THE DEVELOPMENT OF FOOD FREQUENCY QUESTIONNAIRE AND ASSESSMENT OF 15-YEAR-OLD MALAYSIAN ADOLESCENT DIETARY INTAKE

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THE DEVELOPMENT OF FOOD FREQUENCY QUESTIONNAIRE AND ASSESSMENT OF 15-YEAR-OLD MALAYSIAN ADOLESCENT DIETARY INTAKE

ABSTRACT

At present, there is a worrisome increasing prevalence of obesity and cardiovascular risk among adolescents in Malaysia, which could have a major impact on the health of the later adult population of the country if no proper action is taken. Although there are several methods available for the assessment of the dietary intake of a population, the food frequency questionnaire (FFQ) is one of the dietary tools commonly used to assess the habitual intake of a population. Different versions of the FFQ are needed to assess different populations' dietary habits and patterns. The aim of this study was to investigate the socio-demographic factors that influence the dietary intake of the Malaysian adolescent population and also to develop a FFQ that suits the multi-ethnic Malaysian adolescent population that can be used in future diet–disease relationship studies. In part one of the study, diet data from the Malaysian Health and Adolescents Longitudinal Research Team Study (MyHeARTs) 2014 database were used to investigate the macro- and micronutrient intake of Malaysian adolescents by sex, place of residence, ethnicity, parent's education, body mass index (BMI) and household income. The nutritional status of the adolescents was also examined. In part two of the study, collective food data from the MyHeARTs 2012 database were used to construct the Malaysian Adolescent FFQ (MyUM Adolescent FFQ). A total of 78 participants aged between 13 and 15 years old in 2014 were selected through convenience sampling for the test-retest study. A total of 156 MyHeART study participants who were 15 years old in 2014 were randomly selected for the comparative validity study. They completed a 7-day diet history (7DDH) and subsequently completed the self-administered MyUM Adolescent FFQ. In part 1 of the study, the mean intake of energy, protein and sodium for both sexes were significantly higher than the Malaysian recommended nutrient intake (RNI), while the mean intake of fibre, vitamin D, potassium, calcium, magnesium and phosphorus were significantly lower than Malaysian RNI for both sexes. Although the male adolescent iron intake was adequate, the female iron intake was significantly below the recommended amount. Except for crude dietary fibre, sugar and vitamin D, the boys had significantly higher macro- and micronutrient intake compared to the girls. There were also significant differences in the macro- and micronutrient intakes and in the nutritional status indicators by residency, ethnicity, parent's education, household income and BMI. In part 2 of the study, the intra-class correlation between the first and second administration of the FFQ was 0.71 to 0.88 for macronutrients and 0.67 to 0.85 for micronutrients. Energy-adjusted correlations for protein, carbohydrate, and fat were 0.54, 0.63 and 0.49, respectively. Cross-classification analyses revealed that more than 70 percent of adolescents were in either the same or adjacent quartile of nutrient intake when the data of the 7DDH and the FFQ were compared. No serious systematic bias was evident in the Bland–Altman plots. In conclusion, a comprehensive national strategy is required to deal with the long-term hazard of chronic diseases in Malaysia. The 200-item MyUM Adolescent FFQ that was developed by this study has moderate to good comparative validity for the assessment of most macro- and micronutrients, and therefore can be used in future studies to assess the diet of multi-ethnic adolescents in Malaysia.

Keywords: Dietary assessment, Adolescent, Food Frequency Questionnaire, Reproducibility, Validity

PEMBENTUKAN BORANG SOAL SELIDIK FREKUENSI PEMAKANAN DAN PENILAIAN PENGAMBILAN DIET REMAJA MALAYSIA YANG BERUMUR 15 TAHUN

ABSTRAK

Pada masa kini, terdapat peningkatan prevalens obesiti dan risiko kardiovaskular yang membimbangkan dikalangan remaja di Malaysia. Ianya boleh memberikan impak yang besar kepada kesihatan penduduk dewasa negara pada masa akan datang, jika tiada tindakkan sewajarnya diambil. Walaupun terdapat beberapa kaedah dalam penilaian pengambilan diet, borang soal selidik frekuensi pemakanan (FFQ) adalah satu kaedah yang digunakan bagi menilai pengambilan diet lazim bagi sesuatu penduduk. Penduduk berbeza memerlukan FFQ yang berbeza bagi menilai corak dan tabiat pemakanan mereka. Kajian ini bertujuan untuk meneroka dengan lebih mendalam faktor-faktor sosio-demografi yang mempengaruhi pengambilan diet golongan remaja Malaysia, juga pembentukkan FFQ yang sesuai dengan remaja Malaysia yang berbilang kaum, bagi tujuan kajian diet dan penyakit di masa akan datang. Dalam bahagian pertama kajian, data diet dari MyHeARTs 2014 telah digunakan bagi analisa pengambilan makro dan mikronutrien remaja, juga status pemakanan berdasarkan jantina, lokasi residensi, bangsa, tahap pendidikan ibu bapa, indeks jisim badan dan pendapatan isi rumah. Dalam bahagian ke-dua kajian, data diet dari MyHeARTs 2012 telah digunakan bagi pembentukkan FFQ remaja Malaysia. Tujuh puluh lapan peserta berumur diantara 13 dan 15 tahun pada tahun 2014 telah dipilih melalui persampelan mudah bagi kajian kebolehulangan. Seratus lima puluh enam peserta MyHeARTs yang berusia 15 tahun pada 2014 telah dipilih secara rawak bagi kajian perbandingan kesahihan FFQ, dimana mereka diminta untuk melengkapkan sejarah diet 7 hari (7DDH) dan seterusnya mengisi dengan lengkap FFQ. Dalam bahagian pertama kajian, bagi kedua-dua jantina, didapati purata pengambilan tenaga, protein dan natrium adalah jauh lebih tinggi daripada RNI

Malaysia, manakala purata pengambilan serat, vitamin D, kalium, kalsium, magnesium dan fosforus adalah jauh lebih rendah dari RNI Malaysia. Walaupun pengambilan zat besi bagi remaja lelaki mencukupi, namun pengambilan zat besi bagi remaja perempuan adalah jauh lebih rendah daripada saranan RNI. Melainkan serat, gula dan vitamin D, pengambilan makro dan mikronutrien bagi remaja lelaki adalah lebih tinggi daripada remaja perempuan. Terdapat juga perbezaan ketara pengambilan makro dan micronutrient, juga status pemakanan remaja diantara lokasi residensi, bangsa, tahap pendidikan ibu bapa, pendapatan isi rumah dan juga indeks jisim badan. Dalam bahagian ke-dua kajian, didapati Korelasi Intra-Kelas (ICC) kebolehulangan FFQ adalah 0.71 ke 0.88 bagi makronutrien, manakala bagi micronutrient pula adalah 0.67 ke 0.85. Korelasi yang disesuaikan dengan tenaga bagi protein, karbohidrat dan lemak adalah masing masing 0.54, 0.63 dan 0.49. Analisis klasifikasi silang menunjukkan bahawa lebih dari 70 peratus pengambilan nutrien remaja telah diklasifikasikan di dalam kuartil sama atau bersebelahan apabila membandingkan 7DDH dan FFQ. Tiada bias sistematik yang serius didapati melalui analisa taburan Bland-Altman. Kesimpulannya, strategi nasional yang komprehensif diperlukan bagi menangani ancaman bahaya penyakit kronik di Malaysia. FFQ remaja MyUM yang mempunyai 200 item ini mempunyai perbandingan kesahihan sederhana dan tinggi dalam penilaian pengambilan diet, dengan itu boleh digunakan bagi kajian diet pelbagai ethnik remaja di Malaysia pada masa hadapan.

Kata kunci: Penilaian pemakanan, Remaja, Borang soal selidik frekuensi pemakanan, kebolehulangan, Kesahihan

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LIST OF SYMBOLS AND ABBREVIATIONS

BMI	:	Body mass index
BMR	:	Basal Metabolic Rate
CI	:	Confidence Interval
CVD	:	Cardiovascular disease
DRI	:	Dietary Reference Intake
FFQ	:	Food Frequency Questionnaire
HC		Hip circumference
MyHeART		Malaysian Health and Adolescent Longitudinal Research Team
NCD		Non-communicable disease
NHANES		National Health and Nutrition Examination Survey
RDA		Recommended Dietary Allowances
RNI		Recommended Nutrient Intake
US RDA		United States Recommended Dietary Allowances
WC		Waist circumference
WHO		World Health Organization
7DDH		Seven days diet history

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

The adolescent period is an important stage of human development. It is a point at which young people experience psychological and physiological changes and are receptive to new ideas, and it is also the time when the influence of peers is significant and they are open target for the marketing of products and lifestyle choices (Reilly et al., 2005; K. E. Storey et al., 2009; R.-J. Yang, Wang, Hsieh, & Chen, 2006). Adolescence is also often seen as the healthiest period of a person's life and it is often neglected by health programmes. Adolescents are considered too old to be included in paediatric health programmes and they are often excluded from programmes that are aimed at adults. However, this perception of the 'healthy adolescent' ignores the fact that diseases in adulthood, particularly non-communicable diseases (NCDs) and obesity, begin from the unhealthy behaviours adopted during adolescence and childhood.

Thus, this chapter will provide an overview of the problem, related to NCD among adolescent worldwide and Malaysia specifically. This chapter will also describe the need to identify differences in dietary intake within adolescent populations and the need and rationales of the development of dietary assessment tool that specific to the multi-ethnic Malaysian Adolescent population.

1.1 Background of the study

The term adolescent as defined by the World Health Organization (WHO) refers to young people who are aged 10 to 19 years old, of whom there are currently 1.2 billion worldwide, representing 18 percent of the total world population. More than half of the world's adolescents are from Asian countries (Langevin-Falcon et al., 2012).

Globally, at present, the number of overweight adolescents is increasing and most of these overweight adolescents are becoming obese in adulthood (Gordon-Larsen, Adair, Nelson, & Popkin, 2004; B. M. Popkin & Gordon-Larsen, 2004; M. L. Storey, Forshee, Weaver, & Sansalone, 2003). Today, such adolescents are particularly vulnerable healthwise because they are exposed earlier on in life and for a longer period of time to health risks such as obesity, diabetes, cardiovascular disease (CVD) and cancers compared to the adolescents of preceding generations (Biro & Wien, 2010; Gordon-Larsen et al., 2004; M. L. Storey et al., 2003).

1.2 Global picture of obesity among adolescents

Prior to the twentieth century, the prevalence of childhood/adolescent overweight and obesity, although observed in some parts of the world and cultures, was uncommon. However, over the years, overweight and obesity among adolescents has become widespread and has increased substantially worldwide in recent times. A 2013 systematic review of cross-sectional studies conducted from 1999 to 2011 worldwide on overweight and obesity among adolescents found that the prevalence of overweight and obesity is high, especially among boys (Bibiloni, Pons, & Tur, 2013). Also, the prevalence of overweight and obesity among adolescents in high-income countries such as the United States of America (USA) increased noticeably from 10.5 percent in 1988–1994 to 15.5 percent in 1999–2000 (Ogden, Flegal, Carroll, & Johnson, 2002). Moreover, upper-middle- income countries such as China have experienced a similar trend, where, in year 2010, 19.2 percent of the child and adolescent population in the country were obese, and there has been a rapid increment of obesity among boys, of approximately 9 percent per year from 1985 to 2010 (Sun, Ma, Han, Pan, & Xu, 2014). African countries, most of which are low-income countries, despite the presence of under-nutrition, are also not free from the problem of overweight and obesity. In the case of African adolescents, a study of selected African countries showed that in 2014 the prevalence of overweight ranged from 8.7 percent in Ghana to 31.4 percent in Egypt, while obesity ranged from 0.6 percent in Benin to 9.3 percent in Egypt (Manyanga, El-Sayed, Doku, & Randall, 2014).

Figure 1.1 illustrates the worldwide obesity prevalence, based on systematic review by Bibiloni et al in 2013.

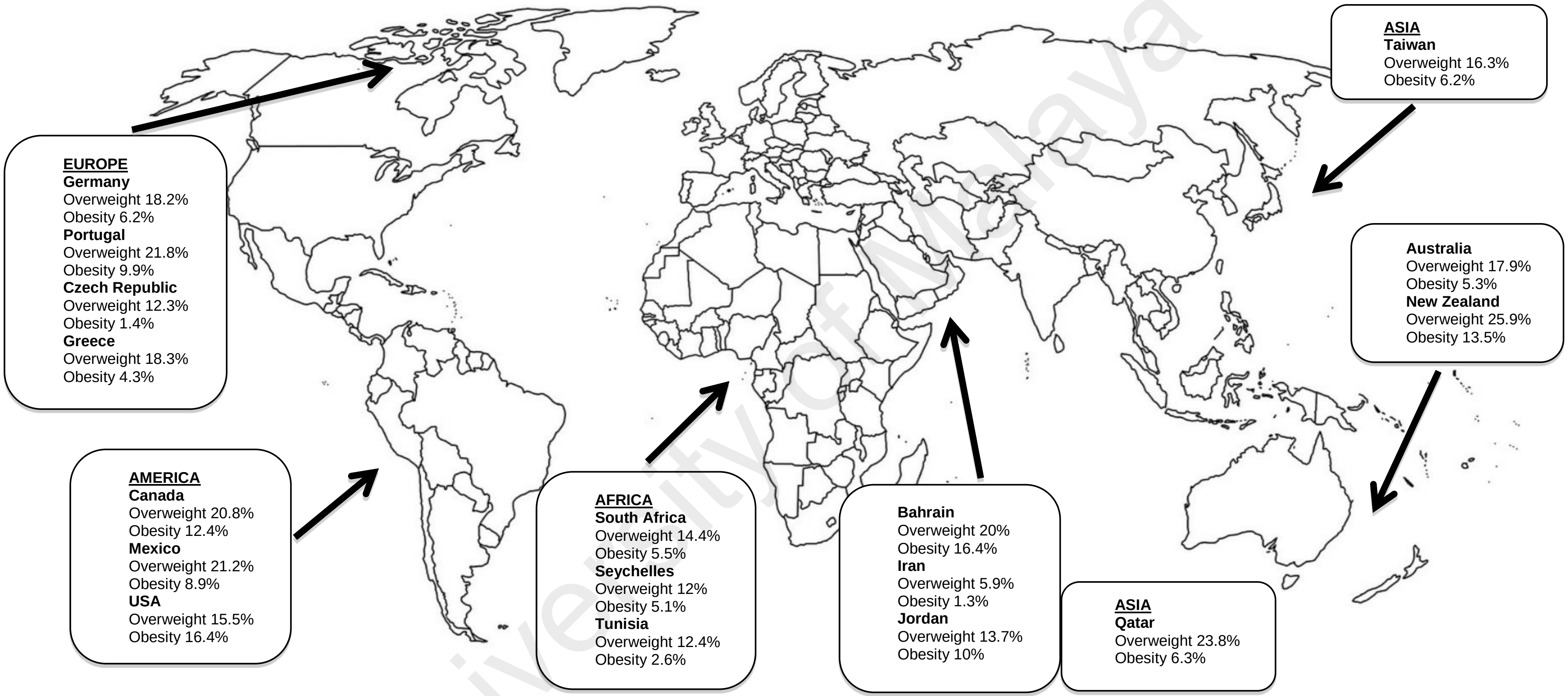

Figure 1.1: World Prevalence of Obesity

Note. Map created from a systematic review on prevalence of obesity among adolescent (Bibiloni et al., 2013)

1.3 Prevalence of non-communicable diseases among adolescents

The prevalence of NCDs in adults is related to unhealthy behaviours and practices typically initiated in adolescence. Like a domino effect, as obesity among adolescents increased worldwide, cardiovascular risk among adolescents also increased.

