UNIVERSITI PUTRA MALAYSIA

DIETARY PATTERNS AND THEIR ASSOCIATION WITH OBESITY AND CARDIOMETABOLIC RISK FACTORS AMONG ADOLESCENTS IN THE SOUTHERN REGION OF PENINSULAR MALAYSIA

NOR AISHAH BINTI EMI

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By

NOR AISHAH BINTI EMI

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Chair : Geeta Appannah, PhD
Faculty : Medicine and Health Sciences

While the importance of high intake of energy dense foods for the development of cardiovascular disease (CVD) has been emphasised recently in the Western countries, this was not fully elucidated among Malaysian adolescents. Diet is a modifiable risk factor for CVD in adulthood and is therefore, likely to also be an important early CVD risk factor in adolescence. This cross-sectional study aimed to examine the associations between adolescents' dietary pattern (DP) and cardiometabolic risk factors (CRF) and obesity. DP offers a new approach in nutritional epidemiology as compared to single nutrient or food groups which is more practical to be translated into recommended advice for use among adolescents. Reduced Rank Regression (RRR) used to derive DP in this study is a hybrid method which combines both exploratory and hypothesis-oriented approach simultaneously. CRF is referred to any risk factor which may increased the odds of developing CVD and diabetes mellitus. CRF assessed in this study are abnormal biochemical levels including fasting blood glucose, serum insulin and lipid profile as well as the presence of dyslipideamia. Obesity which is one of the major CRF is catagorised separately from CRF in this study in order to examine its independent association with identified DP.

A total of 933 adolescents aged 13 years old from three southern states in peninsular Malaysia, namely Negeri Sembilan, Melaka and Johor agreed to participate in this study. Anthropometric measurements including weight (kg), height (m) and WC (cm) of adolescents were measured, and BMI z-score was calculated according to the 2006 World Health Organisation (WHO) BMI-for-age growth standards. Biochemical data of 507 adolescents were measured. Self-reported physical activity and socio demographic information were collected from the study adolescents and their parents.

Five hundrends and eighty three adolescents provided valid dietary information assessed using a validated food frequency questionnaire (FFQ). The RRR was used to identify a DP that explained the most variation in four chosen response variables, namely dietary energy density, fibre density, percentage of energy from total fat and percentage of energy from sugar. The response variables chosen in this study are hypothesized to be associated with CRF and obesity based on prior scientific evidence from previous studies in Western countries. The identified 'high sugar, high fibre, high energy density and low fat' DP, which explained 35% of the variation in all response variables was characterised by high intakes of sugar-sweetened beverages, fruits, sweets and low intakes of meat and meat-based dishes, and cereal and cereal-based dishes. The associations were examined using regression models between DP and cardiometabolic risk factors adjusted for sex, school location, mother's educational level, dietary misreporting, physical activity and BMI. There was a 0.124 mmol/L (95%CI: 0.002, 0.086) increase in the adolescent's triglycerides level for every 1 unit SD increase in the identified DP z-score. Adolescents with higher adherence to the identified DP had three times higher odds of having dyslipidaemia (OR=2.68; 95%CI: 1.290, 5.565), elevated total cholesterol (OR=2.68; 95%CI: 1.290, 5.565) and abnormal LDL-C level (OR=3.01; 95%CI: 1.553, 5.189) compared to adolescents with lower adherence to this DP. Female and male adolescents in the third tertile of the DP had significantly three times higher odds of having elevated LDL-C (OR=2.48; 95%CI: 1.16, 5.31) and 28 times higher odds of having elevated serum insulin (OR=27.55; 95%CI: 1.171, 648.263) compared to their counterparts in the first tertile of the DP, respectively. There was no significant association reported between identified DP and obesity among this study adolescents.

