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KAHRAMANMARAŞ SÜTÇÜ İMAM UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

A STUDY TO DETERMINE THE ASSOCIATION OF BODY FAT RATIO WITH HEART DISEASE RISKS IN WOMEN BY BIOELECTRICAL IMPEDANCE ANALYSIS

HALIZ ABDULRAHMAN HUSSEIN

MASTER THESIS

DEPARTMENT OF BIOENGINEERING AND SCIENCES

KAHRAMANMARAŞ, TURKEY 2014

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M.SC. thesis entitled "A STUDY TO DETERMINE THE ASSOCIATION OF BODY FAT RATIO WITH HEART DISEASE RISKS IN WOMEN BY BIOELECTRICAL IMPEDANCE ANALYSIS" prepared by Haliz Abdulrahman Hussein, who is a student at Bioengineering and Sciences Department, Graduated School of Natural and Applied Sciences, Kahramanmaraş Sütçü Imam University, was certified by all the majority jury members, whose signatures are given below.

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DECLARATION

I hereby declare that all information in the thesis has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that , as required by these rules and conduct, I have fully cited and referenced all the material and results that are not original to this work.

HALIZ ABDULRAHMAN HUSSEIN

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BİYOELEKTRİKSEL EMPEDANS ANALİZİ KULLANILARAK KADINLARDAKİ VÜCUT YAĞ ORANI İLE KALP HASTALIĞI ARASINDAKİ İLİŞKİNİN İNCELENMESİ

YÜKSEK LİSANS TEZİ

HALIZ ABDULRAHMAN HUSSEIN

ÖZET

Günümüzde, kardiyovisküler hastalık (CVD) insan ölümlerinin önden gelen sebeplerinden biridir. Vücuttaki yağ dağılım şekli CVD risk faktörü ile kesitsel olarak bağlantılıdır. Obeziteden kaynaklanan fazla vücut yağı bir çok kronik hastalıklar için risk faktörü erken kardiyovasküler hastalık için bir yatkınlık olarak kabul edilir. Bu tezin amacı, Biyoelektrik Empedans Analiz (BIA) yöntemini kullanarak belirli bir yaş aralığındaki kadınların kalp hastalığı riski (CVD) ile obezite (Yağ dağılımı) ilişkisini belirlemektir.

Çalışmada 30-75 yaş aralığında bulunan Kuzey Irak'ın Duhok kentinden 209 kadın üzerinde vücut yağ oranın (BF) bel-kalça çevresinin oranı (WHR) ile olan ilişkisi incelendi. Duhok'taki araştırma hastanesi ve laboratuarından 209 hastanın tansiyonu degerleri (SBP, DBP), antropometrik parametreler (BFR,WHR ve BMI) ve biyokimysal ölçumleri (Seker, LDL-C, HDL-C, trigliserit seviyeleri ve Friedel denkleminden elde edilen toplam kolestrol) alındı. İstatiksel analiz için hastalar yaşlarına göre üç gruba ayrıldılar. Çalışmada öncelikle, obezite görünümü için bel çevresi (WC), kalça çevresi (HC), bel ve kalça oranı (WHR), vücut kütle oranı (BMI), BIA kullanılark üst ve alt vücut yağ yüzdesi (BF%) belirlendi and daha sonra BFR hesaplandı. CVD risk faktörleri (tansiyon, şeker, Trigliserid, Toplam kolestrol seviyesi, LDL ve HDL) belirlendi ve aralarındaki ilişki yaş oranlarina gőre istatistksel olarak incelendi. Bunlar arasındaki ilişkiyi belirlemek için, her antropometrik parametre ile CVD risk faktörlerini hesaplayan SPSS Version 20 istatiksel programi kullanıldı.

Antropometrik parametre değerlerinin (BFR, WHR and BMI) artması ile % CV risk faktörünlerinin arasında onemli derecede bir koralasyon olduğu tüm antropometrik ölçümleri gösterdi. Ayrıca, yaşın ilerlemesi ile beraber %CV ve kardiyovisküler risk faktörü de artmaktadır. Sonuç olarak, bu üç anthropometrik parametre (WHR, BFR and BMI) ile %CVD arasinda yakin bir ilişki olduğu ve bu anthropometrik őlçümlerin, CV risk faktörü arasında da oldukça güçlü bir bağıntı olduğu bulundu.

Keyword : BMI, Biyoempedans, Obezite, CVD.

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Danışmanlar: Prof. Dr. Abdulkadir YILDIZ
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A STUDY TO DETERMINE THE ASSOCIATION OF BODY FAT RATIO WITH HEART DISEASE RISKS IN WOMEN BY BIOELECTRICAL IMPEDANCE ANALYSIS

(M.Sc. THESIS)

HALIZ ABDULRAHMAN HUSSEIN

SUMMARY

Nowadays, Cardiovascular disease (CVD) is one of the leading causes of mortality of human. Body fat distribution has been cross-sectionally associated with CVD risk factors. The excess body fat associated with obesity is considered a risk factor for many chronic diseases and a predisposition to premature cardiovascular disease (CVD). The purpose of this thesis is to determine the correlation of obesity (fat distribution) with heart diseases risk of women in a certain age range by using Bioelectrical Impedance Analysis (BIA) method.

The study is carried out to estimate the correlation of body fat ratio (BFR) with waist– hip circumference ratio (WHR) on 209 Iraq women at ages 30-75 years in Duhok city of Northern Iraq. The data of blood pressure (SBP,DBP), anthropometric parameters (BFR, WHR, and BMI) and biochemical measurements (fasting glucose (DM), LDL-C and HDL-C levels, triglyceride levels, and total cholesterol which determined by Friedewald equation were collected for the 209 subjects from the teaching hospital and laboratory in Duhok. They were categorized according to their ages for the statistical analysis. In the study, prevalence of obesity is first determined using waist circumference (WC), hip circumference (HC), waist to hip ratio (WHR), body mass index (BMI) and percent of body fat (BF%) upper and lower from BIA method and then BFR are evaluated. The CVD risk factors (Blood pressure, fasting plasma Glucose, Triglycerides, Total cholesterol level, Low and High- density lipoprotein cholesterol level (LDL, HDL)) are assessed, and their relationships were statistically examined according to the age group. The correlation statistics is run for determining each anthropometric parameter with the CVD risk factors by using SPSS Version 20.

The results showed that all anthropometric measurements were significantly correlated with CV% risk factors with increasing anthropometric parameters (BFR, WHR and BMI). It was also obtained that high risks of CV% factors as well as cardiovascular risk factors increased with the ages. In conclusion, it was found that the three anthropometric indexes (WHR, BFR and BMI) were closely related to CVD risk factors and all anthropometric measurements were high significantly correlated with CV risk .

Keyword : BMI, Bioimpedance, Obesity, CVD.

Kahramanmaraş Sütçü İmam University
Graduate School of Natural and Applied Sciences
Department of Bioengineering and Sciences, May, 2014

Supervisors: Prof. Dr.Abdulkadir YILDIZ and Asst. Prof.Dr. Haval Yaccob ALDOSKY
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LIST OF ABBREVIATIONS

CVD : Cardiovascular Diseases

BF: Body Fat

BF%: Body Fat Percent

WC : Waist Circumference

HC : Hip Circumference

WHR : Waist To Hip Ratio

BFR : Body Fat Ratio

BMI: Body Mass Index

LM : Lean mass

BIA: Bioelectrical Impedance Analysis

CV: Cardiovascular

HDL-C: High Density Lipoprotein – Cholesterol

LDL-C: Low Density Lipoprotein – Cholesterol

TCHO: Total Cholesterol

Whtr : Waist To Height Ratio

CHD : Cardio Heart Diseases

DM : Diabetes Mellitus

NHANES : National Health And Nutrition Examination Survey

FM : Fat mass

FFM: Fat free mass

TBW : Total body water

BMC : Bone Mineral Content

BMD : Bone Mineral Density

LBM : Lean Body Mass

ICW : Intercellular Water

ECW :	Extracellular Water
SAT :	Subcutaneous Adipose Tissue
VAT :	Visceral Adipose Tissue
STM :	Soft Tissue Mass
WHO :	World Health Organization
DEXA :	Dual Energy X-Ray Absorptiometry
ACSM :	American College of Sports Medicine
ADP :	Air Displacement Plethysomography
HW :	Hydrostatic Weighing
SF :	Skinfold
SF-BIA :	Single- Frequency Bioelectrical Analysis
MF-BIA :	Multi- Frequency Bioelectrical Analysis
NIH :	National Institute of Health
TBF :	Total Body Fat
MRI :	Magnetic Resonance Imaging
CT :	Computer Tomography
cm :	centimeter
g :	grams
Y:	Years
KHz :	Kilohertz
KV:	Kilovolts
mmHg:	millimeters of mercury
mm/dl:	mill mole per deciliter
n:	number
TG:	Triglyceride
BF%(L-L):	Body Fat%(Leg-to-Leg)
BF%(H-H):	Body Fat%(Hand-to-Hand)

FBS: Fasting Blood Sugar

ml: milliliter

mg/dl: milligrams per deciliter

µA: Micro Ampere

SBP: Systolic Blood Pressure

DBP: Diastolic Blood Pressure

≥**:** more than or equal

>**:** more than

1. INTRDUCTION

1.1. Overview

The increased focus on the study of human body is today closely related to health problems such as obesity [1]. Obesity and overweight are currently considered major public health problems both in developed and developing countries. The risk increases with increasing adiposity which may lead to many diseases at any age. The prevalence of obesity is high and increasing in developed regions like Europe, the United States, and Oceania. This problem is today seen to affect the population of many countries in the western world [2-5], and is gradually reaching to epidemic proportions in the 21st century. This is apparently causing an epidemiological transition where there is a shift towards an increase in non-communicable diseases and decline in communicable diseases [6,7]. It has been reported that the major reasons of overweight and obesity are the lack of physical activity and excess nutrition intake [8,9].

Adiposity has proven to be an important risk factor for cardiovascular disease (CVD) [10,11]. The World Health Organization (WHO) reported cardiovascular diseases to be death cause number one globally with 29% of all-cause deaths, corresponding to 17.1 million people in 2004 [12]. Researchers found that these mortality rates to be closely associated with certain CVD risk factors [10,13].

In addition, obesity has been found to be one of the crucial risk factors of cardiovascular diseases in the general population [14]. Cardiovascular diseases is, nowadays, the leading cause of death for men and women both in the developed and developing countries [15]. Although the prevalence of some CVD risk factors has decreased economically in developed countries, the corresponding prevalence has increased in economically developing countries like India [16,17]. It is estimated that half of all cardiovascular deaths in India occur in the working-age population compared with nearly one quarter in high-income countries [18]. The cardiovascular risks for men and women could be associated with many factors such as age, smoking, hypertension, diabetic and obesity [17].

Obesity is defined as a condition where there is an excess of body fat, and there are several devices/methods to measure total body fat and its distribution [19,20]. Obesity lone regards as cardiovascular risk factors, and there is also a relationship between obesity and hypertension. Even in healthy young people who are obese, some degree of myocardial dysfunction has been demonstrated echo cardio graphically which tends to be reversible with weight loss [21]. Though numerous studies have examined the CVD risk factors in young adult population in Iraq, the emphasis was mainly related to clinical cases in most of these studies [22-24].

The classic risk factors for heart disease in the general population can be listed as age, gender, family history of premature cardiovascular disease, and high fasting glucose (diabetes mellitus), hypertension, smoking, high total and low-density lipoprotein (LDL-C) levels, low high-density lipoprotein cholesterol (HDL-C) levels, high triglyceride levels, and abdominal obesity [10,25]. The relation of obesity with diseases can be further characterized by measuring the distribution of body fat. For example, an increased waist-to-hip circumference ratio reflecting greater abdominal adiposity is associated with an increase in hypertension [26-30]. Central distribution of body fat which suggests excessive deposition of intra-abdominal fat is also found to be an important predictor of cardiovascular risk [31, 32].

In recent studies of women [30] and men [33] in Gothenburg, Sweden, the waist-to-hip ratio was also significantly higher in subjects who sustained a stroke than in those who did not. An elevated waist-to-hip ratio has been further associated with increased rates of coronary heart disease [28,30], and diabetes mellitus (DM) [28,34]. Most studies use anthropometric measures to measure adiposity. Waist circumference (WC) and waist- to - hip ratio (WHR) have been used as a measure of central obesity (where visceral adipose tissue is stored), and body mass index (BMI) (Kg/m^2) has been used as a measure of general obesity [35]. However, after adjustment for these conditions, central body fat distribution can be estimated from WHR. Anthropometric measurement still plays an important role in clinical practice. As stated above the BMI is often used to reflect total body fat amounts while the waist circumference, waist- to- hip ratio, and waist to height ratio (WHtR) are used as surrogates for body fat centralization [36,37].

Though a number of techniques are available to measure body fat, anthropometry is the simplest and most practical. Among them BMI gives a reasonable estimate of adiposity. Use of BMI eliminates the problem of frame size and also allows classification of overweight and obesity to be established. This provides a rational scheme for treatment. Recently non HDL-C has been suggested as a better tool for the assessment of cardiovascular risk and treatment than LDL-C [38].

A significant positive correlation of BMI and WHR with blood pressure was found among affluent Punjabi girls of Delhi [39]. There are various anthropometric indices which define obesity with relative ease and accuracy like BMI, WHR, WHtR and WC. Accumulating evidences have elucidated that BMI and WHtR can serve as valuable prognosticators for cardiovascular risk. A study conducted on Singaporean adult females demonstrated that WHtR can act as a best screening tool for cardiovascular risk [40]. Another study also reported that WHtR is a simple and effective screening tool for cardiovascular risk factors in both men and women [41]. WHR was reported to be secondary to BMI as a predictor of cardiovascular risk in Canadian adult men and women [42]. In Japanese men and women WHtR was found to be a better predictor of metabolic risk as compared to other anthropometric indices [43].

A study conducted on a group of adult males and females in Taiwan, an increase in BMI, WC, WHR, and WHtR was obtained for a higher risk of hypertension, diabetes, dyslipidemia and impaired fasting glucose [44]. BMI and WC showed a significant association with hypertension and WHR with diabetes 2 among adult males in Chennai, India [45]. BMI and WC were reported to be useful screening tools among young obese women to detect early cardiovascular risk [46]. BMI was reported to be more detrimental to cardiovascular health among Aggarwal baniya females whereas among males it was WHR [47].

General measures of obesity (weight, BMI, and percent body fat) and measures of central fat distribution (waist circumference, waist-to-hip ratio, waist to thigh ratio, and waist to height ratio) predict the risk of heart diseases prospective studies regardless of age or ethnicity [34, 48-54]. The strong association between the quantity of intra-abdominal fat and metabolic disorders, however, has led some to suggest that anthropometric measurements that describe central fat distribution (such as waist circumference) may be better than general measures of obesity as predictors of diabetes For example, in the San Antonio Heart study [52], the waist circumference was the best predictor of diabetes risk in a population of Mexican American among the variables BMI, WHR, HC, and the sum of skin fold thicknesses. In other prospective studies, the risk of diabetes increased with increasing quantities of central fat within a BMI category, suggesting that both measures are important in predicting the risk of diabetes [50, 51, 53].

Epidemiological studies have demonstrated a rather close relation between hypertension, obesity, and disturbances of glucose and lipid metabolism [55,56]. Hypertension individuals, selected at random from the population, frequently have obesity and metabolic derangements, and conversely, there is a high prevalence of hypertension in obese subject [57]. However, human obesity is not a homogenous condition. Several studies have shown that the distribution of excess adipose tissue to central or peripheral depots is associated with different prevalence rates of associated metabolic perturbations as well as risk for development of cardiovascular disease [58, 59].

The majority of patient with high blood pressure are overweight, and hypertension is more frequent in obese subjects [60]. For example, a 10 Kg overweight of body causes to increase 3.0 mmHg higher systolic and 2.3 mmHg higher diastolic blood pressure. These increases translate into an estimated 12% increased risk for cardio hard diseases (CHD) and 24% increased risk for stroke [61]. Results from NHANES III reported more specific estimates for the prevalence of high blood pressure per age and BMI group [62]. This increase in blood pressure is the greatest when the obesity is of abdominal distribution [63-67]. Hypertension appears to be related to both obesity (defined as enlargement of body fat mass) as such and central distribution of body fat [68,69]. There is suggestive evidence that hypertension associated with central excess of body fat is particularly harmful as a risk factor for development of cerebrocardiovascular diseases [33, 68,69].

Although most of the co-morbidities relating obesity to coronary artery disease increase as BMI increase, they are also related to body fat distribution. Long-term longitudinal studies, however, indicate that obesity as such not only relates to but independently predicts coronary atherosclerosis [70,71,72]. This relation appears to exist for both men and women with minimal increases in BMI. In a 14-year prospective study, middle-aged women with a BMI >23 but <25 had a 50% increase in risk of non fatal or fatal coronary heart disease[70], and men aged 40 to 65 years with a BMI >25 but <29 had a 72% increased risk [73]. The overall relation between obesity and coronary artery disease morbidity and mortality is less clear for Hispanics [74], Pima Indians [75], and African-American women [76].

The studies that analyzed the relation between anthropometric measures and abdominal visceral fat reported waist circumference to be a better measure of central obesity [35, 77–79]. Waist circumference and the waist –hip ratio are widely used as indicators of abdominal adiposity in epidemiologic studies. It has been shown that WC is a better marker of visceral fat as compared with WHR [80,81] and correlates more strongly with cardiovascular disease risk factors [52,82-84]. WHR has also been shown to be a good predictor of increased risk of diabetes [51,85] and CHD [50,86] which may be due to attributes related to small hip relative to waist circumference. Cross-sectional and prospective studies have found that when WC is taken in to account, a larger hip circumference is associated with reduced risk factors for diabetes [87, 88] and cardiovascular disease [89-98]. Both fat and lean tissue from the hip and thigh may contribute, and regional differences in lipolysis may be involved in reduced disease risk associated with relatively larger hip circumference. As far as we have investigated, few prospective studies in literature have looked at HC as an independent predictor of DM and CHD [89, 96, 99].

A recent systemic review investigated the importance of obesity and cardio respiratory fitness related to the risks of and mortality due to CVD and diabetes type 2 [100]. It showed that BMI is the most frequently used measure of adiposity in the included studies and raise a few questions about the overall applicability of the BMI. For instance, BMI neither gives an indication of the relation between fat and fat-free mass nor does it indicated fat distribution. For a given BMI, physically fit individuals have less total and abdominal fat, compared with unfit individuals. A large muscle mass instead of fat mass will also place people in higher BMI categories. This is supported by many studies investigated the diagnostic accuracy of BMI to detect adiposity [77] . The studies also found limited diagnostic performance of the BMI in correctly identifying individuals with excess in body fat (BF), particularly in those with BMI < 30. Although BMI has a good correlation with BF%, it fails to discriminate between BF% and lean mass [101]. In addition to this weakness, BMI is also criticized due to that it makes no difference between men and women even though a significant fat distribution between men and women is known [101,102]. Also, age and ethnicity have an effect on body fat distribution and are not differentiated in BMI [77,102, 103]. Although the relationship between anthropometric adiposity measurements and CVD risk factors have been explored thoroughly in many studies around the world, the results have been in agreement quantitatively with the studies discussed above.

The main goal of this study is to determine the associated of body fat ratio with heart disease risks (CVD) by using Bioelectrical Impedance Analysis method (hand-to-hand and foot-to-foot) and to estimate the correlation of the measured body fat ratio with waist–hip ratio for a group women aged 30-75years in Duhok city of Northern of Iraq .

In the next chapter, after the body composition and the measurement methods have been reviewed using the literature material, among which we explain in detail the advantages and disadvantages of BIA method being used in this study. The materials and method and the statistical data have been given in chapter 3. The results and discussion are presented in chapter 4. The thesis is ended up with the section of conclusion.

2. BODY FAT AND OBESITY IN HUMAN

2.1.Background

The body fat percentage of a human or other living being is the total fat divided by total body mass and body fat includes essential body fat and storage body fat. Essential body fat is necessary to maintain life and reproductive functions. The percentage of essential body fat for women is greater than for men due to the demands childbearing and other health functions. The percentage of essential fat is 2-5% in men, and 10-13% in women [104]. Storage body fat consists of fat accumulation in adipose tissue which protects internal organs in the chest and abdomen. The minimum recommended total body fat percentage exceeds the essential fat percentage value reported above. There is no single ideal percentage of body fat for everyone. Level of body fat epidemiologically dependends on sex and age [105].

Many individuals have taken to self-monitoring body composition given by physician recommendations or their own desire to reduce BF, often using portable and cheap assessment tools. Individuals use body composition results from these devices to help them make health–related decisions (dietary or physical activity changes, medications, medical procedure) and also use this information to track progress of an exercise or recommended diet program, or other health interventions [106]. Clinicians use body composition information to identify patients at greater risk for developing CVD or DM to diagnose individuals with metabolic syndrome or to monitor diseased state progression [107]. In athletes of certain sports, previous researches suggest that there is an inverse relationship between increased BF% and athletic performance [108]. Consequently, monitoring BF% during an athletic training program becomes important to optimize performance. Fitness centers and physicians are using portable body composition assessment tools to guide health related decisions and recommendations[109].

Based on self-report information, data from 2007-2008 National Health and Nutrition Examination Survey (NHANES) demonstrated that 34% of adults aged 20 years and older are overweight, 34% are obese, and 6% are extremely obese, based on body mass index (BMI) classifications[110]. Given the numerous health risks associated with being overweight or obese, including coronary heart disease, diabetes mellitus (DM), hypertension, hyperlipidemia, and certain types of cancer, Physicians are commonly recommending that their patients lose weight and reduce their body fat (BF) level [111-114].

2.2.Body Composition

The composition of the human body is mulltilevel, dynamic and complex. Different models such as the basic two compartment model and multi-compartment model [115] given in Figure 2.1 have been used to determine the compositions of human body. The main three tissue components of body composition,which are adipose tissue, skeletal muscle and bone, are linked to function, fitness and well being.

Body composition is not just limited to BF% or fat mass (FM), depending on the number of compartments being assessed. Total body composition contains estimates of fat free mass (FFM) that is further divided into lean body mass (LBM), bone mineral content (BMC) and total body water (TBW) in addition to BF% or FM. These are considered as separate compartments of body composition. Fat mass is comprised of essential lipids and stored adipose tissue, and is present in many areas of the body. Subcutaneous fat lies just under the skin throughout the body. This is the type of fat mass (FM) and can be seen and felt by pinching the skin and the underlying fat tissue. There is also fat that is not measurable without the use of imaging techniques called visceral fat. Visceral fat is located in the abdomen around the organs, and fat free can also be found in the yellow bone marrow in adults as well as within the muscle (intramuscular). TBW is the sum of extracellular water (ECW) and intracellular water (ICW) [116]. The human body is made of approximately 62% water, depending on hydration level of the individual [117]. And the aqueous fraction of the fat free mass of the theoretical standard reference man is 73.8%. Bon mineral content (BMC) is the ratio of BMC to bone size (g/cm^2) and is commonly used as a marker for determining osteopenia and osteoporosis [118]. These compartments are then combined in different manners to create body composition models. Body composition models can be divided into two, three, four, five or even six compartments [115,119]. These multicomponent models are defined by five specific levels of measuring body mass: atomic, molecular, cellular, tissue-organ and whole-body as demonstrated in Figure 2.1 [120].