Studies worldwide show that the prevalence of hypertension among adolescents is on the rise (Sorof, Lai, Turner, Poffenbarger, & Portman, 2004). In addition, a lot of studies have established a relationship between obesity and hypertension among adolescents. In the USA, the prevalence of hypertension among all adolescents regardless of their weight is approximately 3.5 percent. However, when BMI is taken into account, the prevalence of hypertension is much higher among obese compared to non-obese adolescents (Flynn & Falkner, 2011). Moreover, it has been predicted that by the age of 20 years old, 70 percent of obese adolescents in the USA will have at least one risk factor for CVD (Freedman, Mei, Srinivasan, Berenson, & Dietz, 2007).

The same pattern of cardiovascular risk is also seen in Asia. Studies in Vietnam, a country which has an increasing rate of overweight and obesity; also report the presence of cardiovascular risk factors among adolescents (P. V. N. Nguyen, Hong, Hoang, Nguyen, & Robert, 2013; T. H. Nguyen, Tang, Kelly, van der Ploeg, & Dibley, 2010). A deterioration of cardiac function is also shown to exist in pre-diabetic obese adolescents in Turkey (Eklioğlu, Atabek, Akyürek, & Alp, 2016). However, in contrast, Japan shows an opposing trend because the prevalence of overweight and obesity among adolescents is declining (Shirasawa et al., 2015).

1.4 Prevalence of Obesity and NCDs among adolescent in Malaysia

According to Malaysian population statistics for 2015, the adolescent population numbers almost 5.5 million (Hasan, 2015). Malaysian adults have the highest obesity rate in Asia, with almost half of the population being either overweight or obese (M. Ng et al., 2014), and it seems that this problem has extended to the Malaysian adolescent population; as noted by a 2011 study, one in five adolescents in Malaysia is obese (Farah Wahida, Mohd Nasir, & Hazizi, 2011). A systematic review of the prevalence of overweight and obesity among Malaysian adolescents that was conducted in 2015 reports that overweight ranges between 4.5 to 69 percent and obesity ranges between 3.5 to 16 percent for both sexes respectively (A. M. Hazreen, Mohd Shahfiq, Azimah, Su, & Farizah, 2015).

A large cross-sectional study among 3542 Malaysian children aged 0.5 to 12 years old in 2013 shows a slightly lower prevalence of overweight and obesity at 9.8 percent and 11.8 percent, respectively, but these are still alarming figures from a public health perspective (B. K. Poh et al., 2013).

As regards NCDs, the prevalence of hypertension and diabetes among adolescents in Malaysia has reached 3 percent and 8 percent, respectively (Rajakumar, Ann, Gill, Xin, & Kalasalingam, 2012). Another study in the same year reports that one in every five obese adolescents in Malaysia has already developed metabolic syndrome (Jalaludin et al., 2012). These percentages of cardiovascular risk at such an early age are worrisome, and if the roots of this problem are not addressed early on this could have a major impact on the health of the later adult population of the country.

1.5 Public Health Policies and Programs on Nutrition in Malaysia

Recently in 2016, Ministry of Health Malaysia has published the new edition of National Plan of Action for Nutrition of Malaysia III 2016-2025, to address the increasing threat of obesity and NCD in Malaysia (Don et al., 2016). Currently, nutrition programs and activities in Malaysia carried out based on the model of Nutrition throughout the life cycle by WHO (I Darnton-Hill, C Nishida, & WPT James, 2004). For preschoolers (5-6 years old), Ministry of Health, together with Social Welfare Department, implementing nutrition programs such as reviewing the menu served to the children, healthy and safe meal preparation, as well as nutritional status monitoring of the children. In primary and secondary schools, School Feeding Program (Rancangan Makanan Tambahan, RMT) and School Milk Program (Program Susu 1Malaysia) has been conducted since 1970's. There are also School Canteen Guidelines, that guides the monitoring of food sold in the canteen, also the development of menu's for boarding school children. Healthy catering training was also conducted for school canteen operators, to increase their skills and knowledge in school canteen meal preparation. As outlined by Guidelines on the Prohibition of Sales of Food Outside School Perimeters, the sale of unhealthy food is prohibited, which enforced by local authority. Ministry of Education also has incorporated several topics on nutrition and health in science, physical and health education syllabus. Ministry of Health, also routinely monitor the health of the school children via School Health Team, under Health District Office programs. The nutritional status of the school children is monitored routinely through weight, height and fitness level measurement, and recorded in the Student Health Record (Rekod Kesihatan Murid). Another program for adolescent includes, monitoring of nutritional status and provision of healthy menu in the National Service Training Program, especially for those school leavers adolescent.

The obesity rate among adolescent and children, however, still rising, despite various programs implemented (Farah Wahida et al., 2011; A. M. Hazreen et al., 2015). Thus, questioned the effectiveness of the programs in tackling the issues of obesity and NCD's in Malaysia. At the moment, there is no specific subject of nutrition in primary and secondary schools in Malaysia. Public health policies in Malaysia, mainly focus on adults and there is limited programs for children and adolescent. Presently, there is also no nutrition program to all restaurant operators and food service business in Malaysia. Public health messages, mainly nutrition component, must be adapted to the cultural and socioeconomic context in Malaysia, as through this, we will be able to see, what contribute to obesity, and as well NCD.

1.6 Dietary assessment tools in measurement of dietary intakes

The association between diet and mortality and morbidity is well recognized. The prevalence of chronic diseases such as CVD, diabetes and cancer are often linked with unhealthy dietary patterns and poor lifestyles (Ian Darnton-Hill, Chizuru Nishida, & WPT James, 2004).

Poor eating habits among adolescents will lead to poor health in adulthood (P. M. Emmett & Jones, 2015; Mikkilä, Räsänen, Raitakari, Pietinen, & Viikari, 2004; Nigg & Amato, 2015; Northstone, Smith, Newby, & Emmett, 2013; Pearson, Salmon, Campbell, Crawford, & Timperio, 2011). Thus, knowledge of adolescents' dietary intake is extremely important. The identification of adolescent dietary intake can help in planning in the future direction of initiatives to promote a healthy lifestyle including healthy dietary intervention among adolescent, particularly in the school setting.

There are several ways in which to assess a person's habitual diet, including a weighed food record, simple 24-hour recall, a food frequency questionnaire (FFQ) and a 7-day food diary (Shim, Oh, & Kim, 2014). The need for prospective investigations of chronic diseases in later life and their potential relation with current diet is one of the reasons why there is a need to accurately measure people's habitual diet. While ensuring the accuracy of a dietary assessment is important, at the same time the assessment must also be feasible for use with a large-scale population so that it can give sufficient power to detect modest relative risk and so that it will also be able to demonstrate a dose-response relationship if any (S. Bingham, 1987).

In the weighed food record method of assessment, each and every food or drink needs to be weighed before it is consumed. This method is often used in nutritional epidemiological studies as the gold standard because the precise weight of the food to be eaten can be calculated and this can give precision to the portion sizes of the intake of an individual (S. Bingham et al., 1995). However, this method is expensive and can cause a high respondent burden and a risk of misreporting because it depends on the motivation of the participant to weigh each meal for multiple days.

In the 24-hour diet recall method, the participant needs to remember in detail all the food and drink they have consumed over the past 24 hours. A study on children has shown that this is a valid approach to adopt in the assessment of dietary intake (Leslie A. Lytle et al., 1993). The strength of this method is the low respondent burden and, at the same time, it can be used in large-scale surveys. It is convenient because it can also be administered by telephone. However, the single-day observation provides a poor measure of dietary intake not least because this method is memory dependent and there may be discrepancies in the estimation of portion sizes.

The multiple recall method is an extension of 24-hour diet recall. In this method, the participant is required to remember in detail all the food and drink consumed over the past few days. A study has shown that 3-day diet recall is a valid tool in estimating dietary intake (Johnson, Driscoll, & Goran, 1996). This method can improve the precision of dietary assessment compared to the simple 24-hour diet recall. It has a low respondent burden, is suitable for large-scale surveys and can be administered via the telephone. However, since it is memory dependent, it does have weaknesses in respect of estimating portion size and bias in recalling bad or unhealthy food.

The FFQ is a questionnaire that is presented to the respondent together with a list of food items and the respondent is required to state how often they consume each item in terms of number of times per day, per week or per month. The food listed is chosen to match the specific reasons for a particular study, and is not meant for use in an actual dietary assessment (B. M. Margetts & Nelson, 1997). The FFQ is designed to collect dietary information from a large number of people and usually it is self-administered. This method has a low respondent burden, is suitable for large-scale surveys and can be self-completed and posted. However, there is the drawback of over-reporting the eating of healthy food and the under-reporting of consuming unhealthy food. This method often needs to be validated by another reference method (Sheila A Bingham et al., 1994). The FFQ is used worldwide to capture the usual food intake of an individual (W Willett, 1998). The FFQ is a choice that is regularly used in research studies because it is inexpensive and less time consuming when compared to other methods such as the multiple-day food diet recall and the food diary (Marks, Hughes, & van der Pols, 2006; Steinemann et al., 2017). However, the FFQ needs to be specific because different populations consume different types of food. Thus, a FFQ that is used in one population might not be relevant to others. The FFQ developed for a particular population can assess the intake of that population, but it must be tested to ensure its validity and reliability.

Although it has a lot of limitations, the FFQ has been accepted as a valid tool in large-scale studies on nutrition. When compared with the FFQ, diet history is often lengthy, open-ended and unstandardized when administrated and analysed. The diet history when administered in a case-control study is also highly subject to bias and it is not suitable for large cohort studies because it is also time consuming (Kristal, Peters, & Potter, 2005). Other methods of dietary assessment, such as the double label method are not suitable for cross-sectional studies because they are costly. Thus, the FFQ is important because it can offer some form of accuracy in dietary assessment and, at the same time, it is feasible for use on a large scale. Studies have shown that adolescents are able to quantify portion size and recall dietary intake. Therefore the FFQ is appropriate and suitable for use in research involving adolescent dietary assessment (Ambrosini, de Klerk, O'Sullivan, Beilin, & Oddy, 2009; Helaine RH Rockett et al., 1997; Stefanie Vandevijvere et al., 2013).

1.7 Rationale of the study

1.7.1 Dietary intake and socio-demographic variation of adolescents in Malaysia

Several studies have looked at the effect of dietary intake on the health of adults and the elderly in Malaysia (Noor, 2002). However, there is a paucity of detailed information on the dietary intake of adolescents in Malaysia. Not many studies done on dietary intake among Malaysian adolescent. Some of these studies used the three days diet record to examine dietary intake and this resulted in a poor participant response rate, while other studies had a small sample size and could not be generalized to the whole adolescent population in Malaysia (Y. Chin & Mohd Nasir, 2009; Huat et al., 2006; Law, Mohd Nasir, & Hazizi, 2013; Abdullah Nurul-Fadhilah, Teo, Huybrechts, & Foo, 2013; Rezali et al., 2015; Zalilah, Khor, Mirnalini, Norimah, & Ang, 2006). Thus, an exploration of the dietary intake of adolescents that looks particularly at socio-economic and demographic variations in dietary intake is very important. Therefore, it is the intention of this study to identify the dietary intake of Malaysian adolescents so that suitable nutritional and educational campaigns can be planned and implemented. It is hoped that, as a result, obesity among adolescents can be reduced and their CVD risk can be prevented.

1.7.2 Development and comparative validation of Food Frequency Questionnaire for Adolescent in Malaysia (the MyUM Adolescent FFQ)

A lot of FFQs have been developed for the elderly, for adolescents and also for children in nearly almost every part of the world (Kolodziejczyk, Merchant, & Norman, 2012; Ortiz-Andrellucchi et al., 2009). However, to the best of our knowledge, the scope of the FFQs developed for the Malaysian context is somewhat limited. The FFQs that have been developed are mainly for adults or particularly for pregnant women. Moreover, the FFQs for adults were designed mainly to estimate fat and cholesterol intake (Eng & Moy, 2011; Loy, Marhazlina, Nor, & Hamid, 2011). A FFQ for ethnic Malay adolescents was developed a few years ago, but it was mainly for a specific east cost of Malaysia, namely Kelantan (A. Nurul-Fadhilah, P. Teo, & L. H. Foo, 2012a), where the diet is known to be different from that in the other states in Malaysia; the former having a higher preference for sugar (Abdullah, Teo, & Foo, 2016). To date, there are no known FFQs for adolescents that have been designed for all three major ethnic groups (Malay, Chinese and Indian) in Malaysia. Thus, this study has developed the MyUM Adolescent FFQ to provide a more accurate assessment of the dietary intake of Malaysian adolescents, that is specific to the whole Malaysian adolescent population.