A DP high in free sugar but not fat was associated with increased risk of having dyslipidaemia, and abnormal levels of triglycerides, total cholesterol and LDL-C among study adolescents. Further longitudinal study are recommended to investigate the association between Malaysian adolescents' diet and cardiometabolic risk factors, to prevent reverse causality. Identification of early dietary behaviours among adolescents might offer valuable information for prevention strategies of cardiometabolic risk development in later life.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

CORAK PEMAKANAN DAN HUBUNGANNYA DENGAN KEGEMUKAN DAN FAKTOR RISIKO KARDIOMETABOLIK DALAM KALANGAN REMAJA DI SELATAN SEMENANJUNG MALAYSIA

Oleh

NOR AISHAH BINTI EMI

Julai 2019

Pengerusi : Geeta Appannah, PhD
Fakulti : Perubatan dan Sains Kesihatan

Walaupun pengambilan makanan yang tinggi tenaga memberi kesan kepada perkembangan penyakit kardiovaskular (CVD) telah diberi penekanan di negara Barat, namun begitu perhubungan ini belum dapat dijelaskan dengan terperinci dalam kalangan remaja di Malaysia. Diet adalah faktor risiko penyakit kardiovaskular boleh ubah dalam kalangan orang dewasa dan berkemungkinan juga merupakan faktor penting dalam risiko CVD dalam kalangan remaja. Kajian keratan rentas ini bertujuan untuk mengkaji hubungan antara corak pemakanan remaja, faktor risiko kardiometabolik (CRF) dan obesiti. Corak pemakanan menawarkan pendekatan baru dalam kajian epidemiologi pemakanan berbanding dengan menggunakan kumpulan nutrien atau makanan tunggal kerana ianya lebih praktikal untuk diterjemahkan dan digunakan untuk memberi nasihat pemakanan kepada golongan remaja. Pendekatan melalui regressi pengurangan berperingkat (RRR) yang digunakan untuk memperoleh corak pemakanan dalam kajian ini adalah pendekatan hibrid yang menggabungkan kedua-dua pendekatan yang berorientasikan pengkajian dan hipotesis secara serentak. CRF merujuk kepada faktor risiko yang boleh memberi kesan kepada perkembangan CVD dan penyakit kencing manis. CRF yang dikaji dalam kalangan remaja kajian ini ialah tahap glukosa, insulin dan profil lipid yang tidak normal dalam darah berserta dengan dislipidemia. Obesiti merupakan salah satu CRF yang paling penting, oleh itu ianya dikaji secara tunggal untuk mengetahui hubungannya yang tidak berkebergantungan dengan corak pemakanan.

Sejumlah 933 remaja berumur 13 tahun dari tiga buah negeri di selatan semenanjung Malaysia, iaitu Negeri Sembilan, Melaka dan Johor bersetuju untuk menyertai kajian ini. Pengukuran antropometri termasuk berat (kg), tinggi (m) dan lilit pinggang (cm) diukur dalam kalangan remaja dan z-skor untuk indeks jisim tubuh (BMI) dikira merujuk kepada standard pertumbuhan BMI berdasarkan umur, Pertubuhan Kesihatan Sedunia (WHO) 2006. Data biokimia

dinilai dalam 507 orang remaja. Maklumat mengenai aktiviti fizikal dan sosio ekonomi dikumpulkan dalam kalangan remaja dan ibubapa.

Lima ratus lapan puluh tiga orang remaja memberi maklumat pemakanan menggunakan borang kekerapan pengambilan makanan (FFQ) yang telah disahkan. RRR digunakan untuk mengenalpasti satu corak pemakanan yang menerangkan variasi paling tinggi dalam empat pembolehubah tindak balas yang dikenali sebagai ketumpatan tenaga dalam makanan, ketumpatan serat, peratus tenaga daripada lemak dan peratus tenaga daripada gula. Pembolehubah tindak balas yang dipilih di dalam kajian ini dihipotesiskan mempunyai hubungan dengan CRF dan obesiti berpandukan kajian saintifik yang dilakukan di negara Barat sebelum ini. Satu corak pemakanan iaitu 'tinggi gula, tinggi serat, tinggi ketumpatan tenaga dan rendah lemak' yang menerangkan 35% variasi dalam semua pembolehubah tindak balas telah dikenalpasti, mencirikan pemakanan yang tinggi pengambilan minuman bergula, buah-buahan, pemanis dan kurang pengambilan daging dan makanan berasaskan daging serta kanji dan makanan berasaskan kanji. Hubungan antara corak pemakanan dan faktor risiko kardiometabolik dikaji menggunakan model regressi yang diselaraskan mengikut jantina, tempat persekolahan, tahap pembelajaran ibu, ketidaktepatan dalam memberi maklumat pemakanan, aktiviti fizikat dan BMI. Terdapat 0.124 mmol/L (95%CI: 0.002, 0.086) peningkatan dalam kadar trigliserida remaja bagi setiap 1 unit SD peningkatan dalam corak pemakanan z-skor. Remaja yang mengikuti corak pemakanan yang dikenalpasti mempunyai tiga kali ganda peluang untuk menghidap dislipidemia (OR=2.68; 95%CI: 1.290, 5.565), kadar kolesterol tinggi (OR=2.68; 95%CI: 1.290, 5.565) dan kadar lipoprotein ketumpatan rendah abnormal (OR=3.01; 95%CI: 1.553, 5.189) berbanding remaja yang kurang mengikuti corak pemakanan tersebut. Remaja perempuan yang mengikuti corak pemakanan tersebut mempunyai tiga kali ganda peluang untuk mendapat kadar lipoprotein ketumpatan rendah yang tinggi (OR=2.48; 95%CI: 1.16, 5.31), manakala remaja lelaki yang mengikuti corak pemakanan tersebut mempunyai 28 kali ganda peluang untuk mendapat kadar insulin tinggi dalam darah (OR=27.55; 95%CI: 1.171, 648.263) berbanding remaja yang kurang mengikuti corak pemakanan tersebut. Tiada hubungan yang dapat dilihat diantara corak pemakanan yang dikaji dengan obesiti dalam kalangan remaja.

