EFFECTS OF MODIFIED LIFESTYLE INTERVENTION EDUCATION ON ARTERIAL STIFFNESS, INFLAMMATORY AND METABOLIC RISK MARKERS IN OVERWEIGHT AND OBESE SUBJECTS

FARAH DIANA BINTI ARIFFIN

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FARAH DIANA BINTI ARIFFIN

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ACE	Angiotensin converting enzyme
ACSM	American College of Sports Medicine
AHA	American Heart Association
AI	Augmentation index
ANOVA	Analysis of variance
BIA	Bio-electrical impedance
BMI	Body mass index
CCA	Common carotid artery
CHD	Coronary heart disease
CO	Cardiac output
CRP	C-reactive protein
CSA	Cross-sectional area
CT	Computed tomography
CV	Coefficient of variance
CVD	Cardiovascular disease

DAP	Aortic diastolic pressure
DBP	Diastolic blood pressure
DEXA	Dual-energy X-ray absorptiometry
DIT	Diet-induced thermogenesis
DM II	Diabetes mellitus type II
E	Elastic modulus
ECG	Electrocardiography
EID	Endothelium-independent dilation
ELISA	Enzyme linked immunosorbent assay
ET-1	Endothelin-1
FBC	Full blood count
FDA	Food and Drug Administration
FFA	Free fatty acid
FFM	Fat free mass
FFQ	Food frequency questionnaire
FMD	Flow-mediated dilation
FPG	Fasting plasma glucose

HC	Hip circumference
HDL-C	High density cholesterol
HOMA	Homeostasis model assessment
HOMA% B	Homeostasis model assessment of β cell secretory
HOMA% S	Homeostasis model assessment of insulin sensitivity
HOMA-IR	Homeostasis model assessment of insulin resistance
HR_{max}	Heart rate maximum
$HR_{reserve}$	Heart rate reserve
hsCRP	High sensitivity C-Reactive protein
IASO	International Association for the Study of Obesity
IGM	Impaired glucose metabolism
IGT	Impaired glucose tolerance
IL-18	Interleukin-18
IL-6	Interleukin-6
IL-8	Interleukin-8
IMT	Intima-media thickness
IOTF	International Obesity TaskForce

IQ	Interquartile range
ITT	Insulin tolerance test
kcal	Kilocalories
kJ	kilojoules
LAGB	Laparoscopic adjustable gastric banding
LAEI	Large artery elasticity index
LCL	Low calorie diet
LDL-C	Low density lipoprotein
LFT	Liver function test
MAP	Mean arterial pressure
MHR	Maximal heart rate
MI	Myocardial infarction
MRI	Magnetic resonance imaging
NCD	Non-communicable disease
NCEP	National Cholesterol Education Program
NHLBI	National Institute of Health National Heart, Lung and Blood Institute
NHMS	National Health and Morbidity Survey

NIDDM	Non-insulin dependent diabetes mellitus
NO	Nitric oxide
NSAID	Non-steroidal anti-inflammatory drug
OGTT	Oral glucose tolerance test
PA	Physical activity
PP	Pulse pressure
PPAQ	Paffenberger´s Physical Activities Questionnaire
PWA	Pulse wave analysis
PWV	Pulse wave velocity
RCT	Randomized controlled trial
RFT	Renal function test
RMR	Resting metabolic rate
SAEI	Small artery elasticity index
SAP	Aortic systolic pressure
SBP	Systolic blood pressure
SD	Standard deviation
siCAM-1	Soluble intercellular adhesion molecule type 1

SVR	Systemic vascular resistance
TC	Total cholesterol
Tg	Triglycerides
TNF- α	Tumor necrosis factor- α
USA	United States of America
VLCD	Very low-calorie diet
VO_{2peak}	Peak oxygen uptake
WC	Waist circumference
WHO	World Health Organization
WHR	Waist to-hip ratio

LIST OF SYMBOLS

>	More than
<	Less than
$\geq$	Equal or more than
$\leq$	Equal or less than
α	Alpha
σ	Standard deviation
δ	Difference of interest
β	Beta
Δ	Difference
μ	Mean

KESAN PENDIDIKAN PERUBAHAN INTERVENSI GAYA HIDUP KE ATAS KETEGANGAN SALUR DARAH, PENANDA KERADANGAN DAN RISIKO METABOLIK DALAM SUBJEK BERLEBIHAN BERAT BADAN DAN OBES