1.8 Research aim and objective

1.8.1 General objective

This study's general objective is to assess the dietary intake of Malaysian adolescents from data provided by the Malaysian Health and Adolescents Longitudinal Research Team's (MyHeARTs) dynamic cohort study and also to develop a FFQ for nutritional assessment that suits the multi-ethnic adolescent population in Malaysia.

1.8.2 Specific objectives

This study has two specific objectives:

i. To describe dietary intake and socio-demographic variation among adolescents in Malaysia; includes sex/gender, residency (urban-rural), ethnicity, parent's education, household income and adolescent's body mass index (BMI).

ii. To develop and to validate a food frequency questionnaire for the multi-ethnic adolescent population in Malaysia (the MyUM Adolescent FFQ).

The above research objectives are achieved through a two-part study. The first part of the study is a cross-sectional study based on the 2014 MyHeARTs dynamic cohort study, where the dietary intake of Malaysian adolescents and the socio-demographic variations in their dietary intake are explored using a 7-day diet history (7DDH) and the data collected for the 2014 MyHeART study as research tools.

The second part of the study is the development of the MyUM Adolescent FFQ, and the comparative validation of the FFQ, by using a 7-day diet history (7DDH) and biomarkers collected for the 2014 MyHeART study as research tools.

1.9 Research Hypothesis

1.9.1 Dietary intake and socio-demographic variation among adolescents in Malaysia

Null hypothesis: There is no difference in dietary intake with regards to demographic and socio-economic status among Malaysian adolescents.

Alternative hypothesis: There is a difference in dietary intake with regards to demographic and socio-economic status among Malaysian adolescents.

1.9.2 Development and comparative validation of a Food Frequency Questionnaire for Adolescents in Malaysia

Null hypothesis: There is no difference in the nutrient intake estimation between the newly developed MyUM Adolescent FFQ and the 7DDH.

Alternative hypothesis: There is a difference in the nutrient intake estimation between the newly developed MyUM Adolescent FFQ and the 7DDH.

1.10 Research contribution

A dietary intake study such as this enables us to understand dietary intake and its role in the health of Malaysian adolescents. By identifying the details of the dietary intake of this group, further action can be taken to reduce their health risks (Leech, Worsley, Timperio, & McNaughton, 2015).

The FFQ developed for this study can be used in the future to provide information on certain foods that are of interest to researchers over a specified time period. It can also be used in retrospective case-control studies, as well as in cross-sectional studies that are specific to the multi-ethnic adolescent population in Malaysia (NIH, 2016a).

1.11 The thesis structure

Chapter 1 presents a general introduction to this research and also covers overview of the problem, related to NCD among adolescent worldwide and Malaysia specifically. This chapter also described the need to identify differences in dietary intake within adolescent populations and the need and rationales of the development of dietary assessment tool that specific to the multi-ethnic Malaysian Adolescent population.

Chapter 2 provides an analytical overview of the significant literature published on and around the research topic. The chapter also outlines the scientific evidence with regards to the concepts and theories behind the conceptual framework.

Chapter 3 describes the methodology of this research and provides a detailed explanation of every part of the study. The chapter covers the processes adopted for the sampling and collection of the data, and also the development of the MyUM Adolescent FFQ.

Chapter 4 presents the findings of the data analysis. The first part of the chapter documents the findings on dietary intake and its socio-demographic variation among Malaysian adolescents. The second part of the chapter presents the results of the development and validation of the newly developed MyUM Adolescent FFQ.

Chapter 5 discusses the findings of this study and compares them with those reported in other studies. It also highlights the strengths and limitations of this study.

Chapter 6 provides a summary of the outcome of the study and makes some suggestions based on the study finding and details its contribution to research and intervention on the health of adolescents.

CHAPTER 2: REVIEW OF LITERATURE

In both developed and developing countries, obesity is a significant and growing problem. Obesity affects every level of the world's population (WHO, 2000). An extensive public health effort has been directed towards fighting obesity globally, but there is as yet no clear evidence of success. Obesity is the most difficult public health issue that the world has ever faced due to complexity of obesity itself (Frood, Johnston, Matteson, & Finegood, 2013).

2.1 Factors contributing to obesity

Obesity occurs when there is an energy imbalance, where more calories are consumed than expended over an extended period of time, resulting in an accumulation of excess body fat (Faith & Kral, 2006; Kimm & Obarzanek, 2002). This energy imbalance is often contributed to by multiple factors such as physiological, social, cultural, environmental, genetic, and behavioural factors and gut microorganisms (Faith & Kral, 2006; Kimm & Obarzanek, 2002). The Foresight Report conducted in the United Kingdom (UK) in 2007 found that over 100 variables directly and indirectly influence the energy balance in the human body (figure 2.1) (Butland et al., 2007).

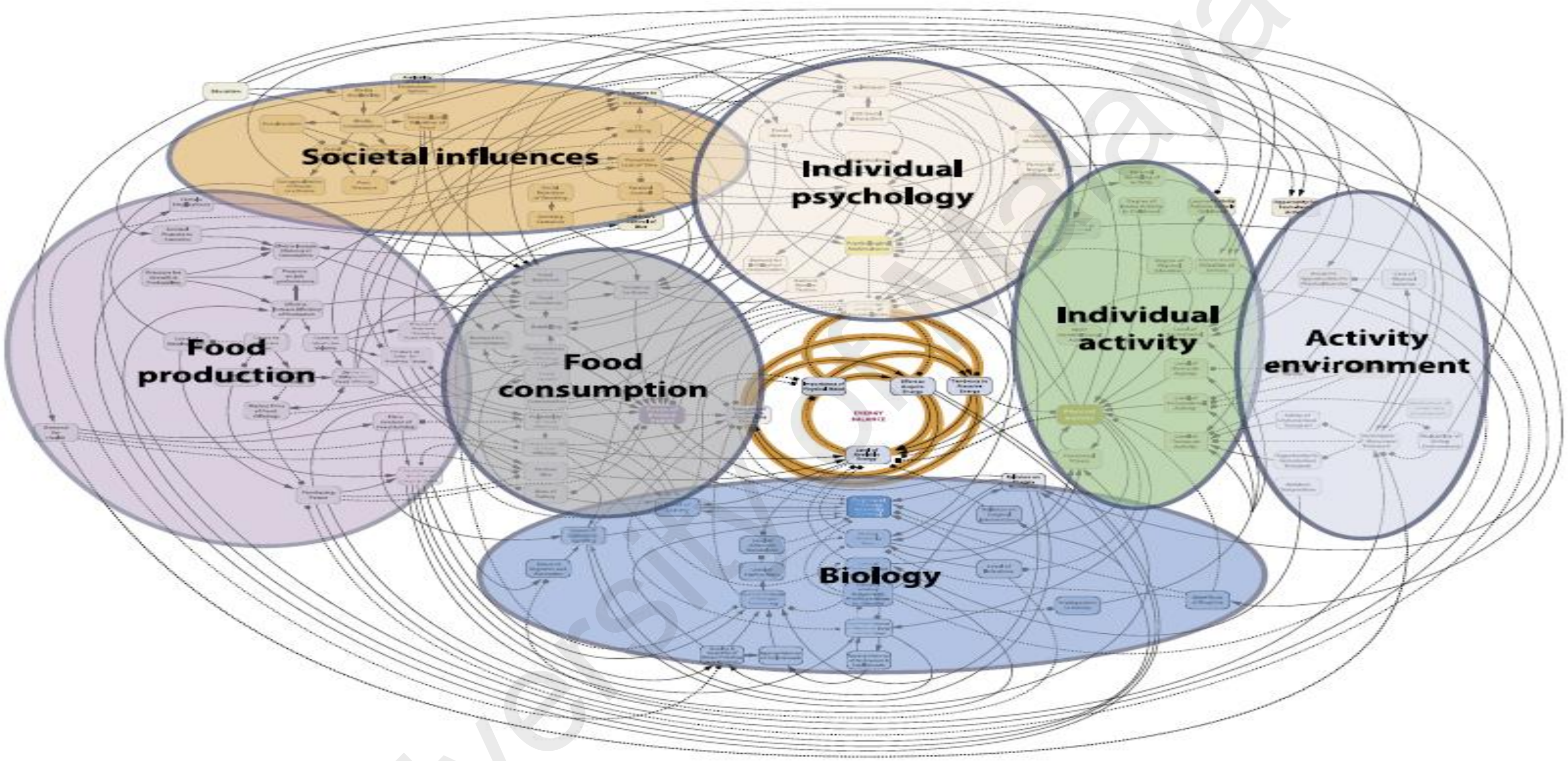

Figure 2.1: Foresight report "complex web" of over 100 direct and indirect variables contributing to obesity (Butland et al., 2007)

The Foresight Report (2007) map divides the complex societal and biological contributing factors of obesity into seven predominant themes (Figure 2.2): biology, activity environment, physical activity, societal influences, individual psychology, food environment and food consumption. The details of these themes are explained in Table 2.1(Butland et al., 2007).

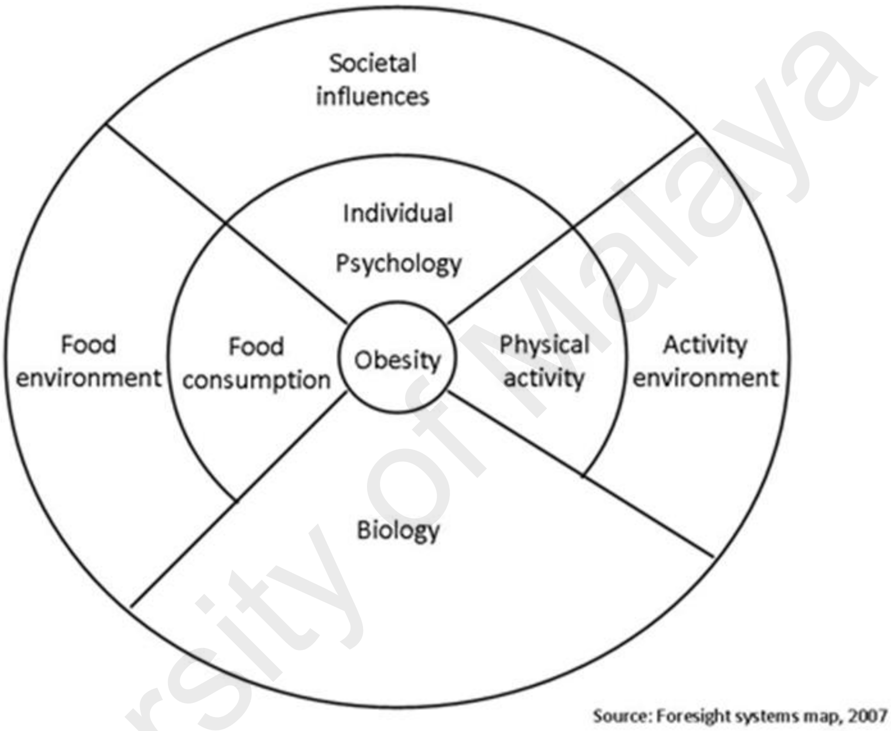

Figure 2.2: Seven predominant themes that contributes to obesity according to Foresight 2007 report (Butland et al., 2007)

Table 2.1: Seven predominant themes contributing obesity according to Foresight 2007 report

Themes	Remarks
Biology	The influence of genetics and ill health
Activity environment	The influence of the environment on an individual's activity behaviour, e.g., road safety, air pollution, provision of cycle shelter that influences an individual's decision on their travel mode to work, i.e., whether to drive or cycle
Physical activity	The frequency and intensity of the activities of an individual, e.g., cycling to work vigorously every day, exercising more than three times per week
Societal influences	The impact of society through the influence of media, education, culture and peer pressure on health
Individual psychology	The individual's psychological drive towards consumption of particular foods, and also their preferred physical activity pattern
Food environment	The environmental decisions on food choices, such as quality and availability
Food consumption	The quality, portion size and frequency of the diet of an individual

(Butland et al., 2007)

Although all these factors play an important role in the development of obesity, environmental and lifestyle behaviours such as dietary intake pattern and physical activity are the major modifiable risk factors that can result in energy imbalance and subsequently obesity in adolescents and children (Al-Kloub & Froelicher, 2009). Thus, in order to improve health and prevent diseases in future generations, it is crucial to ensure the adoption of healthy eating practices and the achievement of targeted physical activity among adolescents, while taking into account the other factors of obesity at the same time.

2.2 Conceptual framework of adolescent dietary intake

Adolescence is a period of nutritional vulnerability. Although this vulnerability might not be as great as during infancy and childhood, adolescence is a period in which young people are exposed to under-nutrition, micronutrient malnutrition, and also obesity. According to Barker's hypothesis, there are two windows of opportunity in which to improve someone's nutrition; during childhood and during adolescence (Wadhwa, Buss, Entringer, & Swanson, 2009). Understanding the lifestyle choices of the adolescent, as well as psychological and social factors, is imperative to ensuring they obtain adequate nutrition.

There are several reasons that cause the adolescent to become nutritionally vulnerable. Their high energy and nutrient requirements for growth, eating pattern and lifestyle, risk-taking behaviours as well as susceptibility to environmental influences put adolescents at risk. Adolescence, in the human life cycle, is a mid-way point that occurs after childhood and before reaching adulthood (Figure 2.3).