Corak pemakanan yang tinggi dengan gula dan bukan lemak mempunyai hubungan dengan peningkatan risiko dislipidemia dan kadar trigliserida, kolesterol dan lipoprotein ketumpatan rendah (LDL-C) yang abnormal dalam kalangan remaja. Sebagai tambahan, kajian longitudinal adalah disyorkan untuk mengkaji hubungan antara corak pemakanan remaja Malaysia dan risiko kardiometabolik untuk mengelakkan sebab akibat berbalik. Mengenalpasti cara pemakanan di peringkat awal dalam kalangan remaja boleh menyumbang kepada pengetahuan berharga untuk strategi pencegahan risiko kardiometabolik pada masa akan datang.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Geeta Appannah, PhD
Associate Professor
Faculty Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

Gan Wan Ying, PhD
Associate Professor
Faculty Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 13 August 2020

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Name and Matric No.: Nor Aishah Binti Emi, GS47333

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This is to confirm that:

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Signature: _____
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Signature: _____
Name of Member of Supervisory Committee: _____

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LIST OF ABBREVIATIONS

ALSPAC	UK Avon Longitudinal Study of Parents and Children
BAZ	BMI for age z-score
BMI	Body Mass Index
CDC	U.S Centers for Disease Control and Prevention
CEHQ	Children's Eating Habits Questionnaire
CHD	Coronary Heart Disease
CRF	Cardiometabolic risk factor
CVD	Cardiovascular Disease
DED	Dietary Energy Density
DP	Dietary pattern
EAT	Project Eat Among Teens
EDTA	Ethylene diaminetetraacetic acid
EI	Energy Intake
FBG	Fasting blood glucose
FFQ	Food frequency questionnaire
FMI	Fat Mass Index
GWAS	Genome-wide association studies
HDL-C	High density lipoprotein cholesterol
HELENA	Healthy Lifestyle in Europe by Nutrition in Adolescence
HOMA-IR	Homeostatic Model Assessment of Insulin Resistance
IDEFICS	Identification and Prevention of Dietary and Lifestyle Induced Health Effects in Children and Infants
IDF	International Diabetes Federation
IOTF	International Obesity Task Force
IQR	Interquartile range
JKEUPM	UPM's Ethics Committee for Research Involving Human Subjects
LDL-C	Low density lipoprotein cholesterol
MOE	Ministry of Education
MOH	Ministry of Health
MUFA	Monounsaturated fatty acid
MyHeART	Malaysian Health and Adolescents Longitudinal Research Team
NCEP	National Cholesterol Education Program
NCNPAS	National Children's Nutrition and Physical Activity Survey
NHANES	National Health and Nutrition Examination Surveys
NHMS	National Health and Morbidity Survey
PAL	Physical activity level
PAQ-C	Physical activity questionnaire for older children
PCA	Principal Component Analysis
PDFQ-3	Previous Day Food Questionnaire
PUFA	Polyunsaturated fatty acid
RRR	Reduced Rank Regression

SAS	Statistical Analysis System
SD	Standard deviation
SEANUTS	South East Asian Nutrition Surveys
SES	Socio-economic status
SFA	Saturated fatty acid
SPSS	Statistical Package for the Social Sciences
SSB	Sweet-sweetened beverages
VLDL-C	Very low-density lipoprotein cholesterol
WC	Waist circumference
WHO	World Health Organisation