ABSTRAK

Obesiti merupakan satu penyakit epidemik sedunia yang mempengaruhi hampir seluruh dunia. Kekerapan obesiti di Malaysia telah meningkat dengan mendadak dalam tempoh masa sepuluh tahun yang lepas. Obesiti meningkatkan risiko masalah perubatan dan penyakit kardiovaskular. Modifikasi gaya hidup melalui kombinasi memperbaiki pengambilan pemakanan dan peningkatan aktiviti fizikal merupakan kaedah penurunan berat badan yang kerap kali disyorkan.

Tujuan kajian ini dijalankan adalah untuk mengetahui kesan menggunakan pendidikan intervensi gaya hidup ke atas penurunan berat badan dan pengukuran antropometrik serta ketegangan salur darah, penanda metabolik dan keradangan.

Kajian ini melibatkan 25 subjek (21 perempuan, 4 lelaki; purata umur 36.8 tahun) yang mempunyai berat badan berlebihan dan obes yang telah menamatkan intervensi modifikasi gaya hidup selama sembilan bulan. Kesemua subjek menerima konsultasi untuk meningkatkan aktiviti fizikal dan mengubah cara pemakanan mereka sepanjang intervensi. Ukuran kajian dilakukan sebelum intervensi, 3 bulan, 6 bulan, dan sembilan bulan selepas intervensi. Tahap ketegangan salur darah diukur dengan

menggunakan parameter halaju gelombang denyutan (PWV) dan indeks augmentasi (AI) yang diperoleh daripada analisa gelombang denyutan (PWA). Ukuran antropometrik (berat, tinggi, indeks jisim badan, lilitan pinggang dan pinggul), komposisi badan (peratusan lemak badan dan lemak viseral), tekanan darah, profil lipid darah dan paras glukosa plasma semasa puasa diukur. Tahap penanda keradangan iaitu protin C-reaktif berkepekaan tinggi (hsCRP) dan penilaian model homeostasis untuk kepekaan insulin (HOMA% S), keupayaan sel merembes insulin (HOMA% B), dan kerintangan insulin (HOMA-IR) juga diukur dalam kajian ini.

Penurunan yang signifikan dilihat pada berat badan (75.8 ± 15.1 kg vs 73.6 ± 17.1 kg, $p = 0.019$), lilitan pinggang dan pinggul (89.2 ± 8.3 cm vs 86.4 ± 9.4 cm, $p = 0.013$ dan 107.2 ± 10.0 vs 104.0 ± 11.8 cm, $p = 0.005$). Peratusan lemak badan dan lemak viseral turun menghampiri nilai signifikan ($p = 0.058$ dan $p = 0.059$). Bacaan tekanan darah sistolik aortik ($p = 0.02$), paras insulin semasa puasa ($p = 0.001$), HOMA% S ($p = 0.003$), HOMA% B ($p = 0.002$), HOMA-IR ($p = 0.007$) dan hsCRP ($p = 0.01$) bertambah baik dengan penurunan berat badan. Walaubagaimanapun, tiada perbezaan yang signifikan dilihat pada parameter ketegangan salur darah, tekanan darah brakial, glukosa plasma semasa puasa dan profil lipid darah selepas intervensi.

Pedidikan selama sembilan bulan dalam intervensi gaya hidup telah menghasilkan penurunan berat badan yang kecil tetapi signifikan dan berkesan dalam menambah baik lilitan pinggang dan pinggul, tekanan sistolik aortik, kepekaan insulin, kerintangan insulin dan hsCRP.

EFFECTS OF MODIFIED LIFESTYLE INTERVENTION EDUCATION ON ARTERIAL STIFFNESS, INFLAMMATORY AND METABOLIC RISK MARKERS IN OVERWEIGHT AND OBESE SUBJECTS

ABSTRACT

Obesity is a global epidemic disease affecting almost all parts of the world. The prevalence of obesity has increased rapidly in the last ten years in Malaysia. Obesity increases the risk of medical problems and cardiovascular diseases. Lifestyle modification by improving dietary intake combined with increasing physical activity is the recommended method for the improvement in body composition.

The objective of this study is to determine the effects of lifestyle intervention education on weight loss and anthropometric measurements, arterial stiffness, metabolic and inflammatory cardiovascular risk markers.

