDC:	Center for Disease Control
CDV:	Cardiovascular Diseases
CHAU:	Chalimbana University
CSO:	Central Statistics Offices
CT:	Computerized Axial Tomography
DRGS:	Directorate Research Graduate Studies
DXA:	Dual Energy X-Ray Absorptiometry
DV:	Dependent Variable
FFM:	Free Fat Mass
FM:	Fat Mass
FTIR:	Fourier Transform Infra-Red
IV:	Independent Variable
NAZ:	Nutrition Association of Zambia
NCDs:	Non Communicable Diseases
NHANES:	National Health and Nutrition Examination Survey
NISIR:	National Institute for Scientific and Industrial Research
NRDC:	Natural Resources Development College
PBF:	Percentage Body Fat
ROCS:	Receiver Operating Characteristics
SD:	Standard Deviation
SFT:	Skin Folds Thickness
SFTM:	Skin Folds Thickness Measurement
TBW:	Total Body Water
UNZA:	University of Zambia
UNZABREC:	University of Zambia Biomedical Ethics Committee
WHO:	World Health Organization
ZABS:	Zambia Bureau of Standards

CHAPTER 1
INTRODUCTION

1.1 Background to the study

Accurate measurement of body fat mass (BFM) is considered a critical factor for evaluation of nutritional and health status of an individual. Overweight and obesity due to excess body fat content across the different age groups present an emerging nutritional problem (Pardee, 2009; Lim et al., 2012). As body fat mass increases, risks of non-communicable diseases (NCDs) such as type 2 diabetes, cancers, cardiovascular and hypertension also rise (WHO, 2000; CDC, 2009; Wiggin & Keats, 2014). Global trends of increasing overweight and obesity threaten public health and contribute to the burden of disease (Danaeil et al., 2011; Jia-H & Lubetkin, 2010). Globally, obesity has risen from 29.3% in 1980 to 37.5%in2013, while NCDs have contributed to 60% of all deaths (Besa et al., 2013; Thorkild & Sorensen, 2014). According to the recent global estimate, over nutrition has become a worldwide health threat compared to under nutrition (Hruschka & Brewis, 2014). In developing countries Zambia inclusive, malnutrition is changing from under nutrition to over nutrition resulting into double burden. The demographic and epidemiological shifts are in need of urgent attention (Pardee, 2009; CDC, 2009).

Measurement of body fat content is also regarded as a powerful tool in predicting risks of morbidity and mortality in order to control death and disease rates resulting from being overweight or obese (Pietrobelli & Tato, 2005). Thus measurement of body fat content requires more adequate and accurate methods for appropriate diagnosis. The traditional commonly used method; body mass index (BMI) measurement is not adequate because conversion of height and weight into an index does not take into account the body composition. BMI measures body weight as a whole without segmentation (Rani, 2015; Leigh, 2010; Bohn et al., 2015). BMI can only be used as a screening tool to BFM for the assessment of human nutrition status. Thus, BMI has the potential to misclassify body fat content if used as a proxy. For example, a person may be classified as being underweight but with high fat mass. This could be due to genetic differences. For example, people who are naturally small may show low BMI but may have normal or high fat content. Some diseases such as diarrhea may lead to drastic loss of excessive body water and may show decreased body weight, low BMI but body fat content may not be affected in the same way. In addition an individual may be overweight but with low fat mass and may be normal but with high or low fat mass.

Misclassification of BMI is a problem that has been observed worldwide. In the United States, for instance, it was observed that obese patients, 25% and 48% for men and women respectively were misclassified with regard to body fat content (Shah and Braverman, 2012). Similarly Tomiyama(2016) found that 50% of overweight and 29% of obese individuals were metabolically healthy. Moreover 30% of individuals with normal weight were found to be cardio metabolically unhealthy.

Consequences of misclassifying individual health may lead to stigmatizing heavy individuals with high BMI values as being unhealthy. This may impact negatively on their mental and physical status. Furthermore, individuals classified as overweight or obese by BMI are often given instructions to intentionally lose weight. If these individuals in the actual sense are healthy, the intentional weight loss may increase the risk of health complications including mortality. Individuals classified solely based on BMI, may also be denied appropriate preventive care or diagnosis may be delayed (Tomiyama et al., 2016).

Currently, most developing countries are dependent on BMI as the most affordable and easier method for assessing human nutrition status despite the Global emerging nutritional problem of overweight and obesity. This transition is mainly associated with change in life style that include sedentary work, Western diets and lack of physical activities as countries especially developing countries achieve economic growth (WHO, 2009). Non-communicable diseases such as type 2diabetes, cancers, cardiovascular and hypertension are on the rise(WHO, 2009; CDC, 2009; Pardee, 2009; Lim et al., 2012; Wiggin & Keats, 2014). It is therefore, imperative to adopt better body measuring tools that can be used to predict body fat content accurately.

Several methods are available for measurement of body fat mass some of which are simple or complex, indirect or direct and traditional or advanced (Rani, 2015). The more accurate developed techniques in determining body composition include hydro densitometry, air displacement plethysmography (BOD-POD and PEA-POD), dual-energy x-ray absoptiometry (DXA), bioelectrical impedance (BIA) and imaging methods. Computerized axial tomography (CT) and magnetic resonance imaging (MRI) are some of the available imaging methods (Ong et al., 2015; Ellis, 2002; Chumlea, 2006; Leigh, 2010; Gultekin, 2014; Doubell, 2015; Keagy, 2010). Most of these advanced techniques are complicated and expensive and in certain cases impractical for use for large population and field work.

However, BIA is the chosen method because it is simple, easy to use quickly, relatively cheap, non-invasive and free observer bias and precise. In addition the BIA equipment is portable making it very suitable for field work, surveys and large populations. The principle of [BIA technique is based on tissue rich in water and electrolytes being much more resistant to the passage of electrical current than adipose tissue. This technology determines the electrical impedance of body tissues which provides an estimate of total body water (TBW). Values of TBW derived from BIA are converted to free fat mass (FFM). Then body fat mass (BFM/FM) is calculated by finding the difference between total body weight and free fat mass (Kyle et al., 2004; Keagy, 2010; Toro-ramos, 2012, Gultekin et al., 2014). However, BIA compared to BMI is more expensive and the readings get affected if one underwent heavy physical exercise, excessive drinking of water including alcohol.

Zambia just like most developing countries is experiencing a rise in the prevalence of overweight and obesity. According to the "Nutrition Transition" survey, individuals in developing countries are increasingly living in urban areas that facilitate a sedentary life style and Zambia recorded 15-20% overweight and 4-6% obesity (Pardee, 2009). Further studies revealed "Prevalence and determinants for overweight and obesity among residents of Mining Township in Kitwe" that males were at 21% and females were at 27% giving the average of 27'7% for both overweight and obesity (Zyaambo et al., 2011). Also overweight and obesity in Kaoma and Kasama rural districts of Zambia reflected 10.1% (Besa et al., 2013). The BMI is the commonly used tool for measuring body fat content in Zambia. This tool as stated is inadequate in assessment of an individual's nutrition and health status. Therefore, the proposed research explored the possibility of introducing a tool to complement BMI that can accurately predict body fat content. Accurate prediction of body fat content will translate into correct classification of nutritional and health status of the population in terms having low fat, normal fat and over fat.

The study focused on adults aged 19 years and older because BMI for this category does not have a distinction between males and females and age category whereas BMI for children of the age 5-18 years old does take into consideration sex and age (SonneWheel, 2014).

1.2 Statement of the Problem

The emerging problems of overweight and obesity conditions require a tool that can adequately measure body fat content. BMI which is the commonly used tool is not accurate as it measures the body weight as a whole without segmentation into body compartments such as FM, FFM and TBW (CDC, 2009). Measurements of BMI do not depict body fat directly but only provides approximate values. BMI is generally considered as an inaccurate measurement, for BF but only accurate as a screening tool since it cannot be used to depict body fat. Hence, it has the potential to misclassify body fat content if used as proxy (Sahal &Braverman, 2012; Tomiyama et al., 2016).

In categorizing underweight, normal, overweight and obese, BMI is limited in distinguishing between body fat from lean mass, young adults from old adults and males from females (Ong et al., 2015; Ellis, 2002; Chumlea, 2006; Leigh, 2010, Gulteki, 2014; Keagy, 2010). Athletes, bodybuilders and other people involved in strenuous activities tend to increase their lean body mass and reduce on body fat mass. If BMI is used, high fat mass will be predicted. BMI will be very high as lean mass will not be distinguished from fat mass. Such people may be considered overweight or obese and yet they could be normal.

Consequences of misclassifying individual health are numerous. These include administering inappropriate therapeutic diet to an individual and denying treatment to unhealthy individuals because of wrong diagnosis which can be detrimental (Tomiyama et al., 2016).The use of BMI underestimates or overestimates the individual body fat content. BMI tool also does not differentiate body fat composition among males and females (Ong et al., 2015; Ellis, 2002; Chumlea, 2006; Leigh, 2010;Gulteki, 2014; Keagy, 2010). Increased prevalence of overweight and obesity and related health risks require advanced and accurate methods for measuring body composition (Doubell, 2015). Accurate measurements are also critical in diagnosis and management of diseases especially the NCDs and promotion of health life styles.

1.3 Rationale of the study

A rise in overweight and obesity prevalence lead to increased risks of NCDs (Lim et al., 2012; WHO, 2013), and necessitates urgent need to improve health service delivery. Zambia like other developing countries is increasingly experiencing over nutrition due to change in life style, diet and lack of physical activity (Wiggins & Keats, 2014). Adopting more adequate and accurate methods of measuring body fat content is important for diagnosis and management of overweight and obesity and related health complications. Increased body fat content has an influence on occurrence of NCDs such as heart disease, high blood pressure, diabetes, cancers and other diseases (CDC, 2009). Body fat content analysis is critical in prevention and treatment of NCDs. The traditional BMI, the commonly used anthropometric method is inadequate as it has the potential to misclassify the human's health status with regard to fat composition if translated directly to body fat content.

The research was conducted to provide better understanding into practical application of the BIA technique in the direct measurement of body fat content. The BIA is one of the advanced methods that measures TBW directly, converting to FFM and then BFM. Hence it is considered a better predictor of BFM than BMI which is a proxy that converts body weight and height into an index. BIA is able to distinguish lean mass from body fat mass and does not lead to misclassification.

The outcome of the research was intended to contribute to better understanding of the value of BIA in measuring BFM for assessment of human nutritional and health status as well as to inform policy and practice in Zambia.

1.4 Research questions

I. Does BMI have a significant association with BFM measured by BIA?

II. Do the factors sex and age have a significant influence on BMI and BFM?

III. What is the percentage misclassification in assessing human nutritional status when using BMI against BIA?

1.5 Research objectives

The main objective of this study was to assess body fat percentage using bioelectric impedance analysis (BIA) in relation to body mass index (BMI) among adults aged 18- 55 years in tertiary institutions in Lusaka.

Specific objectives

I. To determine the correlation between BIA and BMI measurements.

II. To examine whether the difference between BMI and BFM measured by BIA is significant.

III. To ascertain whether the effects of sex and age on body fat mass by comparing %BF for males against females and young against old adults are significant.

IV. To assess the nutrition status by BMI method compared to BFM measured by BIA according to WHO standards

CHAPTER 2
LITERATURE REVIEW

2.1 Body composition and health

According to the recent Global estimate, over nutrition has become a worldwide health threat compared to under nutrition (Hruschka & Brewis, 2014). This has led to a situation that increasingly requires accurate determination of nutrition status. In developing countries malnutrition is changing towards increasing numbers of over nutrition conditions. These demographic and epidemiological shifts require urgent attention (Frederick, 2009; CDC, 2009). Despite the emerging problem of overweight and obesity, BMI is still the commonly used measurement tool for assessing human nutritional status. BMI though easy to use is not adequate and accurate (Rani, 2015; Leigh, 2010; Bohn et al., 2015). The use of BMI may lead to misclassification of human health and consequently inappropriate application of preventive and treatment measures (Tomiyama et al., 2016).

Human body composition has a strong bearing on an individual's nutrition and health status**.** Among the body compartments, body fat has been found critical and its content requires constant monitoring throughout the life cycle. This is because excess body fat shortens life expectancy through making a person overweight and obese. Fat distribution is a factor in determining the occurrence of diseases (Snijider et al., 2006). For example metabolic profile is dependent on the fat stored in the central region. Being overweight or obese increases a person risk`s of NCDs such as type 2 diabetes, metabolic syndrome, cardiovascular, cancers, joint pain degeneration, kidney stones and gallstones (Wen et al., 2007).

Fat distribution is organized in compartments. In order to describe body composition into compartments, simple and complex models illustrated in figure 1 (Ellis, 2002).