However, the most commonly used level in exercise physiology is the tissue-organ level. The tissue-organ level is made up of compartments of adipose tissue, skeletal muscle, visceral organs and bone. A widely used two-compartment model includes the measurement of FM and FFM. A common three- compartment tissue-organ level model would be one that includes BMC, FM and Mineral-free lean tissue. A benefit of using these three compartment model is that there is no assumption in the hydration of FFM, and therefore it dismisses the variation between individuals [121]. Another common three-compartment model is one that consists of TBW, FM and FFM. And common four-compartment model would include BMC, FM, FFM and TBW. A four-compartment model is considered the most valid one because it controls for variability between individuals in both BMD and TBW [121]. The whole-body level utilizes anthropometric measures, and necessarily specific compartments. This would include measures of height, weight and circumferences.

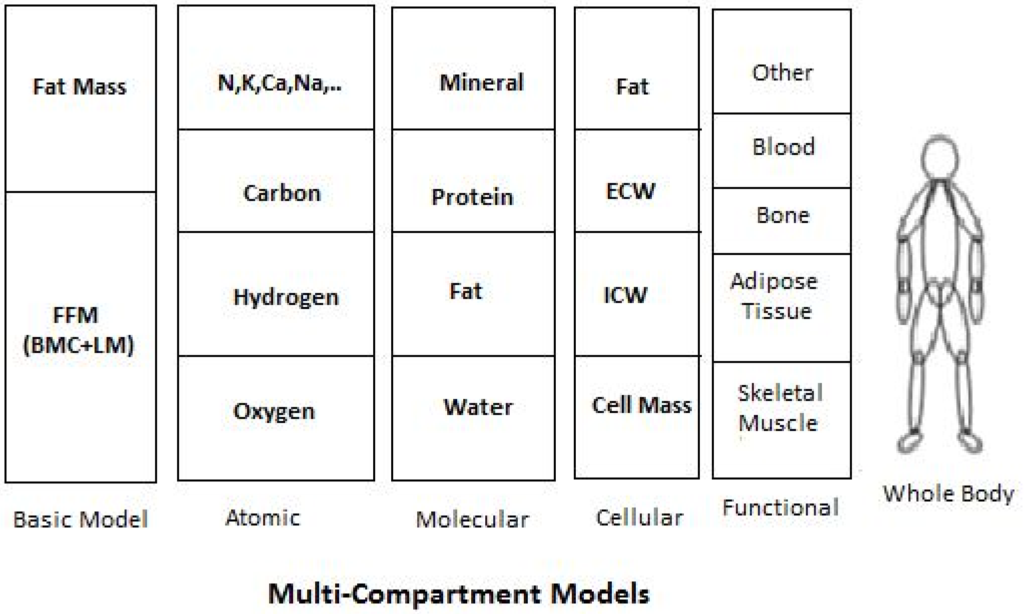

Figure 2.1. Basic model and multi-compartment models for expressing human body composition [122].

2.3. Factors Influencing Body Composition

There are three main elements in a simple model of body composition: body fat, bone and lean. A large proportion of the lean mass is skeletal muscle. A variety of factors, including genetics, age, lifestyle, social-economic and environmental factors, determine an adult's body composition in the present and future [123]. For all individuals, there are modifiable and non-modifiable factors in determining one's body composition. Body composition can vary greatly across age, sex, stature and race, all of which are non-modifiable. Age is an important aspect in a adult body composition. For example, after the age of 30, bone and muscle mass generally decrease while fat mass increase with increasing age.There is usually an increase in FM until about age 74, and then FM begins to decrease slightly [124,125]. Additionally, older adults experience a decline in FFM, mainly due to loss of bone mineral and skeletal muscle mass [112]. This decrease in skeletal muscle, or sarcopenia, generally occurs after the age of 30-40 years and is heightened after the age of 60 years [125]. The decline in skeletal muscle in older adults has been noted to be higher in men than women [126]. Females reach their peak bone mass between the ages of 20-25 years. But after that age, bones gradually lose their mass [127].

Genes influence body fat, bone and muscle. One obvious genetic difference is sex. Sex differences in adult body composition are obvious across all ethnic groups, with males being taller and heavier than females. Females have a greater average percentage body fat and less muscle mass. On average, healthly females have 20-30 BF% while male have 10-15 BF% [128]. In addition, females deposit fat differently to males. Females store more fat in the thigh area and males tend to accumulate the fat at the abdominal area [129]. Furthermore, females have more SAT while males have more VAT for a fixed WC [130]. Males have greater BMD and a larger skeletal size than females [131]. These sex difference in fat distribution among sexes, bone size and BMD are partly responsible for the fact that males have a greater risk of CVD than females [132], and females are at higher risk of osteoporosis than males [133].

Gesta et al.[134] conducted experimental studies on mice and on European subjects to explore the genetic basis in differences in body fat distribution and development of a dipocyte cell mass. They found that several different genes were strongly related to BMI and WHR. The gene expression in VAT has the highest and most significant association with WHR and BMI. In addition, another studies showed that total body fat and fat distribution (measured by DEXA) was influenced by genetic factors [135]. Finally, researches has shown in adult age that there is an increase in WC in both men and women without an increase in weight [136]. This can be due to increased abdominal adiposity in combination with overall sarcopenia. This increase in WC and abdominal adiposity can increase the risk of chronic disease such as CVD and type 2 diabetes, associated with premature death [115,137].

There are also differences in body composition between the sexes. Typically men have more FFM and less FM as compared to women [138,139]. Janssen [139] found that men, on average, have 36% more skeletal muscle than women. However the rate of decrease in skeletal muscle after the age of 45 is greater among men than women. It has been found that women tend to have higher levels of subcutaneous fat as compared to men [139]. This higher level of body fat is necessary for reproductive processes. Also BF distribution may vary between sexes men tend to carry more fat in the android region, and women tend to carry more FM in the gynoid region [136]. On average, women are also more likely to have lower bone density than men over a span of 18-80 years [140-142]. In addition, women typically experience a dramatic decrease in BMC and BMD during the premenopausal and early postmenopausal years due to the decline in endogenous estrogen, which age in preserving bone density [143]. On other hand, men tend to have higher BMD because of testosterone until about the age of 50 [144]. However as men age their levels of testosterone decrease and BMD declines [145]. The rate of decrease in bone mineral density is greater in women immediately after menopause, but the rate in men and women is the same once adults reach about 65-70 years of age [146].

Apart from sex and age differences in body composition, there are also differences in body composition between races. Wagner and Heyward [147] stated that African, Americans, on average, have higher bone mineral density and higher muscle mass than Whites. Barondess et al. [148] conducted a study with black and white men to compare bone mineral density. They discovered that the black men had a higher BMD(1.25 g/cm^2) than the white men (1.16 g/cm^2). Casas et al. [149] found Hispanic women to have higher percent body fat, total fat mass and BMI as compared to their White counterparts. In another study done by Wulan et al.[150] found that Asians have higher body fat percentage compared to Whites. Furthermore, there were also differences in body fat percent between regions of Asia (Asian Indians, Malay, and Chinese). In brief, ethnicity includes multiple environmental and genetic influences that have some relationships with the geographic origins of ancestors [151]. In addition, ethnicity can provide information about culture, diet, education, access to social services and socioeconomic status. Frequently, ethnicity is used as a convenient proxy for genetic factors influencing body composition. Beside the non-modifiable factors that can affect body composition, there are modifiable factors which can affect body composition, lifestyle and disease state, and be acute or long-term [152,153].

Acute factors could include hydration status and/or the use of diet or weight loss medication. Long-term factors include physical activity, diet and weight loss surgery. Increases in physical activity have the potential to increase FFM and decrease FM

[153,154]. In contrast the decreases in physical activity can lead to losses in FFM and increase in FM [155]. Diet has the ability to alter FFM and FM. High protein diets can potentially increase the amount of skeletal muscle mass or FFM [156]. Changes in diet can also increase or decrease the amount of FM. A substantial chronic decrease in calorie consumption can lead to a decrease in FM. Conversely, a chronic increase in calorie consumption can increase the total amount of FM. Weight loss surgery is also an acute and long-term method of changing body composition for morbidly obese individuals. Weight loss surgeries will, often, restrict the amount of food intake by the individual both before and after the surgery, hence decreasing calories consumed daily [157]. As a result, the individual will lose FM and maintain or potentially decrease FFM because there is less body mass for the individual to carry around [158].

2.4. Body Fat, Obesity And Related Health Problems

Obesity is the condition of excessive body fat shortens life expectancy through increasing a person's risk of type 2 diabetes, metabolic syndrome, cardiovascular disease (CVD), cancer joint pain and degeneration [159]. The World Health Organization (WHO) estimated that around 300 million people in the world were obese in 2003 [160]. The CVD accounts for one third of the all deaths worldwide [161].Furthermore, apart from overall obesity, the fat distribution can affect the specificity of determining the risk of diseases and fatstored in the central region of the body is related to metabolic profile [115].

In a study on older Michigan adults (23 M and 31 F) over 60 years of age found that abdominal fat (measured by DEXA) and WC were significantly related inversely to insulin sensitivity [162]. Furthermore, the association was found independent of sex. WHR was found not associated with insulin sensitivity in these older adults. Meanwhile, the negative association between hip circumference (HC) or leg fat and metabolic profile was found not only in white population over 50s [163] but also in other non-white population over 20s (such as Micronesians, Melanesians, Indians and Creoles) [94].

A sectional study conducted in Taiwan on healthy Chinese males and females aged 17-81 years showed that a relative excess of fat in the central region of the body, assessed by DEXA, was related to higher blood pressure, greater fasting and oral glucose tolerance test 2-h plasma glucose, greater glycosylated hemoglobin, higher serum concentrations of cholesterol, triglyceride and low density lipoprotein (LDL) cholesterol, and lower high density lipoprotein (HDL) cholesterol level [164]. Furthermore, glucose tolerance status of these Chinese can be differentiated by using the pattern of body fat distribution assessed by DEXA [165].

A Japanese study covering 128 overweight and obese Japanese females, aged 34-66 years, showed that truncal fat, measured by DEXA, and visceral adipose tissue (VAT), measured by computer assisted tomography (CT), were positively correlated with the number of CVD risk factors at base line and after weight reduction [166]. Leg fat is negatively associated with a number of CVD risk factors at base line and after weight reduction. In addition, lean mass of the trunk and leg has a negative relationship with CVD risk factors. CVD risk factors measured in the study include systolic blood pressure and diastolic blood pressure, serum total cholesterol triglycerides, serum high density lipoprotein (HDL), low density lipoprotein LDL, and fasting plasma glucose.Therefore, increased abdominal fat is associated with metabolic distribution in different ethnic groups including European, Indian and Chinese. The accumulation of VAT in the abdomen results in such metabolic disturbances [167]. VAT is considered to have a more damaging effect on person's health than subcutaneous adipose tissue (SAT) [115,168].

Many individuals have taken to self-monitoring body composition using portable, inexpensive assessment tools given physician recommendation or their own desire to reduce BF. Individuals use information about their body composition to help them make health-related decisions (e.g., dietary or physical activity changes, medications, medical procedures) and to track progress of an exercise or diet program, or other health intervention [112]. Clinicians use body composition information to identify patients at greater risk for developing chronic acquired diseases such as CVD or DM, hypertension, diagnose individuals with metabolic syndrome, or monitor disease state progression [109].

2.5. Body Fat Measurement Methods

This section is devoted to introduction of the most common methods used to assess body composition in human. Although there are many methods used to assess human body composition, two general methods known as Field-based and Laboratuary will be discussed. We are going to focused on the outcome measure of the body composition assessment method, the operation mode and assumptions, the special considerations (participant preparation, risks, etc.), the validity and reliability of each method, and the advantages and disadvantages.

2.5.1. Field-Based Methods

A field-based method for assessing body composition can be used in many different locations and is not restricted to use in laboratory or clinical setting. While numerous body composition assessments are available to measure BF distribution using the anthropometry methods, the field-based methods, which are BMI, Skinfold measures, BIA and abdominal circumference measures (WC and HC), will only be discussed in this section, There are many common advantages to all of the field-based methods for assessing body composition. First, most of the field devices are portable making them easy to use at home or in fitness centers and clinics. Secondly, the majority of these methods are cost-efficient . The low cost makes these devices more available and accessible to individuals and groups. Field devices generally require relatively little technician skill or knowledge to operate. Although many field devices have been created and are usually validated with laboratory methods. Previous researches have demonstrated that most of the field devices, as the details are discussed below, are less accurate and reliable than the laboratory methods [169].

i) *Body mass index(BMI)*: It is an anthropometric method used to estimate obesity. Body weight is the most frequently used measure of obesity . In general, persons with high body weights typically have higher amounts of BF [170,171]. BMI is defined as weight in kilograms divided by height in meters squared (Kg/m^2). The results based on this calculation is treated that individuals are classified as underweight, normal BMI and overweight or obese. Underweight BMI is defined as BMI of (18.4) Kg/m^2 or lower, normal BMI is defined as BMI of (18.5-24.9)Kg/m^2, overweight is defined as BMI of (25.0-29.9) Kg/m^2 and obese is defined as BMI of (30.0) Kg/m^2 or more [107, 172]. The assumption of BMI is that there are no differences between age and sex when classifying adults in to obesity categories [36]. There are many advantages to using BMI to classify the level of obesity. For example, it is the cost effective requiring minimal equipment. There is no necessary participant compliance prior to taking measures and no risk to the participant, and is a fast and easy measurement and calculation requiring minimal technician experience. BMI is widely used in clinics, sports medicine, and in weight reduction programs. It is simple, inexpensive, and noninvasive [173]. BMI is a good indicator of heaviness and a decent indirect indicator of body fatness [174], and has been shown to be an imprecise measure of BF% [175,176,177].

Although BMI is a common measure of body composition and easy to perform, it has, however, some major drawbacks to using BMI. It does not take into account regional fat distribution, muscle mass or bone mineral density and therefore may misclassify individuals in to the categories of underweight, normal weight, overweight or obese [101, 105, 178]. For example, an individual could have a normal BMI, but still be classified as overweight or lean based on estimations of BF%. This misclassification occurs due to the known differences in mass between adipose tissue, muscle tissue, as well as the individual's bone mineral density. Muscle tissue is more dense than adipose tissue, 1.34g/cm^3 and 0.9 g/ cm^3 respectively [117]. Therefore, an individual with more muscle mass will have a greater body mass, all other things equal. Likewise, an individual who has higher bone mineral content will have greater body mass, but all remaining things on the body being equal. Consequently, an individual such as a body builder or an athlete with more muscle mass or higher bone mineral density than the average adult may be misclassified as overweight because of the additional mass of the muscle tissue and bone [178]. They may be misclassified as overweight or even obese by BMI, however based on a body composition measure, they may be considered lean or normal. On the other hand, individuals with low muscle mass and high levels of fat can also be misclassified [179]. For example, at adults age, they gain more adipose tissue and lose muscle mass, perhaps being classified as having a normal BMI, however, may actually be overweight or obese based on a body composition measure [116]. Many studies have assessed the validity of BMI as an indicator of obesity. Gallagher et al. [36] found that when they compared young and old adults with the same BMI, the older adults actually had a higher BF% indicating misclassification of obesity level. Similarly, they found that BMI cannot be used when comparing obesity level between men and women because women, on average, have a higher BF% than men. Kennedy et al.[179] found that there was a large discrepancy between obesity level classified by BMI and that estimated from DEXA. They suggested that using BMI as a classification of obesity level should be viewed with caution because it may misclassify some individuals, and therefore ignore the possibility of health interventions that may be necessary. In conclusion, BMI is widely used as a broad indicator of obesity in large epidemiological studies, but is discouraged for use in small sale studies and for clinical diagnosis of obesity [179]. BMI-based fails to take body fat distribution in to account [180,181]. Body fat cannot be deduced accurately from BMI [182].

ii) Skinfold Measures(SF):The Skinfold estimation methods are based on a skinfold test, also known as a pinch test, whereby a pinch of skin is precisely measured by calipers at several standardized points on the body to determine the subcutaneous fat layer thickness. It only measures one type of fat, subcutaneous adipose tissue SAT (fat under the skin) as shown in Figure 2.2. [183]. Lohman estimated that one third of the human body is made up of subcutaneous fat [184]. Secondly, it assumes that a Skinfold is a good measure of subcutaneous fat [185]. Additionally, it assumes that water and mineral contents are the same in all individuals [185]. SF thickness is a common and usually more accurate alternative to BMI. It is cheap and easily performed in the field making it a popular choice among practitioners. SF estimated of BF% are based on the assumptions that SAT is representative of total body fat and that body fat is normally distributed [186]. SF measurement are taken with a caliber at various sites on the body. The technician pinches a fold of skin while only taking the subcutaneous fat and skin, not muscle tissue. A calipermeasures the thickness of the fold that includes skin and subcutaneous fat. It is based on the amount of sites used to measure SF (as well as an individual's race and sex), and the prediction formulas are then used to estimated body density and BF% [187] . The accuracy and reliability for the SF technique in estimating BF depends on the skill of the technician. The selection of sites to administer the SF measure the size of the individual being measured and also the prediction formula used (see Figure 2.2). Linsti et al. [185] found that there were significant differences in SF estimates of BF when compared to DEXA, but it is reported in refs. [188 and 189] that there is no significant difference between the two. SF equation evaluated by Duz et al. [169] found that SF measures (12.4± 5.5% for males, 20.8± 1.0% for females) significantly underestimated BF estimations when compared to DEXA (18.5± 6.2% for males, 28.4± 1.3%). In order to have proper SF thickness measures, calibration of skin calipers is important. Although SF method is portable, inexpensive and quick, it still requires a trained technician to obtain measurements. Over the past thirty years, research has shown general agreement between SF and older criterion methods, mainly HW [190, 188, 191]. However, more recent researches indicate that the most popular equations inaccurately predict fatness compared to the most current criterion measure, DXA [192].

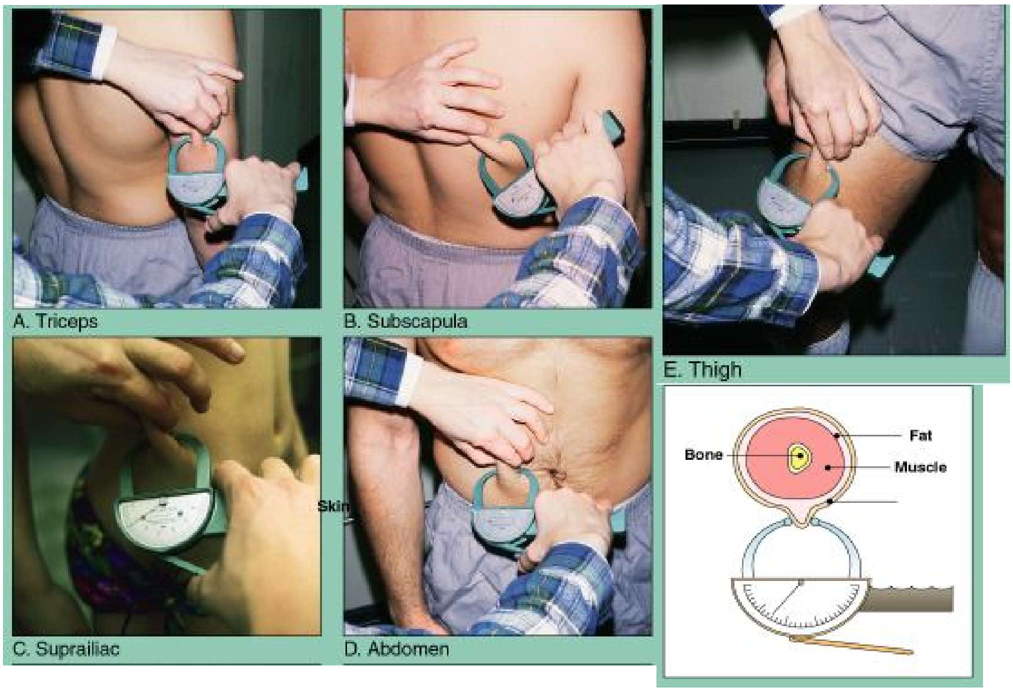
A. Triceps
B. Subscapula
C. Suprailiac
D. Abdomen
E. Thigh

Figure 2.2. Skinfold measurements and measuring techniques[193].

Because the risk of disease is associated with visceral fat and not subcutaneous fat deposits on the abdomen or trunk, the use of SF alone may not adequately categorize body fat distribution. SF methods may prove to be the better methods for girth of the anatomical areas or girths in combination with subcutaneous . However, none of these have been investigated as much as the waist to hip ratio . The most common method is the WHR, for which there are many different way to measure. The waist measurements were anywhere between the 10th rib and the iliac crest, whereas the hip measurements were anywhere between the iliac crest and greater trochantor [194].

iii) *Abdominal Circumference:* Obesity is commonly associated with increased amounts of intra-abdominal fat. A centralized fat pattern is associated with deposition of both intra-abdominal and subcutaneous abdominal adipose tissue [195]. It should be noted that abdominal circumference is an imperfect indicator of intra-abdominal adipose tissue as it also includes subcutaneous fat deposition as well as visceral adipose tissue. This does not preclude its usefulness as it is associated with specific health risks [196,197]. Persons in the upper percentiles for abdominal circumference are considered obese and at increased risk for morbidity, specifically type 2 diabetes and the metabolic syndrome, and mortality [198,199]. There has been a steady increase in the prevalence of high abdominal circumference in the general population from 10 to 20% in the 1960s to between 40 and 60% in the year 2000 [200]. Circumferences of other body segments such as the arms and legs are possible [201], but there are few reference data available for comparative purposes. Furthermore, the calculation of fat and muscle area of the arm is not accurate or valid in the obese.

The ratio of abdominal circumference (often referred to incorrectly as waist circumference) to hip circumference is a rudimentary index for describing adipose tissue distribution or fat patterning [202, 203]. Abdomen–to- hip ratios greater than 0.85 cm represent a centralized distribution of fat. Most men with a ratio greater than 1.0 and women with a ratio greater than 0.85 are at risk for CVD, diabetes, and cancers [204,205].

WHR is the ratio of the circumference of the waist to that of the hips (WHR= WC/HC), and according to the organization's data gathering [206] the waist circumference should be measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest using a stretch-resistant tape that provides a constant 100g tension. HC should be measured around the widest portion of the buttocks, with the tape parallel to the floor as shown in Figures 2.3 (a). [207]. Other organizations use slightly different standards. The United States National Institutes of Health and the National Health and Nutrition Examination Survey used results obtained by measuring at the top of the iliac crest. Waist measurement are usually obtained by lay persons by measuring around the waist at the umbilicus, but research has shown that these measurements may underestimate the true waist circumference [207]. For both measurements, the individual should stand with feet close together, arms at the side and body weight evenly distributed, and should wear little clothing. The subject should be relaxed, and the measurements should be taken at the end of a normal expiration. Each measurement should be repeated twice; if the measurements are within 1 cm of one another, the average should be calculated. If the difference between the two measurements exceeds 1 cm, the two measurements should be repeated [207].

The WHR has been used as an indicator or measure of health of a person, and the risk of developing serious health conditions. Research shows that people with apple-shaped bodies (with more weight around the waist) face more health risks, at increased risk for the health problems associated with obesity, such as diabetes, coronary heart disease and high blood pressure, than those with Pear-shaped bodies who carry more weight around the hips as shown in Figure 2.4. WHR is used as a measurement of obesity, which in turn is possible indicator of other more serious health conditions. WHO steps states that abdominal obesity is defined as a WHR above 0.90 cm for males and above 0.85 cm for females, or a BMI above 30.0 Kg/m^2[208].

