DEVELOPMENT OF NUTRITION AND LIFESTYLE INTERVENTION MODULES AND ITS EFFECTIVENESS AMONG WORKING ADULTS WITH METABOLIC SYNDROME IN MAURITIUS

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by

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LIST OF ABBREVIATIONS

ACE	Angiotensin converting enzyme
ADA	American Diabetes Association
AGT	Angiotensinogen
ANG I	Angiotensino I
ANG II	AngiotensinII
ApoB	Apo lipoprotein B
BIA	Bioelectric impedance analysis
BMI	Body Mass Index
BP	Blood pressure
CG	Control group
COA	Coenzyme A
CT	Computed tomography
CVD	Cardiovascular diseases
DAGs	Diacylglycerols
DASH	Dietary approaches to stop hypertension
DEXA	Dual-Energy X-Ray Absorptiometry.
DM	Diabetes mellitus
DR	Diet recall
EGIR	European Group for The Study of Insulin Resistance
FFA	Free fatty acids
FFQ	Food frequency questionnaire
GLM	General Linear Model
HbA1c	Glycated haemoglobin
HBM	Health belief model
HDL-c	High density lipoprotein cholesterol
ICC	Intra-class correlation coefficient
IDF	International Diabetes Federation
IG	Intervention group
IMTG	Intramuscular triglycerides
IPAQ-SF	International physical activity questionnaire-short form
IQR	Interquartile range

IS	Insulin sensitivity
LDL-c	Low density lipoprotein cholesterol
MDP	Mediterranean dietary pattern
MET	Metabolic equivalent task
MetS	Metabolic syndrome
MoHQL	Minsitry of Health and Quality of Life
mRNA	Messenger ribonucleic acid
NCDs	Non-communicable diseases
NCEP-ATP III	National Cholesterol Education Program - Adult Treatment Panel III
NEFA	Non-esterified fatty acids
NIDDM	Non- insulin dependent diabetes mellitus
OR	Odd ratio
RAS	Renin angiotensin system
RMR	Resting metabolic rate
SD	Standard deviation
TAGs	Triacylglycerols
TNF	Tumor necrosis factor
USM	Universiti Sains Malaysia
WC	Waist circumference
WHO	World Health Organisation

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PEMBANGUNAN MODUL INTERVENSI PEMAKANAN DAN GAYA HIDUP SERTA KEBERKESANANNYA DALAM KALANGAN PEKERJA DEWASA YANG MEMPUNYAI SINDROM METABOLIK DI MAURITIUS

ABSTRAK

Mauritus, secara rasmi Republik Mauritus adalah negara kepulauan yang terletak di Lautan Hindi dan merupakan sebahagian dari sub-Sahara Afrika. Di rantau ini, Mauritius terkenal dengan sejarah ekonominya, namun begitu ianya juga dikenali mempunyai prevalen yang tinggi penyakit kronik akibat dari evolusi tansisi pemakanan. . Memandangkan sindrom metabolik (MetS) telah diiktiraf sebagai wabak global, belum ada kajian temapatan intervensi pemakanan dan gaya hidup tempatan dijalankan dalam kalangan orang dewasa Mauritus yang bekerja yang mempunyai risiko MetS. Kajian ini dibahagikan kepada 3 fasa utama seperti: (1) Pembangunan alat penyelidikan baru untuk menilai tabiat makan (2) Kajian keratan rentas dan (3) Kajian intervensi. Kajian Fasa I bertujuan membangunkan dan menilai kesahan serta kebolehulangan soal selidik kekerapan makanan (FFQ) yang baru dalam kalangan orang Mauritus. Hasil kajian menunjukkan FFQ yang baru dibangunkan telah secara sederhana dalam an menganggarpengambilan tenaga dan nutrien berbanding dengan kaedah ingatan diet. Pekali Korelasi Spearman bagi tenaga, protein, karbohidrat dan lemak masing-masing 0.75, 0.57, 0.39 dan 0.53, menunjukkan korelasi sederhana hingga baik. Plot Bland Altman menunjukkan kesepakatan yang baik (antara ± 2SP) antara FFQ yang dibangunkan dan ingatan diet 24 jam. Korelasi intra-kelas (ICC) yang digunakan untuk menilai kebolehulangan FFQ adalah 0.73 bagi tenaga dan julat antara 0.55 hingga 0.65 bagi makronutrien dan 0.31 hingga 0.69 bagi mikronutrien, oleh itu menunjukkan kebolehpercayaan sederhana hingga baik. Bagi Fasa II, prevalens MetS adalah sebanyak 24.4%. Analisis korelasi menunjukkan korelasi sederhana hingga kuat yang signifikan bagi berat badan (r=0.603, p<0.001), IJT (r=0.665, p<0.001), lemak viseral (r=0.684, p<0.001) dan RMR (r=0.463, p<0.001). Selain itu, dengan peningkatan pengambilan tenaga, terdapat hubungan yang signifikan dengan peningkatan bilangan faktor risiko metabolik (r = 0.305, p<0.001). Walaupun hubungan yang signifikan diperolehi bagi protein (r = 0.191, p = 0.011), karbohidrat (r = 0.280, p<0.001) dan lemak (r=0.179, p=0.017) dari segi pengambilan makanan, tiada hubungan yang signifikan antara aktiviti fizikal dan bilangan faktor risiko metabolik telah dikenalpasti. melalui 12 minggu intervensi pemakanan dan caragaya hidup, penemuan kajian menunjukkan perbezaan signifikan yang signifikan dari segi glukosa darah semasa puasa (p=0.001), Kolesterol HDL semasa puasa (p<0.001), Kolesterol LDL semasa puasa (p=0.041) dan nisbah kolesterol total/ HDL (p<0.001). Malah, hasil yang signifikan diperolehi bagi ukur lilit pinggang (p=0.002) dan viseral (p=0.002) dalam kumpulan intervensi. Sewaktu tempoh 3 bulan susulan, ukur lilit pinggang (p=0.008), glukosa darah semasa puasa (p<0.001) dan HDL-k (p=0.007) menunjukkan kesan signfikan melalui masa. Interaksi kumpulan masa diperhatikan untuk tekanan darah sistolik dengan p=0.004 dan kuadrat eta separa multivariat sebanyak 0.379.