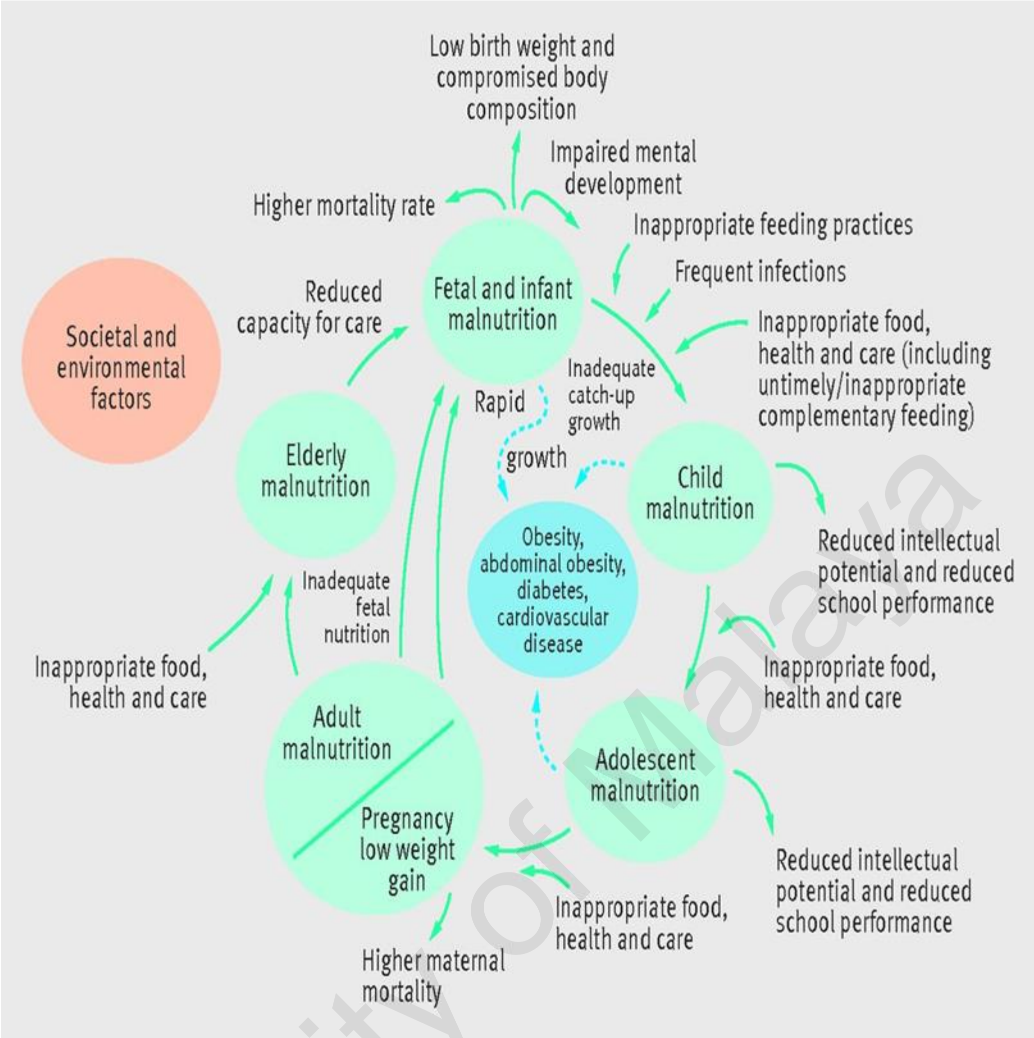

Figure 2.3: Nutrition through the life cycle – proposed causal link (I Darnton-Hill et al., 2004)

Inadequate or over-nutrition can potentially retard growth and sexual maturation, or cause obesity and metabolic disease, even though this may be result from malnutrition during childhood or infancy. Under- or over-nutrition can affect the current health of the adolescent, and put them at high risk of chronic diseases in the future. Combined with the unhealthy dietary intake pattern of the adolescent, the long-term effect on health during adulthood can be detrimental. Socio-economic factors may impose physiological stress and affect the nutrient intake of the adolescent. Sexes in certain cultures, especially in the case of girls, puts adolescents at high risk of malnutrition due to gender discrimination

(WHO, 2005). The factors that determine the nutrient intake of the adolescent will be discussed in more detail later. The conceptual framework that identifies the issues related to the nutritional intake of the adolescent is illustrated in Figure 2.4. This framework is adapted from UNICEF (1990).

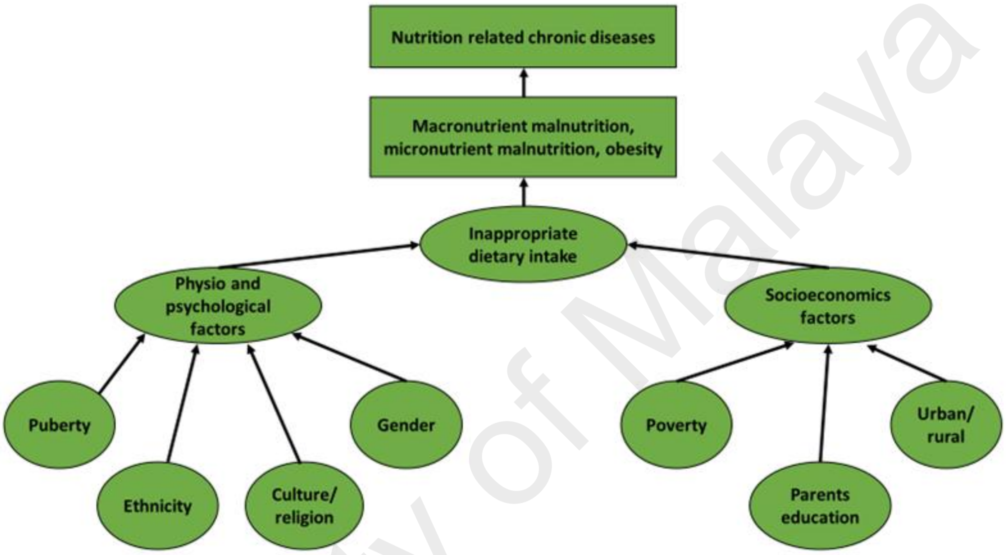

Figure 2.4: Conceptual framework of dietary intake determinant

2.3 Global phenomena of adolescent energy and nutrient consumption

The WHO together with other international bodies has taken several steps in disseminating healthy eating promotions and guidelines to the public. These include the promotion of a high intake of vegetables and fruit and a low intake of food containing saturated fat. However, the majority of children and adolescents in the USA today consume too much fat and sugar and not enough fruit and vegetables, and not much calcium either (Slining, Mathias, & Popkin, 2013). Also, more than half of Brazilian adolescents consume less than one serving of vegetables per day. At the same time, Brazilian children and adolescents have an excessive intake of energy, and they also have an inadequate intake of vitamin A, vitamin E and zinc as well (da Silva, Timoteo, dos Santos, Fontes, & da Rocha, 2010; Rieth, Moreira, Fuchs, Moreira, & Fuchs, 2012). A study done recently also shows that there is high fat and carbohydrate intake among the adolescent population in Germany (Alexy, Freese, Kersting, & Clausen, 2013). Even Aboriginal communities in Canada show inadequate intakes of fibre, folate, vitamin A, vitamin C, calcium and vitamin D with a concomitant excessive consumption of sugar-sweetened beverages, snacks and fast food among the adolescent population (A. Gates, Skinner, & Gates, 2015). In China, the trend of food intake among the adolescent population is similar to elsewhere in the world, i.e., a growing consumption of a high-fat diet, although the consumption of carbohydrates has slightly reduced (Cui & Dibley, 2012). These dietary changes in adolescents are in line with the global nutrition transition, and the pandemic of a high-fat diet and low vegetable intake. Over-nutrition and an obesogenic environment are contributing to the pandemic of obesity and cardiovascular risk among adolescents all over the globe, particularly in low-income and developing countries (Barry M Popkin, 1994, 2006; Barry M Popkin, Adair, & Ng, 2012).

2.4 Gender and nutrient intake in adolescent

The substantial growth experienced during adolescent years causes increased demand for energy and nutrients, more, in fact, than at any other time during the human life cycle. The physical growth and nutrition of the adolescent are strongly related. In order to achieve full growth potential, optimal nutrition in adolescence is vital. Under or over diet consummate can result in either delayed growth and delayed sexual maturation, or diet-related chronic diseases such as diabetes, hypertension, heart disease and even cancers (M Story & Stang, 2005).

The high demand for energy and nutrients is similar for boys and girls before the onset of puberty. At the peak of the adolescent growth spurt, the energy and nutrient requirement may be twice as high as in the remaining periods of adolescence. During puberty, the nutrient needs for adolescents are gender-specific, according to body composition by sex and respective biological changes (M Story & Stang, 2005). Anabolism for example, is part of the metabolism that is related to muscle growth and requires a substantial amount of energy. Anabolism is most concentrated during the early adolescent period, up to 18 years old (Markofski & Volpi, 2011).

While body composition is primarily influenced by ethnicity and genetic and environmental factors, the sex differences in terms of body composition hold across all ethnic groups and has been observed in all populations. The between-sex body composition differences are seen not only in the percentage of body fat mass, but also in body fat distribution (Wells, 2007). From the onset of puberty, females are known to have a higher percentage of body fat mass compared to their male counterparts (Chumlea et al., 2002).

Whereas females store more fat because they consume more energy than they expend, males have been shown to consume more energy compared to the female, even after adjusting for their fat-free mass (Chumlea et al., 2002; Ashima K Kant & Graubard, 2006). Females are known to be able to conserve energy efficiently and store it as fat so they need to reduce their dietary intake by a greater proportion in order to attain weight loss to the same degree as males. This is also observed in pregnancy, where there is an increase in female body fat mass even without evidence of an increase in energy intake, or reduced energy expenditure. This points to metabolic adaptation, which also contributes to the gender difference in body fat mass (Pietrobelli et al., 2002; Wu & O'Sullivan, 2011). This can be seen in exercise metabolism, where, although the female fat-to-glucose fuel mixture conversion is higher than the male during exercise, females seem to lose less fat compared to males in order to reach the same energy deficit. This could be due to efficient fat storage in females during non-exercise periods compared to males, while allowing fuel for energy during exercise (Anderson, Grant, Gotthelf, & Stifler, 2006; Ronald N. Cortright, Chandler, Lemon, & DiCarlo, 1997; Ronald N Cortright & Koves, 2000; Donnelly & Smith, 2005; Hoyenga & Hoyenga, 1982; Rolls & Rowe, 1979; Wu & O'Sullivan, 2011). In addition to effective fat storage, the release of post-prandial fatty acid from adipose tissue and the oxidation of ingested fat in females during postprandial metabolism are also reported to be lower compared to males. The uptake of postprandial fatty acid by subcutaneous tissue in the upper body and lower body adipose tissue are also higher in females compared to the male sex (Blaak, 2001; Jensen, 1995; Santosa & Jensen, 2008; Uranga, Levine, & Jensen, 2005). Hormonal changes, such as an increase oestrogen during puberty, are partly responsible for efficient fat storage in females through reducing postprandial fatty acid oxidation while increasing fatty acid incorporation into triglycerides (Gibney, Johannsson, Leung, & Ho, 2005; Lwin et al., 2008; Ockner, Lysenko, Manning, Monroe, & Burnett, 1980; Weinstein, Soler-Argilaga, Werner, & Heimberg, 1979). Sex hormones also evidently promote adipogenesis in some regions of the body depending on male or female genetics. Thus, this explains the greater subcutaneous gluteal and femoral deposits of fat, as well as the greater visceral adipose tissue deposit and larger waist to hip ratio in females compared to male (Mayes & Watson, 2004).

2.4.1 Global macro- and micronutrient intake – gender perspective

Although males are known to consume more energy compared to females, recently there have been inconsistent reports on the intake of energy, and macro- and micronutrients of male and female adolescents around the globe.

While cross-sectional studies in Canada and Spain show that there is a higher energy intake among male than female adolescents (Hanning et al., 2007; Velasco et al., 2009; Wadsworth et al., 2012), in Sri Lanka for example, there is no significant different in energy intake between the two sexes, although the BMI is significantly higher in females compared to their male counterparts (Hettiarachchi, Liyanage, Wickremasinghe, Hilmers, & Abrams, 2006). Also, the energy intake level is higher among Tunisian female adolescents compared to male adolescents (Aounallah-Skhiri et al., 2011). However, a recent study among Brazilian adolescents reports no gender differences in energy consumption among adolescents (Souza et al., 2016).

While the intake of total carbohydrate is insufficient among Polish, Brazilian, Spanish and Bangladeshi adolescents, the intake is worst among Canadian female adolescents (Hanning et al., 2007; Kabir, Shahjalal, Saleh, & Obaid, 2010; Leal, Philippi, Matsudo, & Toassa, 2010; Llull, del Mar Bibiloni, Martinez, Pons, & Tur, 2011; Stefanska, Falkowska, & Ostrowska, 2012). However, Pakistani and northern Italian adolescents consume more total carbohydrate than the recommended value (Aziz & Hosain, 2014; Toselli, Argnani, Canducci, Ricci, & Gualdi-Russo, 2010). Male adolescents in the Philippines have significantly higher energy and total carbohydrate intake than female adolescents (Magbuhat, Borazon, & Villarino, 2011).

Female adolescents in Spain consume a diet that is higher in total fat compared to males (Ruiz et al., 2015). However, the total fat intake among Canadian male adolescents is higher compared to their female counterparts, although the intake of both genders is below the recommended level (Hanning et al., 2007). Along with an excessive intake of protein, Polish adolescents are also noted to consume an excessive amount of total fat, and this is especially the case in overweight and obese males (Stefanska et al., 2012). A similar tendency is also seen in Swiss children and adolescents, where the total fat intake was 20 to 50 percent higher than their recommended intake (Aeberli, Kaspar, & Zimmermann, 2007). The trend of a high-fat intake has also been observed in India, Turkey, Bahrain, Brazil, the United States of America (USA), Costa Rica, Slovenia, Italy and few other European countries (Bas et al., 2005; Fidler Mis, Kobe, & Štimec, 2012; Gupta et al., 2010; Leal et al., 2010; Leslie A. Lytle et al., 2002; Martone et al., 2010; Monge-Rojas, 2001; Moreno et al., 2014; Toselli et al., 2010). Nevertheless, in Pakistan and Bangladesh, adolescents consumed a deficient amount of total fat, although total carbohydrate intake among Pakistani adolescents is higher than recommended (Aziz & Hosain, 2014; Kabir et al., 2010).

Almost all the recent studies of cholesterol intake among both male and female adolescents, in USA, Europe and Asia report that cholesterol intake exceeds recommended levels (Bas et al., 2005; Gharib & Rasheed, 2011; Monge-Rojas, 2001; Toselli et al., 2010; Velasco et al., 2009).