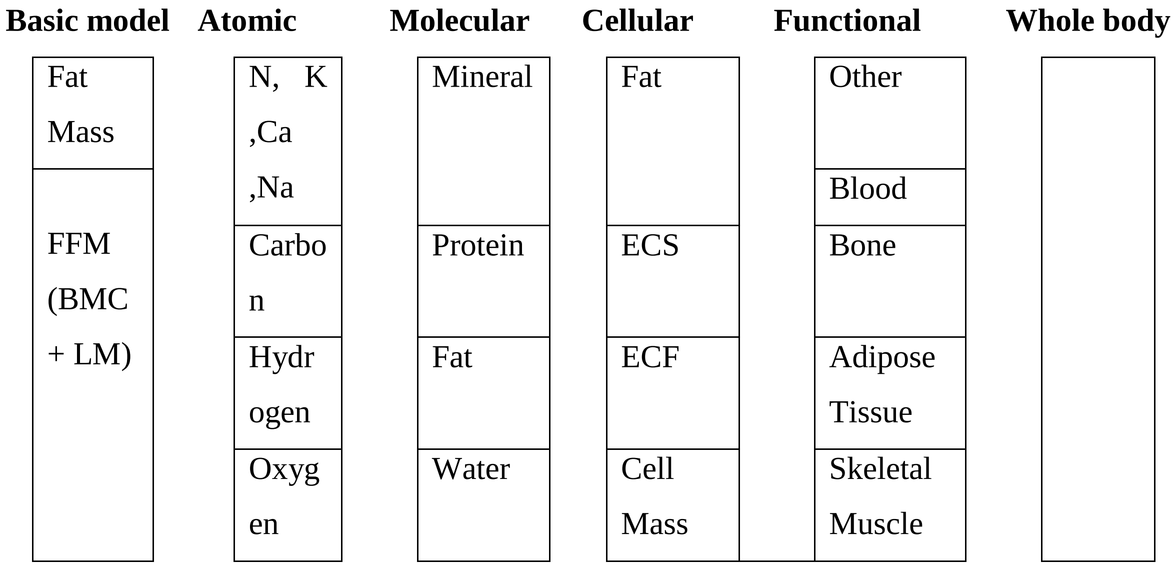

Figure 1: Basic model and multi-compartment model for expressing human body composition (Ellis, 2002)

A two-compartment model measures the body into FM and FFM. Four-compartment model at molecular level further segments FFM into mineral, protein and water whilst at cellular level FFM is split into extracellular solids, extracellular fluids and cell mass. At functional level a five-compartment model (skeletal muscle, adipose tissue, bone, blood and others) is constituted. These models are applied depending on the details of body composition being examined.

Total body fat is deposited in different sections of the body as either essential or storage fat. Essential fat is the fat required for normal physiologic functioning. In females, essential fat also includes gender-specific fat, the primary sites for which are the mammary glands and pelvic region. This additional fat is biologically important especially for childbearing and other hormone-related functions. Essential fat is stored in the marrow of bones as well as in the heart, lungs, liver, spleen, kidneys, intestines, muscles and lipid tissues of the central nervous system (Rani, 2015).

Storage fat accumulates in adipose tissue and includes the fatty tissues that protect the various internal organs as well as the larger subcutaneous fat that is beneath the skin surface. Unlike the gender-specific fat, storage fat in males and females is similar, 12 percent and 15 percent respectively (Keagy, 2010; Rani, 2015).

There are marked gender differences in body composition between males and females which include males being taller and heavier than females. However, body fat percentage shows the greatest difference. Table 1 gives recommended percentages in body composition in relation to gender.

Table 1: Body composition of an ideal male and female

BODY COMPOSITION		
AGE =20-24	**MALE**	**FEMALE**
Height	1.73m	1.63m
Weight	70Kg	57Kg
Total fat	15%	27%
Essential fat	3%	12%
Storage fat	12%	15%
Muscle	45%	36%
Bone	15%	12%
Remainder	25%	25%

Source: Rani, 2015.

The differences in body composition between males and females have been illustrated in table1. Males are taller, heavier with more muscle whilst females contain more body fat content, less muscle and shorter.

2.2 Factors influencing body fatness

An individual's body type is inherited from parents (genetic). Some people are born with tendency to be lean, muscular, or fat. Depending on the activities undertaken, the body composition can be transformed. For instance people, who regularly engage in physical activity, typically have a larger percentage of lean body than those who are inactive. Inactivity tends to accumulation of excess fat. Basal metabolism energy varies from person to person. Some people have higher basal metabolism than others and this means their caloric intake is high. Maintaining body fat levels throughout life should begin from early stages of life. Children who are too fat develop extra fat cells that make it more difficult to control fatness levels later in life (Laura, 2012).

2.3 Functions of body fat

The body burns and uses calories for energy and it follows that the more vigorous activity one does the more energy the body uses and the more calories is needed. Similarly an inactive person uses less energy each day than an active person and thus needs to consume fewer calories. Most males need more calories than females per day because they are larger and have more muscle mass which is more active than fat mass. Fat provides insulation by helping the body to adapt to heat and cold. Fat protects the body organs and bones from injury as it acts as a shock absorber. Fat helps the body to use the fat soluble vitamins such as vitamins A, D, E and K effectively. Fat is stored as energy that is available when the body needs in energy are low, thus sparing the proteins. In reasonable amounts, fat helps a person look the best, thus increasing the feelings of well-being (Wen et al., 2007).

An individual requires some minimum amount of body fatness to at least provide for essential body fat, because health problems also result if fat levels in the body become too low. Under fat persons experience abnormal functioning of various body organs. Exceptionally low body fat levels result in serious health problems, particularly among teenagers as they undergo secondary growth spurt. Reproductive organs for instance will not develop to full potential in the absence of adequate fat (Rani, 2015).

On the other hand having too much body fat content which is beyond normal body fat levels is unhealthy. Overweight and obese people have a higher risk of health complications such as; heart disease, high blood pressure, diabetes, cancers and other diseases. Other complications of being over fat also include reduced chances of successful surgery, getting tired more quickly and easily than a lean person, and in most cases less efficient at work and recreation (Wen et al., 2007; Keagy, 2010).

Levels of normal, under normal and over normal of body fat content are illustrated in Tables 2 and 3.

Table 2: Body fat mass for average adult females

Source: WHO, 2004

Table 3: Body fat mass for average adult males

Source: WHO, 2004

2.4 Global prevalence of overweight and obesity

Globally prevalence rates of overweight and obesity show a similar trend in the increase between developed and developing countries. From 1980 to 2013, developed countries showed a movement of 28.8% to 36.9% for men and 29.8% to 38.0% for women. Whist developing countries showed a shift from 8.1% to 12.9%for children and adults (Besa et al., 2013; Thorkild & Sorensen, 2014). Developing countries are increasingly faced with double burden of diseases; high rates of infectious disease and under nutrition and also rapid rise in NCDs (Frederick, 2009; Wiggins & Keats, 2014).

Zambia has not been spared from the epidemiological transition from communicable or infectious to non-communicable diseases. In 2005 it was documented that cardiovascular disease, chronic respiration disease, cancer and diabetes were responsible for 60% of all deaths globally (WHO, 2008). For the period 1998 to 2008, Zambia`s female adults prevalence of overweight (%BMI >25) was 15% to 20% whilst for obesity (%BMI >30) was 4% to 6%.Comparison within the same period 1998 to 2008, prevalence of underweight (%BMI <18.5) indicated 9.6% a much lower percentage (CDC, 2009; Frederick, 2009; Lim et al., 2012).

Population based surveys of Kaoma and Kasama rural districts in 2008 to 2009 showed prevalence rates of 7.6% for overweight and 2.5% for obesity (Besa et al., 2013). Kitwe urban showed prevalence rates of 21.0% males with 27.3% females for overweight and8.0% males with 23.5% females for obesity. Lusaka urban showed 15.5% males with 30.0% females for overweight and 5.1% males with 18.6% females for obesity. Higher prevalence rates were recorded in urban areas and much higher among females (Zyaambo et al., 2012). In all these findings, BMI is the most method that has been applied because of it being simple and cheap. BMI, the common method is used as proxy for body fat content. Body fat content is a critical factor in determining human nutrition and health throughout the life of an individual (Pietrobelli & Tato, 2005). Accurate measurements of body fat content are required, hence the need to use alternative tools to complement BMI.

2.5 Measuring body fat

The changing shape of malnutrition to double burden has sharpened the health care professional's perspective on techniques for evaluating body fat content (Fredrick, 2009). Accurate measurements of body fat are required in order to consult with individuals about desirable body weights and appropriate proportional body fat mass for optimal health. Techniques for preventing and managing overweight and obesity are complex. Numerous methods for estimating quantities of body fat are available, and each has its own limitation, be it technical or biological. There are simple or complex, indirect or direct and traditional or advanced measurements for body composition (Rani, 2015). Traditional methods include anthropometric measurements such as; body mass index (BMI), skin folds and circumferences. Advanced and more accurate methods include hydro densitometry, air displacement plethysmography (BOD-POD and PEA-POD), dual-energy x-ray absoptiometry (DEXA), bioelectrical impedance (BIA) and imaging methods. Computerized axial tomography (CT) and magnetic resonance imaging (MRI) are some of the available imaging methods (Ong et al., 2015; Ellis, 2002; Chumlea, 2006; Leigh, 2010; Gultekin, 2014; Doubell, 2015; Keagy, 2010).

Among the traditional methods, BMI is widespread, longstanding because of being simple, inexpensive, non-invasive and applicable on large populations (CDC, 2009). Similarly BIA is the most widely used among the advanced methods because of its simplicity, and it is also quick, relatively cheap, non-invasive, suitable for large population and the equipment is portable (Kyle, 2004).

2. 6 Body mass index (BMI)

Body mass index (BMI) is a measure of weight adjusted for height, calculated as weight in kilograms divided by the square of height in meters (kg/m2). BMI for children and adults is interpreted differently. For adults BMI classifications do not depend on age or sex whilst for children and adolescents between 2 and 18 years old BMI is interpreted relative to child's age and sex (CDC, 2009). For adults aged 18 years and above, BMI is interpreted by using standard weight status categories that are the same for all ages and for both men and women. The standard weight status categories associated with BMI ranges for adults are shown in Table 4.

The index BMI is a proxy measure of body fat because it measures excess weight rather than excess fat (Pietrobelli & Tato, 2005). Despite this fact, studies have shown that BMI is correlated to more direct measures of body fat, such as underwater weighing and dual energy x-ray absorptiometry. Furthermore, studies have shown that BMI levels correlate with body fat and with future health risks. High or low BMI predicts future morbidity and death (Chahar, 2014; Pietrobelli & Tato, 2005).

The widespread and longstanding application of BMI contributes to its utility at the population level. Its use has resulted in an increased availability of published population data that allows public health professionals to make comparisons across time, regions, and population subgroups (Fosbel &Zerahn, 2015).

Factors such as age, sex, ethnicity, and muscle mass can influence BMI. Nonetheless BMI does not distinguish between excess fat, muscle, or bone mass, nor does it provide any indication of the distribution of fat among individual. For example, older adults tend to have more body fat than younger adults for an equivalent BMI. On average, women have greater amounts of total body fat than men with an equivalent BMI. On average Muscular individuals, or highly-trained athletes, may have a high BMI because of increased muscle mass.

Table 4: WHO BMI categorization

BMI	**WEIGHT STATUS**
Below 18.5	Underweight
18.5 - 24.9	Normal
25.0 - 29.9	Overweight
30.0 and above	Obese

Obesity is further classified as type I (30 -34.9), type II (35 – 39.9) and type III (40 and above). Source: WHO, 2008

2.7 Bioelectrical impedance analysis (BIA)

The BIA device offers a great potential for non-invasive assessment of body composition because it is safe, portable, easy to use and much cheaper than other Instrumental techniques. From the measurement of reactance and resistance, the total body water (TBW) and free fat mass (FFM) could be calculated and converted into body fat mass (BFM) using a variety of equations embedded in each instrument (Kyle et al., 2004).

BIA is a widely used method for estimating body composition. The technology is relatively simple, quick, and non-invasive. The principle of the BIA technology is that it measures body fat by determining the electrical impedance of body tissues, which provides an estimate of TBW. Body offers two types of resistance (R) to an electrical current; capacitative R (reactance) and resistive R (simply called resistance).The capacitance arises from cell membranes, and the R from extra- and intracellular fluid. Combination of the two is the impedance which gives values of TBW. From

BIA derived values of TBW, estimates of FFM and BF are calculated. BIA provides a reliable estimate of TBW under most conditions. It can be a useful technique for body composition analysis in healthy individuals and in those with a number of chronic conditions such as mild-to-moderate obesity, diabetes mellitus, and other medical conditions in which major disturbances of water distribution are not prominent (Ozer et al.,2014; Toro-ramos, 2012).

BIA measurements are affected by numerous variables including body position, hydration status, consumption of food and beverages, ambient air and skin temperature, recent physical activity, and conductance of the table materials being used for examining. Reliable BIA requires standardization and control of these variables. A specific, well-defined procedure for performing routine BIA measurements has to be practiced. Therefore, experts and instrument manufacturers should set up instrument standards and procedural methods.