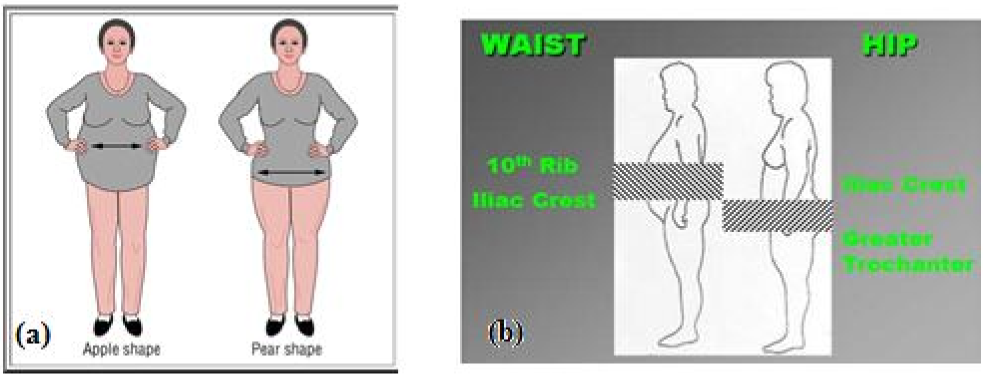

Figure.2.3. (a) The shape of obesity (“Apple” and “Pears”),(b) WHR measurement places[135].

WHR has been found to be a more deficient predictor of mortality in older people than waist circumference or BMI [209]. If obesity is redefined using WHR instead of BMI, the proportion of people categorized as at risk of heart attack worldwide increases threefold [210]. The body fat percentage is considered to be an even more accurate measure of relative weight. Of these three measurements, only the WHR takes account of the differences in body structure. Hence, it is possible for two women to have the same BMI but vastly different WHR. Even in ancient civilizations globally, female representations are most often in the 0.6-0.7 range for WHR, suggesting a preference towards lower WHR [14]. WHR have been shown to be a better a predictor of CVD disease than WC and BMI [211]. However, other studies have found that WC, not WHR, to be a good indicator of cardiovascular risk factors [212], body fat distribution [213], and hypertension in type 2 diabetes [214].

Visceral fat accumulation may underlie the adverse metabolic profile associated with obesity. Indeed, WC and WHR, as indicators of abdominal adiposity [215], have been shown to be better than BMI, an indicator of total adiposity [216], for identifying individuals at higher risk of developing atherosclerotic diseases [217]. It is plausible that BMI may be less sensitive than waist circumference or WHR at capturing the underlying and disparate metabolic effects of fat depots. A case control study involving populations worldwide recently reported that WHR was associated with acute myocardial infarction independently, and is more strongly than BMI [14]. However, the prospective relation between fat distribution and coronary heart disease is less clear because findings have been inconsistent [30,73,76,86 ,96 ,99]. Many prospective studies reported fewer coronary heart disease events, whereas others relied on self-reported anthropometry. Comparison of risks between sexes is limited because many studies involved only women or men.

Furthermore, WC and HC have been shown to have separate and opposite cross-sectional associations with metabolic factors [90, 93]. The prognostic relevance of these separate associations for future coronary heart disease events is less clear [96, 99]. They examined the prospective relation between indices of fat distribution and future coronary heart disease among men and women in the general population and determined whether this association is independent of BMI and other conventional coronary heart disease risk factors. Several previous studies have examined the association of BMI, WHR, or WC, with coronary heart disease, the results of these studies have conflicted with some suggesting that BMI was better than or at least as good as markers of abdominal obesity. Others suggested that markers of abdominal obesity could be better than BMI, but only in younger individuals or only in women. Further, none was able to clearly indicate whether WC or WHR was the best predictor of myocardial infarction ,and the data relating hip size to CVD are sparse. Most of these studies had few cardiovascular events (usually less than a few hundred) and so their statistical power to compare different measure was low and the apparent subgroup results reported may well be due to chance. WHR and WC measures have the advantages of being quick, non-intrusive and useful for large scale population surveys. The WHR is a simple measure that can be taken at home by anyone to monitor their own body composition levels. WHR has disadvantages in making comparisons between varying groups of people such as is often seen in different cultural groups . Asian women, for example, have small hips and WHR measures are much less valid as an indicator of health risk. Negroid women, on the other hand,have large hips and buttocks and their health risk may be misinterpreted from WHR measures. Overall WHR, or waist alone, may provide a quick and simple indication of health risk . Waist alone can then be used to examine the success of a fat loss program in those groups where abdominal fat is stored readily [86].

BMI is a frequently used measure of adiposity in both clinical and research settings. However, WC has been used as a measure of abdominal adiposity in research settings and has shown stronger associations with CVD risk factors than BMI [52,83]. Skinfold thickness is also used as ameasure of adiposity, but studies comparing its predictive ability to other measures of adiposity have produced inconsistent findings [30]. An additional measure of adiposity is bioelectrical impedance analysis BIA [218]. Which can be used to estimate an individual's total body fat (TBF) and BF%. However, weather TBF and BF% maintain stronger associations with CVD risk factors compared with simpler measures, such as BMI or WC, remains unknown [219, 220]. BIA will be discussed further in the BIA method section.

2.5.2. Laboratory- Based Methods

Laboratory-based methods for assessing body composition are often large, non portable methods. There are common advantages of the laboratory-based methods for assessing body composition. First, majority of these methods have demonstrated great accuracy and have been validated against cadaveric analysis because exact measurements can't be done in vivo for use in laboratory and clinical settings by pervious research [221]. Secondly, most, but not all, procedures using laboratory techniques are relatively quick. There are common disadvantages associated with the laboratory-based techniques. The majority of these methods require costly equipment, ranging from as little as USD $ 5,000 up to millions of dollars, resulting in many of these methods being inaccessible for most clinicians, researches and the public.

In addition to being costly, most of the equipment is generally large and not portable. Lastly, almost all methods require a trained and knowledgeable technician to operate the equipment and analyze results. Dual-energy x-ray absorptiometry (DEXA), hydrostatic weighing (HW), air displacement plethysmography (ADP) are all commonly used laboratory methods for body composition analysis that will be discussed below.

DEXA: Although DXA was originally developed as a tool for measuring bone mineral composition, it has been accepted as a valid method for measuring body composition, specifically BF% [186]. In recent years DEXA has been considered a gold standard method for assessing body composition [120]. It is an indirect method based on attenuation of X-rays projected through the supine human body, the intensity of the beam of the X-rays on the dorsal side of the body is related to the thickness, density and chemical composition of the body [122]. High energy (70 KV) and low energy (40 KV) X-rays are simultaneously applied but the radiation dose is much lower than that used in CT (see Figure 2.4). The relative absorption (R values) of fat, lean and bone tissue are assumed to be based on theoretical and experimental studies. Therefore, DEXA not only provides an image of theanatomical position of the bone in the body, but also estimates three body composition values, or it assesses three compartments of the body : FM, BMC and LM. Total body weight is determined by the sum of FM, and FFM. FFM is the sum of BMC and LM, and the soft tissue mass (STM) is the sum of FM and LM [222]. Pritchard, Nowson, Strauss, Carlson, Kaymakci and Wark [223] found that DEXA had greater precision when estimating FM when compared to HW, with a coefficient of variability of 1.8% for percent BF and 2.1% for FM.

Figure 2.4. DEXA uses a whole body scanner and two different low-dose x-rays to read bone mass and soft tissue mass [194].

DEXA is a quick, safe, can be used on almost all populations, and requires little pre-testing guidelines to be followed by the individual [224,225]. There are disadvantages of using DEXA to assess body composition. Because of the size of the Lunar Prodigy table, there are usage restrictions based on a participant's size. The total table size is 262 cm long and 89 cm wide and however, the area for scan is much smaller. Individuals, who are taller than 193 cm and wider than 60 cm, will not receive accurate assessments as their entire body will not fit within the scan area. The weight limit for the device is 159.0 Kg, limiting usage to those weighing at or less than amount. DEXA is an expensive and non-portable device, and therefore may not be available for use by all individuals. DXA gives estimates of whole body and lean muscle mass with a precision of error equal to or smaller than other non-invasive methods [226]. Unfortunately, DXA is expensive and requires a laboratory with a trained technician. Thus, most individuals do not have access to DXA and instead are forced to use less accurate field methods such as BMI, SF, and BIA.

Hydrostatic weighing (HW): HW has been considered a gold standard by some in the field and has been used as a criterion method in validating new body composition assessment methods HW also known as Hydrodensitometry or underwater weighing, is a classic measure of body composition [224, 225]. HW estimates body composition in two compartments- FFM and FM by first measuring body volume, then body density in terms of body mass and volume is defined as [224].

$$\text{Body density} = \text{Body mass} / \text{Body volume} \tag{2.1}$$

HW estimates body volume by using Archimedes principle, that is the low of buoyancy. The principle state that (anybody partially or completely submerged in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the body) [224]. The body is immersed in a tank of water and then weighed. Lean people more under water; they sink. People with more fat weigh less under water; they float. Measurements of lung capacity are also taken because the amount of air in lungs influences the weight. When individual are submerged under water while under water mass or water displacement is measured. Measure of body volume are corrected for residual air in the lungs and in the gastrointestinal tract (see Figure 2.5.). There are four main assumptions for HW: i) the components of the fat and FFM are known and additive. ii) the density of all tissues is constant for all individuals. iii) lean body mass (FFM and bone) and FM, the proportions of water, mineral and protein comprising the FFM are constant within and between individuals, vi) the individual being measured difference from the reference body only in the amount of BF or adipose tissue[112].

Figure 2.5. Hydrostatic weighing tank measuring BF based on Archimedes principle [194].

There are advantages to using HW to assess body composition. The method has been demonstrated as accurate. Additionally a water tank is not necessarily needed. The procedure can be done in any pool, of proper depth for complete submersion, which can be accessed. However, there are disadvantages of using this technique due to the fact that there are more practical techniques available for assessing body composition. There is great amount of participant compliance required for accurate measurement. Participants should follow specific pre-testing guidelines [112]. Additionally, the technique itself requires a lot of participant compliance, and may be impossible for some participants to do. For example, some individuals may not be able to correctly position their body, exhale completely when under water, or remain still while under water [227]. Moreover, the procedure is done multiple times until three trials are achieved [109]. Therefore, the procedure can be very time consuming [227]. Lastly, a great deal of technician knowledge and skill is required to complete the procedure. It is more difficult to find validity and reliability information on HW because it is often used as a criterion measure for other methods for assessing body composition.

Air Displacement Plethysmography (ADP): ADP employs a two-compartment model to assess body composition is very similar to HW method and that first measures body volume and calculate body density with air displacement instead of water displacement [112]. Volume is measured using Poisson's low, a variation of Boyle's law that accounts for adiabatic conditions in an enclosed chamber. The only commercially available ADP device is the Bod Pod [228]. While inside the Bod Pod small pressure changes determine the air displacement of the body, body volume is measured. Because body volume is measured, measurements are taken for lung volume to estimate the most accurate total body volume. Body fat percentage is then calculated from body density via the same conversion formulas as HW. There are many assumptions when assessing body composition with the ADP method. First, because the BOD Pod device measures body volume, all of the four main assumptions from HW will apply here. Another assumption is that all of the isothermic effects that affect body volume are being controlled: clothing, body hair, and thoracic gas volume. The Bod Pod is a computerized, egg – shaped chamber as seen in Figure 2.6. Using the same whole-body measurement principle as under water weighing, the Bod Pod measures a subject mass and volume, from which their whole-body density is determined. Using these data, body fat and lean muscle mass can then be calculated [112].

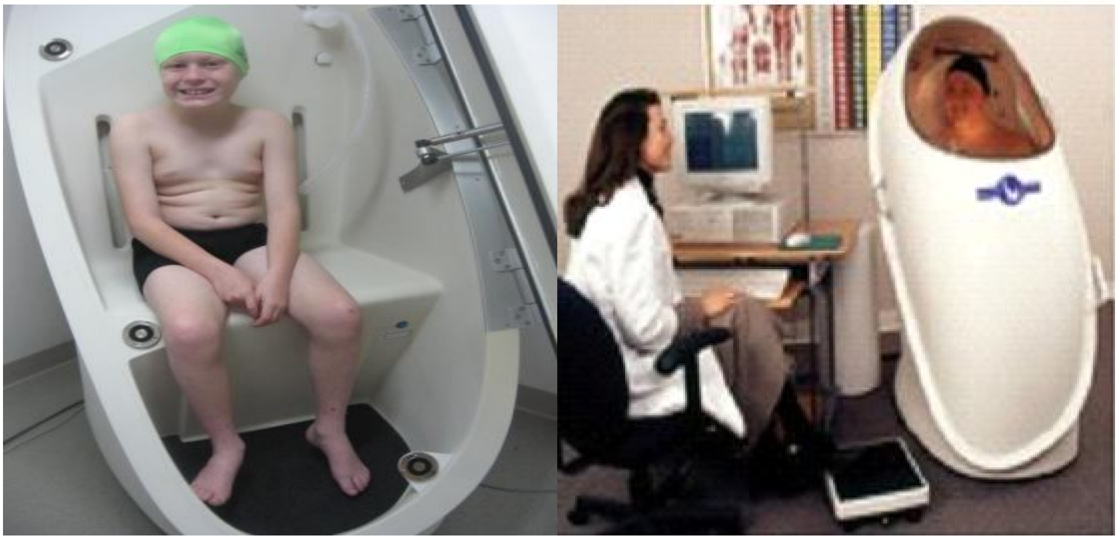

Figure 2.6. Bod Pod chambers measuring body comosition[229].

There are many advantages of using ADP as a method for assessing body composition. For example, the process is quick, safe, non-invasive, painless and comfortable [109]. The system is computerized and does not require a lot of technical skill to operate. Also, the Bod Pod device can be used on many different populations including children, older adults and obese individuals[228]. Because of these advantages, ADP using the Bod Pod may be preferable to utilizing HW [109]. However, there are disadvantages to using ADP to assess body composition. First, there are assumptions of tissue density that are made when measuring body volume. Second, method used to measure the thoracic gas volume can be difficult for some individuals to do, and so that the volume will need to be estimated causing room for error. Most research on the validity and reliability of the Bod Pod has been done in the past 10 years and has used both DEXA and HW as criterion methods. Results have been inconsistent across different populations [228] [~~260~~]. Ball and Altina [230] point out that comparing the Bod Pod to HW as a criterion method may not be appropriate because they are both assessing the body in two compartments, and therefore HW is not technically more accurate than the Bod Pod. Ball and Altena[230] found a large discrepancy when comparing the Bod Pod to DEXA as the criterion, with a range of individual BF% differences from 6.6 to 9.0% . They also noted that the difference in BF% increased as the individual's BF increased. Hence, it is concluded that the estimations of BF% should be used with caution when classifying individuals as obese. Ballard and colleagues [231], however, found with the Bod Pod that mean results of BF% when compared to DEXA as the criterion did not differ significantly (p=1.0). They concluded that the Bod Pod is a valid and reliable method for assessing BF%.

2.6 Bioelectrical Impedance Analysis (BIA) Methods:

BIA is a simple, cheap, noninvasive, reproducible altemative for estimating body composition used widely in both laboratories and field setting. BIA has gained acceptance as an accurate method of estimating BF% in clinics, sports medicine, weight reduction programs, hospitals, and laboratories, and across a spectrum of ages [174,178,232]. BIA is based on the principle that lean tissue has greater electrolyte and water content than fat, and as a result, has less impedance [187]. In short, BIA sends an alternating electrical current via electrodes placed on the skin (usually on the wrist and ankle) to measure resistance. Resistance is component of impedance and is converted to TBW, which is used to estimated FFM [232]. Impedance to the flow of an electrical current is measured as an electrical current passes through the body between two electrodes. The voltage drop in electrical current between electrodes is due to the impedance of the current flow. Body composition is estimated based on the principle that electrical current flows with less impedance in areas that have high water and electrolytes, such as skeletal muscle, compared to less hydrated tissues such as adipose tissue [233]. Whereas adipose tissue, which contains very little water, is a poor conductor or it impedes or resists the flow of electrical current [109]. Thus, the higher the TBW and FFM, the lower the resistance to the electrical flow resulting in a lower impedance value [109]. Fat mass has high impedance while FFM has low impedance [187]. BIA estimates TBW by way of electrical current through segments of the body and ultimately predicts BF and FFM. BIA will be reviewed extensively below [116].

Beginning in the 1930s, early studies using BIA and body composition focused on the relation of impedance of the electrical current to TBW and to physiological variables [224]. In (2004), clinically induced changes in hydration status were first correlated with total body changes in resistance and capacitive reactance [234]. Also, pioneered work relating biometrical impedance changes to dynamic changes in pulsatile blood flow to organs, arterial pulse waveforms and respiration [235]. The applications of impedance plethysmography, that is term given to the measurement of electrical impedance changes across limbs, organs and other body sites to detect dynamic blood volume changes, have been extensively validated by numerous investigators [236]. Most research was done using a frequency of 50 KHz to asses TBW as it is related to things such as blood flow.This low frequency (50KHz)and the current only flows through ECW, and does not permeate the cell membrane to assess ICW. However, at frequencies greater than 100 KHz, the ICW can be assessed [109]. Multifrequancy BIA was introduced in the 1970s when assumptions of BIA were more established to describe the proportion of extracellular water to TBW [116]. Multifrequency BIA was also used to assess body fluid distribution in diseased populations such as those with congestive heart failure and renal disease [224] Until the mid 1980s, BIA devices became available for commercial use and marketed as a way to measure body composition, and thus provide estimates of absolute and /or relative fat mass [115]. Many different BIA devices were on the market for assessing body composition in laboratories, at home, fitness centers...etc. [116]. Because of the wide spread use of BIA technology, the National Institute of Health (NIH) conducted a one-day summit where BIA researches and industry experts discussed safety and standardization of BIA use as well as the validity of the BIA devices to estimate body composition[173]. The experts concluded that BIA is a safe method for assessing body composition such as body position, individuals with certain diseases, individuals with body asymmetry and individuals that are severely obese.

Factors affecting impedance measures given the heavy reliance on water content within tissues, hydration status is critical to valid and reliable measures of impedance [237]. Factors influencing hydration status include food and/or water composition or lack thereof, use of diuretics, alcohol consumption and exercise. The consumption of food and water will directly increase the amount of fluid in the body. Use of diuretics will do exactly the opposite, increasing the excretion of water from the body through urination. Consumption of alcohol, a type of diuretic, will also result in dehydration through an increase in urination. Exercise can affect BIA readings in two ways; the loss of fluid from the body due to sweating and increased blood flow to the skeletal muscle and skin which increases heat and will decrease the impedance of the current [114]. Careful control of all of these variables in a free-living environment does not commonly occur when using a hand-to-hand BIA. But because these variables should be controlled in order to obtain an accurate estimate of BF, guidelines on pre-test instructions have been created.

A few published studies have investigated the BIA devices being used cureently in many fitness facilities, laboratories, clinic and at home. However, the pre-testing guidelines prevent BIA from being a practical way to get valid estimations of body composition. Our body's impedance level can be altered by many factors besides body fat.

For instance, the amount of water in our body, our skin temperature and recent physical activity may adversely affect the results. Therefore, we may be able to get an accurate measurement of our body fat using these scales. The most important rules to observe for getting more accurate calculation of our body fat are not to eat or drink for 4 hours before the body fat measurement test, and then not to have any exercise for 12 hours before the test. Also the American college of sports medicine [104] suggested the following pre-test guidelines to follow prior to taking BIA measurements. Before the test, No alcohol consumption for previous 48 hours, no products with diuretic properties (e.g. , caffeine and chocolate) for 24 hours, no exercise for the 12 hours immediately and no eating or drinking for the 4 hours immediately void bladder within 30 minutes prior to the test. The reason is that hydration level and pre-testing guidelines are so important in accurate impedance measurement. Hence, many segmental devices at home users may not obtain reliable or valid results if pre-testing guidelines are not followed.

BIA assesses body composition based on the impedance of an electrical current that passes through a person's body using Ohm's law. A person's TBW determine the impedance of the currents flow. As explained by [112], there are two bioelectrical principles applied when using BIA. First, biological tissues act as conductors or insulators, and the flow of current through the body will flow the path of least resistance [112]. Second, impedance is a function of resistance (R) and reactance (Xc) [117]. Impedance (Z) is the frequency dependant opposition of a conductor to the flow of an alternating current, Resistance (R) is defined as the pure opposition to the current flow through the body. Reactance (Xc) is defined as the opposition to current flow caused by capacitance (voltage storage) produced by the cell membrane [112]. Therefore, BIA does not necessarily measured FM directly, rather it determine electrical impedance which can be used to estimate TBW. Based on the assumptions concerning the aqueous fraction of the FFM and BF via prediction equations have been generated [172]. The biological principle of BIA measurements also follow certain assumptions. The estimation of body composition measured by whole-body BIA is given by [238],

$$V = \rho L^2/R \tag{2.2}$$

where V is the conductor volume and signifies the volume of TBW or FFM, ρ is the specific resistivity of the body (ohm.cm), L the conductor or stature length (cm), and R is the resistance (ohm) to the current [238,239]. The assumptions for this equation are that "the conductor has a homogenous composition, a fixed cross-sectional area and a uniform distribution of current density" [238]. In brief, this assumes that the body is shaped like a perfect cylinder, meaning that ICW and ECW ratios are constant providing uniform conductance [240]. This is not the case and this assumption is routinely violated. Because limbs have a smaller cross-sectional area than the trunk, "whole body impedance is predominantly determined by resistance in the limbs" [240]. It is also assumed all cells equally, and impedance is equal to resistance [240]. This assumption is also not met because of different factors. An individual's hydration level can vary the throughout the day. This could be due to activities that cause dehydration such as vigorous exercise or consumption of medications or stimulants that have diuretic properties [198,116]. There are also differences in hydrations level of FFM and fat tissue, with FFM being approximately 73% water and fat tissue being relatively an hydrogenous [116]. Because these assumptions are not met, regression analysis has been applied to previous research to mathematically predict estimates of TBW, FFM, and FM from BIA impedance measures, anthropometric measures and demographic variables. Over the years, many prediction equations are developed by multiple researchers. These prediction equations were originally based on cross-sectional studies using hydrostatic weighing as a criterion measure [169]. Prediction equations most often take in to account not only impedance values, but also anthropometric value such as height and weight and the individual's sex and ethnicity to reduce inter-individual difference in impedance values [240]. It is difficult to develop a BIA prediction equation for a diverse population because previous research has shown that race and age may affect body composition and fat distribution [225]. Most prediction equation have been developed and cross-validated for specific population making results only generalizable to like groups [240,225]. Another factor that may affect prediction equations is amount of body fat . Some equations overestimate BF% in lean population and underestimate those that are obese [169,232]. Prediction equations are only as accurate as the criterion method used to produce the equation [238]. If an equation is based ona criterion measure that itself introduces errors when assessing body composition, then that prediction equation will have similar errors of estimate. Because of all these factors , an individual's estimated BF% could differ by as much as 10% when a specific BIA equation is applied [172].