CHAPTER 1

INTRODUCTION

1.1 Study Background

Obesity in children and adolescents is increasingly recognised as a serious, worldwide public health concern. The prevalence of obesity among children and adolescents had shown a marked increase worldwide over the past few decades. Findings from the National Health and Nutrition Examination Surveys (NHANES) reported significant increase in obesity prevalence among children and adolescents aged 2 to 19 years in the United States from 13.9% in year 1999-2000 to 17.2% in 2013-2014 (Ogden, Carroll, Fryar, & Flegal, 2015). Likewise, the significant problem of overweight and obesity in children and adolescents is also reported in middle-income countries (South East Asian Nutrition Surveys [SEANUTS], 2012). According to SEANUTS findings, obesity in children and adolescents was a significant problem in urban areas of Thailand, Malaysia and Vietnam, with prevalence of obesity at 11.8%, 12.7% and 14.9%, respectively (SEANUTS, 2012).

The rising trend of obesity in children and adolescents has also been reported in Malaysia over the past decade. A study conducted by Ismail et al. (2009) reported that the total prevalence of overweight and obesity among Malaysian older children aged 6 to 12 years in the year 2002 was 20.7%, and increased to 26.4% in 2008. Another findings in the SEANUTS study reported the prevalence of overweight and obesity in children aged 6 months to 12 years old were 9.8% and 11.8%, respectively (B.K. Poh et al., 2013). In addition, the National Health and Morbidity Survey (NHMS) conducted by the Ministry of Health (MOH) Malaysia every 4 years reported that the prevalence of obesity among children and adolescents below 18 years old in 2011 was 3.9% (Institute for Public Health [IPH], 2011) and increased to 11.9% in 2015 (IPH, 2015).

Obesity has been widely investigated on its possible adverse health outcomes in children and adolescents, as well as throughout adulthood, especially in terms of cardiovascular health. The term cardiometabolic risk factors was used to refer to conditions associated with increased risk of developing cardiovascular diseases (CVD) such as atherosclerosis, cardiovascular heart disease and myocardial infarction (AHA, 2016).

Obesity is one of the modifiable cardiovascular risk factors linked to cardiovascular disorders. A previous study conducted by Saha, Sarkar, and Chatterjee (2011) among obese children found that they had significantly higher

blood pressure, abnormal lipid profile and high C-reactive protein, higher insulin resistance, hypertriglyceridaemia and high LDL-C level compared to non-obese control group. A systematic review done by Llewellyn, Simmonds, Owen, and Woolacott (2016) who investigated obesity-related morbidities among high body mass index (BMI) children found that obesity was associated with higher incidences of diabetes, coronary heart disease and certain cancers.

A prospective multi-centre study in Finland which started in 1980 among children and adolescents aged 3-18 years with 30 years of follow-up found that overweight or obese children had 6 to14 times higher risk of adult obesity (Juonala, Viikari, and Raitakari, 2013). In addition, findings from a consortium of large children's cohorts reported that overweight and obese adolescents were at risk of having type 2 diabetes, dyslipidaemia, hypertension and carotid artery atherosclerosis during early adulthood (Dwyer et al., 2013). The CVD risks which have been presented in adulthood previously such as metabolic syndrome and obesity can be seen among adolescents in Malaysia. A prospective longitudinal cohort study conducted in Malaysia among adolescents which known as the Malaysian Health and Adolescents Longitudinal Research Study (MyHeARTs) reported the prevalence of metabolic syndrome (adolescents who were obese and had abnormal biochemical marker or high blood pressure) was 2.6% at the age of 13 (Fadzlina et al., 2014). After the previous cohort was followed for two years, the researchers reported a significant reduction in high-density lipoprotein cholesterol (HDL-C) level and central obesity in this study cohort (Majid, Amiri, et al., 2016).