In setting up the analysis usually four (4) electrodes are attached to the human subjects, one each to the ankle and foot and one each to the wrist and back of the hand. Entries of sex, age, weight and height are captured prior to getting the readings. BIA measurement provides an estimate of TBW which is transformed into FFM and FM is calculated from the equation FM = body Wt - FFM. In the computation of FFM, hydration should be known for example, normal hydration for adults is 73.2%, boys 77% and girls 78%. Also predictor error for the equation and race-specific BIA equations have been developed and cross-validation with predicted errors taken into account (Pietrobelli & Tato, 2005; Rani, 2015).

BIA body measurements are found to be inconsistency with very high error up to 10% but with necessary precautions the error can be reduced to 3% and less. These precautions include taking measurements same time of the day as previous, same amount of food/water intake or just first thing in the morning, pre – eating and avoiding physical exercise in 24hrs before taking measurements (Leigh, 2010 & Zulu et al., 2011).

2.8 Use of BMI in relation to other tools in predicting body fat content

A number of studies have been conducted to examine whether BMI is a better predictor of body fat content as compared to other measuring tools such as skin folds thickness (SFT), bioelectrical impedance (BIA) and dual-energy X-ray absorptiometry (DEXA). However there is disagreement in research findings as to whether BMI or BIA and other advanced tools relates closely in depicting body fat content. These findings require further explanation by conducting research that test BMI and BIA tools in determination of body fat content.

2.8.1 Body fat percentage against different methods

Chahar (2014) conducted a study to compare measurements of body fat percentage (%BF) by bioelectrical impedance analysis (BIA) with skin fold thickness measurements (SFTM) and Body Mass Index (BMI) in healthy subjects. Thirty healthy males aged 26 to 49 years were selected as subjects from Gwalior, India.

One way ANOVA result showed significant difference of %BF among different methods. BIA %BF (9.40 ± 4.1%) was significantly different from SFT %BF (19.95 ± 5.9%) and BMI %BF (19.67 ± 4.3 %). On the contrary BIA %BF was significantly correlated with SFT %BF (r=0.667, p<.003) and with BMI %BF (r=0.816, p<.01). Although BIA underestimated %BF by 10.55 kg and 10.27 Kg compared to SFT and BMI respectively. Recommendation by Chahar (2014) was that the error associated with level of body fat is not negligible and requires further investigation. The report by Borrud et al., (2010)presented body composition data from whole body dual energy x-ray absorptiometry scans for persons 8 years of age and older who participated in the National Health and Nutrition Examination Survey (NHANES), 1999–2004. Valid total body measurements were obtained on 16,973 individuals. Through the use of multiple imputations, a useable sample of 22,010 individuals was achieved for analysis. Measures for the total body and regions of the body include total mass, fat mass, percentage fat, lean soft tissue (excluding bone mineral content), and fat-free mass (including bone mineral content).

Means, standard errors, and selected percentiles were calculated for the total body and for regions of the body by sex, race and ethnic, and age population subgroups. Standard errors of the mean were estimated by linearization, which incorporates sample weights and accounts for the NHANES (1999-2004) complex sample design.

Females had higher percentage body fat and fat mass than males. After age 11 years, males had higher lean tissue and fat-free mass than females. Percentage body fat was lowest at ages 16–19 years among males and at ages 8–15 years among females. Among males, non-Hispanic white persons had greater fat mass than either Mexican American or non-Hispanic blacks. Among females, non-Hispanic black persons had greater fat mass than either Mexican American or non-

Hispanic whites. Mexican American males and females had less lean soft tissue than either non-Hispanic white or non-Hispanic black males and females. Among both males and females, lean soft tissue and fat-free mass were lowest at ages 8–11 years (Borrud et al., 2010).

2.8.2 Body fat in association with risk factors

Bohn et al., (2015) evaluated the association between BIA-derived BF and cardiovascular risk factors and investigated whether BF is better suited than BMI in children and adolescents. Sample size of 3,327 overweight or obese children and adolescents were included. From Spearman's correlation and receiver operating characteristics (ROCs)**,** a significant association between both obesity indices and hypertension was present (all $p < 0.0001$), but the correlation with BMI was stronger ($r = 0.22$) compared to BF ($r = 0.13$). There were no differences between BMI and BF regarding their correlation with other cardiovascular risk factors. On the other hand BF significantly predicted hypertension (AUC = 0.61). In conclusion it was found out that BIA-derived BF was not superior to BMI to predict cardiovascular risk factors in overweight or obese children and adolescents but in hypertension.

Other study by Gultekin et al., (2014) of Ankara University Turkey and Dasgupta of Indian Statistical Institute analyzed patterns of fat accumulation during childhood and adolescence. A total of 1,371 Turkish children, aged 7–18 years, were selected randomly from schools in a Cross-sectional sample of 684 female and 687male. Findings revealed a significant increase in BMI, BF, FFM, the trunk fat and the trunk muscle mass over the study periods in both sexes. The mean trunk FFM and trunk FM were higher in males than in the females. On the contrary, the mean trunk FM and whole body FM for females were higher than in males. During the years of adolescence FFM as well as BF increases in males and the gains are considerably greater than in females, who accumulate more body fat in later life.

In New Zealand, Tyrell et al., (2001) determined the accuracy of foot-to-foot bioelectrical impedance analysis (BIA) and anthropometric indices as measures of body composition in children. Both BIA and anthropometry were compared to dual-energy X-ray absorptiometry (DEXA). Eighty-two European constituted sample population and size. BIA showed a high correlation between DEXA and BIA in the estimation of fat-free mass (FFM), fat mass (FM) and BIA-FFM underestimated DEXA-FFM by a mean of 0.75 kg, BIA-FM overestimated DEXA-FM by a mean of 1.02 kg. In conclusion BIA correlated better than anthropometric indices in the estimation of FFM and FM. Foot-to-foot BIA is an accurate technique in the measurement of body composition in two compartment models, FFM and FM.

2.8.3 BMI misclassification against other tools

Globally the body mass index (BMI) is most commonly used to determine adiposity including in the USA. However, BMI presents as an inaccurate obesity classification method that underestimates or overestimates the epidemic and contributes to failed or wrong treatment. Shah and Braverman (2012), undertook a cross – sectional study of adults with BMI, DXA, fasting leptin and insulin of the participants constituting, 63% were females, 37% were males with a mean age = 51.4. Mean BMI was 27.3 (SD = 5.9) and mean percent body fat was 31.3% (SD = 9.3). BMI characterized 26% of the subjects as obese, while DXA indicated that 64% of them were obese. Thirty-nine percent of the subjects were classified as non-obese by BMI, but were found to be obese by DXA. BMI misclassified 25% men and 48% women. A strong relationship was demonstrated between increased leptin and increased body fat. In conclusion the results demonstrated the prevalence of false-negative BMIs, increased misclassifications in women of advancing age, and the reliability of gender-specific revised BMI cutoffs. BMI underestimates obesity prevalence, especially in women with high leptin levels.

Similarly, Tomiyama et al., (2016) undertook a preview to examine cardiometabolic health misclassifications given standard BMI categories. Forty participants aged 18 and above were from nationally representative 2005-2012 National Health and Nutrition Examination Survey (NHANES).Using percentages of metabolically healthy versus unhealthy individuals were stratified by BMI. Nearly half of overweight individuals, 29% of obese individuals, and even 16% of obesity type II/III individuals were metabolically healthy. Moreover, over 30% of normal weight individuals were cardiometabolically unhealthy. Using BMI categories as the main indicator of health, an estimated 74,936,678 US adults are misclassified as cardiometabolically unhealthy or cardiometabolically healthy. In such situations policymakers should consider application of the diagnostic tools related to weight and cardiometabolic health.

2.8.4. Over nutrition situation in Zambia

In Zambia, similar studies have been conducted to determine the prevalence rates of overweight and obesity. NCDs diseases such as cardiovascular, hypertension, some cancers, and diabetes type 2 have correlated with overweight and obesity. Besa et al., (2013) conducted a study in two rural towns Kaoma and Kasama to establish the prevalence rates of overweight and obesity in relation to hypertension. During the same period, a similar study was conducted among residents of a mining township in Kitwe (Zyaambo et al., 2011). Studies that have been conducted in Zambia have only used anthropometrics in assessing nutrition and health status of human. BMI has been the traditional commonly used for predicting body fat content which is critical in the evaluation of human well-being. There are more adequate and accurate methods that are used in depicting body fat content precisely, but these have not been applied in Zambia. This can be attributed to lack of knowledge and skills and their being expensive and complicated.

Generally, advanced tools have not been introduced in Zambia and there is limited available information on their application. None of the studies conducted in Zambia have determined the misclassification of BMI using the other accurate techniques. BMI cannot ascertain the effects of age and sex on body composition particularly body fat. Therefore, this research used the BIA as a tool to complement BMI to predict body fat content more accurately. Evidence from this research will lay a basis for measuring accurate body fat content; contributing to supporting appropriate diagnosis and management of over nutrition and its health risks.

With increased health complications of over nutrition, accurate measurements of body fat mass are very critical in addressing the changing shape of the nutrition problem. Introducing the BIA as a complementary tool for measuring body fat content will be of paramount importance in improving the quality of health service delivery because currently there is limited information on the use of BIA device in depicting body fat mass. Findings from this study will lead to the formulation of policy and practice, particularly to ensure correct nutrition assessment is performed by nutrition and health service delivery or practitioners.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research design

A quantitative and cross-sectional study was conducted from May to July 2017. The design allowed for collecting data on BMI and BFM to assess nutritional status of participants and effect of influencing factors of age and sex.

3.2 Study site

The study was conducted in Lusaka province in which Lusaka the capital city of Zambia with a population of 2,777,434 million people (CSO, 2015) is located. Lusaka province is situated in the central part of Zambia and has good links to all the other nine provinces. Due to its centrality and high level of business activities its population across institutions and settings is comprised of all the tribes that are found in Zambia. Lusaka province was a suitable location for the study as it contains characteristics that the study wanted to capture. Healthy individuals who were not hospitalized selected from four tertiary Institutions within Lusaka province catchment area. The University of Zambia (UNZA) and Natural Resources Development College (NRDC) from Lusaka urban, Chalimbana University (CHAU) and Chongwe College of Education (CCE) from Lusaka rural. These were purposely selected as UNZA trains graduates in human nutrition at Bachelor of Science and Master of Science degrees. NRDC trains graduates in food and nutrition at Diploma level. CHAU and CCE train primary and secondary teachers whose curriculums under the Ministry of education have the inclusion of nutrition in the science subjects.

Orientation of training staff and students to other techniques of assessing human nutritional status enhanced their capacity in the area of food and nutrition. Additionally all the four institutions were located within easy proximity to the Clinical Nutrition Laboratory at National Institute for Scientific and Industrial Research (NISIR) for the measurement instruments that were used for data collection. Quick access from NISIR to these institutions made it possible for the research team to take measurements early in the morning, just after overnight fasting and before breaking the fast as recommended by the research protocol (Zulu et al., 2011).

3.3 Sampling, sample size and composition

For each institution participating in the study, participants from the ages of 18 to 55 were invited to assemble in class rooms or conference rooms. In order to ensure balanced numbers of females and males and young adults and old adults were included in the study, participants were stratified into four groups of young and old adult females and young and old adult males. Participants of the age 18 – 39 years were considered as young adults whilst 40 – 55 years were considered as old adults.

A simple random technique was applied to select study participants. Project code numbers generated for selection of student participants while for the staff it was on voluntary basis. Project code numbers generated from statistics random tables were shuffled together with blank papers. Each participant below 30 years of age was requested to pick a piece of paper. Participants that picked the number that corresponded to the selected random number were included in the study sample. However, the number of older participants was found to be smaller for both females and males hence an even representation between participants aged 40 years and below and 40 years and above was not attained.

Participants sample size was calculated using the formula for proportions at 17% overweight (Frederick, 2008):

$$n = \frac{Z^2 * p\,(1-p)}{d^2}$$

Where:

n - Sample size

Z- Confidence level set at 95% (1.96 z-scores value)

P- Proportion of overweight (17%)

d- Margin of error (at 95% CL -5%)

Calculations: $n= 1.96^2 \times 0.17\ (1-0.17)\ /\ 0.05^2$

The sample size (n) was therefore **217.**

Adjusted with 22 (10%) for attrition and rounded off to 240 but sampled up to 270 for considering the BIA electrodes that were available for the study and advantages of large samples in controlling for confounding factors.

The study targeted food and nutrition, human nutrition and nutrition science students in order to enhance their knowledge about nutritional status assessment methods. CHAU in comparison with the other three institutions had the largest food and nutrition related department; hence the biggest number of participants.

A total sample of 247 participants, comprised 134 females (54%) and 113 males (46%) aged 18-55 years. The total sample included 51 (21%) from UNZA (30 females and 21males), 91 (37%) from CHAU (48 females and 43 males), 54 (22%) from NRDC (32 females and 22 males) and 51 (21%) from CCE (24 females and 27 males). Participants were further categorized into 191 young adults aged 18-39 years (77%) and 56 old adults aged 40-55 years (23%) and decades 20-29 years 57% (142), 30-39 years 20% (49), 40-49 years 18% (44) and 50-59 years 5% (12). The group of participants from CHAU was bigger than all other institutions because CHAU has the biggest department of home economics that handles food and nutrition programmes.