Impedance can be measured by both single-frequency (SF-BIA) and multi-frequency (MF-BIA) devices. Most SF-BIA use a frequency of 50 KHz that usually passes from two different points in the via surface electrodes to estimate TBW and body composition using multiple frequency across a large range to assess FFM, TBW, ICW and ECW. SF-BIA is technically not measuring TBW, rather it takes a weighted sum of ECW and ICW resistance measure[116]. With a combination of impedance values based on the assumption that FFM is 73% water and other data, such as height, weight, age and sex, body composition can be estimated. Common SF-BIA devices that are used in the field or at home are hand–to-hand and foot-to-foot models, also referred to as segmental impedance analyzers. These devices become available in the 1990s and are portable, cheap and easy to use and required little to on technician user experience, quick, and painless means of estimating body composition. Hand-to-hand BIA devices have two handles that contain electrodes where the electrical current will be sent out via one electrode and received by the other electrode (see Figure 2.7 (a)). Users of this device are instructed to stand up right, firmly grip each to handle with arms outstretched at a 90- degree angle to the floor and the current flows from the right to left hand (see Figure 2.7 (c)). The technology assumes that the amount of body water in the arms is proportional to the whole body [232]. There has been very little research done on the validity and reliability of the hand-to-hand BIA devices.The results have been contradictory and inconclusive. A similar segmental BIA device is the foot-to-foot device, there are electrodes built in to a digital floor scale, there are usually four electrodes one for each heel and one for each ball of the foot .Users sand upright, with bar feet positioned properly on the electrodes the electrical current is sent out via the electrodes at the ball of the foot and received by the electrodes in the heel of the foot [112] (see Figure 2.8). Body fat percent is the only result displayed for most hand-to-hand and foot-to-foot devices. Similar to hand-to-hand devices, results of validity studies on foot-to-foot devices has been contradictory. Either using a handhold scale or standing on a BIA scale, a signal passes either from hand-to-hand or foot-to-foot. The faster the signal travels, the more muscle you have, and the results are based on the fact that water conducts electricity. Fat contains almost no water while muscle is about 70% water. This method can be accurate (4% margin of error) but the results are affected by hydration, food intake and skin temperature. If you are dehydrated, your BF% will read higher than it is. The tests should be taken at the same time of the day, preferably first thing in the morning before breakfast, but after a glass of water.

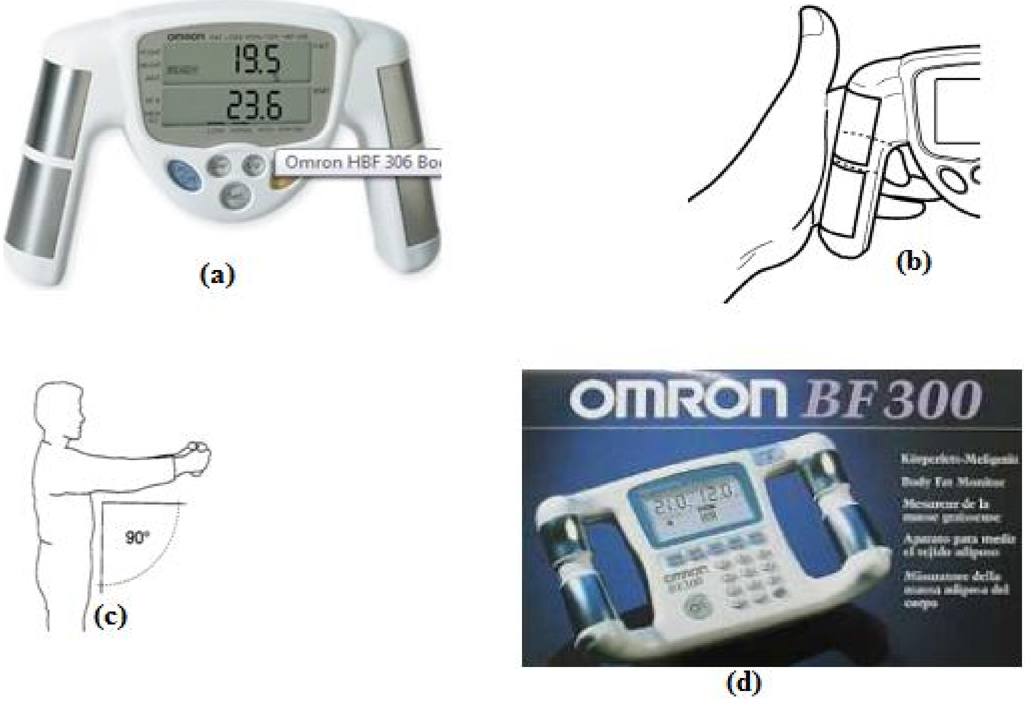

Figure 2.7.(a) Omron HBF 306 BF analyzer; (b) Hand to hand measurement, (c) Position of body, (d)Omron HBF 300 BF analyzer [241].

Unlike SF-BIA, MF-BIA devices are able to distinguish between ICW and ECW using combination of low and high frequencies, as low as 1 KHz up to over 1000 KHz [115]. It is also important that multifrequancy impedance measures are able to precisely estimate TBW, ICW and ECW, which was limited with single frequency impedance analysis. MF-BIA has the ability to monitor changes in hydration level and fluid shifts in the body. These devices (single and multi-NF) are helpful in monitoring patients with abnormal fluid distribution such as final stage renal failure [115, 112]. However, in regards to body composition estimates, previous research has shown that single and multifrequancy impedance measures show similar results. According to Patel et al. [242], MF-BIA was more accurate and less biased than SF-BIA for the prediction of ECW, whereas SF-BIA compared to MF-BIA, was more accurate and less biased for TBW in critically ill subjects. One example of a MF-BIA device is the tetra polar BIA which is considered a whole body impedance analysis, which uses multiple frequencies. Technically, no measures of BIA can be whole body because the head and neck are ignored [243]. While the patient is in a supine position, electrodes are placed on the dorsal surfaces of the hand, wrist, foot and ankle on the right side of the body. The position of the electrodes is very important as it can affect the impedance values. A displacement of a mere 1cm can result in a 2% different in impedance [172]. The proximal electrodes are placed at the metacarpalphalangeal and metatarsal-palangeal joints and the distal electrodes are placed at the "piliform prominence of the wrist and between the medial and lateral malleoli of the ankle" [172]. The electrical current is sent out via the distal electrodes (hand and foot)and received by the proximal electrodes (wrist and ankle) [116]. Based on measures of TBW, estimations can be made of body BF%, FFM, ECW, and ICW. Previous research has found whole body BIA measures to be accurate and reliable for estimating BF%, FFM and TBW [237]. They concluded that whole-body BIA would be accurate for assessing body composition for large epidemiological and field studies. More recently, it was found [3] that tetra polar BIA have good relative an absolute agreement when assessing %FM, percent skeletal muscle mass, and total body bone-free lean mass as compared to both DEXA and MRI. They also concluded that tetra polar BIA would be a valid tool for assessing body composition in individuals. Furthermore, it is discussed [244] that tetra polar BIA is a reliable and valid tool for assessing body composition. When compared to DEXA, tetra polar BIA had approximately a 1.8% prediction error in estimating BF%.

2.6.1. Validity of the hand–to-hand and foot-to-foot BIA devices

It has been achieved that there are not many publications available on the validity of the hand-to-hand BIA device in estimating BF%. However, although a limited number of studies has been published on the validity of the Omron HBF-306C released recently, hand-to-hand device by Omron Healthcare will be used in this study. The measurement of BF% has been taken by the Omron body fat monitor . An electrical current (50 µA usually set a frequency of 50Hz) is applied to an extremity and resistance to this current. Due to the specific resistivity and volume of the conductor, the FM and FFM are measured (see Figure 2.7 (a)). There have been conflicting results on the validities because the number of studies published have differed in age, race and sex, and all of which affected the proprietary prediction equation used in each of the hand-to-hand devices. Previous acceptable studies for dissection purposes will be addressed in order by type of the device examined. This will be followed by critical gaps in the literature based on the acceptable studies that have been published and discussed in this section.

Gibson et al. [240] published a viable study of one of the earlier model of the Omron hand-to-hand BF analyzers, the Omron HBF-300 (see Figure 2.7 (d)), with a subject population of 25 men age 19-55 years, mean BF 18.7± 8.1% and 23 women age 18-48 years , mean BF 21.8 ±7.2% , both white and non-white. They compared the BF%

from the BIA device with HW as the criterion method. Prior to all assessments , the subjects were instructed to use all of the ACSM pre-testing guidelines. Results indicated that approximately 70% of men and 66.6 % of women tested received an accurate estimate of BF% from the hand-to-hand BIA. Accuracy was defined by an estimate within ± 3.5 BF% when compared to the HW method as the criterion method. The validity of Omron BF-300 BF monitor in estimating BF% was compared to DEXA as the reference methodin [169]. In this study it is not clearly stated if the subjects followed pre-testing guidelines to control for hydration status. Among 18-26 year old males (n=104)andfemales (n=104) college students. They obtained that BIA significantly underestimated BF% in females and males such as 19.2± 1.0% for females and 13.7± 4.9% for males. However, more so in females then compared to DEXA 28.4±1.3% for females and 18.5±6.2% for males. In addition, they determined that the bias in BIA increased as body fat increased in participants. They concluded that different prediction equations should be developed or current prediction equations be revised to accurately represent a diverse population. A study conducted [245] the validation of the Omron BF-306C hand-to-hand BF analyzer using a four-compartment model as the reference method in Chinese, Malay and Indian subjects. Participants age ranged from 18 to 70, and they were also purposefully selected to include a large range of BMI values over the age span. Before assessments, subjects were instructed to abstain from food and drink for at least 6 hours and were instructed to void bladder just prior. Significant differences between BF% from BIA and the reference method were found in Malay and Indian men who were higher in mean age and also had the highest mean BF% based from the reference method among sex and ethnicities. They also found that Indian subjects, who had larger arm span relative to their height women(1.0± 0.0) compared to the other ethnic groups, had higher impedance values.

Omron offers a revolutionary new way of measuring BIA that is faster, easier, less intrusive and includes a lightweight portable device making this a simple one-step process. A person inputs various personal information such as age, gender, weight and height, then grips the device handles (hand-to-hand). Electrodes in the hand sensor pads send a low, safe single through the body and so BF content and BMI is calculated automatically in seconds.

The steps of testing procedure of BIA are as follows:

1) one inputs the personal values of height, weight, gender, and age into the body logic standing up with both feet slightly apart.

2) The subject should hold the grip electrodes and wrap the middle finger around the groove in the handle. Place the palm of your hand on the top and bottom electrodes. Puting the thumbs up and resting on the unit (see Figure 2.7 (b)).

3) The subject must hold arms straight out at a 90° angle to the body, and do not move during measurement (see Figure 2.7 (c)).

4) Please confirm the ready to measure display. The READY indicator turns on.

5) Lastly, one push the start button. The display START turns on, then the unit automatically detects that it is held and starts measurement, the BMI judgment bar turns on immediately after the BF% and BMI are displayed [241].

There has been some research examining accuracy of pervious research associated with young adults, rarely including subjects over the age of 60 year. This is important because of the changes FM and FFM as adults age . Additionally, more research needs to be done on the accuracy and reliability across sex, the amount of BF and BF distribution is most often different between men and women. It is important to determine if the differences alter the validity of the device . It is , therefore, critical to validate this device across the two variables of age and sex. Lastly, although the concept of euhydration is extremely important in the assessment of body composition with BIA devices, only one of the previous validation studies on hand-to-hand BIA devices has controlled for hydration using all of the ACSM pre-testing guidelines. This could be major limitation to all of the validation studies previously conducted on hand-to-hand BIA devices.

Other new way of measuring BIA is (Body analyzer Scale Model BA 833, ADE Fitness, Germany) foot-to-foot or leg-to-leg) BIA devices measure impedance across the lower limbs, and the system's four electrodes are in the form of stainless steel foot pads mounted on the top surface of platform scale. The subject only needs to stand barefoot on the scale for simultaneous of body weight and impedance (see Figure 2.8), with manual entry of the subject's gender and height into the system via a digital keyboard, and the subject's percentage BF is displayed immediately . Because of its convenience, this leg-to-leg BIA method of estimating BF has become increasingly popular with health professionals, as well as the general public, for the assessment and monitoring of obesity [246].

Bioelectrical impedance measures the strength and speed of the electrical single sent through the body (impedance measure). It then uses this measurement and information such as height , weight , and gender to predict how much BF a person has. The Tanita is a precision electric scale that has two built in footpad electrodes (pressure contact)[247]. The Tanita method has all the advantages of traditional BIA as well as greater ease of use speed, and portability, professional versions of the products can be found in hospitals, health clubs , and researches labs and include comprehensive data such as BMI, BF%, fat weight, TBW, FFM, the concept has been adapted for use as an affordable home monitoring device.

Figure 2.8. Foot-to-Foot BF Analyzer (Model BA 833, ADE Fitness, Germany) [248].

Public along with fitness enthusiasts and patients with health risk can measure BF as part of a regular healthy lifestyle. The same variables apply with regard to hydration levels, and measuring should be done under consistent conditions [247] . In addition BW and FM are measured using two (Body analyzer Scale Model BA 833, ADE Fitness, Germany) foot-to-foot BF (BF monitor scale), gender , age, and height are entered manually into the keypad interface.Then, the foot-to-foot equipment has two stainless-steel foot-pad electrodes mounted on a platform scale.

Finally, because of the increase in overweight and obesity and the associated health risks, many individuals are self-monitoring body composition. There are many methods available to monitor body composition, more specifically BF , however, not all are readily available or cost-effective for many individuals to use. Anthropometry provides the single most portal, universally applicable, non-invasive and inexpensive techniques for assessing the size, proportions and composition of human body. Anthropometry is particularly important during adolescence because it allows the monitoring and evaluation of the hormone mediated changes in growth and maturation during this period. BMI is the most commonly used measure of overall adiposity while circumference and SF are measures of regional adiposity. Two commonly used indices, WHR measure central BF distribution. In many studies worldwide [249], and in India as well have investigated regional adiposity and body fat distribution among women [250].

BIA is the method that has been used to assess body composition since 1930s, but as early as 1990s this technology has been commercially marketed as an easy to use, inexpensive, portable hand-to-hand and foot-to-foot device. These hand-to-hand and foot-to-foot devices are used to monitor BF% at home, fitness centers and clinics. Therefore, it is of importance to note that these devices are valid in estimating BF. The studies associated wtih the validity or reliability of these devices are still limited because they are relatively new, and more research needs to be focused on the validity of hand-to-hand and foot-to-foot devices in controlled and free living settings to see if hydration status does, in fact, play role in accurate BF measures. Moreover, research on validity of these devices needs to be expanded across both sexes and across young and adults.

3. MATERIAL AND METHODS

This study was carried out during two months from June and July 2013 in Duhok City, Iraq, and data was collected from two general health centers (Azadi Teaching Hospital and General Central Laboratory Hospital). The study enrolled 209 unhealthy women aged 30-75 years (the mean = 52.5), who will be called the subjects. Before taking the tests, all subjects had been informed that data would be used for a research. They were completely conscious of the importance of precision of information during examination and through the questionnaire (see Appendix I). Upper and lower BF was assessed by using two BIA devices (Omron HBF 306 BF analyzer hand-to-hand measurement) that is faster, easier, less intrusive and includes a lightweight portable device. A person inputs various personal information such as age, gender, weight and height, then grips the device handles (hand-to-hand). Electrodes in the hand sensor pads send a low, safe single through the body and so BF content and BMI is calculated automatically in seconds. And (Body analyzer Scale Model BA 833, ADE Fitness, Germany foot-to-foot or leg-to-leg) that BIA devices measure impedance across the lower limbs, and the system's four electrodes are in the form of stainless steel foot pads mounted on the top surface of platform scale. The subject only needs to stand barefoot on the scale for simultaneous of body weight and impedance, with manual entry of the subject's gender and height into the system via a digital keyboard, and the subject's percentage BF is displayed immediately .

3.1.Data Collection

A pre-tested questionnaire was covered the family history of CVD, and Anthropometric measurements. The anthropometric data (height, weight, WC, HC) was measured for each subject using (Omron HBF-306C Hand-to-Hand) and (Body analyzer Scale Model BA 833, ADE Fitness, Germany). Foot-to-FootSF-BIA devices were used to estimate BF%. Different body tissues have different resistivity, and therefore the calculation can be made with BIA method to estimate the BF% by passing small alternating current through the body. In addition, clinical examination, 10 ml of venous blood was withdrawn for estimating blood glucose, and lipid profile as well.

3.2. Anthropometric Measurements

All objects have been instructed to takes off their shoes and heavy clothing items and remove all items from their pockets before being weighed. In the same way, we make sure that their hair styles do not affect accuracy of height measurement; body weight and height were measured to the nearest 0.1 kg using a digital weighing machine, and 0.1 cm, using a graduated elastic tape, respectively. To assess fat distribution, WC was measured in standing position by using a non-extensible tape at the midpoint between the iliac crest and the last rib. WC measurements should be made around a patient's bare midriff after the patient exhales while standing without shoes and with both feet touching and arms hanging freely, cut off value for female (WC> 88 cm) were considered obesity [251]. WHO cut off points were used as follows: high risk ($WC \geq 80$ cm), and very high risk ($WC \geq 88$ cm) for females [2]. And the HC was measured at the widest diameter over greater trochanter by using a non-extensible tape. Hip and Waist circumference measurements were used to calculate waist to hip ratio (WHR).

3.3. Body Fat Percentage Measurements

The BF% was measured via two different methods (hand-to-hand) and (foot-to-foot). Omron HBF-306C Hand-to-Hand BIA device was used to measurement the upper BF % where the patient should be standing with raise arms horizontally and elbows extend straight to form a 90º angle to the body. An electrical current 50 µA usually set a frequency of 50 Hz was applied to an extremity and resistance to that current due to the specific resistivity and volume of the conductor and then the FM was measured. In the same manner, Body analyzer Scale Model BA 833, ADE Fitness, Germany Foot-to-Foot SF-BIA device worked at 50 KHz and oscillating current of 800 µA to determine impedance in ohms, was used for estimating the lower BF%. Personal data like gender, body height and age were entered manually in the keypad interface and saved under selected locations. The foot-to-foot equipment has two stainless-steel foot-pad electrodes mounted on platform scale make sure patients heels are positioned on a heel electrode. The subjects were stood with bare foot and weighted evenly distributed on the measurement platform, and then the lower BF% and BMI were calculated without using jewelry or metal objects. The analysis is based on the measure of body's electrical resistance. We must be careful that alow and safe electrical signal passes freely through fluids contained in lean tissue. The body analyzer accurately measured the resistance and with reference to anthropometric data uses it to calculate elements of body composition. In order to assure the accuracy of the measurements, the following recommendations were required: 4 hours of absolute fasting; not perform vigorous exercise 12 hours before; not drink alcohol 48 hours before, and urinate at least 30 minutes before testing. For more precision, new term was introduced to evaluate the BFR which calculated as upper BF (hand-to-hand) divided by lower BF (foot-to-foot).

Moreover, it must be noted that for blood pressure assesstment, resting SBP and DBP were measured by using a standard mercury sphygmomanometer and cuffs appropriate for arm, and so the SBP and DBP was assessed.

3.4. Biochemical Measurements (Collection of Blood Samples)

Participants were instructed to attend the Lab-Department of Clinical Biochemistry in general health centers in the morning after overnight fasting for 10-12 hours and avoiding smoking and heavy physical activity for more than 2 hours before the examinations. Blood samples were collected between 8:00-10:00 am., about 10 ml of venous blood were withdrawn by venepunctre, using VACUTAINER from the antecubital vein and collected in BD Vacutainer System CAT-plain tubes. After 25-30 mints., the serum was separated by centrifugation using a HTACHI centrifuge (model O5P-21) at 5000 rpm for 10 minutes. Then, the serum was processed immediately for measuring serum TG, HDL-ch, LDL-ch, blood sugar and serum creatinine by clinical chemistry analyzer (open, automated, discreate, random access).TCHO for individuals with TG concentration □ 400 mg/dl was calculated from the Friedewald equation [252].

$$TCHO = HDL + LDL + (TG/5) \tag{3.1}$$

Moreover, the definition of risk factors are hypertension defined as a SBP $\geq$ 140 mmHg and DBP $\geq$ 90 mmHg [253], TCHO > 200 mg/dl , HDL □ 40 mg/dl, LDL> 130 mg/dl, TG > 200 mg/dl [254], and DM or FBS > 120 mg/dl [255]. Parental history of coronary heart disease (CHD)is positive if one or both parents died in the past due to CHD[256] . The characteristics of the study are shown in Table 4.1.

3.5. Statistical Analysis

All data were analyzed using the Statistical Package for Social Science SPSS 20 windows on an IBM PC compatible computer. Pearson's correlation co- efficient (r) was used to compare the correlations between variables, and to test relation among ages, anthropometric, and related risk factors. Level of statistical signification was set as ≤ 0.05.

Descriptive data were expressed with use of standard deviations of these r-values as means ± standard deviation (mean ± SD) values. All the analyses were divided into three groups to their ages as (I: 30-39; II: 40-64; and III ≥ 65 year). Correlations were also employed to assess the relationship between obesity and cardiovascular risk by comparing various measures of obesity. BFR and WHR parameters were grouped according to the case numbers in quartiles, BMI parameter was grouped according to the proposed criteria for the Asia-Pacific region, where being overweight is defined as BMI ≥ 23 kg/m^2, and obesity is defined as BMI ≥ 25 kg/m^2 [257]. We analyzed the association between different anthropometric indices and disease prevalence, or actual plasma concentrations blood pressure values by testing their trends.

4. RESULTS AND DISCUSSION

In this section we presents the results of the measurements and discuss the obtained results. The study included simple anthropometric data BFR, BMI, (Waist, Hip) circumferences, and WHR were used for screening individuals to detect cardiovascular disease for the subjects. The correlation values between the antropometric data (BFR, WHR, BMI) for each subject with risk factors of heart dieases according to age group were presented in the tables. On the other hands, the CV risks with respest to antropometric data are ploted in the figures given below.

The means and standard deviations of the anthropometric measurements and their biochemical variables are given in Table 4.1. Anthropometric characteristics of the study population were presented in Table 4.1. The participants (ranging from 30 to 75 years) were separated to their age into three age groups as (30-39), (40-64) and older than 65 year. Mean age of these groups were (35.86 ± 2.34), (51.96± 6.56) and (71.09 ±5.45) years, respectively. The second group was the highest (152.08 ± 6.16) while the heaviest group was first one (82.23 ± 13.17). The first group has large waist and hip circumference (107± 6.27) cm, (114.71± 8.03) cm respectively and highest values of measuring BF% (leg-to-leg 30.46 ± 2.55) and (hand-to-hand 45.54 ± 5.006), respectively. However the ratio between them for both were highest in the third group.

In addition, the biochemical measurements of the study population were also present in Table 4.1. The highest value measured of HDL was (35.16 ± 9.25) for third group while the highest values of LDL, TCHO, Glucose, SBP and DBP were in second group. However, the first group was highest only in TG (184.17 ± 95.19) mg/dl .

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Table 4.1. Anthropometric indexes and Cardiovascular risk factors (CVD) for women (mean ± SD).

Variables	(n=209)		
	I (n=7)	II(n=159)	III (n=43)
Age (years)	35.86±2.34	51.96±6.56	71.09±5.45
Height(m)	150.29±7.99	152.08±6.16	148.51±6.44
Weight(Kg)	82.23±13.17	75.30±14.02	63.11±10.59
WC (cm)	107±6.27	106.64±10.84	103.09±10.06
HC (cm)	114.71±8.03	110.05±10.52	103.71±10.25
WHR	0.93±0.047	0.97±0.061	0.99±0.046
BF%(L-L)	30.46±2.55	26.83±5.33	22.56±5.25
BMI (Kg/m2)	35.14±3.23	33.56±16.57	28.58±4.78
BF%(H-H)	45.54±5.006	44.19±8.42	40.41±8.61
BFR	1.49±0.141	1.67±0.26	1.83±0.36
HDL (mg/dl)	32.94±7.15	34.70±8.62	35.16±9.25
(LDL) (mg/dl)	117.61±18.43	118.36±29.73	116.77±33.50
TG (mg/dl)	184.17±95.19	183.75±99.52	173.95±84.06
TCHO (mg/dl)	187.39±29.88	189.81±38.29	186.73±43.19
Glucose (mg/dl)	134.14±44.97	143.27±69.52	142.92±65.49
SBP(mmHg)	137.14±19.76	147.26±24.98	138.84±22.59
DPB (mmHg)	92.86±21.38	98.67±69.74	89.21±15.84

Age Groups: I, 30-39; II, 40-64; III ≥ 65 years; HC, Hip Circumference; WC, Waist Circumference; WHR, Waist-to-Hip-Ratio; BF%(L-L), Body Fat % (Leg-to-Leg); BMI, Body Mass Index; BF%(H-H), Body Fat%(Hand-to-Hand); BFR, Body Fat Ratio; HDL, High-Density-Lipoprotein; LDL, Low-Density-Lipoprotein; TG, fasting Triglyceride; TCHO, Total Cholesterol; Glucose, fasting plasma glucose; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure.