Recent developments in the studies of obesity health outcomes have led to a renewed interest in dietary intake among children and adolescents. Dietary intake is one of the modifiable cardiovascular risk factors. Poor dietary intake had been linked to increased risk of CVD and obesity. A review done by Funtikova, Navarro, Bawaked, Fito, and Schroder (2015) on the impact of diet on cardiovascular health among adolescents found that high intakes of saturated fatty acid (SFA), sodium, as well as particular foods such as meat, fast foods and soft drinks were associated with higher cardiovascular risk factor. Besides, a cross-sectional study conducted by Majid, Ramli, Ying, Su, and Jalaludin (2016) among adolescents aged 13 years in the Central (Kuala Lumpur and Selangor) and Northern (Perak) Regions of Peninsular Malaysia found that obese adolescents from rural areas consumed significantly higher intakes of calories and sugar (1987.6 ± 374.0 kcal/d and 48.9 ± 23.0 g/d) compared to their counterparts.

In terms of the association between dietary intake and disease risk factors, there is growing attention from researchers to focus on dietary patterns (DPs) instead of single nutrient or food group since the last few decades. The term DPs refer to a bigger picture of overall food and nutrient consumption, thus giving more predictive value to disease risk than focusing only on a single nutrient and food group (Hu, 2002). Diet is one of the modifiable factors for the prevention of obesity and cardiovascular risk factors in adulthood, as well as for early CVD risk

factors in childhood or adolescence (Kaikkonen, Mikkil and Raitakari, 2014). The previous MyHeARTs study only assessed adolescents' dietary intake based on single nutrient and food groups (Majid, Ramli, et al., 2016). Meanwhile, the current study aimed to assess adolescents' dietary patterns as the analyses of dietary patterns may considers the overall food intake and take into account the synergistic effects of foods and nutrients which is important in determining diet-disease relationship.In 2006, Schulze and Hoffmann who reviewed the evidences of clinical and observational studies among adult population on DPs and their relation to the risk of coronary heart disease (CHD) and stroke reported that higher intakes of vegetables, fruits and whole grains-based DP might prevent the risk of CHD and stroke. Meanwhile, several unhealthy DPs have been linked as risk factors for CVD such as cardiovascular heart disease, myocardial infarction and atherosclerosis in adults. These included 'western' DP, characterised by high intakes of fatty foods, sugar, meat and refined grains and low intake of fibre, vegetables, fruits and whole grains (Aljefree and Ahmed, 2015).

1.2 Problem Statement

The prevalence of overweight and obesity has escalated every year among Malaysian children and adolescents. Recent findings from NHMS 2015 reported that 11.9% of children and adolescents below 18 years old was found to be obese (IPH, 2015), compared to only 3.9% of obese children or adolescents being reported in NHMS 2011 (IPH, 2011). As a matter of fact, Hazreen et al. (2015) also addressed the rising trend of overweight and obesity prevalence among Malaysian children and adolescents in their recent systematic review. The systematic review revealed that the prevalence of overweight and obesity from 1990 to December 2014, was within the range of 4.5% to 69.0% and 3.5% to 16.0%, respectively.

Obesity in children and adolescents is associated with adverse cardiovascular health problems during adulthood, resulting from established early cardiovascular risk factors and accelerated atherosclerosis processes in childhood or adolescence (Raj, 2012). In Malaysia, the NHMS findings showed that the prevalence of hypercholesterolaemia among adults was increasing continuously from 35.1% in 2011 to 47.7% in 2015 (IPH, 2011; IPH, 2015). Meanwhile, the prevalence of hypertension among Malaysian adults was 30.3% according to NHMS 2015 (IPH, 2015). These upward trends of CVDs among adults in Malaysia is quite alarming. Increased burden of CVDs can lead to a rise in government healthcare expenses due to higher cost of disease managements including treatments, medications and surgeries (Mustapha et al., 2014). Even so, CVDs can be prevented by managing the risk factors such as obesity during early adolescence in order to avoid disease progress later in life. Adolescence is a transition period that correlates with major physiological, biological and psychological changes may be a key time period for the establishment of lifelong dietary habits (Craigie, Lake, Kelly, Adamson, and Mathers, 2011). As such, increase of personal autonomy due to less parental control and more social freedom among adolescents may affect their food choice (Coffey, 2013).

Therefore, early identification of specific dietary habits during adolescence might be beneficial for the prevention of CVD later in lifeMost studies on the relationship between DPs and cardiovascular risk are limited to adults population (Aljefree and Ahmed, 2015; Schulze and Hoffmann, 2006).