3.4 Inclusion and exclusion criteria

On average 3-5 days were spent on selection and recruitment of participants at each institution. Registration of participants involved verification of the age with national registration cards (NRC), particulars of their name and institutions. Only candidates that were aged between 18 and 55 years, not sick and women not pregnant at the time were selected to participate in the project. This age category was considered to be active and suffering from health complications related to old age. Participants that were discovered to have broken the fast by eating and drinking water, excessive physical exercising and beer drinking within 24 hours were dropped from taking part. These precautions were necessary in order to minimize disparities in the body weight, total body water, FFM and ultimately BFM measurements.

3.5 Pre – test

A pre – test was conducted in May 2017 before commencement of field data collection in June 2017. The essence of the pre – test was to validate the tools that were used in the study, ensuring the practicability and grasping of all the concepts. NISIR clinical nutrition laboratory was used and provided the measuring tools that were used for field work as shown in Figure 2. Twenty two volunteers from NISIR comprising staff, interns and students on attachment were selected to pre – test the research protocol. NISIR was chosen on the basis of being a research institution, hence has similar characteristics with the four chosen tertiary institutions. NISIR being a public institution offers internship and students attachments in line with government policy on capacity building.

During the pre – test, repeated measurements were taken in order to ensure replicability of the study method and consistency. Three interns, two from Nutrition Association of Zambia (NAZ) and one from NISIR were also oriented to the research protocol.

Figure 2: Measurement instruments and accessories

3.6 Data collection

Process of data collection was carried out with strict adherence to ethical considerations. The first contact with participants focused on the discussion of research information and signing of consent forms, explanation on taking of anthropometric measurement, BIA measurement and recording of readings. Measurements were taken in three days at UNZA, NRDC and CCE, and five days at CHAU.

3.6.1 Bioelectrical impedance analysis (BIA)

Body fat mass was measured using SFB7 Bioelectrical Impedance Analysis (BIA), ImpediMed Limited, ABN 65089705144, 4B/2404 Loongan Road, Eight Miile Plains QLD 4113, Australia (Figure 2). BIA measurements were best carried out immediately after the anthropometrics were taken and pre-meals to avoid influencing body weight and hydration which exerts resistance to the current being transmitted (Zulu et al., 2010). Participants were given instructions not to exercise or drink alcohol for a period of 24-48 hours prior to the BIA measurements. The battery for BIA device was always fully charged before taking measurements. In setting up the BIA device, date, time, units of measurements and language were adjusted and in built calibration were also initialized. When taking measurements, entries of age, sex, height, weight, race, participant identity code were recorded and electrodes were placed on the left hand and foot of each participant in lying position as shown in Figure 3.

Figure 3: Taking BIA measurements

This meant carrying the medical bed in all four sites. To get the BIA readings, the measure button was pressed and BIA measured TBW through an electric current (50Hz) which was converted to FFM using the appropriate factor for hydration. Then BFM was calculated as the difference between total body weight and FFM (Ellis, 2002; Heyward, 2001). In order to take care and control BIA limitations such as temperature and other influencing factors, measurements were taken in the morning before breaking the overnight fast throughout and the sample size was large enough. Further categorization of the participants for data analysis into females and males, young and old adults and age in decades provided for major confounding variables.

3.6.2 Anthropometric (body weight, height and BMI)

Before anthropometric measurements were taken, participants were requested to remove their shoes, jackets and/or coats, head accessories and emptied their pockets to ensure correct measurements were achieved (Figure 4).

Figure 4: Taking body weight (left) and body height (right)

Standard operating procedures (SOP) and operational instructions accompanying each instrument were used for the anthropometric measuring to ensure correctness and accuracy. The research team that conducted the study comprised qualified nutrition professionals who had training in anthropometry. In addition the research team had training in pre – testing the accuracy of the tools and measurements.

For weight measurements, a digital platform scale and Stadiometer (Seca made in Germany) calibrated by Zambia Bureau of Standards were used. Both the digital scale and Stadiometer were placed on a hard tile surfaced floor in the improvised examination rooms and were checked to be level and stable.

Height measurements were taken on barefoot participants, standing erect and with the head in the Frankfort plane. Height was measured to the nearest 0.1 cm. In some situations estimations using a 30 cm rule were used to adjust for long hair and extended hair style. Weight (kg) was measured with the participant standing in the centre of the platform with weight spread equally between the two legs, and standing with hands loosely hanging next to the sides of the body. Weight was measured to the nearest 0.01 kg. Instruments given in figure 4 were used for taking measurements.

Body mass index (BMI) was then be calculated as weight (kg)/height $(m)^2$ using the scientific Casio fx-100s calculator and the BIA devise, and verified by the reference BMI table and wheel.

3.6.3 Verification of measurements

NISIR has a standing arrangement with ZABS for calibration of the laboratory equipment/instruments ranging from every six months for very sensitive and every after one year for the others. For the purpose of this study a request for re-calibration of the body scale and two Stadiometer (labeled 1 and 2) was made and results are contained in appendixes 7, 8 and 9. Calibration results showed conformity to the accuracy of ±5g for weight and ±2mm for height. However, Stadiometer no.2 had an adjustment of -11mm due to the pulled top part. This was still within the standard error ±2cm in repeated height measurements (Rocknbacch, 2010; Intergrowth 21, 2012).

Calibration of BIA was done according to the instructions given in the Imp SFB7 operational manual. This involved connecting the leads to the test cell according to the colour-coding and after taking measurement, expected values were displayed. Readings obtained throughout the period of data collection were within specified limits.

A post-test was also conducted at NISR and UNZA. Repeat results on weight, height, BMI and BIA were obtained from five participants at NISIR and 18 participants at UNZA. Duplicate results obtained showed no deviation from each other as they were within ±0.5kg for weight, ±2cm for height, ±0.5 for BMI and ±0.5% for BFM (Rocknbacch, 2010; Intergrowth 21, 2012; Imp SFB7, 2006).

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3.7 Data analysis and management

Data was quantitatively analyzed using the Statistical Package for Social Sciences (SPSS) Descriptive statistics was used for description of the study participants' variables (age, sex, social demographic, height, weight, BMI and %BF). These included means and standard deviations (SD). Nutrition and health status was determined using BIA %BF and BMI. Inferential statistics included correlation analysis using Pearson's correlation coefficient that investigated association between BMI and BIA %BF. The significance of the difference between BIA and BMI was established using t-test and ANOVA at 0.05 level of significance. Regression was applied for the examination of causal effect of independent variables (age and sex).Nutritional status and BMI misclassification against BIA were estimated using cross tabulation technique basing on the WHO (2004) standards.

Successful completion of the study will require sharing of information. Findings of the study will be disseminated through meetings and publications.

3.8 Ethical considerations

Prior to commencing the project, the researcher sought ethical approval from the Ethics Committee. Ethical considerations were adhered to throughout the study. Participants in the project were informed of the nature of the study by the research team and participants had an opportunity to ask questions at any time during participation. Participants were assured that no harm would come to them and were free to decline participation in the study if they so wished.

However, measuring of weight, height and BIA may evoke minimal stress in some people. One way of minimizing stress was to ensure that body measurements were taken in a separate room where privacy was assured.

3.8.1 Anonymity of participants

The researcher explained that anonymity would be maintained throughout the study. Data collected was identified only by codes and linked to any participants. Access to the data was limited to the research team and the supervisors. Data was stored in the computer and protected by password. Publications from the research would not be linked to the names of participants. Certificates of informed consent were signed by the participants of the study. Details on each of the participants were treated as confidential and the project was conducted under strictly controlled ethical conditions.

3.8.2 Informed consent

Signing of the consent forms were carried out prior to taking measurements. Participants were given an opportunity to seek clarification pertaining to the information contained in the participants' information sheet distributed at the time of registering. At the time of data collection, further explanation was given to the participants on the relevance of the study and the benefits of participating (Appendix 1). Participants upon understanding what the research was all about appended their signatures to the consent form. Informed consent forms, however, included provision for participants` names which were strictly for the researcher for purposes of registration and in case of making references should there be need. Otherwise on data collection forms, codes assigned to each participant were used as opposed to actual names.

3.9 Limitations

Ensuring that measurements were taken during the fasted state was difficult as it depended on participants' compliance to research protocols. An emphasis was made to the participants on the importance of not breaking the overnight fast prior to taking measurements, but it all relied on sincerity of participants. Achievement of equal representation of female/male participants and young/old adult participants was not obtainable. The targeted departments of food and nutrition departments were found to comprise more females than males and also the majorities were young adults. If research funds were adequate the deuterium dilution technique a "gold standard" method would have been used side by side with the two techniques (BIA and BMI). This would have provided more detailed and wider comparisons. NISIR clinical nutrition laboratory has the Fourier transform infra-red (FTIR) equipment that applies isotopic technique in measurement of body composition.

CHAPTER 4

RESULTS

4.1 Sample size and description

Sample size of 247 participants was enough as it exceeded the calculated sample size of 215 participants using 17% overweight proportion by Frederick (2009). Control of confounding factors such as dietary intake, physical activity and genetics/ethnicity was achieved by the use of a large sample. Participants in these tertiary institutions exhibited similar characteristics in terms of life style and habitation overshadowing extreme cases. Gender balance was taken care of though females (134) were more than males (113) in all the food and nutrition departments (sampling units) of these institutions. Among the food and nutrition departments, CHAU was the biggest in terms number of students and hence highest number of participants (91). This has some advantages because teachers are sent to various schools across the country and impart knowledge and skills to numerous pupils. Ultimately contribute to achievement of optimal nutrition of the Zambian people. Young adults (191) on the other hand were more than old adults (56) which confirmed that there are more youths in tertiary institutions. This is ideal for measures that monitor body composition as young humans get transformed into old humans with increased health and nutrition implications**.**

A total of 247 participants, comprising 134 females and 113 males aged 18-55 years were selected from UNZA (51), CHAU (91), NRDC (54) and CCE (51). Participants were further categorized into young adults aged 18-39 years (191) and old adults aged 40-55 years (56), decades 20 – 29 years, 30 -39 years, 40 – 49 years and 50 – 59 years (Table 5).

Table 5: Sample size and description

INSTITUTION	FEMALES	MALES	AGE CLASS (20-29)	AGE CLASS (30-39)	AGE CLASS (40-49)	AGE CLASS (50-59)	TOTAL NUMBER
CCE	24	27	38	12	1	0	**51 (21%)**
CHAU	48	43	66	8	12	5	**91 (37%)**
NRDC	32	22	23	14	12	5	**54 (22%)**
UNZA	30	21	15	15	19	2	**51 (21%)**
TOTALS	**134 (54%)**	**113(46%)**	**142(57%)**	**49(20%)**	**44(18%)**	**12(5%)**	**247 (100%)**

4.2 Descriptive statistics of the population sample

The sample mean for BMI showed a lower value of 24.50±5.21 ranging from 15.60 to 45.90 compared to 39.71±8.81 for BFM ranging from 17.30 to 59.00. Height measurements had the widest range of 130.70 cm followed by weight with 102.50 kg. The range for age was 19 to 55 years with mean of 30.74. Weight showed the biggest standard deviation (15.3) and variance (232.8) whist BMI reflected the smallest standard deviation (5.2) and variance (27.2). It also followed that the larger or smaller the standard deviation the larger or smaller the standard error of mean respectively, hence weight measurements recorded the biggest error whilst BMI recorded the smallest error (Table 6).

Table 6: Sample characteristics

	Age (yrs)	Weight (kg)	Height (cm)	Body Mass Index	Body Fat Mass (%)
Mean	30.74	66.33	163.91	24.60	39.71
Std. Error of Mean	.622	.971	.674	.332	.561
Median	27.00	64.90	164.00	23.36	39.82
Mode	22.00	54.50	157.50[a]	24.40	33.50[a]
Std. Deviation	9.78	15.26	10.59	5.21	8.81
Variance	95.61	232.75	112.18	27.16	77.62
Range	36.00	102.50	130.70	30.20	41.70
Minimum	19.00	20.20	62.30	15.60	17.30
Maximum	55.00	122.70	193.00	45.90	59.00

$r = 0.660$ $p<0.001$

Both BMI and BFM distributions represented close to perfectly symmetrical distributions as opposed to being negatively or positively skewed. This is observed through the relative small differences in means, medians and modes. However, BMI mean was higher than median by 1.2 implying that there were few high BMI measurements and hence the mean (24.6) was pulled above the median (23.4). Whilst BFM mean was lower than median by 0.1 reflecting few lower BFM measurements pulling the BFM mean (39.7) below the BFM median (39.8).This translated into the majority of participants having measurements of BMI lower than 23.4 and BFM higher than 39.8 (Table 6).

Sample age distribution reflected a positive skewness distribution, with few high age scores and pulled mean (30.7) higher than median (27.0) the age score that divided the distribution into two equal halves when age scores were arranged in ascending order. This implied that the larger number of participants lied in the age category of 27 years (median) and below confirmed by the age score of 22years (mode) found to occur most frequently. Larger values of distribution range (36), variance (95.6) and standard deviation (9.8) signified a wider age dispersion. Applying the ±9.8 (standard deviation) indicated that the majority of participants were aged between 21 years to 41 years and the minority below the age of 21 and above the age of 41 (Table 6).