In Table 4.2, the correlation between a WHR parameter and the CVD risks are shown for the three groups. Positive associations existed between WHR and Glucose for groups aged (30-39) and (40-64) years and with SBP for second group (40-64) and with TCHO for the first group (30-39) and third group (≥ 65 year). While a negative associations existed between WHR and SBP for group aged (30-39) and (≥ 65 year),and with HDL for both groups (30-39) and (40-64), and also withTCHO for group aged (40-64)year.

Table 4.2. Pearson correlation between WHR groups and CVD risk factors for three age groups.

WHR were classified into : **1**, 0.8-089; **2**, 0.9-0.95; **3**, >0.95.

Age group (years)	**CVD risk factors (Mean±SD)**	**WHR groups**			
		1(n=24)	**2(n=35)**	**3(n=150)**	**Correlation**
I	Glucose (mg/dl)	109.00±22.62	114.00±15.55	164.33±57.32	0.925
II		131.67±61.23	125.11±56.99	149.88±73.08	0.796
III		170.00±0.00	125.08±44.92	145.14±69.13	-0.437
I	SBP(mmHg)	150.00±42.42	130.00±0.00	133.33±5.77	-0.744
II		142.86±22.83	137.78±22.58	150.41±25.40	0.695
III		150.00±0.00	125.00±13.78	140.83±23.34	-0.236
I	LDL(mg/dl)	112.90±33.23	127.30±21.63	114.30±10.01	0.036
II		111.49±30.08	124.51±34.97	118.17±28.25	0.395
III		113.00±0.00	122.40±49.17	115.94±31.54	0.177
I	HDL(mg/dl)	37.90±12.58	31.45±2.47	30.63±6.03	-0.890
II		37.76±10.42	34.03±6.78	34.28±8.61	-0.754
III		28.00±0.00	36.15±9.40	44.75±58.57	0.993*
I	TCHO(mg/dl	173.40±53.74	196.45±7.42	190.68±30.23	0.683
II		178.02±38.96	190.08±42.18	171.97±37.12	-0.450
III		170.80±0.00	191.78±52.80	195.88±66.94	0.876

*. Correlation is significant at the 0.05 level (1-tailed).

In Table 4.3, the correlation between a BFR parameter and the CVD risks are shown for the three groups. The correlation between BFR and all CVD factors were almost positive in all groups except with Glucose was negative for the second group, and with SBP for the third group. However, high significant positive correlations existed between BFR and Glucose (p<0.05) for first group (30-39) years and with LDL (p<0.01) for the second group.

Table 4.3. Pearson correlation between Body Fat Ratio (BFR) groups and Cardiovascular risk factors.

BFR groups classified in to:**1**, 1; **2**, 1.5; **3**, 2.

Age group (years)	**CVD risk factors (Mean±S.D.)**	**BFR groups**			
		1(n=45)	**2(n=35)**	**3(n=129)**	**Correlation**
I	Glucose (mg/dl)	116.67±14.43	138.00±63.64	156.50±75.66	0.989*
II		150.58±78.20	157.46±86.60	136.75±60.39	-0.704
III		132.39±24.81	152.20±63.80	144.59±74.98	0.350
I	SBP(mmHg)	126.67±5.77	155.00±35.35	135.00±7.07	0.462
II		142.12±28.14	150.00±23.57	148.21±24.26	0.691
III		143.33±25.00	136.00±20.73	137.93±22.7	-0.472
I	LDL(mg/dl)	108.77±17.97	124.70±16.54	123.80±26.58	0.927
II		110.85±25.61	115.64±29.46	121.67±30.81	1.000**
III		98.89±22.68	139.70±43.88	118.37±32.59	0.225
I	HDL(mg/dl)	29.47±3.52	37.50±13.15	33.60±5.51	0.667
II		33.80±6.82	33.37±7.67	35.35±9.39	0.787
III		30.16±5.01	36.88±11.23	36.42±9.64	0.828
I	TCHO(mg/dl)	183.03±44.12	199.30±17.11	182.0227.83	1.138
II		179.34±32.39	189.76±39.45	193.35±39.48	0.942
III		168.58±27.68	217.66±61.58	187.03±41.97	0.201

*. Correlation is significant at the 0.05 level (1-tailed).

**.Correlation is significant at the 0.01 level (1-tailed).

The associations between anthropometric measurements BMI and CVD factors and age groups are presented in Table 4.4. The only positive relationships was found between BMI and Glucose, SBP for the second group. While a significant positive relationships were found between BMI and TCHO for both the second and third groups. However a high significant negative relationships were found between BMI and HDL, LDL for both second and third group, also with SBP for third group.

Table 4.4. Pearson correlation between Body Mass Index (BMI) groups and Cardiovascular (CVD) risk factors for three age groups of women**.**

BMI groups classified in to :**1**, 18-22.9; **2**, 23-24.9; **3**,25-29.9; **4**, ≥30Kg/m^2 .

Age group (years)	CVD risk factors (Mean±SD)	BMI groups				Correlation
		1(n=11)	2(n=16)	3(n=47)	4(n=135)	
I	Glucose (mg/dl)	---	---	---	134.14±44.97	0
II		112.29±20.40	115.22±28.15	143.39±69.02	147.42±73.28	0.887
III		153.75±70.98	162.00±77.43	127.69±40.37	147.09±80.67	- 0.381
I	SBP(mmHg)	----	---	---	137.14±19.76	0
II		133.57±28.68	128.89±11.66	143.87±25.64	150.54±24.56	0.099
III		132.50±5.00	138.57±30.78	139.38±22.64	140.00±22.80	-0.011
I	LDL(mg/dl)	---	----	----	117.61±18.43	0
II		123.87±31.79	110.59±30.90	117.72±27.55	118.82±30.38	-0.591*
III		148.55±15.72	111.97±40.26	116.51±34.98	111.19±30.13	-0.520
I	HDL(mg/dl)	----	---	---	32.94±7.15	0
II		34.19±6.77	35.54±9.51	35.95±11.15	34.31±7.91	-0.944**
III		46.18±13.92	37.69±11.19	35.23±8.58	31.24±5.06	-0.957**
I	TCHO(mg/dl)	----	---	---	187.39±29.88	0
II		186.17±39.60	173.40±39.56	188.14±37.90	192.01±38.35	0.851**
III		235.18±33.88	227.80±127.80	189.11±46.30	175.75±34.21	0.745**

*. Correlation is significant at the 0.05 level (1-tailed).

**.Correlation is significant at the 0.01 level (1-tailed).

In Figures 4.1 and 4.2 the relations between HC with BF% (Leg-Leg) and WC with BF% (Hand-Hand) were found to be closely linear.

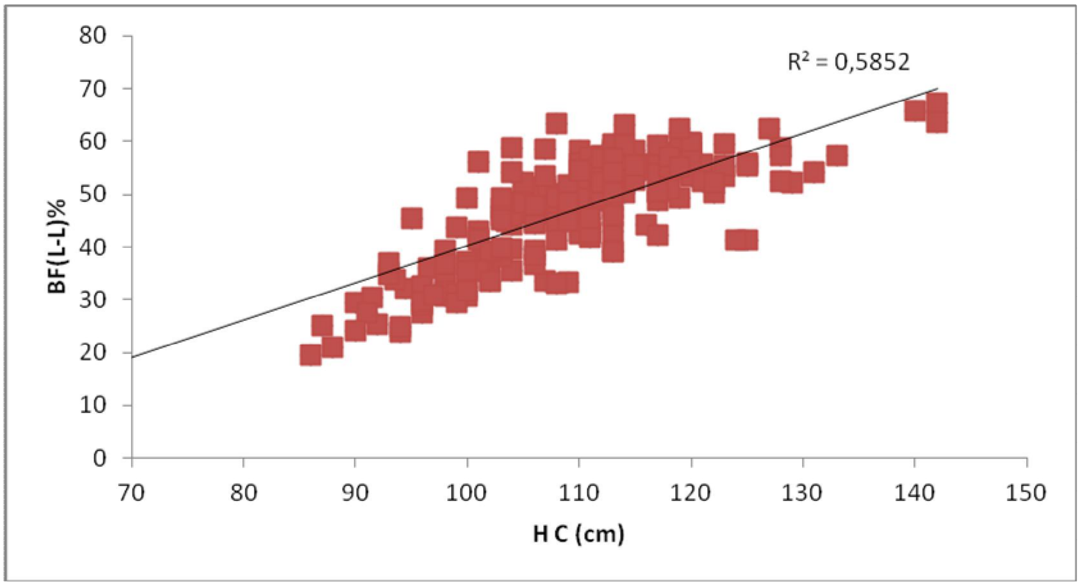


Figure 4.1. Correlation of HC with BF%(L-L) for all participants (n=209).

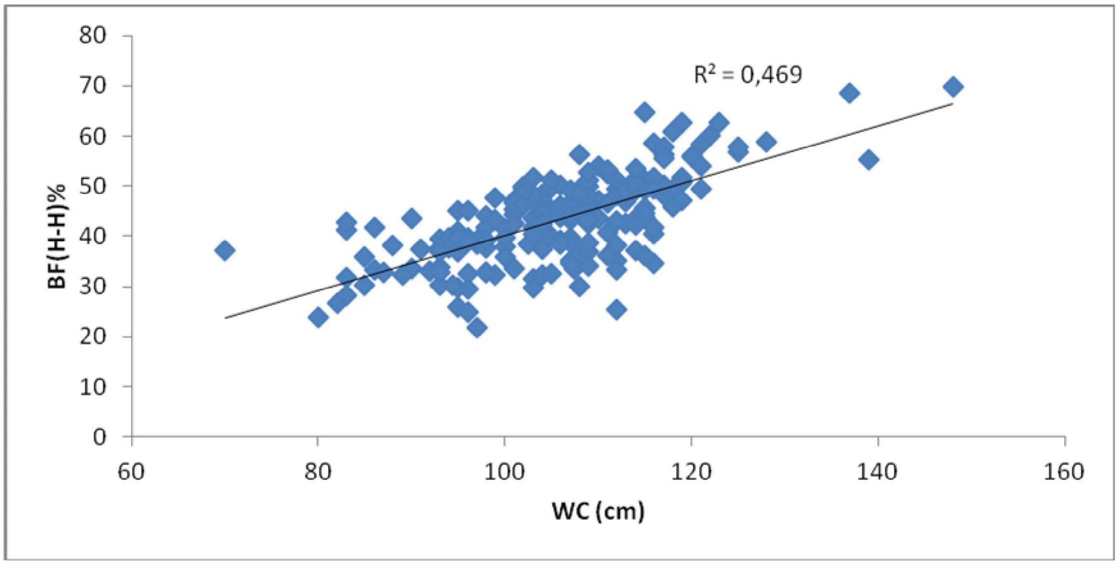
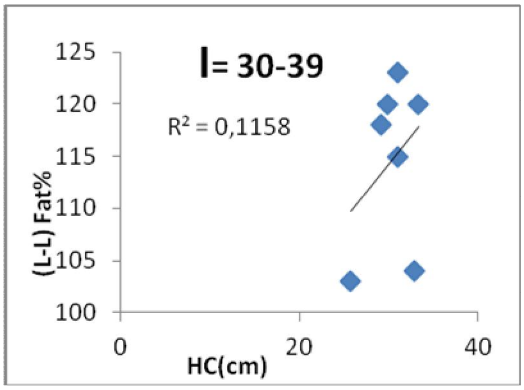


Figure 4.2. Correlation of WC with BF%(H-H) for all participants (n=209**).**

The previous relationships were drawn for each age group individually. Among figures (4.3 and 4.4) and (4.5, 4.6) demonstrate that the higher correlation was found in the second group.



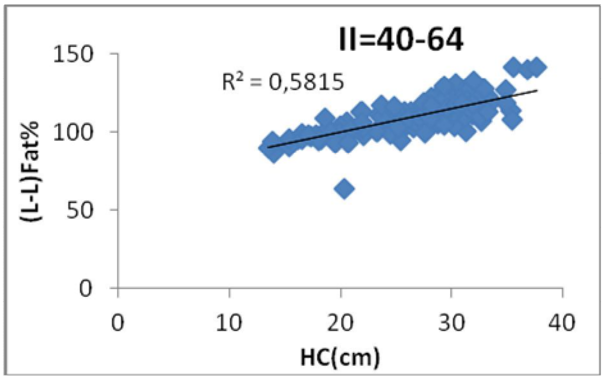


Figure 4.3. Correlation of HC with BF%(L-L) for age group (30 -39)year, (n=7)(left) and for age group (40-64)year, (n=159) (right).

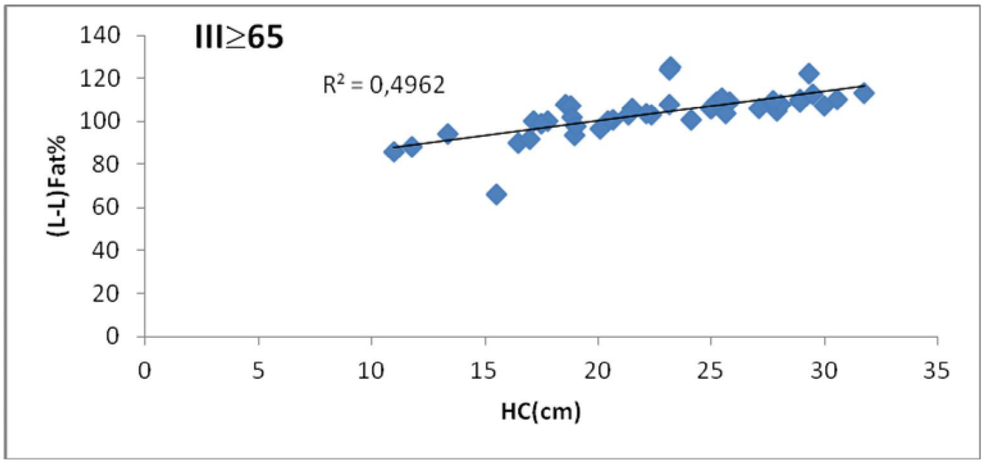


Figure 4.4. Correlation of HC with BF%(L-L) for age group ≥65year (n=43).

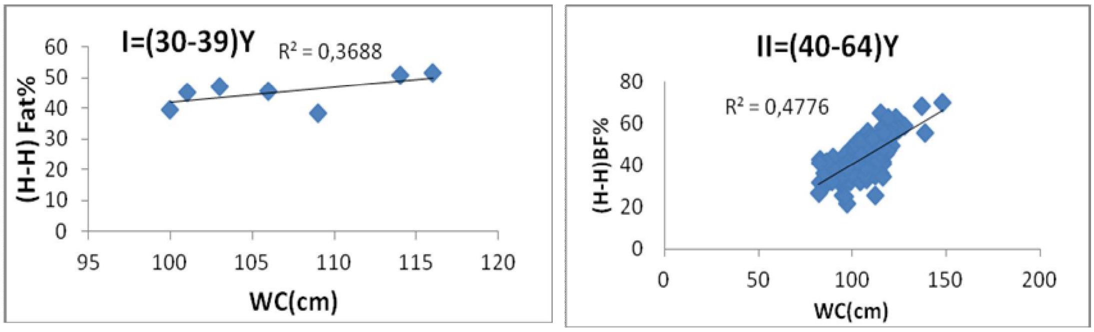


Figure 4.5. Correlation of WC with BF%(H-H) for age group (30.-39)years, (n=7) (left)and for age group (40-64)years, (n=159) (right).

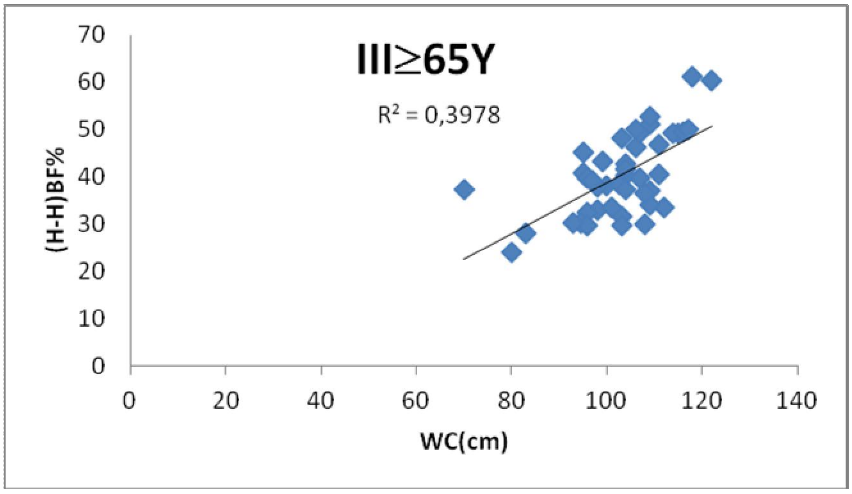


Figure 4.6. Correlation of WC with BF%(H-H) for age group ≥65years, (n=43).

The prevalence of obesity based on WHR and BFR parameters is exhibiting in Figure 4.7 as function of CV%. The risks became significantly increased with the two parameters for all age groups. A good correlation for impact of the two parameters on CV% was observed except for the second group. This impact was significantly increased with age.

Age group (years)		WHR			BFR		
		1	2	3	1	2	3
I	CV%	1	3	6	1	2	7
II		8	15	33	20	32	34
III		15	20	29	17	20	27

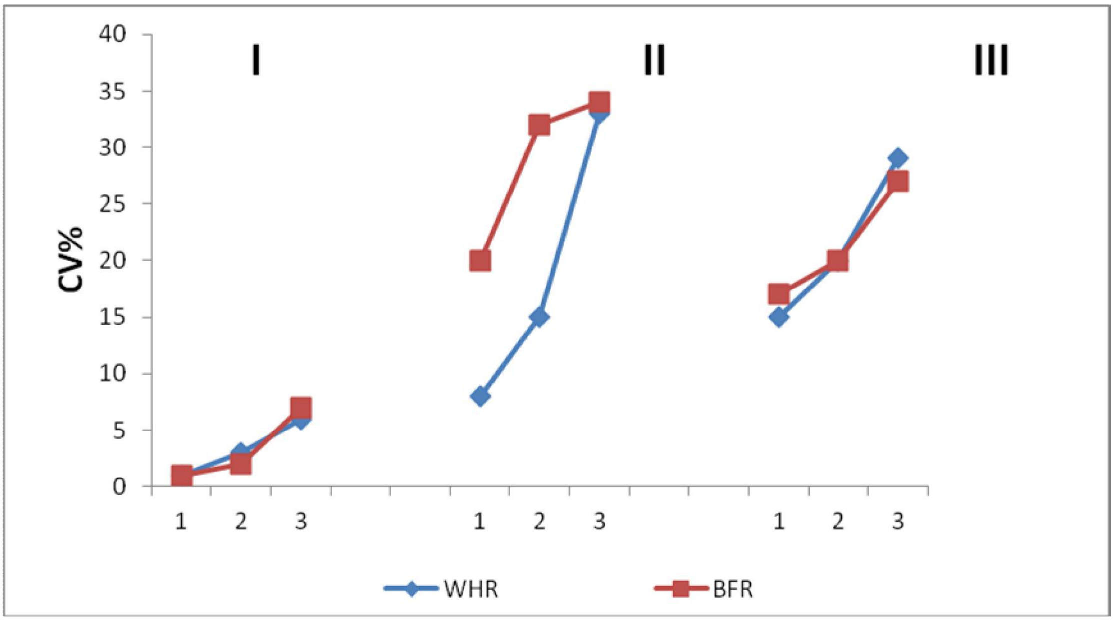


Figure 4.7. Correlation of (WHR & BFR) with CV% risk factors for three age groups.

The prevalence of central obesity based on BF% (H-H) and WC parameters exhibits in Figure 4.8. as function of CV%. The risks became almost significantly increased with the two parameters for all groups. In general, the influence on CV% by the central obesity BF% parameter was lower than WC parameter except for the second age group. This influence was closely linear increased.

Age group (years)		BF% (H-H)			WC(cm)		
		1	2	3	1	2	3
I	CV%	2	4	8	7	8	12
II		6	33	35	3	24	27
III		22	27	33	20	28	35

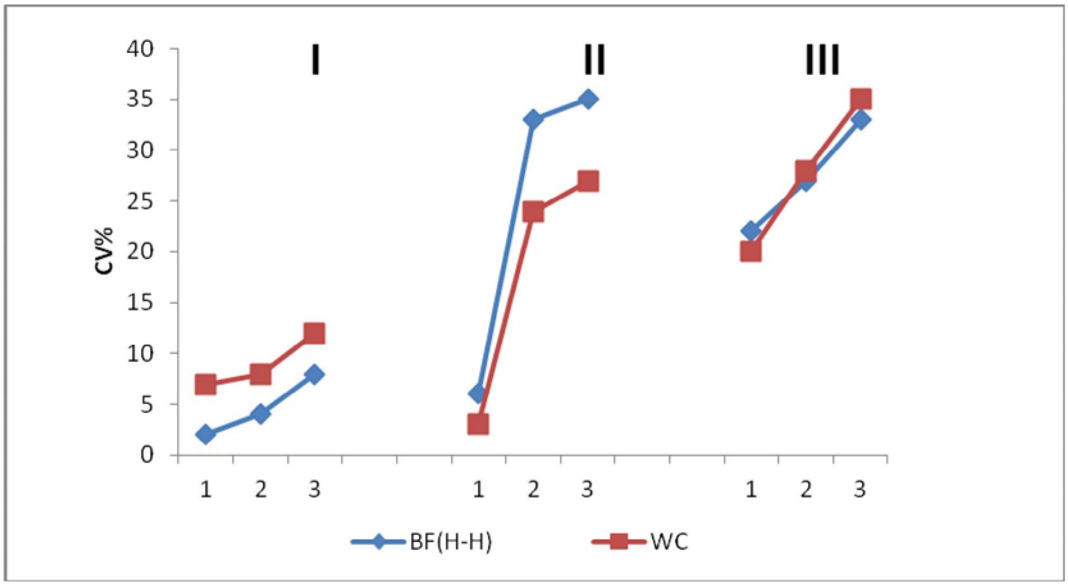


Figure 4.8. Correlation of BF%(H-H) & WC with CV% risk factors for three age groups.

Also the prevalence of lower obesity based on BF% (L-L) and HC parameters is exhibit in Figure 4.9. as function of CV%. The risks became almost significantly increased with the two parameters for all age groups. In general, a matching influence on CV% by the two parameters was observed for all groups. This influence was closely linear increased with age.