Protein is needed for just about every function in the body, from muscle building to brain cell communication. Out of 20 amino acids that make up protein, nine of them are classed as ‘essential amino acids’, and cannot be manufactured in the body. The only way to get these essential amino acids is through the diet. There is no strong evidence of a distinction of protein intake between genders, as protein intake is set at 0.75 g/kg for both sexes. However, the sex dissimilarity in terms of body composition, such as higher fat stores and lower lean content in females is expected to result in a lower requirement per kg in females, in line with their lower basal metabolic rate (WHO, 2007).

Studies in India, Pakistan, and Cameroon have reported that protein intake is below the recommended amount (Aziz & Hosain, 2014; Dapi, Hörnell, Janlert, Stenlund, & Larsson, 2011; Shafiee, Mesgarani, & Begum, 2015). The same pattern has been observed among Canadian adolescents, where the intake is worse among the female adolescent population (Hanning et al., 2007). In contrast, Polish, Swiss, Brazilian, Italian and Bahraini male and female adolescents consume an excessive amount of protein (Aeberli et al., 2007; Gharib & Rasheed, 2011; Stefanska et al., 2012; Toselli et al., 2010). Excessive protein intake is also observed in Spanish adolescents, especially among males (Velasco et al., 2009), while in Turkey and Bangladesh the protein intake is adequate for both sexes (Garipagaoglu et al., 2008; Kabir et al., 2010).

In contrast to the excessive fat intake pattern, fibre intake in most adolescent studies in Canada, Finland, Italy, Poland, Slovenia, Spain, Bahrain, and Iran was found to be below the recommended level for both sexes (Akbari & Azadbakht, 2014; Fidler Mis et al., 2012; A. Gates et al., 2015; Hoppu, Lehtisalo, Tapanainen, & Pietinen, 2010; Llull et al., 2011; Martone et al., 2010; Stefanska et al., 2012; Wadsworth et al., 2012). However, Turkish and Costa Rican adolescents' fibre intake in 2005 and 2001, respectively, is high compared to the recommended intake for both genders (Bas et al., 2005; Monge-Rojas & Nunez Rivas, 2001). There has been low in fibre intake among Turkish adolescent population because a recent study in 2008 showed that it was inadequate (Garipagaoglu et al., 2008). This is probably due to reduction in wholegrain consumption, along with fruit and vegetables, as described by the latest study on Turkish adolescents that was undertaken in 2011 (Acar Tek et al., 2011). Studies on sources of food that contain fibre are not highly appreciated, thus it is important to investigate this aspect of diet further.

In the USA, Tunisia, Bahrain, Brazil and Slovenia, most of adolescents consume more added sugars than recommended, and this finding is consistent across the sexes (Aounallah-Skhiri et al., 2011; Fidler Mis et al., 2012; Gharib & Rasheed, 2011; Souza et al., 2016; Zhang, Gillespie, Welsh, Hu, & Yang, 2015). Even Aboriginal Canadian adolescents have reported an excess intake of sugars (A. Gates et al., 2015). There is a significant difference in the intake of sugars among Spanish adolescents; it is more excessive among females compared to males (Ruiz et al., 2015). However, it is reported that Japanese children's and adolescents' average sugar intake is within the range of the WHO recommendation (Takeichi et al., 2012).

The iron metabolism is different from other metal metabolisms in that there is no physiological mechanism for iron excretion and almost 90 percent of daily iron needs are obtained through endogenous sources, such as the breakdown of circulating red blood cells. Iron is lost through the skin, intestines, urinary tract and airways across all population groups, and maintaining the appropriate balance of iron must be achieved through a proper diet (Hurrell & Egli, 2010). Inadequate iron intake frequently occurs among young children, teenagers, females of childbearing age, and even among physically active women. It is the female population that is at risk of being iron deficient. Most female adolescents experience significant dietary iron insufficiencies through menstrual blood loss combined with limited dietary iron intake. The average iron loss during menses ranges from 5 to 45 mg per cycle. Coupled with substantial growth during the adolescent period, this indicates that there is a need for a higher iron intake among female adolescents compared to male adolescents (McArdle, Katch, & Katch, 2006).

The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study, a survey conducted in 10 European countries, reports that although the iron intake of 97 percent of males and 88 percent of females meets the average iron requirement, the total iron intake is significantly higher among males compared to females, and only 14 percent of girls meet the recommendation for bio-available iron intake (S. Vandevijvere et al., 2013). Also in Europe, a recent study among female Polish adolescents notes that their intake of iron was below the average requirement (Broniecka, Wyka, Bronkowska, Piotrowska, & Biernat, 2014), whereas male adolescents exceed the recommended value of iron intake by 4 mg (Seidler, Ksiazek, & Sobczak, 2013). Canada, Mexico, Turkey and Sri Lanka also report the same trend, where girls are less likely to consume iron at or above the average requirement (Garipagaoglu et al., 2008; Hettiarachchi et al., 2006; Valdez Lopez et al., 2012; Wadsworth et al., 2012). On the other hand, studies on South India and Iran report that the iron intake is below the requirement for both male and female adolescents (Akbari & Azadbakht, 2014; Shafiee et al., 2015). However, Bangladesh adolescents reported iron intake higher than the recommended level (Kabir et al., 2010).

Calcium is one nutrient that is commonly linked with metabolism and the development of bone. Calcium provides hard tissue in the form of calcium hydroxyapatite, and this is presented in over 99 percent of total body calcium. Calcium is essential for mediating vascular contraction and dilation, muscle function, transmission of nerve signals, intracellular signalling and even mediating hormonal secretion. The calcium metabolism is regulated by the parathyroid hormone (PTH)-vitamin D endocrine system. The interplay between the dynamics of calcium, vitamin D and PTH regulate calcium absorption from the gut (Ross, Taylor, Yaktine, & Valle, 2011). Dairy products such as milk, yogurt and cheese are usually popularly identified as containing a high amount of calcium. During adolescence, calcium absorption is maximal due to an increased calcium requirement for bone modelling. The predominant skeletal process that occurs during this time is the longitudinal extension of the growth plate and periosteal expansion. The recommended intake for calcium varies by age and gender. For instance, postmenopausal women require more calcium than men because the menopause leads to bone loss due to a decrease in oestrogen production, which subsequently results in increased bone resorption and decreased calcium absorption. However, the requirement for adolescents is the same for both males and females (Ross et al., 2011).

In the USA, females are less likely than males to get an adequate amount of calcium from food, although vitamin D consumption is reported to be inadequate in both male and female adolescents in the country (Pettinato, Loud, Bristol, Feldman, & Gordon, 2006). The same pattern of inadequate intake of calcium among girls is also seen in Bangladesh, Costa Rica and Turkey (Ahmed et al., 1998; Garipagaoglu et al., 2008; Monge-Rojas & Nunez, 2001). A study on Tunisia also reports that there is an inadequate intake of calcium among the adolescent population, where the female intake is lower compared to the male, even though the energy intake exceeds the recommended intake (Aounallah-Skhiri et al., 2011). Even in countries with a culture of eating yogurt, such as India, the majority of male adolescents consume a markedly lower amount of calcium than the recommended dietary allowance (RDA) (Shafiee et al., 2015). Recent studies in Poland, Spain, Slovenia, Italy, Brazil, the United Arab Emirates (UAE) and particularly in African nations, show that there is an insufficient intake of calcium among the adolescent population, and there is no statistical difference between genders (Ali et al., 2013; Fidler Mis et al., 2012; Martone et al., 2010; Seidler et al., 2013; Semproli, Canducci, Ricci, & Gualdi-Russo, 2011; Souza et al., 2016; Valdez Lopez et al., 2012). Also, from 1989 to 2002, the low calcium intake among Polish adolescents saw no improvement (Chwojnowska et al., 2002).

Vitamin D is one of many nutrients in the body that is essential for the normal absorption of calcium and phosphorus. It helps put these minerals into bones and teeth, and also strengthens bone, thereby preventing fractures. In addition, vitamin D helps keep the immune system functioning, thus enabling the human body to resist some types of ailment. Growing children and adolescents with a deficiency in vitamin D may contract osteomalacia or osteoporosis. The RDA of vitamin D for children and adolescents is 600 IU/day or 15 mcg per day. Vitamin D can be found in various types of food such as cod liver oil, salmon, sardines, egg yolk and even cheese. Most milk and yogurts in the market are fortified with vitamin D. This vitamin is also produced in the body through skin exposure to ultraviolet (UV) light from the sun. However, how well the body makes vitamin D after the skin is exposed to UV light depends on several factors, such as the colour of the skin and duration of exposure (NIH, 2016b).

Overall, the vitamin D intake among adolescents is not satisfactory. The majority of children and adolescents in the USA fail to meet the current vitamin D recommendation (Au et al., 2013). Also, Aboriginal Canadian are reported to have an inadequate intake of vitamin D (A. Gates et al., 2015). Vitamin D intake in the majority of adolescents in Latin America and the Caribbean is also observed to be inadequate (Brito et al., 2013). The same pattern can also be seen among adolescents in European countries and in Iraq (Diethelm et al., 2014; Zaghloul et al., 2013).

Zinc is one mineral that is vital for protein formation, gene expression, and it is also associated with more than 100 specific enzymes in the body. Its role in growth and sexual maturation makes it one of the most important minerals during adolescence. A zinc deficient adolescent will experience growth failure and delayed sexual development (Sandstead et al., 1967). Zinc can be found in wholegrains, red meat and also shellfish. Zinc and iron compete for absorption. Thus, an increase in the intake of one can reduce the absorption of the other. Thus adolescents who take an iron supplement are at risk of becoming zinc deficient, as are those adolescents who are vegans and those who consume a minimal amount of animal products (M Story & Stang, 2005).

The intake of zinc in Brazilian adolescents was reported to be inadequate in 2010 (da Silva et al., 2010). Zinc intake in Canada was also below the recommended level in year 2001 (Hanning et al., 2007). However, from a between-sex comparison of zinc intake, Canadian, Mexican, Polish and Sri Lankan male adolescents have a higher intake of zinc compared to their female counterparts (Hanning et al., 2007; Hettiarachchi et al., 2006; Seidler et al., 2013; Valdez Lopez et al., 2012).

Sodium is an essential mineral. In the body, it exists in the form of an electrolyte. Sodium is often maligned as the cause of hypertension when, in fact, it also plays numerous vital roles in the body. Sodium is important for the regulation of fluids and blood pressure, the contraction and relaxation of muscles, and also the transmission of nerve impulses. Muscles and nerves need electrical currents to function. By controlling the flow of electrically charged molecules, which include sodium, muscle and nerve cells generate electrical currents. These electrical currents stimulate muscle contraction, and also enable nerves to conduct electrical communications (Mahmud, Rahman, & Vassanelli, 2012).

Despite the importance of sodium, the body only needs a small amount of this mineral. In an effort to reduce CVD, the WHO recommends a salt intake of 5 g per day for adults, and that this is adjusted downward based on energy requirement for children and adolescents. The sodium requirement is the same for both genders (WHO, 2012b).

A recent Poland-based study shows that there is a high sodium intake among the adolescent population, where both girls and boys exceed the recommended value by 2.1 and 2.8 times, respectively (Seidler et al., 2013). Adolescents of both genders in Brazil, the USA, Slovenia and the UK are also noted to consume sodium in amounts above the recommended level (Fidler Mis et al., 2012; Souza et al., 2016; Veiga et al., 2013; Zhu et al., 2014). Also a study in the USA showed that there is higher consumption of sodium among male compared to female adolescents, and the same finding is also reported for Turkey (Acar Tek et al., 2011; Cogswell et al., 2014). However, boys in rural Kenya, in contrast to other children and adolescents in other parts of the world, consume a diet that is deficient in sodium (Semproli et al., 2011). There is a limited number of studies available on salt intake among Asian adolescents. A study among university students aged 17 to 20 years old in Thailand shows that their consumption of salt is double that of the recommended value (Pavadhgul, Sunthonwaraluk, Srisorachatr, & Temcharoen, 2009).

The function of potassium in the body is closely related to that of sodium. It is a very significant body mineral, and important to the body's cellular and electrolytic functions. There is approximately 3500 mmol of potassium in the human body, and most of this potassium is present inside the cells. An equal amount of sodium exists outside the cells. Potassium is also vital for nerve conduction and muscle contraction functions (Oberleithner et al., 2009; Young, 2001). Some studies suggest that consumption of potassium may be beneficial for the reduction of blood pressure in humans (Chang et al., 2006; Cook et al., 2009; Kawasaki, Itoh, & Kawasaki, 1998; Q. Yang, Liu, Kuklina, & et al., 2011). The WHO recommends that potassium intake from food should be increased. This is one of the efforts to prevent the risk of high blood pressure in children and adolescents. The WHO states that the recommended intake of at least 90 mmol/day should be adjusted downward for children, based on energy requirements (WHO, 2012a).

Whereas the intake of sodium is high among Polish adolescents, their intake of potassium, is low and below the recommended amount for both genders (Seidler et al., 2013). Along with other macro- and micronutrients, the diet of boys in Kenya is also deficient in potassium (Semproli et al., 2011).

Almost all the chemical reactions in the body require an enzyme to enable biochemical reactions to take place. The enzyme system commonly consists of three components: specific protein molecules, organic compounds (often a vitamin such as pyridoxine), and a charged mineral (such as copper, zinc, manganese or magnesium). Magnesium is a co-factor in more than 300 enzymatic reactions in the human body, making it one of the extremely important minerals required by the human body. Some of the major functions that require magnesium are protein synthesis, nerve function, blood sugar control, neurotransmitter release, and blood pressure regulation, as well as energy metabolism. Green leafy vegetables such as spinach and chard, pumpkin seeds, yogurt, almonds, avocados, figs and bananas are some of the types of food that contain a high amount of magnesium (Schachter, 2017).

A study in Poland found that there is low magnesium consumption among male and female adolescents (Seidler et al., 2013). Turkish adolescents also have an inadequate magnesium intake, which is worse among female adolescents compared to their male counterparts (Garipagaoglu et al., 2008).