This prospective intervention study involved 25 overweight and obese subjects (21 females and 4 males; mean age 36.8 years) who completed a nine months education programme on modified lifestyle intervention. During the intervention, all subjects were regularly counselled to increase physical activity levels by Sports Science lecturer and to modify their diet by dietitians. Study measurements were performed at baseline, 3, 6, and 9 months. Arterial stiffness was estimated non-invasively using pulse wave velocity (PWV) and augmentation index (AI) obtained via pulse wave analysis (PWA). Anthropometric measurements (weight, height, body mass index,

waist and hip circumference), body composition (body fat percentage and visceral fat), blood pressure, lipid profile, and fasting plasma glucose were also measured. Levels of the inflammatory marker, high sensitivity C-reactive protein (hsCRP) and homeostasis model assessment (HOMA) for insulin sensitivity (HOMA% S), insulin secretory capacity (HOMA% B), and insulin resistance (HOMA-IR) were also measured in this study.

There were significant reductions in body weight (75.8 ± 15.1 kg vs 73.6 ± 17.1 kg, p = 0.019), waist and hip circumferences (89.2 ± 8.3 cm vs 86.4 ± 9.4 cm, p = 0.013 and 107.2 ± 10.0 vs 104.0 ± 11.8 cm, p=0.005) after nine months intervention. Body fat percentage and visceral fat levels were marginally reduced (p = 0.058 and p = 0.059). Significant improvements were seen in aortic systolic blood pressure (p = 0.02), serum fasting insulin (p = 0.001), HOMA% S (p = 0.003), HOMA% B (p = 0.002), HOMA-IR (p=0.007) and hsCRP (p=0.01) after 9 months. However, no significant differences were seen in arterial stiffness parameters, brachial blood pressure, fasting plasma glucose and lipid profile after intervention.

Nine months lifestyle intervention education programme resulted in a small but significant weight loss which was associated with significant improvements in waist and hip circumference, systolic aortic blood pressure, insulin sensitivity, insulin resistance and hsCRP.

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Background

Obesity is a global epidemic problem that affects both developed and developing countries. The history of obesity started over 20 000 years ago since the Stone Ages (Bray, 2009). World Health Organization (WHO) had classified obesity as a global epidemic disease that has become a leading public health issue (WHO/IASO/IOTF, 2000) and one of the ten most common cause of preventable health risks (Wilborn *et al.*, 2005). Besides being a major risk factor for type II diabetes, coronary heart diseases (CHD), hypertension, stroke, osteoarthritis, gallbladder disease, sleep apnea and certain forms of cancer, obesity also leads to adverse effects on blood pressure, serum cholesterol, triglycerides and insulin resistance.

In 2005, WHO reported that 1.6 billion adults aged ≥ 15 years were overweight (BMI 25.0 – 29.9 kg/m^2) and 400 million were obese (BMI ≥ 30.0 kg/m^2). In 2010, International Association for the Study of Obesity (IASO) and International Obesity Task Force (IOTF) estimated that approximately 1.0 billion adults were overweight (BMI 25.0 – 29.9 kg/m^2) and about 475 million were obese. These figures indicated the increase in prevalence of obesity all over the world. The obesity prevalence in Malaysia increased more than triple in the last ten years (NHMS, 1996; NHMS, 2006). It was reported that Malaysia has the highest obesity rate in the South East Asia region and ranked as the sixth in the Asia-Pacific region (Mokhtar, 2011).

Obesity is a non-communicable disease (NCD) that requires long term strategies for effective prevention and management. Lifestyle modification that consists of changes in dietary, physical activity and behavioural therapy is an approach in the prevention and management of obesity. Change in eating habits combined with increase in physical activity had been used widely for the management of obesity (Jones and Wadden, 2006) and is associated with significant reductions in metabolic risk, morbidity and mortality (Ross and Bradshaw, 2009). A comprehensive program of lifestyle modification is effective in inducing weight loss from 5% to 10% (Wadden *et al.*, 2004; De Luis *et al.*, 2008).