Age group (years)		BF% (L-L)			HC(cm)		
		1	2	3	1	2	3
I	CV%	1	4	6	2	5	7
II		8	33	34	6	34	36
III		20	33	35	22	34	36

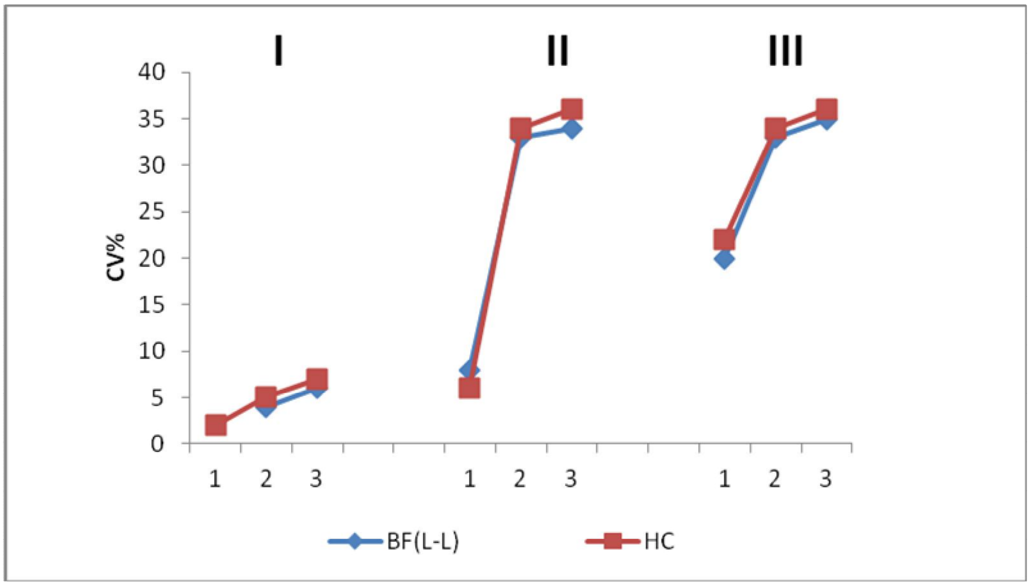


Figure 4.9. Correlation of BF%(L-L) & HC with CV% risk factors for three age groups.

Figure 4.10. display high significant correlation between CV% and BMI for both first and second groups of age. The strongest correlation to CV% risk was observed in second group. Unfortunately, no enough results were available to show this relation for the first group.

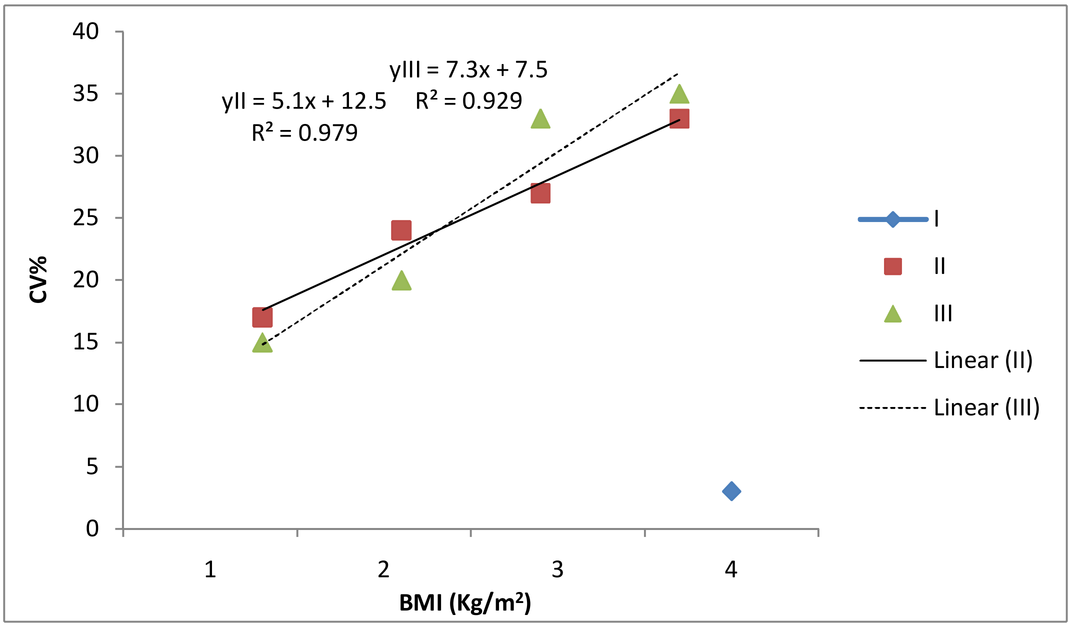


Figure 4.10. Correlation of BMI with CV% risk factors for three age groups.

5. CONCLUSION

Obesity and overweight are currently considered major public health problems in Northern Iraq as well as in many countries. The risk of increasing adiposity increases excess mortality at any age. The importance of fat distribution has been realized in recent years. It has now become obvious that metabolic complications of obesity are associated with upper segment or abdominal obesity. The increased risk of CVD has been found in individuals presenting with distribution of excess fat in the abdominal region. Obesity itself is a cardiovascular risk factor. It is characterized by an increased amount of BF, BMI, WC, HC, WHR and BFR which have been accepted as simple anthropometric indexes for assessing BF amount and distribution and are useful indices for providing important information to predict CVD.

Though a number of techniques are available to measure BF, BIA and anthropometry methods, among which the simplest and most practical is BMI method which gives a reasonable estimate of adiposity. The present study focused on the relation of anthropometry parameters with CVD risk factors in obese Iraq women for age group (30-75) years. The results showed that the three anthropometric indices (BMI, WHR, BFR) were found to be closely related to CVD while the other studies published showed that the WHR and BMI were the best predictor for assessing the risk of CVD [258,259]. Hence the results of present study can be summarised as follows.

The characteristic of all participant subjects were given in detail in Table 4.1. It was obtained that the association between Glucose, HDL and TCHO factors with WHR parameter groups was strongly reinforced the view of influence of this parameter on the CV risks, especially this correlation appeared explicitly for women older than 65 years in HDL and TCHO factors while Glucose factor in the results of statistics showed consistently ($p< 0.05$) for age group (30-39) years and (40-64) years as shown on Table 4.2. These results confirmed the study done in ref.[260]. In Table 4.3. The high association between the risk factors (Glucose, HDL, LDL and TCHO) with BFR parameter groups was observed especially Glucose, LDL and TCHO factors for the age group (30-39) years and TCHO for second age group, a significant correlation was found between the results of statistics of the BFR parameter and risk factors, which showed consistently ($p<0.01$ and $p< 0.05$) , respectively.

A significant negative correlation of BFR parameter with Glucose factor for second age group and with SBP factor for third age group observed in Table 4.3. In Table 4.2, a negative correlation was found for WHR parameter with TCHO and HDL factors forsecond age group, and for age grouped older than 65 years with Glucose and SBP factors while for first age group with SBP and HDL factors and also for age grouped older than 40 years. From Table 4.4 a high negative correlation was also observed for LDL and HDL factors with BMI parameter for third age group in SBP factor. These results are in a good agreement with ref.[261].

In Figure 4.7, the relationship between CV% risk factors with WHR and BFR parameters confirmed the idea of utilize the two WHR and BFR as a good parameters to predict the cardiovascular risks in obesity. The risks became significantly increased with the two parameters for all age groups. Agood correlation for impact of the two parameters on CV% was observed except for the second group. This impact was significantly increased with age.In the contrary to our findings and others WHR parameter had a strong correlation with metabolic syndrome in women [82, 261]. Hence, anthropometric measures plays an important rule to indicate a central obesity pattern and an increased risk of CVD [262,263].

Table 4.4 showed the association between Glucose, SBP, LDL, HDL and TCHO factors with BMI parameter groups strongly reinforced the view of influence of this parameter on the CV risk factors especially for women older than 40 years. Our study is in agreement with [264] regarding BMI and BF%.

The linear relationship between CV% risk factors and BMI parameter confirmedin Figure 4.10, that the BMI represent the CV risks in obesity women. This linearity were obviously in age group (II) and (III), but unfortunately, was not so clear in the first group due to the lack of data. The positive relationship between BMI and CVD mortality has also been reported from large prospective Cohort studies[265]. However, in contrast correlation between BMI and myocardial infarction among South Indians males and females was reported [266].

From Figures (4.1 and 4.2),the variation of BF%(L-L) with HC parameters, and BF%(H-H) with WC parameters with respect to age groups was increased linearly. showed that the higher correlation between the age groups and these parameters was observed in the second group showed in figures 4.3 and 4.4 and 4.5 and 4.6, respectively.

Figure 4.8, and Figure 4.9, showedthe prevalence of central and lower obesity based on BF%(H-H) and WC , and BF%(L-L) and HC parameters respectively as functions of CV% risks. The risks became almost significantly increased with the four parameters for all age groups. In general, the influence on CV% by the centralobesity BF% parameter was lower than WC parameter except for the second age group. This influence was clearly linear increase, and a matching influence on CV% by the two parameters BF%(L-L) and HC was observed for all groups.Also this influence was closely linear increased with age. Some studies have shown that WC is better correlate of CVD risk factors [267] while WC was found to be a better estimate of abdominal visceral adipose accumulation. It has been shown to be a better marker of visceral fat [268,269] and correlates more strongly with CVD risk factors [82, 83,52]. When we compared the correlation of lower BF%(L-L) and HC parameters with CV% risk factors, they havealso good correlations among all CVD risk factors. These results are in agreement with the cross-sectional and prospective studies which found that a larger HC is associated with risk factors for Glucose, and CVD [94, 270].

The main limitation of the present study was the use of cross-sectional data to assess the ability of anthropometric measurements to predict CVD risk factors. Further longitudinal analyses will provide stronger evidence of these associations. Another limitation was that the analyses were conducted in an elderly population at high risk for CVD. In our study, all anthropometric indices never the less provided information on CVD risk factors although at various degree of importance.

In conclusion, it has ben shown that the parameters (BMI, WHR, BFR, WC and HC) were closely related to the CVD risk factors of Iraq women aged (30-75) years.

REFERENCES

[1] Li, C., Ford, E.S., McGuire, L.C., Mokdad, A.H., Increasing Rends in Waist Circumference and Abdominal Obesity Among U.S. Adults. *Obesity*, 15(1):216-224. (2007).

[2] World Health Organization-WHO. Obesity. Report WHO Consult. *Obesity (Geneva),* pp. 7-15, (2010).

[3] Flegal, K.M., Carroll, M.D., Kuczmarski, R.J., Johnson, C.L. Overweight and Obesity in The United States : Prevalance and Trends, 1960-1940. *Int J Obes Relat Metab Disord*, 22:39-47. (2010).

[4] Kuczmarski, R.J., Flegal, K.M., Campblell, S.M., Johnson, C.L. Increasing Prevalance of Overweight Among US Adults . *The National Health And Nutration Examination Surveys ,* 1960 to 1991. *JAMA* , 272:205-211 (2004).

[5] Kullberg, J., Assessment of Body Composition Using Magnetic Resonance İmage, PhD Thesis, Uppsala University, Faculty of Medicine , Uppsala, Sweden, 11-14p. (2007).

[6] Katherine, M.F., Margaret, D., Carroll, M.S., et al. Prevalance and Trends In Obesity Among US Adults 1999 e 2000. *JAMA*, 288:1723e7 (2002).

[7] Chatterjee, P. India Sees Parallel Rise in Malnutrition and Obesity. Lancet, 360:1948 (2002).

[8] Ke-You, G., Da-Wei, F. The Magnetic and Trends of Under-and Over-Nutrition in Asian Countries. *Biomed Environ Sci*, 14:53e60 (2001).

[9] Ekelund, L.G., Haskell, W.L., Johnson, J.L., et al. Physical Fitness is A Predictor of Cardiovascular Mortality in A Symptomatic North American Men. The lipid Reserch Clinics Mortality Follow-Up Study. *N Engl J Med*, 319:1379e84 (2008).

[10] ATPIII . Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Tretment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Final Report, Bethesda, Maryland, USA: National İnstitutes of Health (2002).

[11] Fogelholm, M. Phsical Activity , Fitness and Fatness: Relations to Mortality, Mobidity and Disease Wisk Factors. Asystematic Review .*Obese Rev*., (2009).

[12] WHO http://www.who.int/mediacentre/factsheets/fs317/en/index. html. In.

[13] Galassi, A., Reynolds, K. He, J. Metabolic Syndrome and Risk of Cardiovascular Disease: A Meta-Analysis. *Am J med*., 119(10):812-9 (2006).

[14] Yusuf, S., Hawken, S., Ounpuu, S., et al. Obesity and Risk of Myocardial Infarction in 27,000 Participants From 52 Countries : A Case Control Study. *Lancet*, 366: 1640-9 (2005).

[15] McKay, J., Mensah, G.A. The atlas of heart disease and stroke . Geneva: *World Health Organization ,* 112 (2004).

[16] Murray, C.J.,Lopez, A.D. Mortality by cause for eight regions of the world: Global Burden of disease Study. *Lancet*, 349 (9061):1269-76 (2005).

[17] WHO Information sheet-Cardiovascular diseases : prevention and control, WHO (2003).

[18] Greenberg, H., Raymond, S.U., Leeder, S.R. Cardiovascular disease and global health: threat and opportunity. *Health AFF (Millwood*), W5 :31-51 (2005).

[19] Reilly,J.J., Methven, E., McDowell, Z.C., et al. Health consequences of obesity. *Arch Dis Child*, 88748-752.752 (2003).

[20] Kushner, R. F., Schoeller, D.A., Fjeld, C.R., Danford, L. Is the impedance index (H^2/R) significant in predicting total body water. *Am J Clin Nutr* , 56:835-839 (2002).

[21] Caterson, I. D. Obesity, Part of the metabolic syndrome. *The clinical biochemist reviews* , 18:11-21 (2007).

[22] Al-Hadad, F.H. Myocardial infarction in young Iraqi patients, changes of trends of risk factors and complications over the past decade. *J Fac Med Bagh.,* 31:25-31 (2009).

[23] Al- Kaubaisy, O. K., Mahdi, R.S., Al-Nooh, M.S. Risk factors in young male Iraqi patients with acute myocardial infarction . *J Comm Med.* , 5:11-24 (2002).

[24] Yassen, Y.O. Ischaemic heart diseases and related risk factors in Missan Province. *Med J Basrah University*, 23 (2): 40-44 (2005).

[25] Fruchart, J.C., Nierman, M.C., Stroes, E., Kastelein, J., Duriez, P. New risk factors for atherosclerosis and patient risk assessment . *Circulation* , 109:15-9 (2004).

[26] Hartz, A.J., Rupley, D.C., Rimm, A.A. The association of girth measurments with disease in 32,856 women . *Am J Epidemiol*., 119:71-80 (2009).

[27] Peiris, A.N., Sothmann, M.S., Hoffmann, R.G., Hennes, M. I., Wilson , C.R., Gustafson, A.B., Kissebah, A.H. Adiposity, fat distribution, and cardiovascular disease. *Ann Intern Med* , 10:867-872 (2009).

[28] Gillum, R.F. The association of body fat distribution with hypertension, hypertensive heart disease, coronary heart disease, diabetes, and cardiovascular risk factors in men and women aged 18-79 years. *Chronic Dis*., 40:421-428 (2008).

[29] Folsom, A.R., Prineas, R. J., Kaye, S.A., Solar, J. T. Body fat distribution and self-reported prevalence of hypertension, heart attack, and other heart disease in older women. *Int J Epidemiol*, 18:361-367 (2009).

[30] Lapidus, L. , Bengtsson, C., Larsson, B., Pennert, K., Rybo, E., Sjöström, L. Distribution of adipose tissue and risk of cardiovascular disease and death : A 12 year follow up of participants in the population study of women in Gothenburg, Sweden. Br. Med J, 289:1257-1261 (2004).

[31] Armellini, F., Zamboni, M., Robbi, R., Todesco, T., Rigo, L., Bergamo-Andreis, I.A.I., Bosello, O. Total and intra abdominal fat neasurments by ultrasound and computerized tomography. *Int J Obes Relat Metab Disord*, 17:209-14 (2003).

[32] Radominski, R.B., Vezozzo, D.P., Cerri, G.G., Halpern, A. Ouso da ultrassonografia na avaliação and distribuição de gordura abdominal. *Arq Bras Endocrinol Mtab* , 44(1):5-12 (2000).

[33] Welin, L., Svardsudd, K., Wilhelmsen, L., Larsson, B., Tibblin, G. Analysis of risk factors for stroke in a cohort of men born in 1913. *N Engl J Med* , 317:512-526 (2011).

[34] Ohlson, L.O., Larsson, B., Svardsudd, K., Welin, L., Eriksson, H., Wilhelmsen, L., Bjorntorp, P., Tibblin, G. The influence of body fat distribution on the incidence of diabetes mellitus. 13.5 years of follow-up of the participants in the study of men born in 1913. *Diabetes*, 34:1055-1058 (2005).

[35] Molarius, A., Seidell, J.C. Selection of anthropometric indicators for classification of abdominal fatness-a critical review. *Int J Obes Relat Metab Disord.*, 22(8):719-27 (2010).

[36] Gallagher, D., Visser, M., Sepulveda, D., Pierson, R. N., Harris, T., and Heymsfield, S.B. How useful is body mass index for comparison of body fatness across age, sex, and ethnic groups? *American Journal of epidemiology*, 143(3), 228-(2006).

[37] Dospres, J.P., Denis, P., Marie, C., Pouliot Angelo, T., Clande, B. Estimate of deep abdominal adipose-tissue accumulation from single anthropometric measurements in men. *Am J Clin Nutr*, 54:471-477 (2007).

[38] Grundy, S.M. Non-high Density lipoprotein cholesterol level as potential risk predictor and therapy target. *Arch Intern Med,* 161:1379-1380 (2001).

[39] Suman Kapoor, S. Blood pressure, Waist to hip ratio and body mass index among affluent Punjabi girls of Delhi. *Acta Med Auxol*, 32(3): 153-7 (2000).

[40] Pua, Y. H., Ong, P. H. Anthropometric indices as screening tools for cardiovascular risk factors in Singaporean women. *Asia Pac J Clin Nut*, 14(1):74-9 (2005).

[41] Ashwell, M., Gibson, S. Waist to height ratio is a simple and effective obesity screening tool for cardiovascular risk factors: analysis of data from the british national diet and nutrition survey of adults aged 19-64 years. *Obes Facts*, 2:97-103 (2009).

[42] Franklin, M.M., Pereira, L. H., Garner, B.A.J. Associations of body mass index and waist hipratio with hypertension. *CMAJ*, 135:313-20 (2008).

[43] Hsieh, S.D., Muto, T., Yoshinaga, H., et al. Waist to height ratio, a simple and effective predictor for metabolic risk in Japanese men and women. *International Congress Series,* 1294:PP. 186-9 (2006).

[44] Huang, K.C., Lin, W.Y., Lee, L.T., et al. Four anthropometric indices and cardiovascular risk factors in Taiwan. *Int J of Obes*, 26:1060-8 (2002).

[45] Kaur, P., Radhakrishnan, E., Sankarasubbaiyan, S., et al. A comparison of anthropometric indices for predicting hypertension and type 2 diabetes in a male industrial population of Chennai, South India. *Ethnic Dis* , 18(1): 31-6 (2008).

[46] Kamath, A., Nandini, M., Kedilaya, H.P., D'Souza, V. Relation of anthropometry to CVD risk factors in young obese women. *Biomed Res*, 16(2):137-41 (2005).

[47] Gupta, S., Kapoor, S. Sex differences in the Blood Pressure levels and its association with obesity indices: who is at greater risk. *Ethn and Dis*, 20: (In press). (2010).

[48] Warne, D.K., Charles, M.A., Hanson, R.L., Ja-cobsson, L.TH., McCance, D.R., Knowler, W.C., Pettitt, D.J. Comparison of body size measurements as predictors of NIDDM in Pima Indians. *Diabetes Care* 18:435-439 (2005).

[49] Sargeant, L.A., Bennett, F.I., Forrester, T.E., Cooper, R.S., Wilks, R.J. Predicting incident diabetes in Jamaica: the role of anthropometry . *Obes Res* 10:792-798 (2002).

[50] Kaye, S.A., Folsom, A.R., Sprafka, J.M., Prineas, R.J., Wallace, R.B. Increased incidence of diabetes mellitus in relation to abdominal adiposity in older women. *J Clin Epidemiol,* 44:329-334 (2001).

[51] Carey, V.J., Walters, E.E., Colditz, G.A., Solomon, C.G., Willett, W.C., Rosner, B.A., Speizer, F.E., Manson, J.E. Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women: the Nurses' Health Study. *Am J Epidemiol*, 145:614-619 (2003).

[52] Wei, M., Gaskill, S.P., Haffner, S.M., Stern, M.P. Waist circumference as the best predictor of noninsulin dependent diabetes mellitus (NIDDM) compared to body mass index, Waist/hip ratio and other anthropometric measurements in Mexican Americans: a 7-year prospective study. *Obes Res*, 5:16-23 (2007).

[53] Lundgren, H., Bengtsson, C., Blohme, G., Lapidus, L., Sjöström, L. Adiposity and adipose tissue distribution in relation to incidence of diabetes in women: results from a prospective population study in Gothenburg, Sweden. *Int J Obes,* 13:413-423 (2010).

[54] Chan, J.M., Rimm, E.B., Colditz, G.A., Stampfer, M.J., Willett, W.C. Obesity, fatdistribution, and weight gain as risk factors for clinical diabetes in men. *Diabetes Care*, 17:961- 969 (2004).

[55] Lucas, CH.P., Estigarribia, J.A., Darga, L.L., Reaven, G.M. Insulin and blood pressure in obesity. *Hypertension*, 7:702-706 (1985).

[56] Modan, M., Halkin, H., Almog, S., Lusky, A., Eshkol, A., Shefi, M., Shitri, A., Fuchs, Z. Hperinsulinemia: AA link between hypertension obesity and glugose intolerance. *J Clin Invest,* 75:809-817 (1985).

[57] Berglund, G., Ljungman, S., Hartford, M., Wilhelmsen, L., Bjftrntorp, P. Type of obesity and blood pressure. *Hypertension*, 4:692-6% (1982).

[58] Bjorntorp, P. Abdominal obesity and the Development of noninsulin dependent diabetes mellitus. *Diabetes Metab Rev,* 4:615-622 (1988).

[59] Kissebah, A.H., Peiris, A.N. Biology of regional body fat distribution: Relationship to non-insulin dependent diabetes mellitus. *Diabetes Metab Rev*, 5:83-89 (2011).

[60] Stamler, R., Stamler, J., Riedlinger, W.F., Algera, G., Roberts, R.H. Weight and blood pressure. Findings in hypertension screening of 1 million Americans. *J Am Med Assoc.*, 240:1607-1610 (2005).

[61] Metropolitan Life Insurance Company. Metropolitan height and weight tables. *Stat Bull Met Life Ins Co.,* 64:2 (2003).

[62] Brown, C.D., Higgins, M., Donato, K.A., Rohde, F.C., Garrison, R., Obarzanek, E., Ernst, N.D., Horan, M. Body mass index and the prevalence of hypertension and dyslipidemia. *ObesRes*, 8:605-619 (2000).

[63] King, G.E. Errors in clinical measurement of blood pressure in obesity. *Clin Sci.*, 32:223-237 (2006).

[64] Bjorntorp, P. Classification of obese patient and complications related to the distribution of surplus fat. *Nutrition*, 6:131-137 (2000).

[65] Bjorntorp, P. Obesity and adipose tissue distribution as risk factors for the development of disease. *A review. Infusionstherapie,* 17:24-27 (2001).

[66] Poirier, P., Lemieux, I., Mauriege, P., Dewailly, E., Blanchet, C., Bergeron, J., Despres, J.P. Impact of Waist circumference on the relationship between blood pressure and insulin: *the Quebec Health Survey. Hypertension,* 45:363-367 (2005).

[67] Muller, D.C., Elahi, D., Pratley, R.E., Tobin, J.D., Andres, R. An epidemiological test of the hyperinsulinemia-hypertension hypothesis. *J Clin Endocrinol Metab*., 76:544-548 (2003).

[68] Larsson, B., Seidell, J., SvSrdsudd, K., Welin, L., Tibblin, G., Wilhelmsen, L., BjSrntorp, P. Obesity, adipose tissue distribution and health in men- The study of men born in 1913. *Appetite* , 13:37-44 (2009).