Kesimpulannya, intervensi yang dijalankan adalah efektif dan kajian lebih lanjut mengenai kesan intervensi boleh dijalankan berhubungkait dengan sindrom metabolik pada populasi yang lebih besar seperti dewasa tiak bekerja atau surirumah dengan tujuan untuk mengurangi faktor factor risiko tersebut.

DEVELOPMENT OF NUTRITION AND LIFESTYLE INTERVENTION MODULES AND ITS EFFECTIVENESS AMONG WORKING ADULTS WITH METABOLIC SYNDROME IN MAURITIUS

ABSTRACT

Mauritius, officially the Republic of Mauritius is an island nation located in the Indian Ocean and forms part of sub-Saharan Africa. In this region, Mauritius is well-known for its remarkable economic history, however it is well known as its high prevalence of chronic diseases due to markedly evolution of of nutrition transition. While metabolic syndrome (MetS) has established itself as a worldwide epidemic, there is no local study on nutritional and lifestyle intervention available carried out among working Mauritian adults with risks of MetS. The study was divided into 3 major phases notably: (1) Development of new research tool to assess dietary habit (2) Cross-sectional study and (3) Interventional study. The phase I of the study aimed to develop and assessing the validity and reproducibility of a new food frequency questionnaire (FFQ) among Mauritians. The results demonstrated that the newly developed FFQ has moderately over-estimated the energy and nutrient intake as compared to the dietary recall approach. Spearman correlation coefficient for energy, protein, carbohydrate and fat were 0.75, 0.57, 0.39 and 0.53 respectively, showing moderate to good correlations. The Bland Altman plot demonstrated a good agreement (between ± 2SD) between the developed FFQ and the 24-hour dietary recalls. The intra-class correlation (ICC) used to assess the reproducibility of the FFQ was 0.73 for energy and ranged between 0.55 to 0.65 for macronutrients and 0.31 to 0.69 for micronutrients, therefore, demonstrating a moderate to good reliability. For the phase II, the prevalence of MetS was found to be 24.4%. Correlation analysis revealed significant moderate to strong correlations for weight (r=0.603, p<0.001), BMI (r=0.665, p<0.001), visceral fat (r=0.684, p<0.001) and RMR (r=0.463, p<0.001). Additionally, with increasing energy intake, there was a significant relationship to an increasing number of metabolic risk factors (r=0.305, p<0.001). While significant relationship was obtained for protein (r= 0.191, p = 0.011), carbohydrate (r =0.280, p<0.001) and fat (r =0.179, p =0.017) in terms of dietary intake, however there was no significant relationship between physical activity and the number of metabolic risk factors. . The phase III of the study involved a 12-weeks nutrition and lifestyle intervention. Through the 12-weeks nutrition and lifestyle intervention study, the findings demonstrated significant differences in terms of fasting blood glucose (p=0.001), fasting HDL-Cholesterol (p<0.001), fasting LDL-Cholesterol (p=0.041) and total cholesterol/HDL ratio (p <0.001). Furthermore, significant results were obtained for waist circumference (p=0.002) and visceral (p=0.002) in the intervention group. During the 3-months follow-up, waist circumference (p=0.008), fasting blood glucose (p<0.001) and HDL-c (p=0.007) revealed significant effects through time. A time-group interaction was observed for systolic blood pressure with p=0.004 and multivariate partial eta square of 0.379.

In conclusion, the intervention carried out was effective and further studies on the effect of intervention can be improvised in other parameters, which related to metabolic syndrome in a larger population, such as non-working adults or housewives with the aim of reducing the possible risk factors.

CHAPTER 1

INTRODUCTION

1.1 Background

Metabolic syndrome (MetS) can be described as a cluster of metabolic anomalies that intensify the risk of heart disease as well as type 2 diabetes mellitus (Wilson et al., 2005). The disease is also associated with kidney disease and elevated risk for mortality from cardiovascular disease (Chen et al., 2004). This cardiometabolic risk group encompasses elevated fasting plasma glucose, hypertension, elevated triglycerides (TGs), reduced high-density lipoprotein cholesterol (HDL-c), along with increased waist circumference (WC) (Huffman et al., 2014). MetS affects individuals bearing and excess weight and whose trends in sedentary lifestyle define the phenotypical expression of a trait, which has been genetically acquired (Grave et al., 2010). The incidence of MetS in various countries hinges on the defining criteria and in some cases the same has been adjected for waist-circumference with relevance to each population cut-off (Johari & Shahar 2014).

The prevalence of metabolic syndrome is on the rise worldwide and the incidence of 36.3% has been reported in the Mauritian population accounting for 35.1% in women and 37.5% in men (The Mauritius Non Communicable disease survey, 2009). Motillo et al. (2010) reported that the presence of MetS doubles the risk of cardiovascular diseases and also people with MetS are five times more predisposed of having diabetes mellitus. The incidence of this syndrome is increasing alarmingly, chiefly due to the cumulative occurrence of obesity and sedentary lifestyles, being currently a significant public health problem (Alberti et al., 2009).

With metabolic syndrome leading the twin global epidemics which are type 2 diabetes mellitus and cardiovascular diseases, there is an overpowering moral, medical and economic need to detect those individuals with metabolic syndrome at an early stage to provide lifestyle interventions and treatment which may prevent the development of the latter diseases (IDF, 2006). Appropriate alteration in lifestyle geared towards diet and physical activity, is documented as being instrumental and essential in reducing the prevalence of MetS (National Institute of Health Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults, 2001; Grundy et al., 2004; Klein et al., 2004; Yoo et al., 2012). The link between dietary habits and the risk of metabolic syndrome has been explored by several groups of researchers (Azadbakht et al., 2005; Elwood et al., 2007; Esmaillzadeh et al., 2006; Lutsey et al., 2008; Panagiotakos et al., 2007; Ruidavets et al., 2007; Snijder et al., 2007; Wirfält 2001; Shin et al., 2009).