Large arteries act as elastic cushion to reduce cardiac pulsation for maintaining a steady blood flow. During systole, the arterial walls expand and absorb the energy which is then released during diastole. The large arteries of the human body gradually lose their elasticity and become stiffer with increase in age. Arterial stiffness is an index of vascular health that describes the rigidity of the arterial walls. Arterial stiffness is used in the clinical assessment of cardiovascular risk as increased arterial stiffness is significantly associated with cardiovascular diseases (Blacher *et al.*, 1999; Mattace-Raso *et al.*, 2006). Obesity and arterial stiffness are both important cardiovascular risk markers (Seifalian *et al.*, 2010). The relationship between large arterial function and obesity has been investigated by Wildman et al. (2005) who reported a direct relationship between weight changes with pulse wave velocity change. Previous studies showed that obesity impaired arterial elastic properties (Sivitz *et al.*, 2007; Seifalian *et al.*, 2010).

Obesity is also characterized by low grade inflammation and insulin resistance (Ouchi *et al.*, 2003; Wasir *et al.*, 2007; Chou *et al.*, 2009; Al-Tahami *et al.*, 2011). Markers of low-grade inflammation such as C-reactive protein (CRP), tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6) has been reported to predict cardiovascular events (Koenig *et al.*, 1999; Yudkin *et al.*, 1999; Ridker *et al.*, 2000). Elevated levels of the sensitive marker for inflammation, CRP had been found to be correlated with elevated BMI and cardiovascular disease risk factors (Visser *et al.*, 1999).

1.2 Rationale of the Study

The prevalence of obesity continues to increase despite approaches to obesity treatment such as drug therapy, lifestyle modification and behaviour therapy. Lifestyle modification is a set of principles and techniques used to help subjects adopt improved dietary and exercise habits (Jones and Wadden, 2006). The principles and techniques of lifestyle modification varies, which include different durations and types of intervention. Most of previous lifestyle modification studies were conducted in short duration of interventions ranging from 8 to 24 weeks and mostly had exercise and dietary interventions which were structured, intense and monitored at a specific locations (Utzschneider *et al.*, 2004; Dvorakova-Lorenzova *et al.*, 2006; Villareal *et al.*, 2006; Wong *et al.*, 2006). Our study aims to help the subjects practise lifelong healthy lifestyle habits by educating them on modifying their dietary intake to practise a healthy diet and increasing their physical activity levels. Education on modifying dietary intake was conducted by study dietitians while physical activity consultations were conducted by Sports Science lecturer and study investigators. The program was individualized so that subjects can practise a healthy lifestyle in their own environment based on their capabilities which can be affected by factors such as fitness levels, age, any health limitations, societal and environmental influences (WHO, 2000).

Obesity is associated with cardiovascular and metabolic risks (Safar *et al.*, 2006a; Seifalian *et al.*, 2010). Increased inflammation associated with obesity also contributes to the increase in cardiovascular and metabolic risks (Yudkin *et al.*, 1999; Yudkin *et al.*, 2000). There are so far no studies that have studied the effect of lifestyle modification education on anthropometric measurements, cardiovascular, metabolic and inflammatory risk markers in a single study. Santosa *et al.* (2008) conducted a study to achieve moderate weight loss in women by using self-directed diet and physical activity program. They reported that self-selected diet and independently conducted exercise program resulted in weight loss comparable to that observed in more controlled interventions. However, Santosa *et al.* (2008) did not study the effect of self-selected diet and independently conducted exercise program on cardiovascular, metabolic and inflammatory risk markers. These form the basis of conducting this study.

1.3 Objectives of Study

Obesity is associated with increased arterial stiffness which is an indicator of vascular health as well as altered metabolic profile. Thus, the general objective of this study is to determine the effect of nine months lifestyle intervention education on cardiovascular, metabolic and inflammatory risk markers. The specific objectives of the current study are:

i. To determine the effect of lifestyle intervention education on weight and other anthropometric measurements,
ii. To determine the effect of lifestyle intervention education on arterial stiffness, assessed by pulse wave analysis (PWA) and pulse wave velocity (PWV),
iii. To assess effect of lifestyle intervention education on cardiovascular inflammatory risk based on high sensitivity C-reactive protein (hsCRP) levels,
iv. To assess effect of lifestyle intervention education on metabolic cardiovascular risk markers, specifically lipid profile, fasting plasma glucose, insulin sensitivity and resistance.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1. Obesity