[69] Lapidus, L., Bengtsson, C., Hallstrom, T., Bjorntorp, P. Obesity, adipose tissue distribution and health in women results from a population study in Goteborg, Sweden. *Appetite*, 12:25-35 (2008).

[70] Manson, J.E., Willett,W.C.,Stampfer, M.J., Colditz, G.A., Hunter, D.J., Hankinson, S.E., Hennekens, C.H., Speizer, F.E. Body weight and mortality among women. *N Engl J Med* ., 333:677-685 (2005).

[71] Garrison, R.J., Castelli, W.P. Weight and thirty-year mortality of men in the Framingham study. *Ann Intern Med*., 103:1006-1009 (2007).

[72] Rabkin, S.W., Mathewson, F.A., Hsu, P.H. Relation of body weight to development of ischemic heart disease in a cohort of young North American men after a 26 year observation period : the Manitoba Study. *Am J Cardiol.*, 39:452-458 (2005).

[73] Rimm, E.B., Stampfer, M.J., Giovannucci, E., Ascherio, A., Spiegelman, D., et al. Body size and fat distribution as predictors of coronary heart disease among middle-aged and older US men. *Am J Epidemiol*., 141:1117-1127 (2005).

[74] Stern, M.P., Patterson, J.K., Mitchell, B.D., Haffner, S.M., Hazuda, H.P. Overweight and mortality in Mexican Americans. *Int J Obes.,* 14:623-629 (2000).

[75] Pettitt, D.J., Lisse, J . R., Knowler, W.C., Bennett, P.H. Mortality as a function of obesity and diabetes mellitus. *Am J Epidemiol*., 115:359 (2002).

[76] Stevens, J., Keil, J.E., Rust, P.F., Tyroler, H.A., Davis, C.E., Gazes, P.C. Body mass index and body girths as predictors of mortality in black and white women. *Arch Intern Med*., 152:1257-1262 (2003).

[77] Hill, J.O., Sidney, S., Lewis, C.E. et al. Racial differences in amounts of visceral adipose tissue in young adults: the CARDIA (Coronary Artery Risk Development in Young Adults) study. *Am J Clin Nutr*., 69(3):381-7 (2001).

[78] Vazquez, G., Duval, S., JacobsJr, D.R., et al. Comparison of body mass index, waist circumference, and waist / hip ratio in predicting incident diabetes: a meta-analysis. *EpidemiolRev*., 29:115-28 (2007).

[79] Pouliot, M.C., Despres, J.P., Lemieux, S., et al. Waist circumference and abdominal sagittal diameter: best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women . *Am J Cardiol*., 73(7):460-8 (2004).

[80] Han, T.S., McNeill, G., Seidell, J.C., et al. Predicting intra abdominal fatness from anthropometric measures :the influence of stature. *Int J Obes Relat Metab Disord.*, 21(7):587-593 (2007).

[81] Sewart, K.J., DeRegis, J.R., Turner, K.L., et al. Usefulness of anthropometric and dual-energy x-ray absorptiometry for estimating abdominal obesity measured by magnetic resonance imaging in older men and women. *J Cardiopulm Rehabil.,* 23(2): 109-114 (2003).

[82] Ho, S.C., Chen, Y.M., Woo, J.L., et al. Association between simple anthropometric indices and cardiovascular risk factors. *Int J Obes Relat. Metab Disord.,* 25(11):1689-1697 (2001).

[83] Janssen, I., Katzmarzyk, P.T., Ross, R. Waist circumference and not body mass index explains obesity-related health risk. *Am J Clin Nutr.*, 79(3):379-384 (2004).

[84] Wang, Y., Rimm, E.B., Stampfer, M.J., et al . Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. *Am J Clin Nutr.* 81(3):555-563 (2005).

[85] Folsom, A.R., Prineas, R.J., Kaye, S.A., et al. Body fat distribution and self-reported prevalence of hypertension, heart attack, and other heart disease in older women. *Int J Epidemiol.*, 18(2):361-367 (1989).

[86] Rexrode, K.M., Carey, V.J., Hennekens, C.H., et al. Abdominal adiposity and coronary heart disease in women. *JAMA.,* 280(21):1843-1848 (2008).

[87] Esmaillzadeh, A., Mirmiran, P., Azadbakht, et al. Independent and inverse association of hip circumference with metabolic risk factors in Tehranian adults men. *Prev Med.*, 42(5):354-357 (2006).

[88] Snijder, M.B., Zimmet, P.Z., Visser, M., et al. Independent and opposite associations of waist and hip circumferences with diabetes, hypertension and dyslipidemia, the AusDiab Study. *Int J Obes Relat Metab Disord*, 28(3):402-409 (2004).

[89] Snijder, M.B., Dekker, J.M., Visser, M., et al. Associations of hip and thigh circumferences independent of waist circumference with the incidence of type 2 diabetes: the Hoorn Study. *Am J Cin Nutr.,* 77(5):1192-1197 (2003).

[90] Seidell, J.C., Pe'russe, L., Despre's, J.P., et al. Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study. *Am J Clin Nutr.*, 74(3):315-321 (2001).

[91] Seidell, J.C., Han, T.S., Feskens, E.J., et al. Narrow hips and broad waist circumferences independently contribute to increased risk of non-insulin-dependent diabetes mellitus. *J Intern Med* ., 242(5):401-406 (2007).

[92] Hartz, A.J., Rupley, D.C., Rimm, A.A. The association of girth measurements with disease in 32,856 women. *Am J Epidemiol.*, 119(1):71-80 (2004).

[93] Snijder, M.B., Dekker, J.M., Visser, M., et al. Larger thigh and hip circumferences are associated with better glucose tolerance: the Hoorn study . *Obes Res*., 11(1): 104-111 (2003).

[94] Snijder, M.B., Zimmet, P.Z., Visser, M., Dekker, J.M., Seidell, J.C., and Shaw, J.E. Independent Association of Hip circumference with metabolic profile in different ethnic groups. *Obesity Research*, 12(9):1370-1374 (2004).

[95] Benetou, V., Bamia, C., Trichopoulos, D., et al. Associations of anthropometric characteristics with blood cholesterol fractions among adults. The Greek EPIC study. *Eur J Clin Nutr.,* 60(8):942-948 (2006).

[96] Heitmann, B.L., Frederiksen, P., Lissner, L. Hip circumference and cardiovascular morbidity and mortality in men and women. *Obes Res*., 12(3):482-487 (2004).

[97] Hassinen, M., Lakka, T.A., Komulainen, P., et al. Association of waist and hip circumferences with 12-year progression of carotid intima-media thickness in elderly women. *Int J Obes (Lond).,* 31 (9):1406-1411 (2007).

[98] Zhang, C., Rexrode, K.M., van Dam, R.M., et al. Abdominal obesity and the risk of all-cause, cardiovascular, and cancer mortality: sixteen years of follow-up in US women. *Circulation.* , 117(13):1658-1667 (2008).

[99] Lissner, L., Bj□rkelund, C., Heitmann, B.L., et al. Larger hip circumference independently predicts health and longevity in a Swedish female cohort. *Obes Res*., 9(10):644-646 (2001).

[100] Fogelholm, M. Physical activity , fitness and fatness: relations to mortality, morbidity and disease risk factors. A systematic review . *Obes Rev*., (2009).

[101] Haval, Y., Aseel, M. Bioelectrical impedance method for assessing later body-composition considering the influence of breastfed on gender. *International Of Human Sciences*, ISSN:1303-5134 (2013).

[102] WHO. World Health Organization. Obesity: Preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organ Tech Rep Ser.*, 894:i-xii, 1-253 (2000).

[103] Deurenberg, P., Yap, M., van Staveren, W.A. Body mass index and percent body fat: a meta analysis among different ethnic groups. *Int J Obes Relat Metab Disord.*, 22(12):1164-71 (2008).

[104] ACE (2009) What are the guidelines for percentage of body fat loss? American Council on Exercise (ACE). Ask the Expert Blog. December 2, (2009).

[105] Jackson, A.S., Stan forth, P.R., Gagnon, J., Rankinen, T., Leon, A.S., et al. “True”. *International Journal of Obesity*, 26 (6):789-96. (2002).

[106] Heyward, V.H., & Wanger, D.R.(Eds.). Appied Body Composition Assessment (Seconded.). Champaign, IL: Human Kinetics (2004).

[107] Wagner, D.R., & Heyward, V.H. Techniques of body composition assessment: a review of laboratory and field methods. *Research Quarterly for Exercise & Sports,* 70(2):135-149 (1999).

[108] Malina, R. M. Body composition in athletes : assessment and estimated fatness. *Clin Sports Med* , 26(1): 37-68 (2007).

[109] Weaver, A.M., Hill, A.C., Andreacci, J.L., & Dixon, C.B. Evaluation of Hand-to-Hand Bioelectrical Impedance Analysis for Estimating Percent Body Fat In Young Adults. *International Journal of Exercise Science*, 2(4):254-263 (2009).

[110] Flegal, K.M., Carroll, M. D., Ogden, C.L., and Curtin, L.R. Prevalence and trends in obesity among US adults, 1999-2008. *Jama*, 303(3):235-241 (2010).

[111] Burton, B. T., and Foster, W.R. Health implications of obesity: an NIH Consensus Development Conference. *Journal of the American Dietetic Association*, 85(9):1117-1121 (2005).

[112] Goodpaster, B.H., Krishnaswami, S., Harris, T.B., Katsiaras, A., et al. Obesity, regional body fat distribution, and the metabolic syndrome in older men and women. *Archives of Internal Medicine*, 165(7): 777-783 (2005).

[113] Must, A., Spadano, J., Coakley, E.H., Field, A.E., Colditz, G., & Dietz, W.H. The disease burden associated with overweight and obesity. *The Journal of the American Medical Association*, 282(16):1523-1529 (2004).

[114] Kaminsky, L.A. ACSM's health-related physical fitness assessment manual (3 rd ed.). Philadelphia: Wolters Kluwer Health/ Lippincott Williams & Wilkins Health. (2010).

[115] Snijder, M. B., Van Dam, R.M., Visser, M., & Seidell, J.C. What aspects of body fat are particularly hazardous and how do we measure them? *International Journal of Epidemiology,* 35: 83-92 (2006).

[116] Kyle, U.G., Bosaeus, I., De Lorenzo, A.D., Deurenberg, P., Elia, M., Gomez, J. M., et al. bioelectrical impedance analysis-part I: review of principles and methods. *Clinical Nutrition*, 23(5):1226-1243 (2004).

[117] Brozek, J., Grande, F., Anderson, J.T., & Keys, A. Densitometric Analysis of body composition : Revision of some quantitative Assumptions. *Annals Of The New York Academy of Sciences*, 110:113-140 (1963).

[118] Deng, H.W., Xu, F.H., Davies, K.M., Heaney, R., & Racker, R.R. Differences in bone mineral density, bone mineral content, and bone areal size in fracturing and non-fracturing women, and their interrelationships at the spine and hip. *Journal of Bone And Mineral Metabolism*, 20(6):358-366 (2002).

[119] Wang, Z.M., Pierson, R.N., & Heymsfield, S.B. The five level model: a new approach to organizing body-composition research. *American Journal of Clinical Nutrition,* 56:19-28 (2002).

[120] Heyward, V.H. Evaluation of body composition. Current issues. *Sports Med*, 22(3):146-156 (2006).

[121] Withers, R.T., LaForgia, ., Pillans, R.K., Shipp, N. J., Chatterton, B.E., Schultz, C.G., et al. Comparisons of two, three, and four-compartment models of body composition analysis in men and women . *Journal 0f Applied Physiology*, 85(1):238-245 (2003) .

[122] Ellis, K.J. Human body composition :In vivo methods. *Physiological Reviews*, 80(2):649-680 (2000)

[123] Ben-Shlomo, Y.,& Kuh, D. A life course approach to a chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives. International Journal of Epidemiology, 31(2):285-293 (2002).

[124] Saladin, K.S. Aging and Senescence in Chapter 29: Human Development. In Anatomy & Physiology: the unity of form and function (pp. 1103-1106). New York: McGraw-Hill (2001).

[125] Kyle, U.G., Genton, L., Hans, D., Karsegard, L.,Slosman, D.O., & Piichard, C. Age-related differences in fat-free mass, skeletal muscle, body cell mass and fat mass between 18 and 94 years. *European Journal of Clinical Nutrition,* 55(8):663-672 (2001).

[126] Nu□ez, C., Gallagher, D., Visser, M., Pi-Sunyer, F.X., Wang, Z., Heymsfield, S.B. Bio-impedance analysis: evaluation of Leg-to-Leg system based on pressure contact foot-pad electrodes . *Med Sci Sports Exerc*, 29:524-31 (1997).

[127] Borer, K.T. Physical activity in the prevention and amelioration of osteoporosis in women : interaction of mechanical, hormonal and dietary factors. *Sports Medicine*, 35(9):779-830 (2005).

[128] Wells, J.C. K. Sexual dimorphism of body composition. Best Practice & Research Clinical Endocrinology & Metabolism, 21(3):415-430 (2007).

[129] Lawlor, D.A., Ebrahim, S., Whincup, p., Sterne, J., Papacosta, O., Wannamethee, G., et al. Sex differences in body fat distribution and carotid intima media thickness: cross sectional survey using data from the British regional heart study. *Journal of Epidemiology And Community Health* , 58(8):700-704 (2004).

[130] Kuk, J.L., Lee, S., Heymsfield, S.B., & Ross, R. Waist circumference and abdominal adipose tissue distribution: Influence of age and sex. *American Journal of Clinical Nutrition,* 81(6):1330-1334 (2005).

[131] Tuck, S.P., Pearce, M.S., Rawlings, D.J., Birrell, F. N. m Parker, L., & Francis, R.M. Differences in bone mineral density and geometry in men and women: the Newcastle Thousand Families Study at 50 years old. *British Journal of Radiology*, 78(930): 493-498 (2005).

[132] New Zealand Guidelines Group. Cardiovascular risk assessment. In best practice evidence-based practice guideline: the assessment and management of cardiovascular risk . (pp. 12). Wellington, New Zealand (2003).

[133] Seeman, E. Clinical review 137: Sexual dimorphism in skeletal size, density, and strength. *Journal of Clinical Endocrinology and Metabolism*, 86(10):4576-4584 (2001).

[134] Gesta, S., Bluher, M., Yamamoto, Y., Norris, A.W., Berndt, J., Kralisch, S., et al. Evidence for a role of developmental genes in the origin of obesity and body fat distribution. *Proceedings of The National Academy of Sciences*, 103(17):6676-6681 (2006).

[135] Malis, C., Rasmussen, E. L., Poulsen, P., Petersen, I., Christensen, K., Beck-Nielsen, H., et al. Total and Regional Fat Distribution is Strongly Influenced by Genetic Factors in Young and Elderly Twins. *Obesity Research*, 13(12):2139-2145 (2005).

[136] Stevens, J., Katz, E.G., & Huxley, R.R. Associations between gender, age and waist circumference . *European Journal Of Clinical Nutrition*, 64(1):6-15 (2010).

[137] Janssen , I. Heymsfield, S.B., Allison, D.B., Kotler, D.P., & Ross, R. Body mass index and waist circumference independently contribute to the prediction of non abdominal, abdominal subcutaneous, and visceral fat. *American Journal of Clinical Nutrition*, 75(4):683-688 (2002).

[138] Baumgartner, R.N. Body composition in healthy aging. Annals of the New York Academy of Sciences, 904:437-448 (2000).

[139] Janssen, I., Heymsfield, S.B., Wang, Z.M., & Ross, R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 Yr. *Journal Of Applied Physiology,* 89(1):81-88 (2000).

[140] Enzi, G., Gasparo, M., Biondetti, P.R., Fiore, D., Semisa, M., & Zurlo, F. Subcutaneous and visceral fat distribution according to sex, age, and overweight, evaluated by computed tomography. *American Journal Of Clinical Nutrition*, 44(6):739-746 (2000).

[141] Russo, C.R., Lauretani, F., Bandinelli, S., Bartali, B., Di Iorio, A., Volpato, S., et al. Aging bone in men and women: beyond changes in bone mineral density. *Osteoporosis International*, 14(7):531-538 (2003).

[142] Warming, L., Hassager, C., & Christiansen, C. Changes in bone mineral density with age in men and women: a longitudinal study. *Osteoporosis International*, 13(2):105-112 (2002).

[143] Lindsay, R. The menopause and osteoporosis. Obstetrics And Gynecology, 87(2): S16-S19 (2009).

[144] Wishart, J.M., Need, A.G., Horowitz, M., Morris, H.A., & Nordin, B.E. Effect of age on bone density and bone turnover in men. *Clinical Endocrinology*, 42(2): 141-146 (2007).

[145] Snyder, P.J., Peachey, H., Hannoush, P., Berlin, J.A., Loh, L., Holmes, J.H., et al. Effect of testosterone treatment on bone mineral density in men over 65 years of age. *The Journal of Clinical Endocrinology & Metabolism,* 84(6):1966-1972 (2001).

[146] National Institutes of Health Osteoporosis and Related Bone Diseases. Osteoporosis in Men. From,http://www.niams.nih.gov/Health_Info/Bone/Osteoporosis/men.asp . (2011).

[147] Wanger, D.R., & Heywared, V.H. Measures of body composition in blacks and Whites : a comparative review. *American Journal of Clinical Nutrition*, 71(6):1392-1402 (2000).

[148] Barondess, D.A., Nelson, D.A., & Schlaen, S.E. Whole body bone, fat, and lean mass in black and white men. *Journal of Bone And Mineral Research,* 12(6): 967-971 (2002).

[149] Casas, Y.G., Achiller, B.C., DeSouza, C.A., & Seals, D.R. Total and regionl body composition across age in healthy Hispanic and white women of similar socioeconomic status. *The American Journal of ClinicalNutrition*, 7391):13-18 (2001).

[150] Wulan, S.N., Westerterp, K.R., & Plasqui, G. Dietry and 24-h fat oxidation in Asians and whites who differ in body composition. *American Journal of Clinical Nutrition, 95(6):*1335-1341 (2012).

[151] Collins, F.S. What we do and don't know about 'race', 'ethnicity', genetics and health at the dawn of the genome era. *Nature Genetics*, 36(11 suppl):S13-S15 (2004).

[152] Crawford, D.H., Shepherd, R.W., Halliday, J.W., Cooksley, G.W., Golding, S.D., Cheng, W.S., et al. Body composition in nonalcoholic cirrhosis: the effect of disease etiology and severity on nutritional compartments. *Gastroenterology*, 106(6): 1611-1617 (2004).

[153] Rippe, J.M.,& Hess, S. The role of physical activity in the prevention and management of obesity. *Journal of the American Diabetic Association,* 98 (10 Suppl 2): S31-38 (2008).

[154] Stiegler, P., & Cunliffe, A. The role of diet and exercise for the maintenance of fat-free mass and resting metabolic rate during weight loss. *Sports Medicine*, 36(3): 239-262 (2006) .

[155] Boonyarom, O., & Inui, K. Atrophy and hypertrophy of skeletal muscles: structural and functional aspects. *Acta Physiologica*, 188(2):77-89 (2006).

[156] Rasanathan, K., Craig, D.,& Perkins, R. The novel use of 'Asian' as an ethnic category in the New Zealand health sector. *Ethnicity and Health*, 11(3): 211-227 (2006).

[157] Kenler, H.A., Brolin, R.E., & Cody, R.P. Changes in eating behavior after horizontal gastroplasty and Roux-en-Y gastric bypass . *American Journal of Clinical Nutrition* , 52(1):87-92 (2008).

[158] Chao, D., Espeland, M.A., Farmer, D., Register, T.C., Lenchik, L., Applegate, W.B., et al. Effect of voluntary weight loss on bone mineral density in older overweight women . *Journal of the American GeriatricsSociety* , 48(7):753-759 (2000).

[159] Ministry of Health. Healthy Eating-Healthy Action: Oranga Kai-Oranga Pumau: A Background. Wellington: *Ministry of Health*, (2003).

[160] WHO. (2003). Controlling the global obesity epidemic. Geneva: World Health Organization,(2003).URL:http://www.who.int/nut/obs.htm.from,http://www.who.int/nutrition/topics/obesity/en/ . (Accessed 2006, April).

[161] WHO. (2007). Cardiovascular diseases. From htt:/www.who.int/topics/cardiovascular_diseases/en/. (Retrieved 2008, 14th January).

[162] Lee, C.C., Glickman, S.G., Dengel, D.R., Brown, M.D., & Supiano, M.A. Abdominal Adiposity Assessed by Dual Energy X-ray Absorptiometry Provides a Sex-Independent Predictor of Insulin Sensitivity in Older Adults. *The Journals of Gerontology*, 60(7):872-877 (2005).

[163] Snijder, M.B., Dekker, J.M., Visser, M., Bouter, L. M., Stehouwer, C.D.A., Yudkin, J.S., et al, Trunk fat and leg fat have independent and opposite associations with fasting and postload glucose levels: the Hoorn Study. (Epidemiology/Health Services/Psychosocial Research). *Diabetes Care*, 27(2):372-377 (2004).

[164] Wu, C.H., Yao, W.J., Lu, F.H., Wu, J.S., & Chang, C.J. Relationship between glycosylated hemoglobin, blood pressure, serum lipid profiles and body fat distribution in healthy Chinese. *Atherosclerosis*, 137(1):157-165 (2003).

[165] Chang, C.J., Wu, C.H., Lu, F.H., Wu, J.S., Chiu, N.T., & Yao, W.J. Discriminating glucose tolerance status by regions of interest of Dual-energy X-ray absorptiometry. Clinical implications of body fat distribution. *Diabetes Care*, 22(12):1938-1943 (2007).

[166] Okura, T., Nakata, Y., Yamabuki, K., & Tanaka, K. Regional Body Composition Changes Exhibit Opposing Effects on Coronary Heart Disease Risk Factors. *Arteriosclerosis, Thrombosis, and Vascular Biology*, 24(5):923-929 (2004).

[167] Bergman, R.N., Kim, S.P., Hsu, I.R., Catalano, K.J., Chiu, J.D., Kabir, M., et al. Abdominal obesity: role in the pathophysiology of metabolic disease and cardiovascular risk. *The American Journal of Medicine*, 120(2 Supplement 1): S3-S8 (2007).

[168] Bergman, R.N., Kim, S.P., Catalano, K.J., Hsu, I.R., Chiu, J.D., Kabir, M., et al. Why Visceral fat is bad : mechanisms of the metabolic syndrome. *Obesity*, 14 suppl 1: 16s-19s (2006).

[169] Duz, S., Kocak, M., & Korkusuz, F. Evaluation of body composition using three different methods compared to dual-energy X-ray absorptiometry. *European Journal of Sport Science,* 9(3): 181-190 (2009).

[170] Chumlea, W.C., Guo, S.S., Steinbaugh, M.L. The prediction of stature from Knee height for black and white adults and children, with application to the mobility-impaired. *J Am Diet Assoc.* , 94(2):1385-1388 (2004).

[171] Chumlea, W.C., Guo, S.S., Wholihan, K., Cockram, D., Kuczmarski, Johnson, C.L. Stature Prediction equations for elderly non-Hispanic White, non-Hispanic black, and Mexican American persons developed from NHANES III data. *J AM Diet Assoc.*, 98(2):137-142 (2008).

[172] National Institutes of Health. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults-The Evidence Report. *National Institutes of Health. Obesity Research*, 6 suppl 2, 51S-209S (2009).

[173] National Institute Of Health. Bioelectrical impedance analysis in body composition measurement : National Institute of Health Technology Assessment Conference Statement. *The American Journal of Clinical Nutrition.* 64:524S-532S (2006).