Phosphorus is another important mineral. It accounts for up one percent of a person's total body weight. This mineral is present in every cell in the body, although it is most abundant in bones and teeth. Besides its important role in bone and teeth formation, phosphorus is also responsible for the regulation of carbohydrate and fat, the repair of cells and tissues and the production of adenosine triphosphate (ATP). It also works together with the B vitamins in kidney functions, muscle contractions, heart beating and nerve signalling. Phosphorus can be found in almost every type of food. Phosphorus is more easily absorbed from meat products, rather than from plant sources because in the latter only half of the total phosphorus will be absorbed. The recommended dietary intake of phosphorus for adolescents is 1,200 mg (Vernon et al., 1997).

As phosphorus is abundant in almost every food type, the risk of deficiency is low. In fact, in Poland, adolescents, especially males, consume an excess amount of phosphorus (Seidler et al., 2013). The phosphorus intake of adolescents in Turkey is adequate for both boys and girls (Garipagaoglu et al., 2008). However, Iranian adolescents have an inadequate intake of phosphorus in their daily diet (Akbari & Azadbakht, 2014). There was limited recent study on the intake of potassium, magnesium and phosphorus among Asian adolescents.

2.4.2 Malaysian adolescents macro- and micronutrient intake – gender perspective

Even in Malaysia, diet studies on the adolescent population are limited. There are only a few studies that use a large sample size, and most of the studies have focused only on one state or just one small locality. One study on 408 adolescents in 2013 reports that there are higher intakes of energy and of macro- and micronutrients in male adolescents compared female adolescents. Although all the adolescents' nutrient intakes were found to meet the daily requirements, the consumption of calcium, iron, and vitamin A are below the recommended intake and the situation is worse among females (Cynthia, Zalilah, & Lim, 2013). An earlier study conducted in 2012 on 382 adolescents also reports that Malaysian adolescents have a high intake of protein and fats (Rezali, Chin, & Mohd Yusof, 2012).

The dietary iron intake of adolescents in the western part of Malaysia is unsatisfactory because 95 percent of participants in a 2004 study were identified as failing to meet the Malaysian RDA and the deficiency is more severe among females (Foo, Khor, Tee, & Dhanaraj, 2004).

2.5 Socio-economic status and nutrient intake in adolescents

The impact of one or more person on the food intake of others is called social influence. Social influence can affect an individual either direct or indirectly and either consciously or subconsciously. The attitudes and habits of humans towards food choices are influenced by social factors that develop through interaction with others (Feunekes, de Graaf, Meyboom, & van Staveren, 1998). There is not merely a simple relationship between low socio-economic status and poor health. It is influenced by various other factors such as gender, age, culture, environment, and community network, as well as individual lifestyle factors and health behaviours, which cannot be ignored (Acheson, 1998).

As shown by previous population studies, there are differences in the intake of foods and nutrients among social classes. Those in high-income groups in particular have a better chance of having a balanced diet and a high intake of fruit and vegetables (De Irala-Estevez et al., 2000). In the low-income group, the main barriers that stand in the way of getting a balanced diet include cost, accessibility, and knowledge. Being poor can lead to the inability to purchase healthy food and lack of proper cooking facilities can lead to the consumption of unhealthy takeaway food. Problem in transportation can also be a factor for those in the low-income group because it affects their ability to make healthier food choices. Lack of education of the parent and adolescent or misinformation on diet and health can also affect food choices. Such barriers eventually lead to diet-related diseases (Dibsdall, Lambert, Bobbin, & Frewer, 2003).

2.5.1 Economic status, parent's education and nutrient intake - recent findings

A time trend study of food habits in Norway covering the period 2001–2009 shows some positive trends with respect to nutrient intake because adolescents were found to consume more fruit and vegetables in 2005 compared to 2001, and also to consume fewer sweets. As expected, across the years, adolescents with higher socio-economic status are more likely to eat fruit and vegetables compared to those of low socio-economic status, although there seems to be no association between socio-economic status and intake of sweets (Fismen, Smith, Torsheim, & Samdal, 2014). In Canada, a high socio-economic background and educated parents not only predicted the likelihood of adolescents making daily nutritious food choices, but also consuming significantly less added sugar and sweetened beverages (Ahmadi, Black, Velazquez, Chapman, & Veenstra, 2015). In the USA, higher education is associated with lower intake of high energy-dense food (Ashima K. Kant & Graubard, 2013). In the USA, adolescents in the high socio-economic class are also shown to consume higher vitamin D compared to those in the middle and lower socio-economic classes (Moore, Radcliffe, & Liu, 2014). In Morocco, a greater intake of energy from lipids, and a better quality of monounsaturated fat, polyunsaturated fat, and saturated fat are also observed among adolescents whose fathers have a higher level of education compared to those with fathers who have a low level of education (Lopez, Anzid, Cherkaoui, Baali, & Lopez, 2012). Also, better-educated mothers are also associated with children's adherence to recommendations when it comes to macro- and micronutrient intake (Tornaritis et al., 2014). This finding is also consistently observed in various countries across the globe, including Uruguay, India, Spain, a few other European countries, and some Middle Eastern countries (Hatami et al., 2014; Iglesia et al., 2014; Miqueleiz et al., 2014).

In the context of Brazil, adolescents with lower socio-economic status and lower parental education have the highest risk of inadequate intake of phosphorus, riboflavin, and vitamins A and B12 compared to adolescents with higher socio-economic status and parents with a higher level of education (Verly Junior, Cesar, Fisberg, & Marchioni, 2011). In contrast with other parts of the world, a recent study in Brazil, which looked at the trend in fruit and vegetable intake over a three-year period (2008–2011) notes that there is a decreasing trend in fruit and vegetable consumption among adolescents with increasing socio-economic status (Buffarini et al., 2016). Brazilian adolescents are also noted to consume an excessive amount of sugar, and the intake of sugar is higher in those with high socio-economic status (Colucci, Cesar, Marchioni, & Fisberg, 2012).

A limited number of studies have been conducted in this domain on the adolescent population in Malaysia. A study on breakfast habits, which investigates the grain and fibre intake of 2947 adolescents in Malaysia reports that the dietary intake of fibre is higher among those with a higher household income and higher level of parental education (A. Norimah et al., 2015).

2.6 Ethnicity and dietary intake

Ethnicity is one of the important contributing factors to food choices. Throughout the world, a certain ethnic group is either a minority or the majority population in certain parts of a country, and this affects the picture of and the reasons for the rates of certain nutrition-related diseases. This is due to the fact that certain ethnic groups consume certain types of food that might not be commonly eaten by others. Thus, precise information on the composition of the ethnic food consumed is vital so that strategies for addressing nutrition-related diseases in certain ethnicities can be developed and implemented.

If we take the example of the USA, a 2016 cross-sectional study reports that African American children and adolescents have mean daily energy intakes that exceed the dietary reference intakes (DRIs) but they are not meeting the DRI for dietary fibre (Kolahdooz et al., 2016). African American adolescents are noted to have poor adherence to dietary recommendations and a poor quality of diet compared to other races such as whites and Mexican Americans (Kirkpatrick, Dodd, Reedy, & Krebs-Smith, 2012; Y. Wang et al., 2010). Some of the contributors to poor diet among African Americans are social inequality, being poor, and environmental factors such as the availability of cheap and convenient fast food stores (Satia, 2009). However, sodium intake is higher among white compared to black adolescents (Zhu et al., 2014). Nevertheless, the dietary intake of sugar is the same for all ethnicities in the USA (Zhang et al., 2015). In Canada, diet among Aboriginal adolescents is noted to be poor with a high consumption of an energy-dense diet (A. Gates et al., 2015). As for New Zealand, a study in Auckland on 2549 European, Maori and Pacific Islander adolescents notes that there are marked differences in their nutrient intakes; Maori and Pacific Islander adolescents consume more energy, carbohydrate, protein, and fat compared to European adolescents (Sluyter, Schaaf, Metcalf, & Scragg, 2010).

In the case of Malaysia, adults of Malay ethnicity are shown to be the highest consumers of sugar, and the daily intake of sugar exceeds the WHO 50 g/day recommendation (Amarra, Khor, & Chan, 2016). As for Malaysian adolescents, they frequently consume both traditional and modern processed and sweet foods (Amarra et al., 2016). Furthermore, another recent study conducted in Malaysia in 2015 notes that only 19 percent of the adolescent population studied consumes wholegrains, and those that do consume wholegrains do so at a level below the recommendation (A. Norimah et al., 2015). At the moment, there is a limited number of studies available on ethnic differences in the micro- and micronutrient intake of the Malaysian adolescent population.

2.7 Residency and nutrient consumption

A recent 2016 study on African American adolescents living in urban areas in the USA and an earlier 2010 study on Indian adolescents residing in urban areas of India report that the mean daily energy intake and fat intake exceeds the dietary recommendation for both African Americans and Indians, respectively (Gupta et al., 2010; Kolahdooz et al., 2016). In Ecuador in South America, a study on 779 adolescents reports a significantly high intake of sugar, total fat, protein and sodium among adolescents in urban areas compared to those in rural areas. Also, the rural adolescents have a significantly high intake of carbohydrate and fibre compared to urban adolescents (Ochoa-Avilés et al., 2014). In Greenland, the rural adolescent consumption of fruit is lower compared to those reside in urban areas, mainly due to the cost of the fruit and poor access (Niclasen, Rasmussen, Borup, & Schnohr, 2011), while in Poland, rural boys' intake of protein is lower compared to that of urban boys (Suliga, 2009). In China, a reduction of energy intake is observed in rural and urban areas from year 2001 to 2009 among the adolescents. However, among urban adolescents there is lower carbohydrate intake but a higher fat intake than among their rural counterparts (Cui & Dibley, 2012).

A study on 199 rural Malaysian adolescents undertaken in 2004 found that the energy consumed and the iron and nutrient intake is below the recommended intake (Foo, Khor, Tee, & Prabakaran, 2004). Another study on 278 Malaysian Chinese adolescents living in urban areas have a higher intake of protein, fat, and total calories in the overweight group compared to those in the normal weight group (Soo, Manan, Manaf, & Lee, 2011). A recent study on a sample of 1361 Malaysian adolescents shows that there is a higher intake of total energy, protein, carbohydrate, cholesterol, potassium, and phosphorus among adolescents in urban schools compared to adolescents in rural schools (Abdul Majid et al., 2016).

2.8 Dietary assessment methods

In order to get precise information on the diet of a specific population, an appropriate dietary assessment is needed. The diet information gathered is not only used to identify the dietary intake of one particular population, it can also be used to predict that population's cardiovascular risk (Baik, Cho, Kim, & Shin, 2013). Compared to other assessments, such as a risk-taking behaviour assessment (e.g., smoking) or a physical activity assessment, diet is difficult to measure. This is due to the variation in food intake between individuals, day-to-day variation in dietary intake even in the same individual, and variation even in the amount and duration of intake. Furthermore, individuals hardly notice what and how much they consume (Walter Willett, 2013).

In epidemiological studies, the biomarker is one of the methods used to measure the dietary intake of certain nutrients or dietary components (Gorczyca, Prescha, Szeremeta, & Jankowski, 2013; Kanno, Kanda, Sato, Sakamoto, & Kanno, 2016; Land et al., 2014). The use of a dietary biomarker is desirable as it can be used to assess dietary intake and also validate self-reported intake more accurately compared other methods. Additional advantages of dietary biomarkers include the high correlation of these biomarkers with dietary intake levels, freedom from social desirability bias, independence from memory and not reliant on the ability of the subject to describe the type and quantity of the food eaten (Potischman, 2003). With all these advantages, one can conclude that chemical biomarkers can provide a more accurate measurement than dietary intake estimates. However, there are factors that may not present in traditional dietary assessment methods that can skew the biomarker measurement of dietary intake. Such factors may perhaps include genetic variability, physiology, lifestyle, nutrient interaction, and even the biochemical sampling process itself (Potischman, 2003). A number of biomarkers also known to be affected by absorptions and metabolism after consumption, also diseases and homeostatic regulation. Thus, their values cannot be translated directly to obtain a subject's absolute dietary intake (Kaaks, Ferrari, Ciampi, Plummer, & Riboli, 2002). Additionally, data provided by biomarker are unable to provide dietary recommendations to improve a subject's dietary habits, thus the traditional dietary intake approach is more useful from this perspective compared to the biomarker method (Potischman, 2003; Wild, Andersson, O'Brien, Wilson, & Woods, 2001).

There are several dietary assessment methods available. The appropriate tool for a dietary assessment depends on the purpose of the assessment. The purpose of the dietary assessment could be to measure the nutrient intake, to identify the food intake or to identify the eating pattern or habits. Each method of dietary assessment has its own qualities, biases and practical difficulties that need to be considered when choosing one method over others.

One of the objective observation methods that can be used for dietary assessment is the duplicate diet study. In a duplicate diet study, the person being tested provides the researcher with a duplicate portion of all food they eat in an ordinary routine day. The food is collected within a time frame of 24 hours, but it is also possible to apply this method for a period of several days. After the non-edible part of the food is removed, the collected food is weighted and homogenised. This method is not only useful in assessing nutrients in food, but also chemical intake such as pesticide residues and other contaminants (Kroes et al., 2002). One of the advantages of this method is that all the food taken by the subjects is accessible for analysis. This method is the currently the most precise measurement of intake of an individual (WHO, 1985). However, this method requires biochemistry analysis, so it is costly and thus can only be applied to a limited number of participants. Also, the intake information is on the individual level, therefore it is not statistically based. In addition, commitment is required from the participants, and there is a risk of change in the food pattern intake as well as under-reporting of food intake during such studies (European Food Safety, 2011; Kroes et al., 2002).

The food consumption record is another objective observation method for dietary assessment. In this method, a skilled field worker collects information on the subject's diet from food preparation until consumption of the food in the subject's home. This method is useful in developing countries, especially among low-literacy subjects. The disadvantage of this method is that the information collected might not be accurate because the information on how the food is consumed by each individual in the house and what food is consumed outside the house is not collected. A study conducted in Korea from 1969 to 1995 is one example of dietary assessment using this method (Kim, Moon, & Popkin, 2000).