The origin for the word obesity comes from Latin *obesitas* which means fatness or corpulence that is derived from *obēsus* (Dictionary.com). In medical definition, obesity is the condition characterized by excessive fat accumulation in the body either in the subcutaneous (Oxford, 2007a) or adipose tissues that presents a risk to health. Excess fat accumulation is associated with increase in size (hypertrophy) and number (hyperplasia) of the adipose tissue cells. Clinical obesity is considered to be present when a person has a body mass index (BMI) of 30 kg/m^2 or more (Oxford, 2007a) or body fat percentage > 25% for men and > 35% for women (CPG, 2004). Obesity occurs due to a complex interaction between genes and the environment. In most cases, obesity is a prolonged result of excess energy intake than is required for producing enough energy for metabolism, physical activity, growth, and sedentary lifestyle. However, recent evidence indicates that obesity can also be caused by genetic elements (Oxford, 2007a). Obesity has been acknowledged as a clinically important condition that is a major contributor to many chronic diseases including diabetes, cardiovascular diseases and cancer and aggravates numerous health problems, both independently and in association with other diseases (WHO, 1998).

2.1.1. Assessment and Classification of Overweight and Obesity

Overweight occurs when an individual's body weight is greater than the standard weight for a person of the same height. The excess weight may be from muscle, bone, fat or body water. Meanwhile obesity occurs when an individual has excessive fat accumulation, resulting in body weight more than 20% above the average for height, age, sex, and body type (Gale Encyclopedia of Medicine, 2008).

Assessment of overweight and obese can be determined either by determination of total body fat or degree of abdominal obesity. Total body fat can be estimated by several methods including BMI, total body water, total body potassium, bio-electrical impedance (BIA), and dual-energy X-ray absorptiometry (DEXA). Determination of degree of abdominal obesity can be measured accurately by magnetic resonance imaging (MRI) or computed tomography (CT) and practically by anthropometric measurements which are waist circumference and waist-to-hip ratio (WHR). However, the most accurate methods to determine total body fat and degree of abdominal fat are expensive and not readily available for clinical practice.

Overweight and obesity can be classified based on several different ways. The common indices used in clinical practice in classifying overweight and obesity are described below.

a) Body Mass Index

Body mass index (BMI) is the most practical and accepted indices of obesity in populations and clinical practice. It is defined as weight in kilogram divided by height, in meter squared (kg/m^2). BMI is now commonly used to predict obesity-related morbidity and mortality in adults. Classification for the cut-off levels for overweight and obese of 25 kg/m^2 and 30 kg/m^2 by WHO are based on observational studies in Europe and United States of America (USA). From studies among Asian populations, the increased risk of morbidity and mortality of obese-related diseases begin to rise at lower BMI compared to Caucasians. This may be due to the high proportion of body fat in Asian populations (Tai *et al.*, 1999; Deurenberg-Yap *et al.*, 2000; Deurenberg-Yap *et al.*, 2002). It has been shown that Asian population have lower BMI but higher body fat percentage than Caucasians (Wang *et al.*, 1994; Novotny *et al.*, 2006). The WHO along with the International Obesity Task Force (IOTF) and International Association for the Study of Obesity (IASO) has redefined the classification of overweight and obesity using BMI for Asian population. However, the committee of WHO Expert Consultation 2004 recommends retaining the current WHO classification of BMI (WHO, 2000). The recommended BMI cut-off points for Asians and the current WHO classification of BMI are shown in Table 2.1.

Table 2.1: Classification of BMI by WHO in adult Caucasians and recommended classification in adults Asians

Body weight classification	WHO BMI[1] (kg/m^2)	Asian BMI[2] (kg/m^2)
Underweight	<18.5	<18.5
Normal range	18.5 – 24.9	18.5 – 22.9
Overweight	≥25	≥23
Pre-obese / At risk*	25 – 29.9	23 – 24.9
Obese I	30 – 34.9	25 – 29.9
Obese II	35 – 39.9	≥30
Obese III	≥40	

Source: [1]WHO (1998); [2]WHO/IOTF/IASO (2000)

* For Asians classification

b) Waist Circumference

Waist circumference (WC) is a simple and practical method to measure abdominal obesity which is unrelated to height and strongly correlated with BMI and total body fat (Lean *et al.*, 1996). Measurement of waist and hip circumference are influenced by dimensions of several abdominal tissues which are axial and pelvic skeleton, abdominal and back muscles, subcutaneous and intra-abdominal fat, solid and hollow abdominal viscera, blood vessels, and connective tissue (Misra *et al.*, 2005). Increased waist circumference is associated with increased risk for cardiovascular disease and diabetes mellitus type II (DM II), dyslipidemia, and hypertension (NHLBI, 2000; Zhu *et al.*, 2002; Yokoyama *et al.*, 2007).