Fappa et al. (2012), hypothesized that aiming at less goals specifically those that encourage an increase in the consumption of healthy foods, instead of targeting at the application of all recommended modifications, including the exclusion of unhealthy foods and/or the reduction of portion sizes; would be a good approach to manage metabolic syndrome. Despite in-depth investigation in terms of the role carried out by specific nutrients and dietary components (Ness and Powles, 1997; Snijder et al, 2008), establishing an association between overall dietary pattern and health outcomes requires more stringent and detailed research (Julia et al., 2010).

As per current guidelines, it is judicious to support individuals with MetS in the premorbid state in adopting lifestyle modifications encompassing behavioural changes such as increase in physical activity as well as engaging in appropriate dietary management (Lo et al., 2015). Hence, the recognition of the main predicting factors of health behavior, within a theoretical framework, can offer information valuable for health services. The Health Belief Model (HBM) is one of the mostly universally used models in health-related studies that rationalize and predict health behavior (Lo et al., 2015).

1.2 Rationales

In the past 50 years, the world has been victim of the increasing incidence of obesity, which unfortunately has attained pandemic proportions in the last decade (Blüher., 2019). The multi-ethnic Republic of Mauritius has experienced rapid industrialisation over the past decades and this has brought about a rise in the standard of living (Mauritius Non Communicable Disease Survey, 2015).

In the sub-Saharan area, Mauritius is distinguished for its notable economic history but is infamous for its high prevalence of chronic diseases subsequent to the period of nutrition transition. Before the 1970s to 1980s, Mauritius was a low-income and agricultural-centered economy (Luximon and Nowbuth, 2010). Following the later period, the island had experienced a crucial economic growth which coupled with globalization has brought about a decline in food prices and better ease of access to food (Schmidhuber and Shetty, 2005). This shift has also given rise to the famous nutrition transition period, which is emphasized, on a change from nutrient-dense and low-calorie foods to energy-dense and fat-loaded processed foods along with increased consumption of animal products (Schmidhuber and Shetty, 2005). The rise in non-communicable disease has been favored with the evolution of labor-intensive jobs to comparatively more sedentary jobs embracing unhealthy lifestyles (Bhurosy and Jeewon, 2014). Numerous studies on diabetes mellitus along with other NCDs has been carried out in Mauritius contributing to scientific comprehension of the underlying causes of NCDs, which has spawned various health initiatives like the founding of the NCD and Health Promotion Unit (Mauritius Non-Communicable Disease Survey, 2015). Nonetheless, the continuous rise in the prevalence of NCDs is alarming for the whole Mauritian nation.

Metabolic syndrome has established itself as a worldwide epidemic and it is estimated that 25% of the world adult population is victim of such syndrome (Grundy, 2008). It has been reported that there is an elevated cardiovascular risk among diagnosed individuals at risks of MetS, and it most of the time due to the existence or increased risk of type II DM (Barazzoni et al., 2013).

1.3 Significance of Study

The mounting upsurge in lifestyle-related health complications has contributed to a shift from treatment-and-prescription centric (reactive) healthcare system to a patient-centric (proactive) system which is founded on promotion of healthy behavior (Orji et al., 2012). As a matter of fact, the current study consists of an intervention programme designed for MetS and its findings will contribute to improve significantly the Quality of Life of the Mauritian population as well as decreasing the financial burden of the country. The results of the study will help to increase knowledge and comprehension linked to the associated factors of metabolic syndrome. In addition, gaps were identified and further recommendations can be acknowledged in developing and strengthening intervention programmes geared towards the management of MetS. The strength of this research is a noteworthy approach in examining the efficacy of a group-based nutrition and lifestyle intervention. Modules were developed for the intervention study and their contents were geared towards promoting physical activity, enhancing diet quality for reducing obesity and improving cardio metabolic risk factors in a sample of Mauritians with risk of MetS. Up to date, development of such modules as part of an intervention study has not been done in Mauritius.

1.4 Research Objectives

1.4.1 General objective:

To assess the effectiveness of a nutrition and lifestyle intervention on working Mauritian individuals with metabolic syndrome.

1.4.2 Specific objectives:

i. To develop, validate and determine reproducibility of a food frequency questionnaire (FFQ) designed for the Mauritian adults. .
ii. To determine the prevalence of MetS among working adults in Mauritius.
iii. To assess the difference in terms of anthropometric and body composition, biochemical and clinical parameters, dietary intake and physical activity level between subjects with MetS and without MetS in Mauritius.
iv. To measure the difference between the Intervention Group (IG) and the Control Group (CG) in terms of anthropometry and body composition following 12-weeks intervention.
v. To determine the change in anthropometric, blood pressure and biochemical markers after 3-months follow-up in the intervention Group (IG) and the Control Group (CG).
vi. To measure the time and group effect across 3 different time-lines

1.5 Research questions

i. What is the prevalence of MetS among working adults in Mauritius?
ii. Is there any differences in terms of anthropometric and body composition, biochemical and clinical parameters, dietary intake and physical activity level between subjects with MetS and without MetS in Mauritius.
iii. Is there any difference between the Intervention Group (IG) and the Control Group (CG) in terms of anthropometry and body composition following 12-weeks intervention?
iv. Is there a change in anthropometric, blood pressure and biochemical markers after 3-months follow-up in the intervention Group (IG) and the Control Group (CG)?
v. Is there any time-group interaction across the 3 different time –lines?

1.6 Hypothesis

i. Hα: There is significant differences in terms of anthropometric and body composition, biochemical and clinical parameters, dietary intake and physical activity level between subjects with MetS and without MetS in Mauritius.
ii. Hα: There is significant difference between the Intervention Group (IG) and the Control Group (CG) in terms of dietary intake following 12-weeks intervention
iii. Hα: Nutrition Education can improve metabolic risk factors following 12-week intervention.