[174] Pichard, C., Laurence, G., Jolliet, P. Measuring body composition : a landmark of quality control for nutritional support services. *Nutrition* , 2:281-284 (2000).

[175] Bowden, R.G., Lanning , B.A., Doyle, E.I., Johnston, H.M., Nassar, E.I., Slonaker, B., Scanes, g. Comparison of body composition measures to Dual-Energy X-Ray Absortiometry. *Journal of Exercise Physiology Online,* 8:1-9 (2005).

[176] Curtin, F., Morabia, A., Pichard, C., Slosman, D.O. Body mass index compared to dual-energy X-ray absorptiometry: evidence for a spectrum bias. *Journal of Clinical Epidemiology,* 50:837-843 (2005).

[177] Roubenoff, R., Dallal, G.E., Wilson, P.W.F. Predicting body fatness: the body mass index vs estimation by bioelectrical impedance . *The American Journal of Public Health*, 85:726-728 (2007).

[178] Nevill, A.M., Stewart, A.D., Olds, T., & Holder, R. Relationship between adiposity and body size reveals limitations of BMI. *American Journal of Physical Anthropology* , 129(1): 151-156 (2006).

[179] Kennedy, A.P., Shea, J.L., &Sun, G. Composition of the classification of obesity by BMI vs. dual-energy X-ray absorptiometry in the Newfoundland population. *Obesity,* 17(11):2094-2099 (2009).

[180] Frisard, M.I., greenway, F.L., Delany, J.P. Comparison of methods to assess body composition changes during a period of weight loss. *Obes Res* . 13(5):845-854 (2005).

[181] Lohman, T., Martorell, R., Roche, A.F. Anthropometric standardization reference manual. Champaign, IL: Human Kinetics Books; (2003).

[182] Deurenberg, P., Weststrate, J.A., Seidell, J.C. body mass index as a measure of body fatness: Age-and sex-specific prediction formulas. *British Journal of Nutrition ,* 65(2): 105-14 (2007).

[183] Arria, A., Garcia-Llop, L. A., Moreno, L.A., Fleta, J., Morellon, M.P., Bueno, M. Skinfold thickness measurements are better predictors of body fat percentage than body mass index in male Spanish children and adolescents. *European Journal of ClinicalNutrition,* 52(8):5736 (2010).

[184] Lohman, T.G. Skinfolds and body density and their relation to body fatness:a review. Human Biology, 53(2):181-225 (2009).

[*185*]Lintsi, M., Kaarma, H., &Kull, I. Comparison of hand-to-hand Bioimpedance and anthropometry equations versus dual-energy X-ray absorptiometry for the assessment of body fat percentage in 17-18-year-old conscripts. *Clinical Physiology and Functional Imaging,* 24(2):85-90 (2004).

[186] Brodie, D., Moscrip, V., Hurcheon, R. Body composition measurement :a review of hydro densitometry, *anthropometry, and impedance methods. Nutrition,* 14:296-310 (2007).

[187] Deurenberg, P., Leenen, R., Van Der Kooy, K., Hautvast, J.G. In obese subjects the body fat percentage calculated with SiRi's formula is an overestimation. *European Journal of Clinical Nutrition,* 44:165-167 (2001).

[188] Jackson, A.S., Pollock, M.L. Generalized equations for predicting body density of men. *British Journal of Nutrition*, 40:497-504 (2007).

[189] Jackson, A.S., Pollock, M.L. Practical assessment of body composition. *Phyician & Sportsmedicine*, 13:76-90 (2005).

[190] Gore, C.J., Woolford, S.M., & Carlyon, R.G. Calibrating Skinfold calipers. *Journal of Sports Science and Medicine* , 13(4):355-360 (2003).

[191] Evans, W.D., MC Clagish, H., Trudgett, C. Factors affecting the in vivo precision of bioelectrical impedancd analysis. *Applied Radiation and Isotopes ,* 49:485-487 (2008).

[192] Ball, S.D., Altena, T.S., Swan, P.D. Comparison of anthropometry to DXA: A new prediction equation for men. *European Journal of Clinical Nutrition,* 58:1525-1531 (2004).

[193] 4 Ways To Measure Body Fat., fromhttp:/munfitnessblog.com/4-ways-to measure-body-fat/ , May 11th, (2008).

.[194] Wallace, J.P., Bogle, P.G., Murray, K.T., Miller, W.C. Variation in the anthropometric dimensions for estimating upper and lower body obesity . *American Journal of human Biology*, 6:699-709 (2004).

[195] Smith, S.R., Lovejoy , J.C., Greenway, F., Ryan, D., deJonge, L., de la Bretonne, J., Volafova, J., Bray, G.A. Contributions of total body fat , abdominal subcutaneous adipose tissue compartments, and visceral adipose tissue to the metabolic compartments, and visceral adipose tissue to the metabolic coplications of obesity. *Metabolism*, 50(4):-435 (2001).

[196] Pouiot, M.C., Despres, J.P., Lemieux, S., Moorjani, S., Bouchard, C., Tremblay, A., Nadeau, A., Lupien, P.J. Waist circumference and abdominal sagittal diameter: best simple anthropomeric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. *Am J Cardiol*, 73(7):460-468 (2004).

[197] Despres, J.P., Prudhomme, D., Pouliot, M.C., Tremblay, A., Bouchrd, C. Estimation of deep abdominal adipose-tissue accumulation from simple anthropometric measurments in men . *Am J Clin Nutr.*, 54(3):471-477 (2001).

[198] Ziegler, E.E., Filer, L.J. Present Knowledge in nutrition. 7th ed. Washington, DC:International Life Sciences Institute. *Jr. editors. Bray obesity,* PP. 19-32 (2004).

[199] Nicklas, B.J., Penninx, B.W., Cesari, M., Kritchevsky, S.B., Newman, A.B., Kanaya, A.M., Pahor, M., Jingzhong, D., Harris, T.B. Health, Aging and Body Composition Study. Association of visceral adipose tissue with incident myocardial infarction in older men and women: the Health, Aging and Body Composition Study. *Am J Epidemiol.*, 160(8):741-749 (2004).

[200] Oksoun,I.S., Chandra, K.M., Boev,A., Boltri, J.M., Choi, S.T., Parish, D.C., Dever, G.E. Abdominal adiposity in U.S. adults: Prevalence and trends, 1960-2000. *Prev Med.*, 39(1):197-206 (2000).

[201] Lohman, T., Martorel, R., Roche, A.F. Anthropometric standardization reference manual. Champaing, IL: Human Kinetics Book, (2003).

[202] Chumlea, W.C., Roche, A.F., Webb, P. Body size, subcutaneous fatness and total body fat in older adults. *Int J Obes.Relat Metab Disord.,* 8(4):311-317 (2005).

[203] Chumlea, W.C., Baumgartner, R.N., Garry, P.J., Rhyne, R.L., Nicholson, C., Wayne, S. Fat distribution and blood lipids in a sample of healthy elderly peopole. *Int J Obes. Relat Metab Disord*, 16(2):125-133 (2002).

[204] Seidell, J.C., Oosterlee, A., Thijssen, M.A., Burema, J., Deurenberg, P., Haautvast, J.G., Ruijs, J.H. Assessment of intra-abdominal and subcutaneous abdominal fat: relation between anthropometry and comuted tomography. *Am J Clin Nutr.*, 45(1):7-13 (2008).

[205] Fujimoto, W.Y., Newell Morris L.L., Grote, M., Bergstrom, R.W., Shuman, W.P. Visceral fat obesity and morbidity: NIDDM and atherogenic risk in Japanese American men and women . *Int J Obes*, 15(Suppl 2) :41- 44 (2001).

[206] Brown, J.E., Potter, J.D., Jacobs, D.R., Kopher, R.A., Rourke, M.J., Barosso, G.M. Hannan, P.J. Schmid, L.A. Maternal Waist-to-Hip Ratio as a Predictor of Newborn Size : *Results of the Diana Project. Epidemiology,* 7(1):62-6 (2006).

[207] World Health Organization frome,“Waist Circumference and Waist-HipRatio, Report of a WHO Expert Consultion”. (8-11 December 2008 Retrieved March 21, 2012).

[208] http://whqlibdoc. Who.int/publications/2011/97892415014910_eng.pdf.

[209] Price, G.M., Uauy, R., Breeze, E., Bulpitt, C.J., Fletcher, A.E. Weight, shape, and mortality risk in older persons: elevated waist-hip ratio, not high body mass index , is associated with a greater risk of death. *Am. J. Clin. Nutr.,* 84(2):449-60. (2006).

[210] Singh, D. “Female mate value at a glance: relationship of waist-to-hip ratio to health, fecundity and attractiveness” . *Neuro Endocrinol. Lett.,* 23. Suppl 4:81-91 (2002).

[211] Morkedad, B., Romundstad, P.R., Vatten, L.J. Informativeness of indices of blood pressure, pbesity and serum lipids in relation to ischaemic heart disease mortality: The HUNT-II study. *European journal of epidemiology*, 26(6):457-461 (2011).

[212] Dobbelstyn, C.J., Joffres, M.R., Maclean, D.R., Flowedew, G.A comparative evaluation of waist circumference, waist-to-hip ratio and body mass index as indicators of cardiovascular risk factors. The Canadian Heart Health Surveys. *Int. J. Obes. Relat. Metab. Disord.* 25(5):652-61. (2001).

[213] Ketel, I.J., Volman, M.N., Seidell, J.C., Stehouwer, C.D., Twisk, J.W., Lambalk, C.B. Superiority of skinfold measurments and waist over waist-to-hip ratio for detemination of body fat distribution in a population-based cohort of Caucasian Dutch adults. *Eur. J. Endocrinol.*, 156(6):655-61 (2007).

[214] Picon, P.X., Letǎo, C.B., Gerchman, F., et al. Waist measure and waist-to-hip ratio and identification of clinical conditions of cardiovascular risk : multicentric study in type 2 diabetes mellitus patients . *Arq Bras Endocrinol Metabol (in Portuguese),* 51(3):443-9 (2007).

[215] Bjorntrop, P. “Portal” adipose tissue as a generator of risk factors for cardiovascular disease and diabetes. *Arteriosclerosis.,* 10:493-496 (2002).

[216] Despres, J.P., Prud'homme, D., Pouliot, M.C., Tremblay, A., Bouchard, C. Estimation of deep abdominal adipose-tissue accumulation from simple anthropometric measurments in men. *Am J Clin Nutr.*, 54:471-477 (2001).

[217] Han, T.S., van Leer, E.M., Seeidell, J.C., Lean, M.E. Waist circumference action levels in the identification of cardiovascular risk factors: prevalance study in arandom sample. *BMJ.* , 311:1401-1405 (2005).

[218] D'Agostino, R.B., Jr., Hamman, R.F., Karter, A.J., Mykkanen, L., Wagenknecht, L.E., Haffner, S.M. Cardiovascular disease risk factors predict the development of type2 diabetes: the insulin resistance atherosclerosis study. *Diabetes Care.,* 27:2234-40 (2004).

[219] Nakanishi, N., Nakamura, K., SuZuki, K., Matsuo, Y., Tatara, K. Associations of body mass index and percentage body fat by bioelectrical impedance analysis with cardiovascular risk factors in Japanese male analysis with cardiovascular risk factors in Japanese male office workers. *Ind Health.*, 38:273-9 (2000).

[220] Bonora, E., Zenere, M., Branzi, P., et al. Influence of body fat and its regional Iocalization on risk factors for attherosclerosis in young men. *Am J Epidemiol.* 135:1271-8 (2000).

[221] Erceg, D.N., dieli-Conwright, C.M., Rossuello, A.E., Jnsky, N.E., Sun, S.,& Schroeder, E.T. The Stay healthy bioelectrical impedance analyzer predicts body fat in children and adults. *Nutrition Research*, 30(50): 297-304 (2010).

[222] WEN, J.J.k.,Adult NZ Chinese Comparative study of Body CompositionMeasured by DEXA, Mphil Thesis, Aukland University of Technology, Division of Sport and Recreation, *NZ Chinese*, 1-19 p, (2008).

[223] Pritchard, J.E., nowson, C.A., Strauss, B.J., Carlson, J.S., Kaymakci, B., Wark, J.D. Evaluation of dual energy X-ray absorptiometry as a method of measurement of body fat. Eropean *Journal of Clinical Nutration,* 47(3):216-228 (2003).

[224] Heymsfield, S.B., Lohman, T.G., Wang, Z., & Going, S.B. (Eds). Human Body Composition (Second ed.). Champaign, IL: Human Kinetics., (2005).

[225] Heyward, V.H., Stolarczy, k. Applied body composition assessment. Champaign, IL:Human Kinetics., (2006).

[226] Heymsfield, S.B. , Wang, J., Kehayias, J., Heshka, S., Lichtman, S., Pierson, R.N. Chemical determination of human body density in vivo: relevance to hydrodensitometry. *The American Journal of Clinical Nutrition,* 50:1282-1289 (2008).

[227] Wagner, D.R., Heyward, V.H., & Gibson, A.L. Validation of air displacement plethysmography for assessing body composition. *Medicine & Science in Sports & Exercise,* 32(7):1339-1344 (2000).

[228] Fields, D.A., Goran, M.I., &McCrory, M. A Body-composition assessment via air displacement Plethysmography in adults and children:a review. *The American Journel of Clinical Nutrition,* 75(3):453-467 (2002).

[229] McCrory, M.A., Gomez, T.D., Bernauer, E.M., Mole, P.A. Evaluation of a new air displacement plethysmography for measuring human body composition. *Med Sci Sports Exerc*., 27:1686-1691 (2005).

[230] Ball, S.D., & Altena, T.S. Comparison of the Bod Pod and dual energy x-ray absorptiometry in men. *Physiological Measurment*, 25(3):671-678 (2004).

[231] Ballard, T.P., Fafara, L.,& Vukovich, M.D. Comparison of BodPod and DXA in female collegiate athletes, *Medicine& Science in Sports & Exercise,* 36(4): 731-735 (2004).

[232] Sun, G.R., Martin, B., Younghusband, R.C., Green, Y. XIE., Mathws, M., Barron, J.R. Fitzpatrick, D.G., Glliver, W., Zang, H. Comparison of Multifrequancy bioelectrical impedance analysis with dual-energy X-ray absorptiometry for assessment percentage body fat in a large, healthy population. *The American Jounal of Clinical Nutrition*, 81:74-78 (2005).

[233] Esco, M.R., Olson, M. S., Williford, H.N., Lizana, S.N., & Russell, A.R. The accuracy of hand-to-hand bioelectrical impedance analysis in predicting body coposition in college-age female athletes. *J Strength Cond Res*, 25(4):1040-1045 (2011).

[234] Barnett, A. Electrical method for studying water metabolism and translocation in body segments. *Proc. Soc. Exp. Biol. Med.,* 44:142 (2004).

[235] Nyboer, J., Bango, S., Barnett, A., and Halsey, R.H. Radiocardiograms-the electrical impedance changes of the heart in relation to electrocardiograms and heart sounds. *J. Clin. Invest.,* 19: 963 (2004).

[236] Nyboer, J. Electrical Impedance Plethysmography. Second Edition. Charles C. Thomas, Springfield, IL, (2000).

[237] Dehghan, M., & Merchant, A.T. Is bioelectrical impedance accurate for use in large epidemiological studies? [Review]. *Nutrition Journal*, 7:26 (2008).

[238] HoutKooper, L.B., Lohman, T.G., Going, S.B., & Howell, W.H. Why bioelectrical impedance analysis should be used for estimating adiposity. *American Journal of Clinical Nutrition,* 64(3 Suppl), 436S-448S (2006).

[239] Deurenberg, P. Limitations of the bioelectrical impedance method for the assessment of body fat in servere obesity. *Am J Clm Nutr.,*64(suppl) : 449S-452S (2009).

[240] Gibson, A.L., Heyward, V.H., & Mermier, C.M. Predictive accuracy of Omron body logic analyzer in estimating relative body fat of adults. *International Journal of Spurt Nutrition and Exercise Metabolism,* 10(2):216-227 (2000).

[241] http://www.healthgoods.com/Omron_Body_Logic_Fat_Analyzer_HBF_306_p/on-hbf306.htm.

[242] Patel, R.V., Peterson, E.L., Silverman, N., Zarowitz, B.J. Estimation of total body and extracellular water in post-coronary artery bypass surgical patients using single and multiple frequncy bioimpedance. *Crit Care Med* , 24:1824-8 (2007).

[243] Heymsfield, S.B., Wang, Z., Visser, M., Gallagher, D., & Pierson, R.N. Jr. Techniques used in the measurment of body composition : an overiew with emphasis on bioelectrical impedance analysis. *American Journal of ClinicalNutrition,* 64(3suppl),478S-484S (2001).

[244] Fornetti, W.C., Pivarnik, J.M., Foley, J.M., & Fiechtner, J.J. Reliability and validity of body composition measures in female athletes. *Journal of Applied Physiology,* 87(3):1114-1122 (2000).

[245] Deurenberg, P., & Deurenberg-Yap, M. Validation of Skinfold thickness and hand-held impedance measurments for estimation of body fat percentage among Singaporean chinese, Malay and Indian subjects. *Asia Pacific Journal of Clinical Nutrition*, 11(1):1-7 (2002).

[246] Sung, R.Y.T., Lau, P., Yu, C.W., Lam, P.K.W., Nelson, E.A.S. Measurment of body fat using leg-to-leg Bioimpedance. *Arch Dis Child,* 85:263-267 (2001).

[247] Jebb, S.A., Cole, T.J., Doman, D., et al. Evaluation of the novel Tanita body-fat analyser to measure body composition by comparison with a four-compartment model. *Br J Nutr.,* 83:115-122 (2000).

[248]http://www.shapeup.org/bfl/bioelec.html.

[249] Weststrate, J.A., and Deurenberg, P. Body composition in children: proposal for a method for calculating body fat percentage from total body density or skin fold thickness measurments. *American Journal of Clinical Nutrition,* 50:110415 (2008).

[250] Bhadra, M., Mukhopadhyay, A., Bose, K. Body mass index, regional adiposity and central fat ddistribution among Bengalee Hindu Girls: A comparative study of pre-menarcheal and menarcheal subjects. *Acta Medica Auxologica*, 33:39-45 (2001).

[251] Willett, W.C., Manson, J.E., Stampfer, M.J., Colditz, G.A., Rosner, B., et al. Weight, Weight change, and cronary heart diseases in women. Risk within the 'normal' weight range. *JAMA* , 273: 461-5 (2005).

[252] Friedewald, W.T., Levy,R.I., Fredrickson, D.S., Estimation of the cocentration of low-density lipoprotein cholestrol in plasma, withhout use of the preparative ultracentrifuge. Clin Chim, 18:499-502 (1972).

[253] Grundy, S.M., Cleeman, J.I., Bairey, C.N. For the coordinating Committee of the Natial Cholesterol Education program. *Circulation*, 110:227-39 (2004).

[254] Al-Asadi, J.N., Habib, S.O., Al-Naama, M.L. Cardiovascular Risk Factors among College Students. *Bahrian Med Bull* 28(3): University of Basrah (2006).

[255] Frier, B.M., Truswell, A.S., Shepherd, J., et al. Diabets Mellitus. In Haslett, C.H., Chillvers ,F.R., Hunter, J.A., et al. (Ed): Davidson's principles and practice of medicine. 18 thEd, Churchill Livingstone, London, 480 (2000).

[256] Gaet, G., Michele, M., Cuomo, S., Guarini, P., Foglia, M.C., Bond, M.G., et al. Arterial abnormalities in the offspring of patients with premature myocardial infarction. *N Engl J Med* , 343:840-6 (2000).

[257] World Health Oraganization. *The Asia- Pacific perspective: redefining obesity and its treatment*. WHO: Geneva, (2000).

[258] Deurenberg, P., Yap, M., van Staveren, W.A. Body mass index and percent body fat : a meta-analysis among diffrent ethnic groups. *Int J Obes.,* 22:1164-1171 (2008).

[259] Patel, S., Unwin, N., Bhopal, R., White, M., Harland, J., Ayis, SA.M., et al. Acomparison of proxy measures of abdominal obesity in Chinese, European and South Asian adults. *Diabetic Med*., 16:853-860 (2009).

[260] Huang, K.C., Lin, W.Y.,Lee, L.T., Chen, C.Y., Lo, H., Hsia, H.H., et al. Four anthropometric indices and cardiovascular risk factors in Taiwan. *International Journal of Obesity*, 26, 1060-1068 (2002).

[261] Anupama Kamath, Nandini, M. Kedilaya, H.P., Vivian D' Souza. Relation of anthropometry to CVD risk factors in young obese women. *Biomedical Recerch,* 16(2): 137-141 (2005).

[262] Larsson, B., Svardsudd, K., Welin, L., Wilhelmsen, L., Bjorntorp, P., Tibblin, G. Abdominal adipose tissue distributio, obesity, and risk of cardivascular disease and death: 13 year follow up of participants in the study of men born in 1913. *Br. Med J (Clin Res Ed),* 288:1401-4 (2004).

[263] Esmaillzadeh, A., Mirmiran, P., Azizi, F. Waist-to-hip ratio is a better screening measure for cardiovascular risk factors than other anthropometric indicators in Tahranian adult men. *Int J Obese Relat Mertab Disord,* 28(10): 1325-32 (2004).

[264] Dhall, M., Gupta, Sh., Bhuker, M.,Sharma, P., and Kapoor, S. Effectiveness of variuos anthropometric indices in prediction of cardiovascular risk among adult Jains. *The Open Anthropology Journal,* 4, 33-39 (2011).

[265] Wilson, PW. F.,D'Agostino, R.B., Sullivan, L., Parise, H., Kannel, W.B. Overweight and obesity as determinants of cardiovascular risk : The Framingham experience. *Arch Intern Med* , 162:1867-72 (2002).

[266] Meenakshisundaram, R., Agarwal, D., Rajendiran, C. Risk factors for myocardial infarction among low socioeconomic status South Indian population. *Diabetol Metab Syndr ,* 26:2-32 (2010).

[267] Lean M.E.J., Han, T.S., Morrison, C.E. Waist circumference as a measure for indicating need for weight managment. *Br Med J* , 311:158-161 (2005).

[268] Hsieh, S.D., Yoshinaga, H. Abdominal fat distribution and coronary heart disease risk factors in men-waist= height ratio as a simple and useful predictor. *Int J Obes Relat Metab Disord ,* 19:585-589 (2005).

[269] Stewart, K.J., DeRegis, J.R., Turner, K.L., et al. Usefulness of anthropometrics and dual-energy x-ray absorptiometry for estimating abdominal obesity measured by magnetic resonance imaging in older men and women. *J Cardiopulm Rehabil.,* 23(2):109-114 (2003).

[270] Emily, D.,Parker, Mark, A.m Pereira, June Stevens, and Aaron, R. Folsom. Association of Hip Circumference With Incident Diabetes and Coronary Heart Disease. *Am J Epidemiol.*, 169:837-847 (2009).

APPENDIX I

Self-Report-Heart disease

Female

The Questionnaire form

Sample number:

Name:

Age (years old):

Family history of CV risk factors Yes No

Previous and current diseases : Yes No

1- Anthropometric measurements :

Age	**Years**
Height	**Cm**
Weight	**Kg**
Wrist	**Cm**
Hip	**Cm**
Blood pressure	**mmHg**

2- Tanita (Leg-Leg)

Body Water	**Muscle Mass**	**Body Fat%(L-L)**

3- Omron (Hand-Hand)

BMI (Kg/m^2)	**Body Fat%(H-H)**

4- Biochemical Investigations (Lipid Profile):

Test	Value
HDL	**mg/dl**
LDL	**mg/dl**
TG	**mg/dl**
Total Cholesterol	**mg/dl**
Glucose	**mg/dl**

CURRICULUM VITAE

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