According to WHO (1998), abdominal obesity is clinically defined as waist circumference greater than 94 cm in men and greater than 80 cm for women. For Asians, the recommended waist circumference cut-off points were ≥ 90 cm for men and ≥ 80 cm for women (WHO/IASO/IOTF, 2000). Table 2.2 showed the classification of overweight and obesity by BMI, WC and risk of co-morbidities for Asian.

Table 2.2: Classification of overweight and obesity by BMI, WC and risk of co-morbidities for Asian population

Classification	BMI (kg/m^2)	Risk of co-morbidities Waist circumference	
		Men < 90 cm Women < 80 cm	≥ 90 cm ≥ 80 cm
Underweight	< 18.5	Low	Increased
Normal	18.5 – 22.9	Increased	Increased
Overweight	≥ 23.0		
Pre-obese	23.0 – 27.4	Increased	High
Obese I	27.5 – 34.9	High	Very high
Obese II	35.0 – 39.9	Very high	Very high
Obese III	≥ 40	Extremely high	Extremely high

Source: Malaysian Clinical Practice Guideline on Management of Obesity (2004) *c) Waist-to-Hip Ratio*

Waist-to-hip ratio (WHR), calculated as the ratio of waist circumference to hip circumference, is another assessment for abdominal obesity. A high WHR (WHR > 1.0 in men and > 0.85 in women) is accepted as one clinical method of identifying patients with abdominal fat accumulation over the last decade (MASO, 2005). Some report WHR as a better predictor of stroke, coronary heart disease, and mortality due to coronary heart disease than waist circumference (Misra *et al.*, 2005).

d) Body Fat Measurement

Overweight and obesity are assessed by determination of total body fat. Measurement of accurate body fat content can be done by several methods but the techniques are often expensive and not practically used in clinical practice. Several methods or techniques that are used to assess exact amount of a person's body fat are given below.

i. Underwater Weighing

Underwater weighing, or also known as hydrostatic weighing using Archimedes' principle in determining body density. Archimedes principle states that when an object is immersed in a fluid, its buoyant force is equal to the weight of the fluid displaced by the object. Lean tissues which are muscle and bone are more dense in water compared to fat tissue. Thus, a person with higher percentage of fat-free mass will weigh more in the water and has lower body fat percentage. Conversely, persons with more fat mass will have lighter body in the water and have higher body fat percentage.

The procedure for this method requires weighing a person on dry land, then immersing into a large tank of water and later on weighing again underwater. The body density is determined by using a standard equation. By using the body density, percentage of body fat can be estimated using the Siri or Brozek formula. Underwater weighing was considered as the gold standard for measuring body fat percentage.

ii. Dual-Energy X-Ray Absorptiometry

Dual-energy X-ray absorptiometry (DEXA) is a relatively new technology which is very precise and accurate in estimating body composition. It represents a three-compartment model that divides the body into total body mineral, fat-free mass and fat tissue mass. DEXA system uses two low dose x-rays at different sources that read bone and soft tissues mass simultaneously. The differential of the two energies is used to estimate the bone mineral content and the soft tissue composition. DEXA has been used as the new gold standard in estimating body composition for its ease of use and provides a three-compartment model compared to the two-compartment model of underwater weighing.

iii. Bio-electrical Impedance Analysis

Bio-electrical impedance analysis (BIA) is a relatively simple, quick and non-invasive technique to estimate body composition by determining the electrical impedance of body tissues consisting of lean mass, fat, and water. BIA is based on the relationship between the volumes of the body, the height, the body compartments, and its impedance. The principle of BIA technique involves the passing of electric currents through the body at a differential rate depending on body composition (Dehghan and Merchant, 2008). Muscles and blood vessels are body tissues with high water contents that conduct electricity easily whereas body fat is a very poor conductor of electricity. An extremely low electrical current of 50 kHz and less than 500 µA is sent through the body to determine the amount of fat tissue. Since fat tissue is a poor electric conductor, a lot of fat will impede the current more than lean tissue. Estimation of the body fat percentage is based on the measurement of the resistance to the current.