4.3 BMI Distribution between females and males

Females (133) showed BMI mean of 25.91±5.21 higher distribution than 23.06±3.75 for males (114) with a negative correlation of 0.273 for the association between females and males. A negative coefficient (-0.273) causal effect between females and males for BMI was also detected. P-value at 95% was found to be very small ($p<0.001$) and hence significant even at 0.01 confidence limit (Figure 5).

r=-0.273 coefficient=-0.273 p<0.001

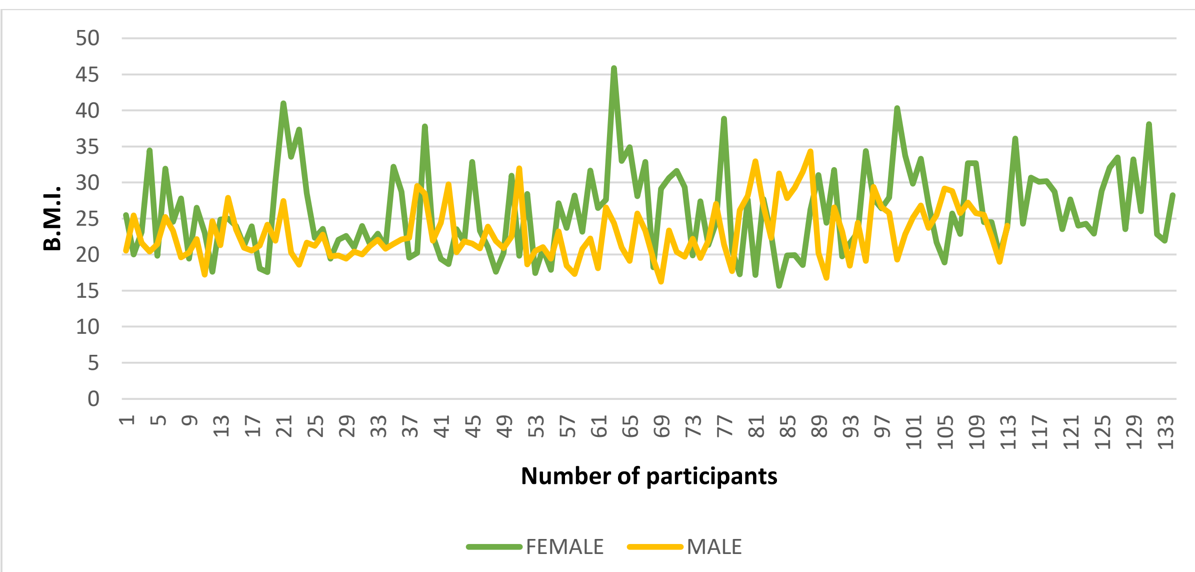

Figure 5: BMI distribution between females and males

4.4 BFM distribution between females and males

BFM for females (133) recorded a mean value of 45.16±7.07 higher than 33.24±7.78 for males (114) whilst correlated negatively (-0.676) with similar causal effect of -0.676.Coefficient between females and males. A very small p-value (<0.001) was also found indicating the significance of the difference (Figure 6).

r=-0.676 coefficient=-0.676 p<0.001

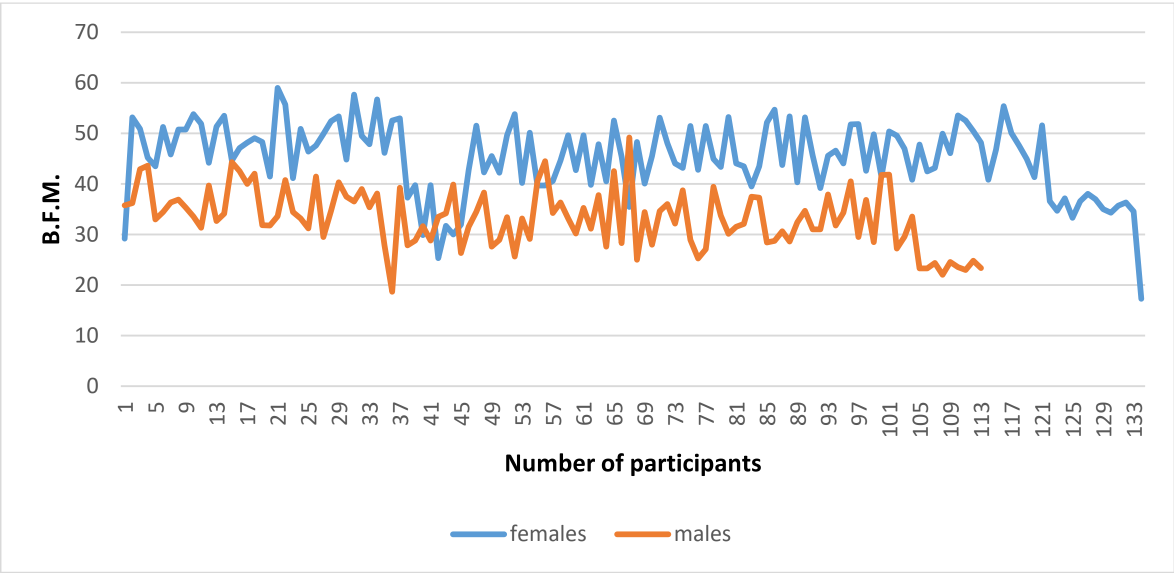

Figure 6: BFM distribution between females and males

4.5 BMI distribution within females and males

Female BMI indicated a normal distribution with a positive skewness of 0.691. This distribution is skewed to the right, hence a smaller median (24.46) than the mean (25.91) as in Figure 7.

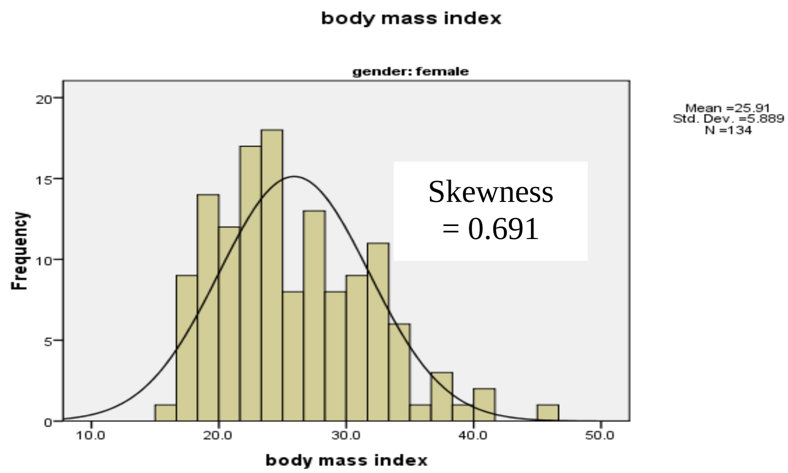

Figure 7: BMI distribution within females

Males indicated a normal distribution with positive skewness of 0.758, mean value of 23.06 higher than the median (22.01). This distribution is skewed to the right, thus most values lie to the left of the mean value (23.06) as shown in Figure 8.

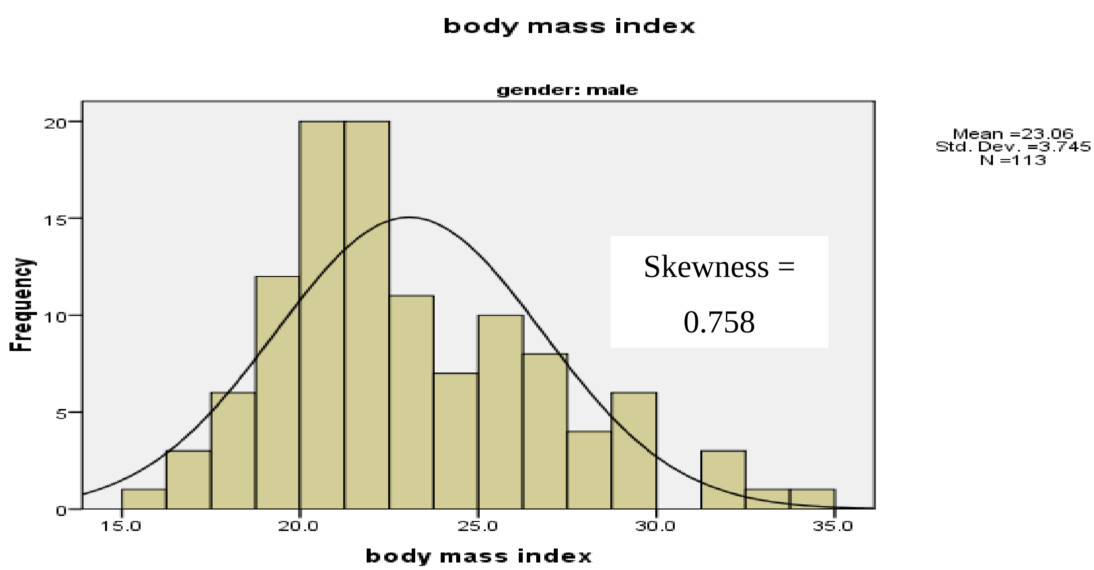

Figure 8: BMI distribution within males

4.6 BFM distribution within females and males

BFM for females showed normal distribution with a negative skewness of -0.817 and higher median (45.59) than mean (45.16). This distribution is skewed to the left; hence most values lie to the right higher than the mean value (45.16) as shown in Figure 9.

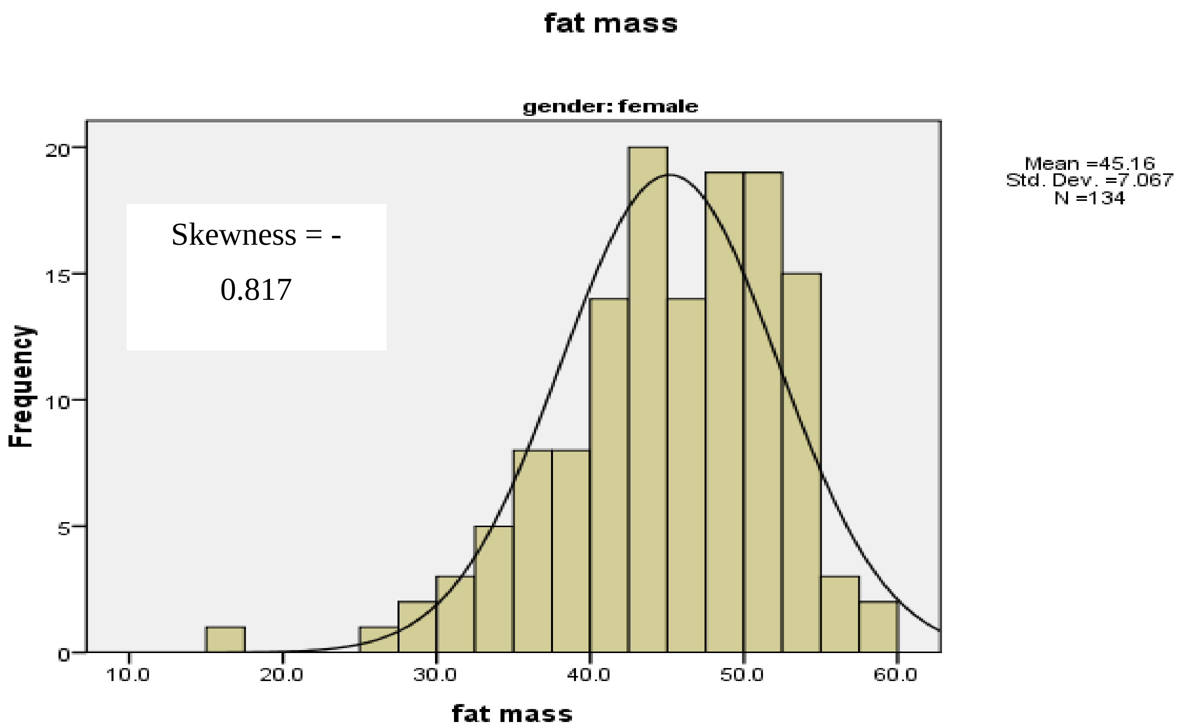

Figure 9: BFM distribution within females

BFM for males showed almost a normal distribution with a positive skewness (0.0691) closer to zero. This distribution has almost no skewness, hence close to a perfectly symmetrical distribution. The difference between mean (33.24) and median (33.39) is almost negligible, thus most values lie in the center around the mean and median (Figure 10)