1.7 Conceptual framework

Figure 1.1 is a schematic representation of the overall concept of the study. The grounds of metabolic syndrome are complex and believed to involve metabolic, hormonal, genetic and lifestyle interactions. Various components contribute to the cardio metabolic risk factors for metabolic syndrome. It is important to note that genetic factors are a predisposition to a particular ailment while lifestyle factors determine whether and how early the disease will develop. Barriers to leading a healthy life might be in the form of poor nutritional knowledge, lack of skills, negative attitudes as well as absence of opportunities in terms of participation in exercise, sports and traditional games. Unbefitting food environment and lack of physical activity affects energy balance promoting abdominal adiposity, which is linked to reduce serum adiponectin. Additionally, an increase in abdominal adiposity contributes to insulin resistance, dyslipidaemia as well as to a dysregulation in the hypothalamic pituitary axis. The mentioned cardio metabolic risk factors for MetS subsequently predispose an individual to diabetes mellitus and cardiovascular disease.

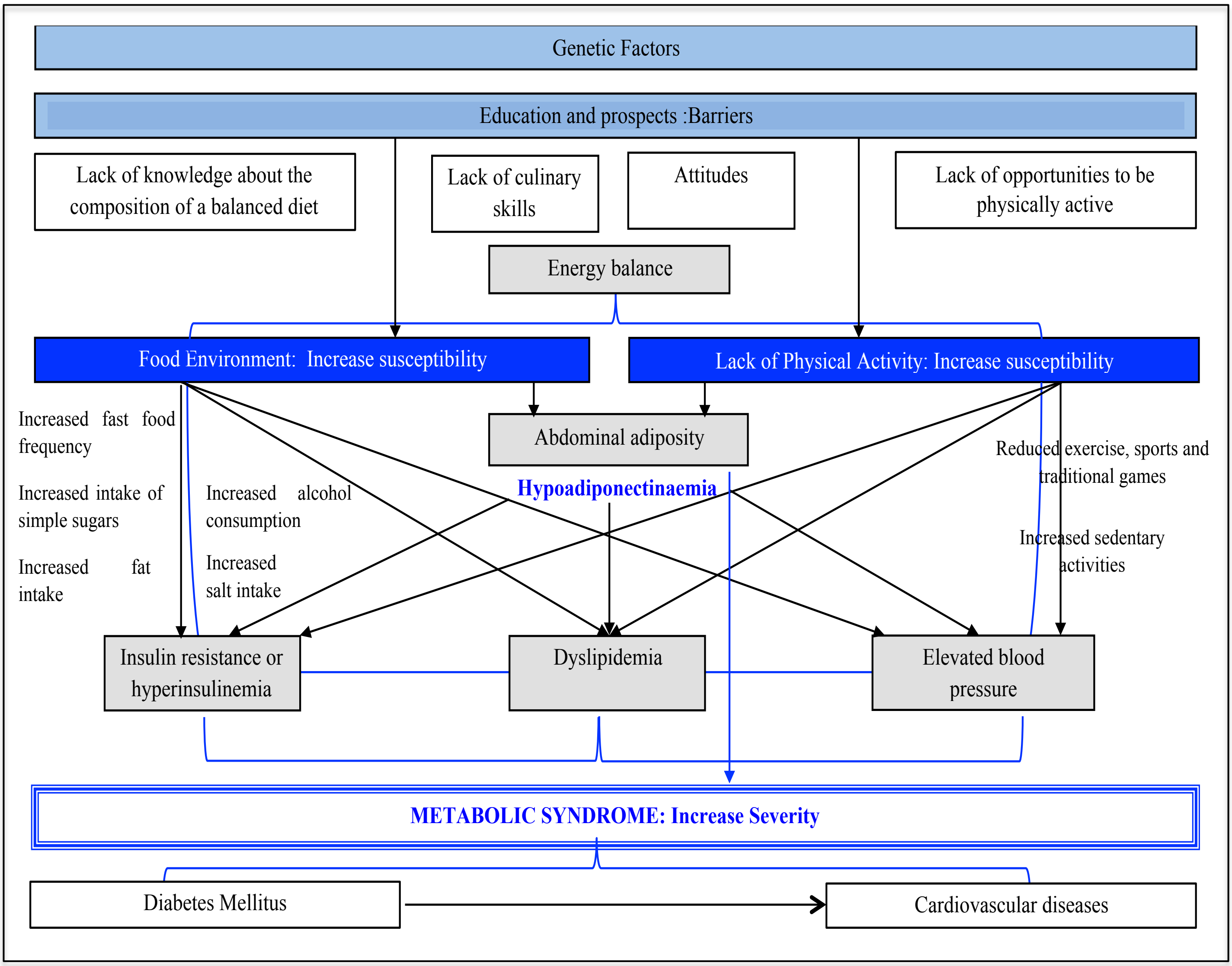

Figure 1.1 Conceptual framework for metabolic syndrome

1.8 Operational Definitions

Abdominal adiposity – also known as central obesity, is the excessive amount of fat accumulated around the stomach and the abdomen.

Balanced diet – a diet that is qualitatively and quantitatively adequate to maintain good health.

Barriers – complications or the hindrances associated with a positive behavior.

Behavioural change – refers to an extensive variety of activities and approaches, which emphasise on the individual, community, and environmental influences on behaviour.

Cardio metabolic risk – refers to a high lifetime risk for cardiovascular disease (CVD).

Insulin resistance – The reduced capacity of cells to react to the action of insulin in transporting glucose from the bloodstream into muscle and other tissues.

High-density lipoproteins (HDL) – A complex of lipids and proteins that acts as a transporter of cholesterol in the blood and which, in high concentrations, is related with a reduced risk of atherosclerosis and coronary heart disease

Low-density lipoproteins (LDL) – Low-density lipoprotein definition, a plasma protein that is the major transporter of cholesterol in the blood: high levels are related with atherosclerosis.