Validation for BIA to be used as an accurate assessment in estimating body composition has been done in previous studies. A study by Kushner et al. (1990) showed a highly significant correlation ($r = 0.971$; $p = 0.007$) between deuterium oxide dilution (D_20) and BIA measured in twelve obese females. Kim et al. (2011) compared the eight-electrode BIA method with DEXA as reference method in the assessment of body composition in Korean adults. The study reported significant correlations between percentage of fat measured using BIA and DEXA technique in men and women respectively ($r = 0.956$ and $r = 0.960$ respectively) with a total error of 2.1% fat in men and 2.3% fat in women. Another study done by Utter et al. (1999)

to determine the validity of the leg-to-leg BIA system in estimating body composition in obese and non-obese women. They compared the body composition between BIA method and underwater weighing. This study showed no significant difference between underwater weighing and BIA in estimating the fat-free mass of the obese and non-obese women. A significant correlation was found between BIA and underwater weighing in estimating fat-free mass for all subjects combined ($r = 0.78$, $p < 0.001$). These studies showed that BIA is a simple, reliable yet accurate method of assessing body composition.

iv. Skinfold Measurement

Skinfold measurement is one common method in assessing a person's body composition and body fat percentage. This technique estimates the body fat percentage by measuring skinfold thickness at specific locations on the body using a skinfold calliper. Skinfold measurement is usually taken on the right side of the body at three or seven sites depending upon the specific testing procedure. The skinfold measurement is taken by firmly grasping the skinfold between the thumb and forefinger and placing the calliper below the pinch site. The percentage of body fat can be calculated by using a software program or formulas.

2.1.2. Prevalence of Obesity

Globally, the obesity rate is increasing at an alarming rate and now considered as a global epidemic. The latest analysis by International Association for the Study of Obesity/International Obesity Task Force (IASO/IOTF) in 2010 estimated that about 1.0 billion adults are currently overweight (BMI 25 – 29.9 kg/m^2) and 475 million are obese.

In Malaysia, the prevalence of obesity almost tripled in the past 15 years. The National Health and Morbidity Survey (NHMS) conducted in 1996 reported that 16.6% of Malaysian adults were overweight and 4.4% obese. The number of obese adults more than tripled over a decade according to the NHMS report in 2006. The prevalence of overweight was 29.1% and obesity was 14.0% in 2006. As per the WHO report in 2008, the prevalence of overweight and obesity in Malaysia were 44.6% and 14.1% respectively. The latest prevalence of overweight and obesity was reported by Mohamud *et al.*, (2011) were 33.6% and 19.5% respectively. The reported prevalence of overweight and obesity in Malaysia based on the WHO study was based on the WHO cut-off point and not based on BMI cut-off points for Asian. The prevalence of overweight and obesity in Malaysia would be higher if based on the cut-off points for Asians.

2.1.3. Health Risks of Obesity

The health risks of being overweight and obese are many and varied, ranging from increases of risks to morbidity and mortality. Morbidity of a number of health conditions increases with the increment of BMI. Overweight and obesity are associated with hypertension, DM Type II, stroke, gallbladder disease, coronary heart disease, sleep apnea, osteoarthritis, and some types of cancer such as breast, liver, prostate, and gallbladder cancer. Obesity is also associated with complications of pregnancy, menstrual irregularities and psychological disorders. Table 2.3 showed the summary of health risks associated with being overweight and obese.

Table 2.3: The health risks associated with overweight and obesity

Greatly increased (RR > 3)	Moderately increased (RR 2-3)	Mildly increased (RR 1-2)
Type II diabetes mellitus	Coronary heart disease	Cancer (breast cancer in postmenopausal women, endometrial cancer, colon cancer)
Gallbladder diseases	Cardiac failure	Reproductive hormone abnormalities
Dyslipidemia	Hypertension	Polycystic ovarian syndrome
Metabolic syndrome	Osteoarthritis (knee and hips)	Impaired fertility
Breathlessness	Hyperuricaemia and gout	Low back pain
Sleep apnea		Increased anaesthetic risk
		Foetal defects associated with maternal obesity

RR = relative risk

Source: WHO (1998)

2.1.4. Etiology of Obesity

Overweight and obesity results from a complex interaction between genetic predispotion, hormones and the environment characterized by long term energy imbalance. Energy imbalance may be due to excessive calorie intake, lack of energy expenditure and/or inherited metabolic characteristics.