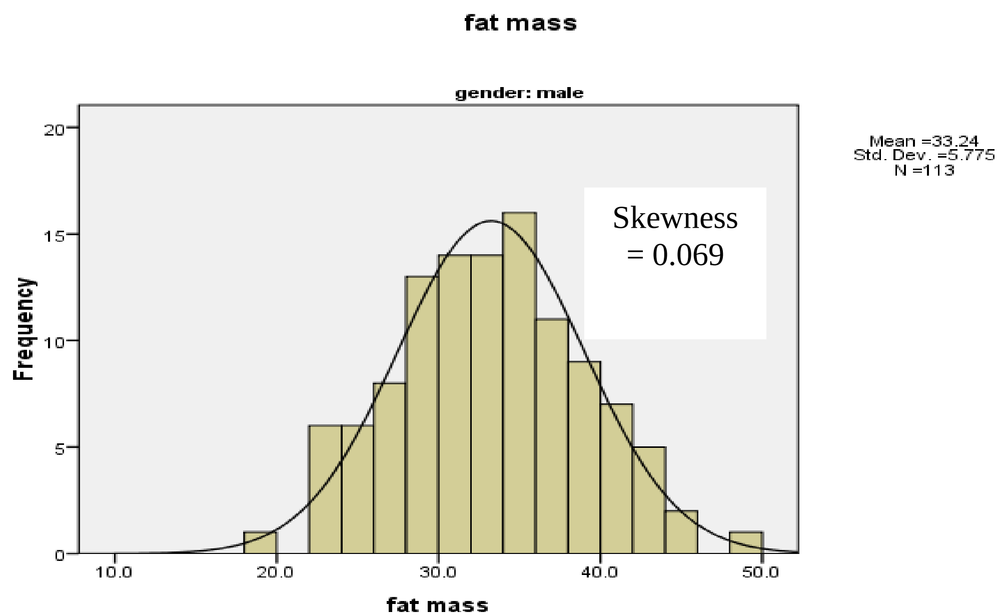

Figure 10: BFM distribution within males

4.7 BMI and BFM distribution in females and males

BMI measurement for females reflected higher values in almost all the distribution characteristics (mean=25.9, median=24.5, mode=19.9, SD=5.9, variance=34.7 and range=30.2) compared to males (mean=23.1, median=22.1, mode=18.5, SD=3.8, variance=14.0 and range=18.1). Lager differences were noted in variance and range implying that there is a wider spread in BMI measurements within females and a narrower spread within males. Females BMI measurements ranged from 15.6 to 45.9 whilst that of males ranged from 16.2 to 34.3. To the contrast males recorded a higher minimum value (16.2) than females' minimum value (15.6). However, BMI measurements for both females and males indicated positive skewness meaning that the means were pulled above the medians. Thus majority of participants had BMI measurements less than 24.5 (median) for females and less than 22.1 (median) for males.

BFM measurements across females and males exhibited similar trend to BMI distribution. Female BFM distribution characteristics (mean=45.2, median=45.6, mode=43.5, SD=7.1 variance=50.0 and range=41.7) were higher than values obtained from males (mean=33.2, median=33.4, mode=33.5, SD=5.8, variance=33.4 and range=30.5).Also to the contrast males recorded a higher minimum value of 18.1 than 16.2 for females though the maximum value for females (59.0) was far much more than males (49.2). However, females distribution showed anegative skewness (-0.817) and positive kurtosis (0.209) whilst male distribution reflected a positive skewness (0.065) and negative kurtosis (-0.273). This implied that majority of female participants had higher values of BFM and clustering towards the middle while the majority of male participants had lower values of BFM and assumed a flatter dome. Figures 5, 6, 7, 8, 9 and 10 have shown BMI and BFM distributions across age and gender.

4.8 BMI and BFM distribution between young adults and old adults

Young adults for combined females and males showed a decrease in both BMI (3.74) and BFM (4.39) and the same trend were observed in females and males separately. Young female adults had a difference of 5.1 in BMI and 5.2 in BFM whilst males exhibited a difference of 2.4 in BMI and 4.2 in BFM (Table 7).

Young adults (20-39) and old adults (40- 55) showed similar means and modes for both BMI and BFM (young adults 22.5 mean, 21.7 median for BMI, 32.2 mean, 31.8 median for BFM and old adults 24.9 mean, 25.5 median for BMI, 36.5 mean, 36.2 median for BFM). Almost a perfectly symmetrical distribution had been obtained translating into increased or reduction in age with increased or reduced BMI and BFM in both young and old adults. However, most frequently score (mode) was detected to be higher (18.5) for BMI in young adults than old adults (16.2) while the most frequently BFM value for young adults (18.7) was lower than old adult BFM value (27.8). BMI dispersion recorded a greater variance of 20.0 in old adults compared to 10.9 for young adults and to the contrast BFM reflected a lower variance of 16.5 in old adults as opposed to 34.4 in young adults. This analysis revealed that old adults have larger values for both BMI and BFM, wider spread in BMI and narrower spread in BFM in relation to young adults. This could also mean that most old adult participants had elevated values of BFM and reduced BMI whilst most young adult participants decreased BFM and elevated BMI (Table 7).

Further segmentation of young adults into female and male young adults and old adults into female and male old adults also revealed the following: Larger increase and almost constant in both BMI and BFM within females during progression from young adults to old adults. Smaller and varying increases were seen in both BMI and BFM within males during graduation from young adults to old adults (Table 7).

Table 7: BMI and BFM of young and old females and males adults

SAMPLE	BODY MASS INDEX		BODY FAT MASS	
Description	**Young adults**	**Old adults**	**Young adults**	**Old adults**
Females and males (247)	23.756 (134)	27.498 (113)	38.714 (134)	43.102 (113)
Females (134)	24.80 (105)	29.91 (29)	44.04 (105)	49.23 (29)
Males (113)	22.48 (86)	24.91 (27)	32.21 (86)	36.53 (27)

4.9 BMI and BFM distribution across decades

Consideration of decades in ascending order reflected an increase in both BMI and BFM and vice versa a decrease in descending order except for 40 – 49 and 50 – 59 decades. In this shift a decrease in BMI from 28.03 to 25.54 has been observed as well as very small increase in BFM from 43.03 to 43.34 (Table 8). This is due to a higher rate wearing out of body tissues compared to the lower rate of built up that occurs at this stage in life cycle.

Table 8: BMI and BFM in decades

	20-29 years		30-39 years		40-49 years		50-59 years	
	BMI	**BFM**	**BMI**	**BFM**	**BMI**	**BFM**	**BMI**	**BFM**
Mean	22.87	37.32	26.31	42.76	28.03	43.03	25.54	43.37
Std. Error	.366	.735	.694	1.044	.894	1.253	1.384	2.486
Median	21.79	37.05	26.16	43.19	27.40	42.29	26.79	46.24
Mode	18.50[a]	51.40	18.60[a]	49.60	16.20[a]	27.80[a]	16.80[a]	29.20[a]
Std. Dev	4.365	8.761	4.859	7.312	5.929	8.313	4.797	8.612
Variance	19.06	76.77	23.61	53.47	35.16	69.12	23.01	74.17
Range	23.20	37.40	22.40	26.50	29.60	31.10	14.80	23.70
Minimum	15.60	17.30	18.60	28.80	16.20	27.80	16.80	29.20
Maximum	38.90	54.70	41.00	55.40	45.90	59.00	31.60	52.90
Sum	3248.10	5299.10	1289.30	2095.30	1233.40	1893.20	306.50	520.50

4.10 BMI and BFM changes with increase in age

BMI has showed increasing values up to the age of 49 years and a decrease above the age of 50. BFM on the other hand has reflected higher and increasing values up to the age of 39 years and minimal increase from 40 to 59 years, but relatively higher values.

These observations can be attributed to body composition changes that occur as the body ages. During old age there is increased body fat content and reduced body fluids, protein and minerals (Figure 11).

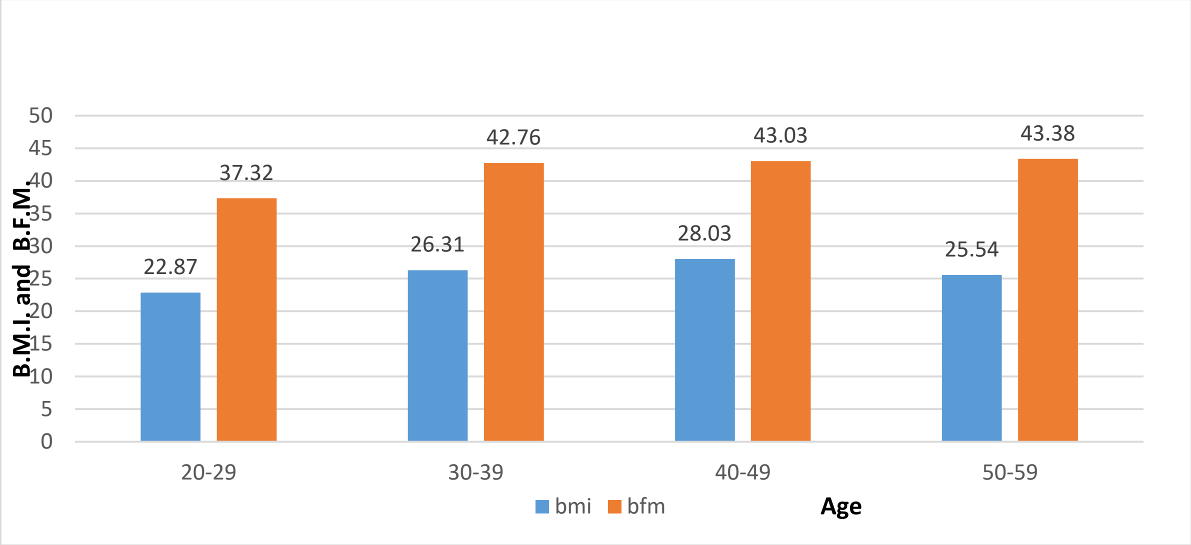

Figure 11: BMI and BFM with increase in age

4.11 Relationships between Variables

Positive and strong association was found between the two dependent variables BMI and BFM, positive and weak association between independent variable age and BMI/BFM (DVs).Independent variable sex reflected an inverse and weak association with BMI, but an inverse and strong association with BFM. Further investigations showed significant differences, that is very small p-value of <0.001 between BMI and BFM, between age and BMI/BFM and between sex and BMI/BFM. Causal effect was also found to be greater with differences in sex compared to differences in age (Table 9).

Table 9: Correlations, significant differences and causal effects between IV and DV

Sample Descriptive	BMI	BFM - BIA	r - Value	p - value	coefficient
Whole (247)	24.60±5.2	39.71±8.8	0.660	<0.001	
Females (134)	25.91±5.9	45.16±7.1	-0.273/-0.676	<0.001	-0.273/-0.676
Males (113)	23.06±3.7	33.24±7.8	-0.273/-0.676	<0.001	-0.273/-0.676
Young Adults (191)	23.76±4.7	38.71±8.7	0.301/0.209	<0.001/0.001	0.301/0.209
Old Adults (56)	27.49±5.8	43.10±8.3	0.301/0.209	<0.001/0.001	0.301/0.209
Whole (247) Age	24.60±5.2	39.71±8.8	0.372/0.273	<0.001	0.372/0.273

4.12 WHO nutritional status classifications

The two techniques, BMI and BFM measured by BIA have been used in classifying the nutrition status of the study participants. Based on WHO categorization BMI indicated that 18 participants were under weight, 134 normal, 58 over weight and 37 obese. BIA categorized one person as under fat, eight as healthy, 25 as over fat and 213 as obese. Matching BMI with BIA showed that out of the 18 categorized as underweight according to BMI, none was under fat, one person was healthy, eight persons were over fat and nine persons were obese. Out of 134 persons that were normal, one person was under fat, five persons were healthy, 16 persons were normal and 111 persons were obese. Out of 58 persons that were overweight, none person was under fat, one person was healthy, another one person was over fat and 56persons were obese. Out of 37 persons that were obese, all 37 persons were also obese by BIA categorization. The diagonal and colored boxes represent number of participants that matched using the two methods and these were only 44 out of a total of 247 the total sample (Table 10).

This clearly indicates that BMI can only be used as a screening tool for predicting body fat content in the assessment of human nutrition status. Whilst other advanced and direct techniques like BIA are more accurate to predict body fat content in the assessment of human nutrition status as seen as shown by the miss match between the two techniques.

Table 10: Cross tabulation of BMI and BFM based on WHO categorization

		BFM status				TOTAL
		under fat	Healthy	over fat	obese	
BMI status	under weight	0	1	8	9	18
	Normal	1	6	16	111	134
	over weight	0	1	1	56	58
	obese	0	0	‘0	37	37
Total		1	8	25	213	247

CHAPTER 5
DISCUSSION

5.1 BMI and BIA measurement techniques.

In this study, two different measurement techniques, BMI as an indirect and BIA as direct measure of body fat were used to predict BFM. The obtained data was used to examine whether the use of BMI and BIA analysis show same values of adiposity. BIA is an advanced technique that measures BFM more accurate compared to BMI. The BMI values (mean=24.6±5.2) obtained from the study participants were lower than the BFM values (mean=39.7±8.8) measured by BIA. This implied that BMI underestimated BFM if directly converted. Despite the difference in the two measurements, the relationship was established using the correlation value (r=0.660) found between BMI and BIA. This was a strong relationship because r-value was greater than 0.5 and positive association indicating an increase in BMI with an increase in BFM and similarly a decrease in BMI with a decrease in BFM.

Further investigations were on whether the difference found between the two techniques was significantly different. The p-value of <0.001 obtained at 95% (0.05) CI was very small and would be significant even at 99% (0.01). This p-value provided strong evidence that despite the positive and direct proportional association between BMI and BFM, a significant difference existed. Therefore, these findings translated into BMI underestimating human body fat content when compared to BIA.