Triglycerides (TG) – it an ester formed from glycerol and three fatty acid groups.

CHAPTER 2

LITERATURE REVIEW

2.1 Metabolic Syndrome

2.1.1 Origins and definitions of metabolic syndrome

In the 1920s, Kylin portrayed the group of metabolic disturbances, which in our era is referred to as metabolic syndrome (MetS), like a cluster comprising of hypertension, hyperglycaemia and gout (Alberti et al. 2006). However, around two decades later, it was reported that android obesity was most commonly attributed to the incidence of metabolic abnormalities observed in diabetes and cardiovascular diseases (Alberti et al. 2006). Recently, there have been several working definitions being established for metabolic syndrome.

Consequently the International Diabetes Federation gathered experts (World Health Organisation, the European Group for the Study of Insulin Resistance (EGIR), and NCEP ATP III) around the world in a workshop to formulate a new acceptable definition for MetS (IDF, 2005). Initially, the International Diabetes Federation (IDF) workshop argued the fact of whether MetS can be defined as being a syndrome in itself as the latter term is described as being a distinguishable group of symptoms and physical or biochemical findings for which the immediate causes are poorly comprehended (Alberti et al. 2006). Even though there was variation in the clinical criteria, all experts agreed on the core components of MetS, which are: obesity, dyslipidemia, hypertension and insulin resistance (IDF, 2005).

Yet, until recently there has been no unified definition regarding the criteria for the diagnosis of MetS among adolescents and children though it is obvious that each element of the syndrome must be scrutinized to prevent ultimate lesions (Mancini, 2009). Based on similar definition utilized for the adult population, a consensus definition has been agreed upon as a tool which will be easy to use for the diagnosis of MetS in the young population so that preventive actions can be undertaken, before the child develops diseases like diabetes and cardiovascular diseases (IDF, 2007).

Nevertheless, the definition being used for the adult population cannot directly be transposed on children as with age and physiological development there will be significant variations in terms of blood pressure, lipids level and body composition (IDF, 2007). In addition, with the advent of puberty, there is rapid and vigorous changes within the metabolic systems coupled with hormonal changes, hence bringing about alterations in body fat and distribution along with increased insulin resistance (Kelly et al., 2011). Consequently, utilisation of single cut- offs is not deemed as appropriate in children, thereby acknowledging the use of percentiles to compensate differences in child development and ethnicity instead of waist circumference, which is usually used for adults (IDF 2007). Table 2.1 depicts the most commonly used criteria for MetS in adults including that of IDF. The worldwide definition as proposed by the IDF will not only provide room for comparison in terms of prevalence of the syndrome in different populations but also allow appraisal in terms of its relationships with various health outcomes (Alberti et al., al., 2006).

Table 2.1 Definitions of Metabolic syndrome

	IDF (2009)	NCEP ATP III (2001)	EGIR (1999)	WHO 1999
	3 or more of the following risk factors	3 or more of the following five risk factors:	Insulin resistance Plus 2 of the following	Diabetes, IFG, IGT or Insulin resistance Plus any 2 of the following
Fasting plasma glucose	Impaired fasting glycemia(≥5.6mmol/) or diagnosed type 2 diabetes	≥ 5.6mmol/l	≥ 6.1mmol/l (110 mg/ dl) but non-diabetic	
Obesity	Men: WC ≥ 90cm Women: WC ≥ 80cm	Men: WC > 102 cm Women: WC > 88 cm	Men: WC ≥ 94cm Women: WC ≥ 80cm	Central obesity *Women:* WHR > 0.85 *Men:* WHR > 0.9 *and/or* BMI > 30
Blood pressure	≥ 130/85mmHg *and/or* treatment	≥ 130/85mmHg *and/or* drug treatment	≥ 140/90mmHg or treatment	≥ 140/90mmHg
Triglycerides	≥1.7mmol/l or specific treatment	≥1.7mmol/l	>2.0mmol/l or treatment	≥1.7mmol/l (150mg/dl) and/or treatment
HDL-cholesterol	Men: <1.03 mmol/l women: <1.29 mmol/l or specific treatment	Men:<1.03mmol/l Women:<1.29mmol/l		Men: < 0.9mmol/l Women: <1.0mmol/l

WHO: World Health Organisation (WHO, 1999), EGIR: European Group for the study of Insulin Resistance (Balkau & Charles 1999), NCEP: National Cholesterol Education Programme (Grundy et al., 2005), IDF: International Diabetic Federation(Alberti et al., 2009), IGT: Impaired Glucose Tolerance, IFG: Impaired Fasting Glucose, WC: Waist Circumference, WHR: Waist Hip Ratio, HDL: High Density Lipoprotein

2.1.2 Prevalence of metabolic syndrome

Recent studies have reported an increase in the prevalence of metabolic syndrome owing to epidemiological transition, urbanisation and alterations in lifestyle (Misra and Khurana, 2008). The urbanisation factor leads to higher intake of energy-dense processed foods, reduction in physical activity, alcohol and substance abuse in the sub-Saharan African region (Assah et al., 2011). Demographic transition has resulted in a shift towards a higher incidence of ageing population contributing to increase in the prevalence of metabolic syndrome (Admassie et al., 2017). A recent study carried out among working adults in Eastern Ethiopia revealed a prevalence of 20.1% among its participants based on the IDF criteria (Motuma et al., 2020). The latter study observed a significantly higher prevalence among female individuals, those in the age group of 35– 44 years, 45-54 years, and 55-64 years and those with daily sedentary behavior exceeding more than 8 hours.