To date, only a few observational studies have evaluated DPs in relation to cardiometabolic risk factors in adolescents and mostly were conducted in the Western countries (Ambrosini et al., 2012; Appanah et al., 2015; Johnson, Mander, Jones, Emmett, and Jebb, 2008b). There was a study by Abdullah, Teo, and Foo, (2016) which was conducted among adolescents in Petaling district, Selangor to investigate the association between DPs with obesity, but no significant association was found between them. The authors indicated there was high possibility that normal weight respondents will become obese in later life due to having the same DPs as obese respondents.

Until now, researchers in Malaysia only focused on specific nutrients or food groups to investigate the relationship of diet intakes and certain disease risks (Loh, Moy, Zaharan, Jalaludin, and Mohamed, 2017; Yang et al., 2017). Few studies have been published on DPs among Malaysian adolescents (Abdullah et al., 2016; Garba, Rampal, Hejar, and Salmiah, 2014; Nurliyana, Mohd Nasir, Zalilah, and Rohani, 2014). However, previous studies had only focused on the relationships between DPs and cognitive ability (Nurliyana et al., 2014) and dietary habits among adolescents (Garba et al., 2014).

To date, no study has investigated on DPs in relation to obesity and cardiometabolic risk factors among Malaysian adolescents, and specifically by using the Reduced Rank Regression (RRR) approach to derive DPs. The RRR determines linear function of predictor variables (food groups) by maximising the explained variation in nutrients (response variables) related to the disease of interest (Hu, 2002). Dietary energy density (DED), percentage of energy from total fat intake, percentage of energy from total sugar intake and fibre density were selected as response variables in this present study. These selected response variables showed significant associations with obesity and other cardiometabolic risk factors in previous prospective studies in Australia and UK (Ambrosini et al., 2010; Appannah et al., 2014). The RRR approach uses both exploratory and hypothesis oriented methods in DP analysis compared to the Principal Component Analysis (PCA) approach which had been used in previous studies in Malaysia (Abdullah et al., 2016; Garba et al., 2014; Nurliyana et al., 2014). The present study aimed to close the gap by investigating the association between identified DPs using RRR approach with obesity and cardiovascular risk factors in adolescents aged 13 from Southern region of Peninsular Malaysia.

1.3 Study Significance

In view of the high prevalences of obesity in children and adolescents as well as CVD risk factors among adults in Malaysia, it would be interesting to investigate the current DPs among Malaysian adolescents and its relationship with obesity and cardiometolic risk factors. Adolescence is a time of marked psychological and physiological development however little information is known on the dietary habits and their relationships with cardio metabolic risk factors during this period. As dietary habits are carried over from childhood across adolescents' age and into adulthood, establishing healthy DPs at a younger age is of great importance for avoiding chronic diseases in later adult life. Excess in energy intake from food intakes can contribute to the development of obesity during childhood and subsequently increase the risk of CVD if obesity still persist during adulthood (Chung, Onuzuruike, and Magge, 2018).

Thus, recognising the relationships between DPs and risk factors for CVD during childhood and adolescence may be useful in understanding the diet-disease pathway and in identifying potential programmes or interventions for future CVD prevention. In addition, the present study further investigates the possible determinants of these identified DPs among adolescents. It would be beneficial in identifying specific groups of adolescents with higher adherence to these identified DPs for potential CVD interventions. The findings gathered from this study will corroborate to those reported in the Western and subsequently highlight the importance of healthy dietary intake early in life. In addition, this study provided an exciting opportunity to advance Malaysia's public health knowledge on obesity and cardiometabolic risk factors in adolescents, in terms of their food intake.

1.4 Research Questions

- What are the socio-demographic background of study adolescents and prevalances of overweight, obesity and abdominal obesity as well as the proportion of abnormal values of biochemical parameters in male and female study adolescents?

- What are the DPs identified using RRR that explain the most variation in four dietary response variables, namely DED, fibre density, percentage of total energy from fat and percentage of total energy from sugar proposed to be associated with obesity and cardiometabolic risk factors among study adolescents aged 13 years old from southern peninsular Malaysia?

- What are the relationships between socioeconomic, lifestyle determinant and the adherence of the identified DP among study adolescents?

- What are the associations between the identified DP, obesity and abdominal obesity among study adolescents?

- What are the associations between the identified DP and cardiometabolic indicators among study adolescents?

1.5 Study Objectives

General objective:

To determine DPs and their associations with obesity and cardiometabolic risk factors among adolescents aged 13 years old from southern peninsular Malaysia.