2.1.4.1. Genetic factors

Genetic factors play a role in the development of overweight and obesity but the mechanism is still not known. Almost 30% to 40% of the variance in BMI can be attributed to genetics but it varies from study to study (Pi-Sunyer, 2002). Obesity can be either monogenic or polygenic in inheritance. Five single gene defects have been identified to be associated with overweight and obesity which are; 1) agouti gene, 2) leptin gene, 3) leptin receptor gene, 4) melanocortin-4 and melanocortin-3 receptor gene defects, and 5) serotonin (Vassalo, 2007). Mutations discovered in genes play roles in appetite control, food intake, and energy homeostasis (B.Hu, 2008). Obesity is also a hallmark of several genetic syndromes abnormalities caused by mutation abnormalities such as Prader Willi syndrome, Bardet-Biedl syndrome, Alstrom syndrome, Cohen syndrome, Albright’s hereditary osteodystrophy, and Carpenter syndrome (Farooqi and O'Rahilly, 2006; Goldstone and Beales, 2008).

2.1.4.2. Environmental factor

The environment is one of the major factors contributing to being overweight and obese. Environmental factors primarily involve disorders in energy intake and energy expenditure.

2.1.4.2.1. Energy Use Imbalances

Energy is consumed through carbohydrate, protein and fat intake in the diet. Total energy intake refers to all energy consumed from food and drinks that can be metabolized inside the body (WHO, 2000). Positive energy balance occurs when energy intake exceeds energy expenditure. The excess calories from dietary intake will be converted and stored as body fat in the adipose tissue. The accumulation of excess body fat stored may lead to overweight and obesity (Wilborn *et al.*, 2005). Lichtman et al. (1992) reported that excessive food consumption is associated with obesity. Conversely, negative energy balance occurs when energy intake is less than energy expenditure, promoting decreases in body fat and weight loss.

Both in the developed and developing countries, there is an overall abundance of palatable and caloric-dense food. The ease in finding abundance of food which are available in the supermarket, fast food restaurants and even vending machines promote high caloric consumption (WHO, 1998). Many of the significant socio-cultural traditions especially special occasions or holidays promote overeating and the preferential consumption of high calorie foods (WHO, 1998). Malaysia especially with a multi-racial population has many special occasions and celebrations such as ‘Hari Raya’, Chinese New Year, and Deepavali. All the celebrations come along with abundance of food that promotes the excessive calorie intake.

2.1.4.2.2. Energy Expenditure

Energy expenditure is composed of basal metabolic rate, the thermic effect of food, and physical activity (Wilborn *et al.*, 2005). The proportion to the total energy expenditure varies according to the regularity and intensity of physical activity. In sedentary adults, the basal metabolic rate contributes nearly 60% of total energy output, the thermic effect of food accounts around 10% and the remaining 30% from physical activity (WHO, 2000). The lack of physical activity or sedentary lifestyle also leads to overweight and obesity. The trends towards industrialization and modernization decrease the amount of energy expenditure. The increased utilization of motorized transport, mechanized equipments, and labours saving devices both in the home and at work limit the necessity of physical activity. These developments decrease work-related activity and increase sedentary daily routines consisting of sitting at work and sitting in front of computer or television for most of the hours (WHO, 1998; WHO, 2000).

2.1.5. Management of Obesity

Management of obesity can be either pharmacological or non-pharmacological interventions or both. The treatment of obesity is optional according to different levels of BMI and other risk factor. Table 2.4 showed the treatment options for different levels of BMI and other risk factors in Asians populations. The aim for the management of obesity is to reduce body weight, prevention of weight gain, maintain a lower body weight over the long term, and treat co-morbidities or underlying causes (CPG, 2004). The initial goal of obesity management is to reduce body weight by 10% from baseline (CPG, 2004). Randomized controlled trials showed that weight loss from 5 to 15% reduces the risk factors of cardiovascular diseases (Wilson *et al.*, 1999; Tuomilehto *et al.*, 2001). The benefits of 10% weight loss on reducing cardiovascular diseases and improving health risks in obesity are shown in Table 2.5.