In Brazil, a study carried out to determine the prevalence of MetS among workers of a Company of Generation and Distribution of Energy in Rio de Janeiro city, found the prevalence of the syndrome to be as high as 48.6% as per the IDF criteria (Chini et al., 2014). The study demonstrated that the prevalence increased accordingly with age reaching a prevalence of 58.7% in individuals more than 60 years of age. Another study carried out among Taiwanese Hospital workers, demonstrated an overall prevalence of 12% in the sample population, according to the American Heart Association /National Heart, Lung, and Blood Institute criteria (Yeh et al., 2018).

In Malaysia, a study carried out by Chee et al. (2014) showed that the prevalence of MetS among government employees was 48.9%. In the same region of the world, another study revealed an overall prevalence of 20.6% among staffs in a

Malaysian public university using the JIS Harmonised criteria (Manaf et al., 2021). The latter study reported a higher prevalence among male individuals (24.9%) as compared to female (18.3%). The incidence of MetS was attributed to factors such as BMI, elevated blood pressure, and diabetes and moderate physical activity level.

2.2 Risk factors for MetS

2.2.1 Body fat distribution and abdominal obesity

The everlasting epidemic of obesity across all age groups has accentuated the importance of body fat in both short term and long term health (Reilly et al., 2003). There are several factors which are associated with obesity namely diet, physical activity level, and environmental factors. The aggregate calorie intake of an individual has been reported to contribute to obesity. The increasing incidence of obesity is understood to be an outcome of the excessive consumption of sweetened beverages or energy-dense, big-portion, and fast food meals.

Visceral adipose tissue thickness is related with the risk of CVD (Alexopoulos et al., 2014) of which metabolic syndrome is a risk factor (Motillo et al., 2010 & Gami et al., 2007). Body fat distribution can be evaluated by various equipment, such as computed tomography (CT) and magnetic resonance imaging (MRI), which are accurate and directly gauge the amount of visceral fat while however being high-cost methods whereby extensive training of evaluators are required as well as the exposure to radiation in the case of CT (Goran & Gower 1999). Bioelectric impedance analysis (BIA) is a modest method of assessing percentage body fat, is less accurate in contrast to the gold standard methods comprising of DEXA (Newton et al. 2005).

In large epidemiological studies, anthropometric indices like body mass index (BMI), waist circumference and waist-to-hip ratio (WHR) are commonly employed with BMI being utilized for overall adiposity while waist circumference and waist-to-hip ratio for abdominal adiposity (Cheong et al., 2015). Waist circumference is extensively accepted as a proxy marker for visceral adipose tissue (Kawada et al., 2015) and allegedly superior than BMI in terms of intra-abdominal adiposity (Klein et al., 2007).

There exist two major types of adipose tissue compartments being subcutaneous adipose tissue and visceral adipose tissue (Ackerman et al., 2011). The adipose tissue is generally recognized as being an active endocrine organ which secretes numerous adipokines (Trayhurn & Wood., 2004) such as as leptin, the inflammatory cytokines tumor necrosis factor α (TNF-α) and interleukin-6 (IL-6), plasminogen activator inhibitor 1, resistin, and angiotensinogen in addition to the anti-inflammatory cytokine adiponectin (Scherer, 2006). Fantuzzi (2005) and Schrager et al. (2007) mentioned that there is mounting evidence showing that abdominal obesity is linked with an upregulation of interleukin-6 and tumour necrosis factor-α which are both proinflammatory cytokines. The latter contribute to a decrease in muscle mass and muscle strength hence demonstrating a link in terms of abdominal obesity leading to sarcopenia in the long run (Cesari et al., 2005 and Stenholm et al., 2008).

It has been reported in various studies that there is disparity in terms anthropometric measures in forecasting cardiometabolic risks and that it might vary across gender (Wang et al., 2009), ethnicity (Camhi et al., 2011) as well as age (Cheng et al., 2010). Since there is a significant difference in terms of waist circumference cut-offs across individuals of different ethnicity, it is inappropriate to utilize only a specific cut-offs for the whole population around the globe in order to determine cardio- and cerebro-vascular health risk linked with obesity (WHO Expert Consultation 2004, Balkau et al. 2007 and Herrera et al., 2009). For instance, as compared to the western population, the Asian population requires a lower cut-off for both BMI and WC to determine obesity and abdominal obesity respectively (Tan et al., 2004).

Table 2.2 Ethnic specific values for waist circumference

Country/Ethnic group		Waist Circumference
Europids	Male Female	≥ 94cm ≥ 80cm
South Asians Based on a chinese, Malay and Asian-Indian population	Male Female	≥ 90cm ≥ 80cm
Chinese	Male Female	≥ 90cm ≥ 80cm
Japanese	Male Female	≥ 90cm ≥ 80cm
Ethnic South and Central Americans	Use South Asia recommendations until more specific data are available	
Sub-Saharan Africans	Use European data until more specific data are available.	
Eastern Mediterranean and Middle East (Arab Populations	Use European data until more specific data are available	

2.2.2 Insulin Resistance

Insulin is the principal anabolic endocrine signal, and it has an important role in carbohydrate, lipid, and protein metabolism (Baumgard, et al., 2016). Insulin is exclusively produced by β-cells in the pancreatic islets of Langerhans where along with α and δ cells; involved in glucagon and somatostatin secretion, respectively (Baumgard et al., 2016). Insulin resistance can be referred to the state whereby a particular concentration of insulin being released produces a lower biological response than anticipated and it is understood to be a common pathological foundation for MetS (Chang et al., 2011 & Guinhouya et al., 2011, cited in Wang et al, 2015). A close relationship has been established between obesity, increased inflammation, insulin resistance and cardiovascular disease with free fatty acids (FFAs) being part of this mechanistic rationalization (Boden 2008, cited in Ormseth et al., 2011). FFAs consist of carbon chains with a methyl group at one end of the molecule and a carboxyl group at the other end.