Specific objectives:

1) To identify socio-demographic background of study adolescents and prevalances of overweight, obesity and abdominal obesity as well as the proportion of abnormal values of biochemical parameters in male and female study adolescents.

2) To identify DPs that explain the most variation in the following four dietary response variables proposed to be associated with obesity and cardiometabolic risk factors using RRR:

   a) Dietary energy density (DED)

   b) Fibre density

   c) Percentage of total energy from fat

   d) Percentage of total energy from sugar

3) To identify determinants of the identified DP including:

a) Socio-economic status: sex (male/female), ethnicity, adolescents' school location (urban/rural), maternal and paternal education level and parental income

b) Lifestyle factors: physical activity level

4) To determine the associations between the adherence to the identified DP and BMI z-score, waist circumference (WC) z-score, and the odds of being overweight or obese and abdominally obese in male and female study adolescents.

5) To determine the associations between the adherence to the identified DP and cardiometabolic indicators; glucose level, lipid profile, insulin and Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) and the odds of having abnormal biochemical level, dyslipidaemia and insulin resistance in male and female study adolescents.

1.6 Study Null Hypothesis

Ho1 : There are no significant relationships between socio-economic determinants (parental education, parental income maternal, adolescents' school location (urban/rural), sex (male/female), and ethnicity), lifestyle determinants (physical activity score) and adolescents' adherence to a identified DP that explain the most variation in all dietary response variables chosen in RRR analysis.

Ho2 : There are no significant associations between the identified DP (level of adherence/DP z-score) and BMI z-score, WC z-score, and the odds of being overweight or obese and abdominally obese in the study adolescents, and in both females and males.

Ho3 : There are no significant associations between the identified DP (level of adherence/DP z-score) and biochemical parameters; glucose level, lipid profile, insulin and HOMA-IR and the odds of having abnormal biochemical level, dyslipidaemia and insulin resistance in the study adolescents, and in both females and males.

1.7 Conceptual Framework

The conceptual framework for this study is as shown in Figure 1.1. The adherence to DP was chosen as the independent variable, while obesity, abdominal obesity and other cardiometabolic risk factors were chosen as dependents variables for this study. The associations between DP and dependent variables were reported previously in studies among Western adolescents (Ambrosini et al., 2012; Ambrosini, Johns, Northstone, Emmett, and Jebb, 2016; Appannah et al., 2015; Huybrechts et al., 2017).

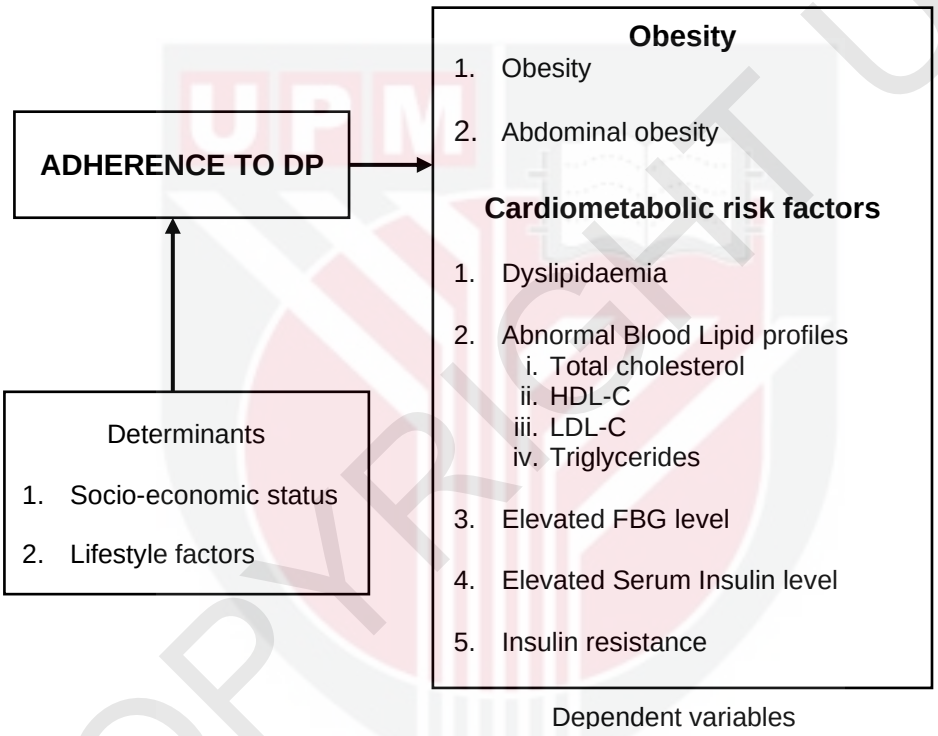

Figure 1.1: Conceptual Framework of Adolescents' DP and Their Association With Cardiometabolic Risk Factors