The study by Chahar (2014) in Gwalior, India compared three different methods (BIA, BMI and SFTM) in predicting body fat. The results showed a significant difference between BIA and BMI/SFTM (p<0.01 with BMI and p<0.003 with SFTM). A strong positive correlation (r= 0.816 with BMI and r=0.667 with SFTM), although BIA underestimated body fat (over 10 kg) compared to both BMI and SFTM. Positive correlation and significant difference between BIA and BMI found by Chahar (2014) were in agreement with the findings of the current study. However, our findings showed disagreement that BIA underestimated body fat; instead it was BMI that underestimated body fat.

Similar findings by Tyrell et al., (2001), in New Zealand determined the accuracy of BIA and anthropometric index (BMI) as measures of body composition (FFM and FM). BIA measurements indicated higher values for FM and lower values for FFM compared with BMI measurements that reflected lower values of FM and higher values for FFM. Tyrell elal., (2001)concluded that BIA was better than BMI in the estimation of FM because BMI had recorded lower values of BFM. Qualifying that BIA is a more accurate tool in the measurement of BFM than BMI.

Another study by Bohn et al., (2015) evaluated the association between BIA-derived BFM/BMI with cardiovascular risk factors. Their findings indicated a strong correlation between BMI and BIA-derived BFM ($r=0.58$; $p<0.001$), a significant association between both obesity indices and hypertension ($p<0.001$) with positive correlation for both BMI ($r=0.22$) and BIA-derived BFM ($r=0.13$).Thus, Bohn et al,. (2015) findings further illustrated the significant difference and positive correlation between BMI and BIA-derived BFM in the measurement of body fat content and in predicting overweight/obese health implications. Similarly the current study demonstrated the accuracy of BIA at predicting BFM. This is important consideration in management of overweight and obesity.

In nutshell parallel measurement of BFM by BMI and BIA showed that BMI must be carefully interpreted when used on lean and obese persons. BMI underestimated BFM and this must be taken into consideration when interpreting BMI data. Positive correlation and significant differences found between the two techniques in this study and other studies give provisions for better perdition of body composition related health implications.

5.2 Influence of age and sex on BMI and BFM

Findings from the study reflected a positive correlation between age (IV) and BMI/BFM (DVs), r-values of 0.372/ 0.273. A rise in age translated into an increase in both BMI and BFM and a fall in age translated into a decrease in both BMI and BFM. On the other hand, an increase in age by one year effected an upward adjustment of BMI by 0.372 (coefficient=0.372) and BFM by 0.273 (coefficient=0.273). However, this did not imply that the oldest person had the highest BMI/BFM or that the youngest person had the lowest BMI/BFM because there are other influencing factors such as genetics.

During growth, from childhood to adulthood, human body increases in size and changes its components. The influencing factors include genetics, nutritional intake, physical activity, age, gender and endocrine balance (Peietrobelli and Tato, 2005). Some of these changes are very evident as can be observed from the following: A small body being transformed into a big body, little strength or weak body into more strength or strong body and after reaching the peak age 35 – 40 years, the human body starts deteriorating in some body components. Young humans have increased body fluid, tissues, minerals and reduced body fat whilst old humans have reduced body fluid, tissues, minerals and increased body fat. Remarkable differences between females and males are also observed. The rate of growth in females is faster than in males as evidenced by differences in body size. Males on the other hand have more strength which enable them do more strenuous activities because they contain more muscle compared to females with more adiposity.

This positive association of age and BMI/BFM signified that the human body keeps on growing beyond adolescent and throughout adulthood. Increase in body size as age advances is indicated by increase in body height and weight, though height reaches maximum during transition to adulthood and reduces during old age. The increase of both BMI and BFM observed up to 50 years meant that the increase in body fat content was proportional to the decrease in other body components such as body tissues, minerals and fluids. At more advanced age the increase in body fat is less than the decrease in other body components and this is very evident in most people through shrinkage of the body and collapsing of the skin. Other signs and symptoms include body weakness and bones becoming fragile. This is also matched very well with the study by Gultekin et al., (2014) which revealed a significant increase in BMI, BF, FFM, and the trunk FM and trunk muscle mass over the study periods in both sexes.

The differences in BMI and BFM between females and males were very significant ($p<0.001$) and translated into a down ward shift of 0.273 in BMI (coefficient=-0.273) and 0.676 in BFM (coefficient=-676) in males as related to females. However, the differences in BMI comparing males to females are smaller than differences in BFM. Though BMI differences were smaller, there were significantly deferent, hence it important that the BMI categorization is specific to females and males. The available WHO standards for nutritional status using BMI (WHO, 2008), do not distinguish between young adults and old adults and between male adults and female adults. This may also lead to misclassification.

Thus, findings by Glutekin et al., (2014) indicated that during the years of adolescence FFM as well as BFM males and gains are considerably greater than in females, who accumulate more BFM in later life. This inverse relationship agrees with the findings of this study that males in relation to females have reduced BFM and BMI, except that in adulthood increases in females are greater than in males.

PBF values of young and old age groups were significantly different either measured by BIA instrument or calculated by different formulas. Greatest fatness with older age was found even if BMI was the same as young population. The current study indicated strong correlation between BMI and BIA, positive though weak correlations of age to BMI/BFM (r=0.372/0.273) and strong but negative correlation of sex to BMI/BIA (r=-0.273/-0.676). Old adults showed higher mean values in both BMI and BFM compared to young adults. Mittai et al.(2011) study, however, reflected no difference in BMI for young adults and old adults which contradicted our findings.

In human life cycle, generally, older females and males have larger body size than younger ones. If there are significant differences in fat content between groups, it should also follow that the differences in BMI are significant because body fat is part of BMI (whole body). Minimal or nil differences in BMI can only be recorded when there is zero or very small increase in body fat content assuming that FFM has constant rates. The current study is in agreement with this by having reflected significant differences between young and old adults in both BMI and BFM.

A combination of females and males showed highest FM in age group 50 – 59 but with decreasing retains. BMI on the other hand showed increase in successful age groups up 49 years and a drop from 50 years. A relative negative skewness was recorded in females BFM as opposed to the counterpart males, signifying that the majority of females had higher values in BFM. Females BMI was also higher than males, positive skewness though females were more skewed to the left. This clearly gives an interpretation of changes in body composition in relation to age and sex. Body fat content increase as age advances in both females and male, but with higher values in females.

Comparing the rate of increase in body size of females and males, faster increasing rate due to accumulation of more body fat content has been observed in females as opposed to males. Lean mass on the other hand accumulates more in males but in less magnitude. This results into the majority of females having bigger body size and the majority of males having smaller body size. However, within females and within males' increases in body size seems to be normal and gradual though higher in females (Rani, 2015).

Other body components such as water decrease with successive increase in age, protein and mineral increase and reach maximum at age group 35 – 40 years. Beyond the age of 40 years protein and mineral especially calcium are seen to decline, body fluids continue to decrease whilst body fat continue to increase (Pietrobelli and Tato, 2005; Wen et al., 2007; Geissler and Powers, 2011).

5.3 Classification of nutritional status using WHO cut offs for BMI and BFM

Determination of participants' nutritional status using WHO standards through cross tabulation revealed that based on BMI categorization, 18underweight, 134 normal, 58 over weight and 37 obese. BFM classified one person as under fat, eight as health, 25 as over fat and 213 as obese. Matching BMI with BFM measured by BIA examined that out of 247 participants; only 44 participants (six normal/healthy, one over weight/over fat and 37 obese/obese) matched in classification of nutrition status using the two methods. This translated into 82% misclassification of nutrition status using BMI with reference to BIA.

Findings from the study that were undertaken by Shah and Braverman (2012) showed BMI misclassification of 25% for men and 48% for women and concluding that the prevalence of false-negative BMIs, increased misclassification in women with increase in age. The implication of misclassifying humans' nutrition status is wrong diagnosis leading to inappropriate preventive, treatment and monitoring measures. For example depriving unhealthy people from being provided with the nutrition care that they deserve. In other situation some people instead of receiving instructions to maintain their healthy status would also be wrongly advised.

Consequences of misclassification are increased rates of morbidity and mortality that can deprive any nation of productive humans. If this is not controlled the economy of the country may be affected negatively as good nutrition practices contribute to good human health and ultimately productivity. The study findings have evoked an important issue on the use of BMI based analysis in routine clinical practice and in many research reports. BMI based analysis is in use without consideration of age (young and old adults), sex (females and males), body composition (fat and muscle) and ethnic variations among populations, “leading to misclassification problem”.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study revealed that BMI underestimated BFM when used as a proxy, which results into human nutrition status misclassification and inappropriate provision of nutrition and health services. Remarkable differences in BFM between males and females exist thus different standard values should be used. BFM increase with increase in age hence young adults and old adults should be separated in assessment of nutrition status. BIA is a direct and accurate method in measurement of BFM compared to BMI when used directly to predict body fat content.

This study has demonstrated that BMI in relation to BIA further examined and confirmed a positive association, a rise in BMI resulting in a rise in BFM and a fall in BMI resulting in a fall in BFM. Increase in age translated into increased BMI/BFM and reduction in age translated into reduced BMI/BFM. Thus old adults showed higher values of BMI and BFM, but with minimal increase in BFM and reduced BMI observed at advanced age of 50 years and above. This signified the accumulation of body fat content during old age and the loss of other body components such as body fluid, tissues and minerals. Lower BMI and BFM values were observed in males in relation to females and higher values seen in females compared to males. Greater variation and lower increases in males BMI/BFM and almost constant and higher increases in females observed during age progression, implying that females contain more body fat and less lean mass.

BIA – derived BFM reflected higher values with ageing compared to BMI that showed a drop advanced age resulting from the decrease in other body compartments. BIA also depicted greater BFM differences between females and males in relation to BMI.

The study has shed light on the application of BMI and BIA in complementing each other in determining human nutritional status. Comparison of BMI with BIA in relation to body composition influencing factors; age and sex point to careful application of BMI in routine clinical practice and research with due considerations to limitations in managing and controlling NCDs.

6.2 Recommendation

Based on the findings of this study, it is important that BIA is used to complement BMI, the commonly used technique, in diagnosis and management of problems associated with overweight and obesity in health centers and research institutions.

In the application of BMI, consideration should be paid to age and sex in diagnosis for clinical nutrition practice to avoid misclassification of human nutritional status. Within the context of this study, WHO cut – offs for BMI should be reviewed to take into account the differences between age groups and sex. Standards for young adults should be separated from old adults as well as standards for males from females because of the remarkable differences that exist.

Application of BIA can be relied upon to complement other methods to provide accurate measurements and targeted support to control NCDs such as overweight and obesity. Other studies can be conducted to compare BIA with other advanced techniques of assessing human nutrition status and also to determine whether BIA is a better predictor of health risks of especially NCDs.

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APPENDICES

Appendix 1: Timeline

SCHEDULE OF RESEARCH ACTIVITIES

OCTOBER, 2016 TO AUGUST, 2017

	MONTHS														
ACTIVITIES	**2016 Oct**	**2016 Nov**	**2016 Dec**	**2017 Jan**	**2017 Feb**	**2017 Mar**	**2017 Apr**	**2017 May**	**2017 Jun**	**2017 Jul**	**2017 Aug**	**2017 Sept**	**2017 Oct**	**2017 Nov**	**2017 Dec**
Concept Note	✓	✓													
Research Proposal	✓	✓	✓												
Ethical Clearance			✓	✓											
Data Collection				✓	✓	✓									
Data Cleaning						✓	✓								
Data Analysis and Interpretation							✓	✓	✓	✓					
Report Writing				✓	✓	✓	✓	✓	✓	✓					
Submission to Supervisors										✓					
Incorporation of Comments										✓					
Final Report Submission											✓	✓	✓	✓	✓
Publication											✓	✓	✓	✓	✓

Appendix 2: Budget

RESEARCH BUDGET

Description (Item/Activity)	Unity cost (ZMK)	Sub total cost (ZMK)
1. **Fees for Ethical clearance**		**500.00**
2. **Consumables**		
Electrodes	4,000.00	
Cotton wool, disinfectant, scale batteries and other cleaning materials.	500.00	
Stationary	500.00	**5000.00**
3. **Transport (Fuel)**		
Preliminary preparations UNZA, NRDC, CHAU, CCED AND NISIR	700.00	
Pre-Test NISIR Field work	100.00	**800.00**
4. **Data collection**		
UNZA	500.00	
NRDC	500.00	
CCE	1,000.00	
CHAU	1,000.00	**3,000.00**
5. **Refreshments for participation as they are kept waiting**		**5,200.00**
Grand total cost (ZMK)		**K14, 500.00**

Appendix 3: Participant Information Sheet

INFORMATION FOR PARTICIPANTS IN THE STUDY:

To assess body fat using BIA among adults aged 18-55 years in tertiary institution in Lusaka.