Individuals afflicted with insulin resistance suffers from impaired glucose tolerance or metabolism with abnormal response to glucose which can be in the form of hyperglcaemia and/or apparent hypoglycaemia, or a decrease in the production of insulin efficacy following intravenous administration of the hormone resulting in reduced insulin-mediated glucose clearance (Kaur, 2014). On the other side of the coin, to be insulin sensitive, a individual needs to be of normal body weight (Bravata et al., 2004) without the presence of abdominal or visceral adiposity (Carey et al., 1996), is moderately active as well as adopting a diet is low in saturated fats (Vessby et al., 2001).

Insulin resistance along with MetS and atherogenicity are positively associated with an elevated risk of non-insulin dependent diabetes mellitus (NIDDM) and CVDs (Jamshidi et al., 2014). Insulin resistance is conceivably partially produced by prolonged lipid overload in skeletal muscle, chiefly caused by longchain acyl-CoAs, diacylglycerols (DAG) and ceramides (Coen & Goopaster, 2012; Golay&Ybarra, 2005).

2.2.3 Dyslipidaemia

In the skeletal muscle, lipids are stored as triacylglycerols (TAG) in lipid droplets and are commonly named intramuscular triacylglycerol (IMTG) which are utilized as a source of energy by healthy individuals as and when required e.g. during exercise (Blaak, 2003 & van Loon & Goopaster, 2006). There are proofs that increased IMTG is related with greater levels of lipotoxic intermediates such as DAG and ceramides that might hinder insulin signalling (Kelley et al., 2002).

Having a clear-cut comprehension of mechanisms of lipoprotein metabolism is essentially and clinically important as lipoproteins are risks factors for atherosclerosis (Ramasamy, 2016). Dyslipidemia is described as a gamut of qualitative lipid abnormalities replicating changes in the structure, biological activity and metabolism in atherogenic lipoproteins and antiatherogenic HDL-C, comprising of an increase of lipoproteins containing apolipoprotein B (ApoB), elevated TGs, increased levels of small particles of LDL, and low levels of HDL-C (Kaur, 2014). Latest statistics has shown that obesity along with the adverse health consequences related with it, predominantly Type II diabetes mellitus and metabolic syndrome are normally associated with a disparity in lipid profile (Rahimlou, 2016). Franssen et al (2011) reported that metabolic dysplidimia regarded as one of the most common abnormalities of obesity with the former being attributed to an increased triglyceride levels while however a decreased High-Density Lipoproteins (HDL) levels.

2.2.4 Hypertension

Hypertension, which is commonly defined as a persistent resting systolic/diastolic blood pressure ≥140/90 mmHg, has attained epidemic proportions round the globe (Moliner-Urdiales, 2014). Hypertension is an established component of metabolic syndrome (Yadav et al., 2014). Blood pressure levels are intensely linked with visceral obesity along with insulin resistance (Ferrannini, 2002), which are the salient pathophysiologic features of MetS. Adipose tissue which a major endocrine organs secrete a range of bioactive components such as adipocytokines whose secrete gets subsequently altered with the development of obesity resulting in metabolic disorders (Yanai, 2008). The accumulated adipose tissue produces and secretes a series of adipocytokines like leptin, tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), angiotensinogen, and non-esterified fatty acids (NEFA), which promote the development of hypertension (Katagiri 2007). The Renin Angiotensin System (RAS) produces angiotensin II (Ang II) from angiotensin I (Ang I) and angiotensinogen (AGT) with the help of renin and angiotensin-converting enzyme (ACE) (Frigolet et al., 2013). Recent studies have reported that the adipose tissue of rodents as well as that of rodents bears all the components of RAS (Frigolet et al., 2013). Human visceral adipose tissue constantly displays appreciably higher AGT mRNA in comparison with subcutaneous adipose tissue (Giachetti et al., 2000). Adipocyte dysfunction, which is still a topic of great debate among scientists (Frigolet et al., 2013) had been linked with increased pro-atherogenic, pro-diabetic and pro-inflammatory hormone secretion along with a reduction in adiponectin release (Hajer et al., 2008).

2.3 Other factors associated with MetS

2.3.1 Age

Even though metabolic risk factors is related a genetic component (Desai et al., 2015), it is agreed up that the prevailing increased prevalence in the majority of developed countries is owing to a significantly augmented exposure to metabolic insults that has a minimum of two major foundations notably an obesogenic environment and an aging population (Danaei et al., 2011; Yousefzadeh& Sheikhvatan 2015). In the latter populace, the gradual occurrence of metabolic disorders can happen because of extended lifespans.

There is an established relationship between central obesity and its associated consequences among the elderly. The occurrence of insulin resistance is expected to be one of the most significant risk factors for metabolic diseases in the geriatric population (Suastika et al. 2011). Insulin resistance develops as a result of decrease in lean body mass with an increase in body fat, most specifically visceral fat that occurs as part of the ageing process. A study carried out by Suastika et al. (2011) reported that individuals who were more than 60 years old were at 1.4 times more at risk of developing MetS. Another study carried out by Cornier et al. (2008) noted that, there was a higher prevalence of metabolic syndrome among adults over the age of 65 years.

2.3.2 Stress

While the link between physiological mechanisms connecting obesity, cardio-metabolic risk factors, diabetes, and CVD have been established through many studies, very little in known on the effect of psychological factors (Gowey et al., 2019). An increase in the level of perceived stress and depressive symptoms have been associated with excess body weight along with metabolic risk factors. (Bergmann et al., 2014).

An extended exposure to work stress may distress the autonomic nervous system and neuroendocrine activity, leading to the development of MetS (Chandola et al., 2006). In a case-control study carried out by Brunner et al. (2006), participants with the metabolic syndrome exhibited an elevated raised cortisol and normetanephrine output with a diminished variability in heart rate. Additionally, a reduction in cardiac autonomic capacity has been associated to the metabolic syndrome. Rubin (2004) has stated that psychobiological studies have demonstrated that that amplified stress reactivity and compromised recovery following a period of stress, as evaluated by blood pressure and inflammatory markers, predict metabolic syndrome on a five-year progression.