Another method of dietary assessment is the subjective report. This type of method is used to collect data an individual's food and nutrient intake with the help of a trained interviewer or by self-report. One of the few examples of the subjective report is the weighed food record. In the weighed food record method of assessment, an individual or an investigator needs to weigh each and every item of food and drink before it is consumed. A description of the food and its weight is recorded, and the left overs of the food remaining after consumption are also recorded. A weighed record can be compiled for 3 to 7 days. The 7-day weighed records is often regarded as the gold standard of dietary assessment because the precise weight of the food eaten can be calculated and this can give the precise portion size of the intake of an individual (S. Bingham et al., 1995). This method is widely used, and one of the benefits of this method is the precision of its portion sizes. However, this method is expensive and has a high respondent burden, and there is also the chance of misreporting what has actually been consumed.

The estimated food record is another method of dietary assessment that is similar to the weighed food record, except that the quantification of the food and drink is estimated rather than weighed. Household measures such as cups or spoons, food photographs and food models are used for food intake estimation. The researcher then converts this estimation into a weight, and the food and nutrient intake is then calculated. It is a widely used method and has a lower respondent burden than the weighed food record method (Chinnock, 2006). A comparative study has shown that a seven-day estimated diet record is in closest agreement with 16 days of weighed food intake and has the next highest correlation with biomarkers after the FFQ and 24-hour diet recall methods (S. A. Bingham et al., 1997). However, the estimated food record method is quite expensive and there is a chance of misreporting because the portion sizes of the food taken are only estimations. There is also a risk that the record is completed after the food has been consumed, and is thus based on memory instead being recording at the time the food was taken (Gillman, Hood, Moore, & Singer, 1994). Another concern is that there is a possibility of change in dietary behaviour among participants during their completion of the estimated food record (M. Buzzard, 1998).

The 24-hour diet recall is a retrospective method of dietary assessment, where the subjects are interviewed by a trained interviewer about their food and drink consumption in the past 24 hours. A lot of studies use the 24-hour recall method because of its ability to attain thorough information on the food taken by subjects. The interview can be carried out in person, or by telephone, and it is increasingly popular to conduct the interview via the internet. There is no significant difference in the dietary data obtained through face-to-face 24-hour recalls compared to telephone-based 24-hour recalls (Brustad, Skeie, Braaten, Slimani, & Lund, 2003). The single 24-hour recall is not considered to be representative of habitual diet at the individual level, but it is considered to be adequate for surveying the intake of large groups and estimating group mean intakes. Four repeat 24-hour recalls are recommended to assess the diet of low-income communities, and repeat recalls can also be used to assess typical diet at the individual level (Holmes, Dick, & Nelson, 2008). Eight repeat 24-hour diet recalls are able to capture the variation in macronutrient intake (Jackson, Byrne, Magarey, & Hills, 2007), which is important because intake can vary on different days with Sunday being the day with greatest variation in diet intake. The chronological order of consumption is reported in the 24-hour recall method. During the interview, as per the usual protocol that is practised by most of the studies using this method, first the participants recall their intake and report it to the interviewer without being interrupted. This step is then followed by detailed and probing questioning about their intake. The details reported include the quantity of food consumed. A review of everything that has been recalled is then conducted, thus allowing the addition of elements of the food intake that were not remembered in the first step (Amoutzopoulos et al., 2015a).

After the age of 8 years old, the ability of a child to recall their diet increases markedly (M. B. E. Livingstone & Robson, 2000). For children younger than 8 years old, the ability to recall, even a short time after consumption varies. Familiarity and preference increase the ability to recall food intake. However, leftover food is not reported (Warren et al., 2003). Among children aged 7 years old, specific prompting on their preferences and food categories or providing visual aids may hurt more than help their recall accuracy. However, among 10-year- olds, prompting about food category produces small improvements in recall accuracy with minimal loss of precision (Baxter, Thompson, & Davis, 2000). There is no specific order of recall, forward or reverse, that improves 10-year-old children's recall (Baxter et al., 2003). It is preferable to inquire about dietary intake during the last 24 hours than the previous day because it has been found that recency has a positive effect on children's recall (Baxter et al., 2004). Multiple diet recall, for all ages, are not suitable for the individual level and are only valid for population level (Montgomery et al., 2005). In adolescents, a few studies suggest that adolescent students can accurately describe the food they have consumed by using recall and record techniques if proper probes and adequate instruction are provided (Domel et al., 1994; Frank, 1994). Single 24-hour diet recall and multiple 24-hour diet recalls have been used as a method of dietary assessment in lots of studies because of the low respondent burden. The procedure most of the time does not alter the food intake pattern of the subjects. Literacy is not required because the interview is usually run by skilled staff, and the interview only takes around 20 to 30 minutes per subject. However, this method is dependent on the respondent's ability to recall their diet intake accurately and there is a risk of recall bias. Also, this method can be expensive due to the high interviewer burden (Amoutzopoulos et al., 2015a).

On the other hand, the FFQ is a method of dietary assessment designed to assess the habitual diet of subjects by enquiring about the frequency of the food items or specific food groups consumed over a specific period of time, such as 6 months or a year. There may be a short list or extensive list of specific food items. The number of food items in the FFQ can range from five to 350 (J. Cade, Thompson, Burley, & Warm, 2002). The FFQ can be either self-administered by using a paper or web-based format, by face-to-face interview or even through telephone interview. Subjects are asked how often they eat a particular food or beverage. The response categories often range from never to six or more times per day, where subjects are expected to choose one of these options (Amoutzopoulos et al., 2015a). The FFQ has been used widely in epidemiological studies, especially diet and disease link studies. The two well-known FFQs are the Willet questionnaire and the Block questionnaire (Gladys Block et al., 1986; W. C. Willett et al., 1985). In large epidemiological studies, diet data from FFQs are compared with a specific disease outcome such as risk factors for disease such as cholesterol, and also for diseases such as cancers. The FFQ can also be used to identify the food pattern. The FFQ is designed to assess intakes within a population, thus it cannot be relied upon to obtain an absolute intake. Over-estimation is common in the FFQ, especially with a lengthy food list. Also the measurement of error is greater in the FFQ than in other methods such as the diet record (Amoutzopoulos et al., 2015a).

2.8.1 Difference in dietary intake between adolescents and adult

A dietary intake evaluation is tough due to the rising complexity of the food supply and the day-to-day inconsistency in a person's diet (Favé, Beckmann, Draper, & Mathers, 2009). The 24-hour diet recall, food record and FFQ are the traditional self-report methods for dietary evaluation that rely on participants' memory and capability to estimate portion sizes (Katherine L Tucker, 2007). Adults and adolescents both have a tendency to under-report total energy intake by as much as 30 percent (Bandini et al., 2003; Blanton, Moshfegh, Baer, & Kretsch, 2006; Champagne, Baker, DeLany, Harsha, & Bray, 1998; Champagne et al., 2002; Mahabir et al., 2005; Amy F Subar et al., 2003). Adolescents, as described earlier, are in a phase of rapid growth that requires an upsurge in energy intake, and they tend to eat more frequently and have more unstructured eating events outside their home (Neumark-Sztainer, Story, Perry, & Casey, 1999). Hence, the development of dietary assessment methods that can be incorporated into the life style of the adolescent is particularly difficult, but needs to be done. Also, adolescents are often forgetful and lack compliance in recording their dietary intake because there is a lot of day-to-day variability in the timing and composition of their eating events (M. Livingstone, P. Robson, & J. Wallace, 2004). They are also reported to be easily irritated when reminded to complete their food record by their parents (Goodwin, Brule, Junkins, Dubois, & Beer-Borst, 2001). Compared to adolescents, adults have a more regular routine. Adults have more consistent mealtimes, although this is influenced by the demands and characteristics of their working environment (Frances E Thompson, Subar, Loria, Reedy, & Baranowski, 2010).

2.8.2 Dietary assessment methods used in adolescent studies (2006 – 2016)

Most of the studies on adolescents prefer to use the single or multiple 24-hour recall as the dietary assessment method because it is cheap and has a low respondent burden. For instance, a seven-day 24-hour dietary recall was used to assess the sodium intake of 766 USA adolescents in 2014 (Zhu et al., 2014), while a more recent study on 3333 USA adolescents used two 24-hour diet recalls to assess added sugar intake (Zhang et al., 2015). In Canadian, a systematic review of studies undertaken on the food habits of Aboriginals found that almost all the studies used the 24-hour recall method to assess dietary intake (A. Gates et al., 2015). This method has also been used in non-Aboriginal studies in Canada as well as in Brazil, Poland, Bolivia, Africa, India, the Middle East, China and Europe to assess adolescent dietary intake (Ali et al., 2013; Broniecka et al., 2014; da Silva et al., 2010; Diethelm et al., 2014; Jani et al., 2015; Perez-Cueto, Almanza-Lopez, Perez-Cueto, & Eulert, 2009; Semproli et al., 2011; Souza et al., 2016; S. Vandevijvere et al., 2013; Wadsworth et al., 2012; Z. H. Wang et al., 2013).

The diet record has also been used in adolescent diet intake studies in Latin America, Europe, and also Asia (Anzid et al., 2014; Aparicio Vizuete, Lopez-Sobaler, Lopez Plaza, Perea Sanchez, & Ortega Anta, 2013; Dybkowska, Swiderski, & Waszkiewicz-Robak, 2011; Garipagaoglu et al., 2008; Guelinckx et al., 2015; Magbuhat et al., 2011; Martone et al., 2010; Richter et al., 2012; Ruiz et al., 2015; Tornaritis et al., 2014; Veiga et al., 2013).

The FFQ has also been used as an assessment method in studies on adolescents. For instance, in a study on fruit and vegetable intake among 568 adolescents in Brazil, a study on the macro- and micronutrient intake of 3190 adolescents in Spain and in a study on 246 Mohawk adolescents in the USA (Ravenscroft & Schell, 2014; Rieth et al., 2012; Velasco et al., 2009). This method has also been used in studies with a large sample size in 33 countries in Europe, and also in India, Sri Lanka, Tunisia, African nations, Mexico, and Pakistan (Ahmadi et al., 2015; Aounallah-Skhiri et al., 2011; Aziz & Hosain, 2014; Dapi et al., 2011; Hettiarachchi et al., 2006; MacKeown, Pedro, & Norris, 2007; Rodriguez-Ramirez et al., 2009; Sanwalka et al., 2010; Shafiee et al., 2015; C. Vereecken et al., 2015).

Some studies use a combination of methods for dietary assessment. Some of these studies use a dietary assessment method and a biomarker to assess the dietary intake of the adolescent population. In the USA, Bangladesh, and Spain for example, the 24-hour diet recall and the FFQ was used for dietary assessment (Hanning et al., 2007; Kabir et al., 2010; Llull et al., 2011; Moore et al., 2014), while in Switzerland, Japan, and Finland 24-hour recall and the food record was utilized (Aeberli et al., 2007; Hoppu et al., 2010; Takeichi et al., 2012). Also, a recent adolescent study in European countries assessed dietary intake using two non-consecutive 24-hour recalls and a FFQ (Moreno et al., 2014). In the same year, a study on salt intake among South London, UK adolescents used a 24-hour photographic food diary and 24-hour urinary sodium excretion as the dietary intake assessment methods (Marrero, He, Whincup, & MacGregor, 2014). In Slovenia, the macro- and micronutrient intake of adolescents was assessed using a FFQ and a three-day weighed record (Fidler Mis et al., 2012), and in Mozambique, 24-hour diet recall and blood and urine samples were used to identify poor micronutrient intake and status among Mozambican adolescent girls (Korkalo, Freese, Alfthan, Fidalgo, & Mutanen, 2015).

2.8.3 Dietary assessment methods used in adolescent studies – Malaysia

Various dietary assessment methods have been used in studies on Malaysian adolescents to describe the dietary intake of this population. In a study in 2004, an assessment of the iron intake of rural adolescents in Sabah was undertaken using 3 days 24-hours diet recall (Foo, Khor, Tee, & Prabakaran, 2004). A more recent study in 2013 used two non-consecutive 24-hour diet recalls to assess the dietary intake of 408 adolescents in Selangor (Cynthia et al., 2013). Also, a 7-days diet history was used as the assessment method to investigate 794 and 289 adolescents for their macro- and micronutrient intake and for their vitamin D with calcium intake, respectively (Abdul Majid et al., 2016; Suriawati, Majid, Al-Sadat, Mohamed, & Jalaludin, 2016). A study in 2017 also used 7-days diet history to assess sugar-sweetened beverage consumption (Loh, Moy, Zaharan, Jalaludin, & Mohamed, 2017).

As for the use of the FFQ, studies on 236 and 454 adolescents that looked at breakfast consumption and at ethnic differences in food intake, respectively, used this method as a dietary assessment method (Abdullah et al., 2016; Nurliyana, Mohd Nasir, Zalilah, & Rohani, 2015). Also, a FFQ that was adapted from an adult version was used in a 2015 study to describe the dietary pattern of 416 Selangor adolescents (Nurliyana et al., 2015).

Although the diet record method is quite expensive compared to the recall method, the former is still the preferred choice for studies on adolescent food intake in Malaysia. In 2011, the dietary practices of 278 Chinese adolescents was investigated using a three-day food record method (Soo et al., 2011) and in 2015 a study on wholegrain intake among adolescents also used the food record as the dietary assessment method (A. Norimah et al., 2015).

2.8.4 Under-reporting/misreporting during dietary assessment

Under-reporting in the context of dietary research is a condition where an invalid dietary record arises from different forms of behaviour including food being eaten but deliberately not being reported (intentional under-reporting), food consumption being reduced or avoided during a period of a study (intentional alteration of diet), and food being eaten but genuinely forgotten (unintentional under-reporting) (Macdiarmid & Blundell, 2007). Any method of dietary assessment can have under-reporting or misreporting. The true prevalence of misreporting is unlikely to be identified even if comparisons were made between different methods of dietary intake assessment (A. E. Black et al., 1991).