There is little or nil information on body fat assessment using BIA in relation to BMI measurement. Body fat content is critical in determining nutrition and health status of an individual. Reasonable amounts of body fat are essential for the well-being of humans and above normal leads to overweight and obese. Consequently overweight and obese pose high health risks of non-communicable diseases such as cardiovascular, hypertension, cancers, type 2 diabetes. BMI is the commonly tool used for estimation of body fat and has been found to be inadequate and inaccurate. Hence BMI has the potential to misclassify the nutrition and health status of an individual. This may lead to inappropriate preventive and treatment interventions.

The research is aimed at introducing the alternative tool bioelectrical impedance analysis which is more adequate and accurate. The researcher is a human food science and nutrition professional, employed by National Institute for Scientific and Industrial Research and executive committee member of Nutrition Association of Zambia. Human nutrition status assessment is one of the critical roles in implementing and evaluation of several nutrition interventions.

BIA measures body fat content whereas BMI is used as a proxy. Use of advanced, adequate and accurate tools will improve service delivery in diagnosis and management of overweight and obesity and NCDs. If you choose to join the study we will ask you to permit us do the following;

1. A day or two before you come for appointment we will request you not to exercise or drink beer because the test results can be affected
2. Ask you for some vital statistics about yourself
3. Ask you not to eat before the measurements are taken.

4. Take your weight and height. Before that will ask you to wear minimum cloths and reasonable hair style that will not affect the weight and height.

5. Measurement of body composition using BIA device. You will be asked to lie on the bed and electrodes will be placed on your foot and hand connected to BIA machine through the leads. You will not feel anything when measuring your body composition.

Additional information

All the information and record collected about you will be kept as confidential. If you wish to know more about the study you may contact the **Researcher: Augustine C Kaunda**

Cell: 0955771589or augustkanda@yahoo.com

Findings of the research can also be shared without link to the names of the participants.

If you have any concerns or complaints about ethics conduct of the project, you should contact the chairperson of **The University of Zambia Biomedical Research Ethics Committee (UNZABREC) – 260-1-256067 or unzarec@unza.zm.**

Appendix 4: Informed Consent

INFORMED CONSENT FOR PARTICIPATION IN A STUDY TITLED

Assessment of body fat content using bioelectrical impedance analysis among adults aged 18-55 years in tertiary institutions in Lusaka.

I have been fully informed of this study and I'm aware that should I wish to participate, I should abide by the research protocols.

Further I understand that the research will bring no harm to me and 'I'm free to participate or not participate in the research. Furthermore, I also understand that by participating in the study, I will not be entitled to any special resources or be given payment or gifts.

This authorization is only valid for this study.

I hereby concert to participate

______________________	______________________	______________________
Signature or thump print	Name of the participant	Date

______________________	______________________	______________________
Signature of witness	Name of witness	Date

Researcher: Augustine C. Kaunda
NISIR P.O box 310158 Lusaka
Cell no: 0955771589
augustkaunda@yahoo.com

the Chairperson
UNZABREC, Ridgeway campus P.O box 50110 Lusaka
tel: 0211 256067
unzarec@unza.zm

Appendix 5: Data Collection Form

BODY MASS INDEX AND BIOELECTRICAL IMPEDANCE DATA COLLECTION FORM

Assessment of body fat content using bioelectrical impedance analysis among adults aged 18-55 years in tertiary institutions in Lusaka.

Participants Demographics:

Date: ------------------------------

Participants ID……………………………….Age ……………………. (Years) Gender …………………

Actual Body Weight ……………………….Kg Height ……………………………….Cm

Field Of Study: ………………………………. Institution name……………………………Tribe…………………………….

BIA Measurements:

TBW (L) ………………………….. TBW (%)…………………………………

FFM (KG)…………………………… FFM (%)…………………………………

FM (KG)……………………………… FM (%)…………………………………..

BMI…………………………………….

Examiner………………………………………………….. Date: …………………………………

Appendix 6: Ethical Approval

THE UNIVERSITY OF ZAMBIA

BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: 260-1-256067
Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
E-mail: unzarec@unza.zm
Assurance No. FWA00000338
IRB00001131 of IORG0000774

27th February, 2017.

Your Ref: 001-01-17.

Mr. Augustine C. Kaunda,
University of Zambia,
School of Agricultural Sciences,
Department of Food Science and Nutrition,
P.O Box 32379,
Lusaka.

Dear Mr. Kaunda,

RE: RESUBMITTED RESEARCH PROPOSAL: "ASSESSMENT OF BODY FAT CONTENT USING BIOELECTRICAL IMPEDANCE ANALYSIS AMONG ADULTS AGED 18-55 YEARS IN TERTIARY INSTITUTIONS IN LUSAKA" (REF. 001-01-17)

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee on 23rd February, 2017. The proposal is approved.

CONDITIONS:

- This approval is based strictly on your submitted proposal. Should there be need for you to modify or change the study design or methodology, you will need to seek clearance from the Research Ethics Committee.
- If you have need for further clarification please consult this office. Please note that it is mandatory that you submit a detailed progress report of your study to this Committee every six months and a final copy of your report at the end of the study.
- Any serious adverse events must be reported at once to this Committee.
- Please note that when your approval expires you may need to request for renewal. The request should be accompanied by a Progress Report (Progress Report Forms can be obtained from the Secretariat).
- **Ensure that a final copy of the results is submitted to this Committee.**

Yours sincerely,

Dr. S.H Nzala
VICE-CHAIRPERSON

Date of approval: 27th February, 2017.

Date of expiry: 26th February, 2018.

Appendix 7: Calibration Certificate for Sesca Scale

CALIBRATION CERTIFICATE

ZABS

Zambia Bureau of Standards
for Safety and Quality Assurance

(The Standards Act CAP 416)

Lechwe House, Freedom Way - South End
P.O. Box 50259 ZA 15101
Ridgeway, Lusaka, Zambia
Tel: +260 211 231385/227075
Telefax: +260 211 238483
Email: metrology@zabs.org.zm

BIPM Associate Member
ISO Correspondent Member

Company Name:	National Institute for Scientific and Industrial Research (NISIR)		
Physical Address:	Kenneth Kaunda Airport Road, Lusaka		
Certificate Number:	ZABSML/MC/16/412	Serial Number:	65 CS
Manufacturer:	Unknown	Unique ID.:	None
Description:	F2 Weight Set-Stainless Steel	Model/Type No.:	Unknown
Calibration Date:	23/08/2016-24/08/2016	Issue Date:	29/08/2016
Location of Calibration:	Metrology Mass Laboratory		
Expiry Date:	22/08/2017		

Calibrated By:	Ngoza Lukali Assistant Metrologist	Signature
Checked By:	Daniel M. Mutale Technical Signatory	Signature
Certified By/For Director:	Fredrick Hamutunda Metrology Manager	Signature

This is the first issue and original certificate

Official ZABS Stamp

ZAMBIA BUREAU OF STANDARDS METROLOGY 29 AUG 2016 LABORATORIES P.O. BOX 50259, LUSAKA.

Page 1 of 4

SADCAS
CAL-8 003

CONDITION OF EQUIPMENT BEFORE CALIBRATION: Ok.

CONDITION OF EQUIPMENT AFTER CALIBRATION: Ok

METHOD USED: ABBA standard method. The weights were examined and calibrated in a temperature controlled environment of 20 ± 0.5°C.

PROCEDURE USED: MOP 002

AIR DENSITY : 1.04 ± 0.04 kg/m3

TRACEABILITY: This equipment was calibrated by means of ZABS comparators, serial numbers 23109604 and 23109603, Mass Standard serial number 0577 of class F1. The measurement results are traceable to the Zambia National Standard for Mass.

RESULTS:

Nominal Value of Weight (g)	Marking on Weight	Actual Value of Weight (g)	Uncertainty (±g)
1000	1000 g	1000.04773	0.00065
500	500 g	500.06616	0.00019
200	200 g	200.00220	0.00017
100	100* g	99.99518	0.00011
100	100 g	99.99763	0.00012
50	50 g	49.99020	0.00011
20	20* g	20.001794	0.000099
20	20 g	20.001453	0.000097
10	10* g	9.99742	0.00012
10	10 g	9.997554	0.000098
5	5 g	4.999926	0.000018
2	2* g	2.000172	0.000015
2	2 g	2.000172	0.000015
1	1 g	1.000090	0.000012
(mg)		(mg)	(±mg)
500		500.0610	0.0093
200	*	200.0945	0.0084
200		200.1452	0.0084
100		100.0686	0.0065
50		49.9334	0.0054
20	*	20.0502	0.0055
20		20.0632	0.0055
10		10.0374	0.0046

A SADCAS Accredited Calibration Laboratory No. CAL-8 003

ZAMBIA BUREAU OF STANDARDS METROLOGY 29 AUG 2016 LABORATORIES P.O. BOX 50259, LUSAKA.

Appendix 8: Calibration Certificate for Stadiometer No.1

CALIBRATION CERTIFICATE

ZABS
Zambia Bureau Of Standards
"For Safety and Quality Assurance"

BIPM Associate Member
ISO Correspondent Member

(The Standards Act CAP 416)

Lechwe House, Freedom Way - South End
P.O. Box 50259 ZA 15101
Ridgeway, Lusaka, Zambia
Tel: +260 211 231385 / 227075
Telefax: +260 211 238483
E-mail: metrology@zabs.org.zm

Company Name:	NISIR Food Science Research Centre		
Physical Address:	NISIR KKIA off Great East Road		
Certificate Number:	ZABSML/DC/17/131	**Serial Number:**	1225296073463
Manufacturer:	Seca	**Unique No.:**	002
Description:	Standio Meter	**Model/Type No.:**	2251721009
Calibration Date:	27/06/2017	**Issue Date:**	12/07/2017
Location of Calibration:	Zambia Bureau of Standards – Dimensional Laboratory, Lusaka		
Expiry Date:	26/05/2018		

Calibrated By: Frank Kabwe, Metrology Technician — Signature

Checked By: Daniel Mutale, Technical Signatory — Signature

Certified By: For Fredrick Hamutunda, Metrology Manager — Signature

This is the first issue and original certificate

Official ZABS Stamp
12 JUL 2017

Page **1** of **5**

CERTIFICATE NUMBER: ZABSML/DC/17/131

5.0 Results

BEFORE ADJUSTMENTS

Nominal Value (Range) (mm)	Standard Value (mm)	Standio-Meter Reading
1500	1500	1500
1750	1750	1750
2000	2000	2000

TABLE OF RESULTS/VALUES OF CALIBRATION:

Nominal Value (Range) (mm)	Standard Value (mm)	Average Standio-Meter Reading (R) (mm)	Error (E) (mm)	Uncertainty U (±) K=2 (mm)
1305	1305	1305	0	1
1500	1500	1500	0	1
1750	1750	1750	0	1
2000	2000	2000	0	1
2300	2300	2300	0	1

Opinions and interpretations:
None

End of Page

ZAMBIA BUREAU OF STANDARDS
METROLOGY
12 JUL 2017
LABORATORIES
P.O. BOX 50259, LUSAKA.

Version No.01-02-2017-V 004

Appendix 9: Calibration Certificate for Stadiometer No.2

CALIBRATION CERTIFICATE

ZABS

Zambia Bureau Of Standards
"For Safety and Quality Assurance"

BIPM Associate Member
ISO Correspondent Member

(The Standards Act CAP 416)

Lechwe House, Freedom Way - South End
P.O. Box 50259 ZA 15101
Ridgeway, Lusaka, Zambia
Tel: +260 211 231385 / 227075
Telefax: +260 211 238483
E-mail: metrology@zabs.org.zm

Company Name:	NISIR Food Science Research Centre		
Physical Address:	NISIR KKIA off Great East Road		
Certificate Number:	ZABSML/DC/17/132	**Serial Number:**	1225352075479
Manufacturer:	Seca	**Unique No.:**	002
Description:	Standio Meter	**Model/Type No.:**	2251721009
Calibration Date:	27/06/2017	**Issue Date:**	12/07/2017
Location of Calibration:	Zambia Bureau of Standards – Dimensional Laboratory, Lusaka		
Expiry Date:	26/05/2018		

Calibrated By:	Frank Kabwe Metrology Technician	Signature
Checked By:	Daniel Mutale Technical Signatory	Signature
Certified By:	For Fredrick Hamutunda Metrology Manager	Signature

This is the first issue and original certificate

Official ZABS Stamp

Page **1** of **5**

5.0 Results

BEFORE ADJUSTMENTS

Nominal Value (Range) (mm)	Standard Value (mm)	Standio-Meter Reading
1500	1500	1488
1750	1750	1738
2000	2000	1988

TABLE OF RESULTS/VALUES OF CALIBRATION:

Nominal Value (Range) (mm)	Standard Value (mm)	Average Standio-Meter Reading (R) (mm)	Error (E) (mm)	Uncertainty U (±) K=2 (mm)
1305	1305	1306	-1	1
1500	1500	1499	1	1
1750	1750	1749	1	1
2000	2000	1999	1	1
2300	2300	2299	1	1

Opinions and interpretations:
None

End of Page

ZAMBIA BUREAU OF STANDARDS
METROLOGY
12 JUL 2017
LABORATORIES
P.O. BOX 50259, LUSAKA