1.8 Operational Definitions

1.8.1 Adherence to DP

DPs manifest a holistic approach towards diet intakes among populations as compared to single nutrient or food groups. Therefore, DPs have emerged as a complementary way to study the role of diet in the development of disease risks. Previous studies in the Western countries among adolescents (Ambrosini et al.,

2012, 2016; Appannah et al., 2015; Huybrechts et al., 2017) used dietary response variables, namely DED, fibre density, percentage of total energy from fat and percentage of total energy from sugar which proposed to be associated with obesity and cardiometabolic risk factors to derive DPs using RRR. Each participant received a z-score based on their adherence to a DP. The DP z-score increased when the intake of the foods characterised in the specific DP increased. DP z-score of each adolescent was categorised into three tertile groups for categorical analysis (Hu, 2002). Adolescents in the first DP tertile group showed lower adherence towards the DP, while adolescents in the third DP tertile group showed higher adherence towards the DP.

One of the dietary response variables used in the RRR analysis was percentage of total energy from sugar. Free sugar, according to WHO, is defined as short-chained carbohydrates namely monosaccharide and disaccharides presented naturally in foods such as fruits or in manufactured products such as refined sugar (WHO, 2015).There should be at least two subheadings to justify having subheadings.

1.8.2 Cardiometabolic Risk Factors (CRF)

CRF can be defined as any factor that increases the risk in developing CVDs and diabetes mellitus, including obesity, abdominal obesity, abnormal level of inflammatory markers and insulin resistance (Chatterjee et al., 2012). However, obesity (including abdominal obesity) which is known as major CRF is catagorised separately from CRF in this study in order to examine its independent association with identified DP. In the present study, CRF such as dyslipidaemia, abnormal lipid profile, elevated FBG level, elevated serum insulin level and insulin resistance were assessed among study adolescents. Each definition of cardiometabolic risk factors are further explained in Chapter 3.

1.8.3 Obesity

Overweight and obesity among adolescents are defined using BMI z-scores of more than one and two standard deviations above the WHO growth standard median, respectively based on their age and sex, according to WHO reference 2007. Abdominal obesity among adolescents is defined according to the Malaysian WC percentile curves of equal or more than the 90th percentile (Poh et al., 2011). The prevalence of obesity among older children in Malaysia as reported by Tung, Shamarina, and Mohd Nasir, (2011) was used as the reference for the sample size in this study.

1.8.4 Determinants of DP

The adherence to certain DPs among adolescents are influenced by many factors, including socio-economic status (Abdullah et al., 2016; Garba et al., 2014; Huybrechts et al., 2017) and lifestyle factors (Abdullah et al., 2016; Naja et al., 2015; Richter et al., 2012). Socio-economic status is a broad measurement of individual capabilities based on incomes, educational level and occupation (Andrew, 2010). Socio-economic status studied among adolescents in this study comprised of sex, ethnicity, school location, parental education and parental incomes.

The lifestyle factors assessed in this study is physical activity.Physical activity is defined as any movement that requires energy to move the skeletal muscles, including exercising, playing, recreational activities and house chores (WHO, n.d.). The total score of physical activity among adolescents was computed from self-administered questionnaires in which higher scores indicated higher physical activity levels (Kowalski, Crocker, and Faulkner, 1997).

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BIODATA OF STUDENT

Nor Aishah binti Emi was born in Kota Bharu, Kelantan in 1992. She started her primary education at Sekolah Kebangsaan Sri Bemban, and continue her secondary schools at Sekolah Menengah Kebangsaan Ismail Petra (Integ). In 2010, she joined a matriculation programme in Biological Sciences at Kolej Mara Kulim, Kedah. She then pursued her degree in Bachelor of Dietetics with Honours at Universiti Sultan Zainal Abidin, Terengganu. She currently completed Master of Science degree in Community Nutrition under the supervision of Dr. Geeta Appannah in Universiti Putra Malaysia, Selangor.

LIST OF PUBLICATIONS

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