2.3.3 Physical inactivity

Physical inactivity, commonly defined as the absence of moderate-to-vigorous physical activity, and sedentary behavior (Wijndaele et al., 2009) have been acknowledged as being important risk factors of metabolic syndrome (Bankoski, 2011). In previous studies carried out on MetS, physical activity data obtained from accelerometer has depicted that physical inactivity is linked with metabolic risk factors in adults (Park et al., 2008). Nonetheless, panoply of studies focused more on risk linked with lack of physical activity instead of sedentary time (Bankoski, 2011). Sedentary behavior is characterised as being involved in activities at the resting level of energy expenditure and comprises of activities such as sleeping, sitting, lying down, playing on the computer, besides watching television (Pate et al., 2008).

2.4 IDF Recommendations for treatment of MetS

With the aim of reducing the risk of acquiring CVD and type 2 diabetes, assertive and inflexible management of the condition upon diagnosis (IDF, 2006). A complete cardiovascular risk assessment in conjunction with primary and secondary form of intervention is important.

2.4.1 Primary intervention for MetS

The IDF (2015) endorses that primary management for the metabolic syndrome is healthy lifestyle promotion comprising of the following:

1. A moderate calorie restriction to achieve a 5-10 % loss of body weight in the first year
2. A change in dietary composition
3. A moderate increase in physical activity

2.4.2 Secondary Intervention

Drug therapy is considered in individuals who are at high risk of CVD and for whom lifestyle therapy has deemed of not being adequate. Though there is an explicit need to find a treatment the could regulate the mechanisms of MetS as a whole, which in turn would have lessen the impact associated with all the risk factors along with the long term metabolic and cardiovascular risk factors; it is unfortunate that such mechanisms are currently unidentified and that the specific pharmacological agents are hence not yet accessible. It is therefore compulsory at present to teat the individual factors of MetS so that the individual risk linked with each component will diminish the overall consequences on CVD and DM risk.

2.5 Management of underlying risks conditions

The principal conditions that stimulate the development of MetS as well as Diabetes Mellitus comprise of overweight and obesity, physical inactivity and being on an atherogenic diet. Dalle Grave et al. (2010) indicated lifestyle modification as being the first line therapy to impede and manage MetS. The most significant therapeutic intervention efficient in individuals with MetS should focus on indulgent weight reduction and regular leisure-time physical activities (Gundy et al., 2004).

2.5.1 Weight Reduction

Obesity is known to be the chief predisposing component for MetS, but its relationship to insulin resistance is poorly understood since not all individuals with MetS are obese (Ruderman, 1998) and not all obese individuals develop insulin resistance (Sims, 2001). Després et al. (2008) formerly suggested that visceral obesity may denote a clinical intermediate phenotype demonstrating the virtual incapacity of subcutaneous adipose tissue to serve as a protective metabolic sink for the clearance and storage of the extra energy obtained from dietary triglycerides, resulting in ectopic fat accumulation in visceral adipose depots, skeletal muscle, liver, heart, etc.

Weight loss promoted by diet and exercise is stereotypically suggested as therapy for obese individuals afflicted with metabolic disease (Shah et al. 2009). Case (2002) reported that even a moderate weight loss accounting for 7 % reduction within a period of 4 weeks can improve metabolic parameters, though a high BMI persists. A realistic goal in terms of weight loss is to decrease body weight by 7 to 10% throughout a duration of 6 to 12 months .

2.5.2 Physical activity

In the management of Metabolic Syndrome, physical activity has a crucial role (Dalle Grave, 2010). Physical activity can be defined as any movement that necessitates skeletal muscles and consequently increases energy expenditure over resting metabolic rate (Sigal et al., 2004). Elevated levels of physical activity and cardiorespiratory fitness have been related to a reduced risk of developing metabolic syndrome (Laaksonen et al., 2002; Ekelund et al., 2005; LaMonte 2005 & Carnethon et al 2003). Cross-sectional studies have confirmed an inverse association between regular physical activity and the serum concentration of inflammatory markers (Mackie & Zafari, 2006). There is mounting evidence showing that inflammation and oxidative stress not only contribute to the atherosclerotic pathway (Ross 1999 & Alexander 1994) but also are complexly involved in the progress of other chronic conditions, such as hypertension, diabetes, metabolic syndrome, cancer, and Alzheimer’s disease. Based on epidemiological studies, there is evidence showing that regular physical activity hinders type 2 diabetes, cardiovascular disease along with premature mortality (Lakka & Laaksoonen, 2007).

The intensity of physical activity appropriate to improve metabolic profile is not defined (Gave-Dalle et al., 2010). In a study carried out by Dumortier (2003), it was reported that low-intensity exercise training for 2 months improved metabolic parameters. The latter author also stated that brisk walking for at least 30 min daily can be suggested as the major form of physical activity at the population level and in the event that there are no contraindications, more vigorous physical exercise or resistance training should be taken into consideration to gain further health benefits.

2.5.3 Dietary patterns in treatment of MetS

Increasing scientific evidence has mushroomed showing that health can be protected with diets which are adequate in fruits, vegetables, legumes, whole grains as well as comprising of fish, nuts and low-fat dairy products (Pitsavos et al., 2006). In MetS, dietary habits as one of the environmental factors have been recognized as being important in the prevention and treatment of this condition (Feldeisen & Tucker, 2007). However, the link between the metabolic syndrome and dietary patterns has not been fully clarified, while a high-fat diet, which leads to obesity and dyslipidemia, is a commonly accepted risk factor for metabolic syndrome (Lottenberg et al., 2012).

The Mediterranean Dietary Pattern (MDP) has acquired significant popularity concerning its seeming protecting effect against MetS (Calton et al., 2014). This pattern comprise of a diet rich in monounsaturated fatty acids (MUFA) from olives and olive oil; quotidian intake of whole grain cereals, fruits, vegetables, and dairy; and weekly intakes of fish, poultry, nuts, and legumes (Calton et al., 2014). Based on a meta-analysis of 50 studies carried out by Kastorini et al.(2011), it was reported