There are several methods available for detecting under/misreporting. One of the insensitive methods for identifying under-reporting is detection of changes in body weight during a study. A study in 1985 using duplicate diets and weighed food records revealed a weight reduction of 1 kilogram on average among subjects during a 16-day recording period (Stockley, 1985). However, this method cannot be used in a short-term assessment. Moreover, no change in body weight does not mean that there were no changes in diet because the subject may have eaten a similar amount of food, but varied the items consumed (Macdiarmid & Blundell, 2007). The measurement of total energy expenditure using double-labelled water (DLW) is another method of detecting under/misreporting. While this technique is able to provide verification of the inaccuracy of dietary intake, it is seldom used in large population studies due to its high cost (M. B. Livingstone, 1995). Due to this limitation on the use of DLW, as a reference for dietary intake large studies often use the ratio of reported energy intake (EI) to basal metabolic rate (BMR) (EI:BMR) as a tool of convenience to detect suspected under-reporting. The assumption made for EI:BMR is that total energy expenditure (TEE) is equal to EI, where

TEE = BMR x PAL (physical activity level) (A. E. Black, 1996; A. E. Black et al., 1991; Goldberg et al., 1991).

Another method used to confirm the validity of the intake of a particular nutrient is the use of biomarkers. Examples of biomarkers that have been used in this way include urinary nitrogen, adipose tissue fatty acids, urinary potassium, serum vitamin C, and serum carotenoids. Biomarkers are independent of the subject's capability or insight in giving exact written dietary information (S. A. Bingham, 1991). However, they may become less useful when there is alteration in the habitual dietary intake during the conduct of a study. Thus, biomarkers precisely mirror what has been eaten, but not the habitual intake of the diet (Macdiarmid & Blundell, 2007). Thus, the possibility of under- as well as over-reporting/misreporting cannot be avoided.

The consumption food with a healthy image may be over-reported by study participants to show that they have healthy diet behaviour (A. Black, Johansson, Welch, & Bingham, 1997; Goldberg et al., 1991). Using the EI: BMR criteria, with a cut-off point for under-reporters of <0.9, a study among Korean adults reported 14.4 percent under-reporting among males and 23 percent under-reporting among females. Under-reporting was also noted to be high among women who live alone and have a low education, and also among obese participants (Kye et al., 2014). A study in Brazil using an energy intake of < 1.35 x BMR for under-reporters and an energy intake of >2.4 x BMR for over-reporters identified that 65.5 percent of the adolescent participants misreported their diet intake. Also, obese adolescent are five times more likely to under-report compared with normal weight adolescents (Santos, Pascoal, Fisberg, Cintra, & Martini, 2010). In France, over-reporting among their adolescent was 11.8%, and related to male gender, poor psychological health and overweight/obesity. While over-reporting has also been associated with male gender and underweight (Chau et al., 2013), a literature review of

28 articles published in 2011 found that children and adolescents tend to under-report EI, similar to adults. The largest biases have been observed in food record methods of dietary assessment, where almost half of the individuals in the 28 studies could be classified as misreporters (Forrestal, 2011). There is a limited number of studies on the misreporting of dietary intake among adolescents in Asia, and there seems to be no study regarding dietary misreporting in Malaysia.

2.9 The Food Frequency Questionnaire

Although the FFQ is known to be vulnerable to over-reporting and recall bias, for large-scale surveys it is still often the preferred choice because it has a low respondent burden and low researcher burden because it can be self-completed, or even posted to the selected subjects (Amoutzopoulos et al., 2015b). As it measures the habitual intake of the population of interest, it is widely used in epidemiological studies, especially in diet and disease link studies (Amoutzopoulos et al., 2015b).

2.9.1 A Food Frequency Questionnaire for Malaysia

The FFQ is culturally specific, thus different populations need different FFQs that suits their culture and their ethnic and religious preferences regarding food (Sharma, 2011). Not many FFQs have been developed for Malaysia. However, recently a FFQ was developed for Malay adolescents (A. Nurul-Fadhilah et al., 2012a). Nevertheless, currently, there is no known FFQ that has been developed for multi-ethnic adolescents in Malaysia. Therefore, the development of a FFQ for multi-ethnic adolescents in Malaysia will enable large-scale surveys in the future and also enable a full description of the diet of the Malaysian adolescent population. Thus intervention can then be tailored and monitored appropriately, especially with respect to the issue of current growing problem of obesity among Malaysian adolescents.

2.9.2 Development of Food Frequency Questionnaire

A FFQ may be developed either from an existing questionnaire or from the basic principle. Modification of an existing questionnaire is a simpler and faster method of developing a questionnaire than doing so from the basic principle. However, a FFQ that was developed a number of years ago can become out of date because the food list may not contain the food types that eaten in the present day (J. Cade et al., 2002). However, when developing a questionnaire from the basic principle the food list is crucial for the success of the FFQ. A food item is important if it contributes to the total intake of individual, or is taken by quite a number of persons in the population and contains a significant amount of the nutrient of interest (J. Cade et al., 2002). Moreover, the development of a comprehensive food list is important to enable the FFQ to investigate the diet–disease relationship (B. Margetts et al., 1995). Sometimes, a comprehensive food list might be unnecessary for a FFQ because there are also short FFQs that are developed for specific nutrients, such as calcium or iron, and also for specific segments of the population (Baddour et al., 2013; Taylor et al., 2009).

2.9.2.1 The food list

Three characteristics need to be possessed by the food items in the food list of a FFQ to make the FFQ informative. Firstly, the food items must be consumed reasonably often by a significant number of people in the population of interest. Secondly, the food items must contain a substantial amount of the nutrient of interest. Thirdly, need to include food that discriminating from one person to the other (Walter Willet, 2013). Dietary information collected from previous surveys from appropriate populations can be used to identify the most common types of food consumed and the recipes of the most common dishes for inclusion in the food item list of the questionnaire (Gladys Block et al., 1986; J. Cade et al., 2002). Another way of identifying food items suitable for inclusion in the food list is through stepwise regression analysis of the dietary data obtained from the population of interest. Foods may also be included on the basis of previous epidemiological studies. For example, one might include a high-calcium food item such as milk because it has as been associated with bone health in previous studies or, in a FFQ related to stomach cancers, the researcher might need to include mushrooms in the food item list because of it associations with stomach cancers in previous studies (J. Cade et al., 2002; Toth, Nagel, & Ross, 1982; Walter Willet, 2013).

2.9.2.2 Number of food items

Previous research suggests that the number of food items in a FFQ does not affect validity (J. E. Cade, Burley, Warm, Thompson, & Margetts, 2004). A recent meta-analysis of FFQ's for adolescent found that the number of food items ranged from 26 to 212 (Tabacchi et al., 2016). However, the list of food items in a FFQ must be long enough to provide adequate information to make an accurate assessment of dietary intake and, at the same time, must not inflict too much burden on the participants because this may result in reporting error (M. B. Livingstone et al., 1992; Serdula et al., 1992).

2.9.3 Reproducibility testing of FFQ

Reproducibility can be confirmed by administering the FFQ at two points in time to the same group of people. The responses are then tested to see if there is an association between the two (J. Cade et al., 2002).

2.9.3.1 Time between administration of FFQ

The duration between the first and second administration of a FFQ varies across studies. Currently, there is no consensus on the most suitable duration between the two administrations of a FFQ for the purpose of reproducibility (Gibson, 2005). In a review of FFQs for children, adolescents, adults and the elderly conducted by Cade and colleagues in 2004 it is reported the time interval ranges from 2 hours to 15 years, and that a higher correlation is produced when a FFQ is repeated within less than one month

(J. E. Cade et al., 2004). This is also the case with physical activity questionnaires, where the test-retest interval ranges from 1 to 2 weeks up to 2 years (Giles & Marshall, 2009; Wolf et al., 1994). In a literature review conducted in 2012 that looks at the foods and food groups in FFQ for adolescent, it is noted that only 14 of the 21 studies reported test-retest reliability, and the time interval between for reliability testing ranges from seven days to one year (Kolodziejczyk et al., 2012). The study with the lowest correlation was with the longest test-retest period, that is, one year duration (Deschamps et al., 2009). It is clear that a balance needs to be achieved between lessening the true changes in the dietary intake over time and evading retained information from the first administration of a FFQ (Gibson, 2005; Walter Willet & Lenart, 2013).

2.9.3.2 Statistical analysis

There are several methods available for test-retest reliability analyses. For the mean and median intake of nutrients, suitable analyses include the paired sample t-test, the degree of misclassification, and the calculation of the differences in the mean and standard deviation of the nutrients between two administrations. Other analyses include limit of agreement and correlation analysis (Gibson, 2005). Ninety percent of the studies reviewed by Cade et al. (2004) used a correlation coefficient in their reproducibility studies. Another 39 percent used absolute intake while less than 10 percent used the Bland–Altman method (J. E. Cade et al., 2004). In a 2012 review of adolescent FFQ, nine out of 14 that reported reliability testing used Spearman's correlation for the reliability analysis (Kolodziejczyk et al., 2012). Three used Pearson's correlation (I. M. Buzzard et al., 2001; Neuhouser, Lilley, Lund, & Johnson, 2009; Speck, Bradley, Harrell, & Belyea, 2001), one used kappa statistics (Kiwanuka, Åstrøm, & Trovik, 2006) and one used intra-class correlations (ICC) (Deschamps et al., 2009; Kolodziejczyk et al., 2012). Some studies have used combined analyses to test for reproducibility. For instance, a 2014 study on adolescents used the Wilcoxon signed rank test, weighted kappa, ICC, and Bland–Altman plot in its reproducibility analyses (Filippi et al., 2014).

2.9.4 Validation of Food Frequency Questionnaire

A validity assessment is a process of evaluating the accuracy of a questionnaire such as a FFQ to ensure that the questionnaire measures what it intends to measure (J. E. Cade et al., 2004; Gibson, 2005). The assessment of a FFQ is usually done by comparing the FFQ to a reference 'method' that has a greater degree of accuracy, such as a diet record, diet recall, biomarker, or even a validated FFQ (J. E. Cade et al., 2004; Gibson, 2005).

2.9.4.1 Dietary assessment method as reference

The FFQ review conducted by Cade and colleagues in 2004 notes that more than 70 percent of the adult FFQs were validated using another dietary method assessment as the reference. Another 19 percent of the FFQs in the review used biomarkers as the reference method (J. E. Cade et al., 2004).

A recent meta-analysis (Tabacchi et al., 2016), out of 16 adolescent FFQs that used other dietary methods as reference instruments, notes that half of them used the food record as their reference method (Ambrosini et al., 2009; Araujo, Yokoo, & Pereira, 2010; Bertoli et al., 2005; Lietz, Barton, Longbottom, & Anderson, 2002; Papadopoulou et al., 2008; Shatenstein, Amre, Jabbour, & Feguery, 2010; Watanabe, Yamaoka, Yokotsuka, Adachi, & Tango, 2011; Watson, Collins, Sibbritt, Dibley, & Garg, 2009). While the other half used 24-hour recall (Cullen, Watson, & Zakeri, 2008; Deschamps et al., 2009; Hong, Dibley, & Sibbritt, 2010; Martinez, Philippi, Estima, & Leal, 2013; A. Nurul-Fadhilah et al., 2012a; B. Slater, Philippi, Fisberg, & Latorre, 2003; C. A. Vereecken, De Bourdeaudhuij, & Maes, 2010). One short FFQ validation study used both 24-hour recall and the previously validated long list Youth Adolescent Questionnaire (YAQ) FFQ as its reference instruments (H. R. Rockett, Berkey, & Colditz, 2007).

The combination of a dietary intake measure with biomarkers is also common in FFQ validation studies (Yokota, Miyazaki, & Ito, 2010). Nineteen percent of adult FFQs in the Cade et al. (2004) review used a biomarker as a reference in the validation assessment (J. E. Cade et al., 2004). An adolescent FFQ validation study in Sao Paulo for example, used 24-hour recall and biomarkers to validate the FFQ that was designed to assess the intake of carotenoids, fruit and vegetables (Betzabeth Slater, Enes, López, Damasceno, & Voci, 2010). In order to validate a FFQ that assessed the fatty acids intake in children and adolescents, a study in Australia used red blood cell membrane fatty acids as its reference (T. Burrows, Berthon, Garg, & Collins, 2012). The same FFQ was also validated using plasma carotenoids in 2009, indicating the ability of the FFQ to assess the intake of fruit and vegetables among children and adolescents (T. L. Burrows, Warren, Colyvas, Garg, & Collins, 2009).

2.9.4.2 Statistical analyses

Even today, there is a lack of agreement over the most appropriate statistical method to validate FFQs. Six different statistical tests were identified in a recent literature review on statistical tests used to evaluate the validity of adult FFQs (Lombard, Steyn, Charlton, & Senekal, 2015). The most common statistical analysis is the correlation coefficient, followed by cross-classification, Bland–Altman analyses, the t-test or Wilcoxon signed rank test, the weighted kappa coefficient, and the percentage difference (Lombard et al., 2015). Most statistical tests are applied in combination because it is not appropriate to use just one of these tests as a sole determinant of validity (Taren, Dwyer, Freedman, & Solomons, 2002) and it has been argued that in order to provide wide-ranging intuitions into numerous facets of validity, one to three statistical tests may not be adequate (Lombard et al., 2015).

2.9.5 Reproducibility and validity study administration

To ensure that a FFQ measures what it needs to measure, the FFQ needs to undergo both a reproducibility and a validity assessment. The order of the procedure for these assessments needs to be planned with care. It has been suggested that the reproducibility assessment should be done before the validation assessment (J. E. Cade et al., 2004) because FFQ test-retest results have been found to have higher correlation in studies that complete the test-retest after the validation reference method has been applied (Gibson, 2005), although it has been found that adopting this sequence might also result in a very low correlation (Walter Willet & Lenart, 2013). It has also been suggested that the FFQ should be administered before and after the reference method to improve the accuracy of the assessment (Walter Willet & Lenart, 2013). Different participant with similar characteristics for reproducibility, which alongside with participant of validity study is another option to reduce these disadvantages, and was performed in few adults and adolescent validation studies (Guerrero et al., 2015; C. T. Nguyen, Tran, & Hoang, 2013; Wong, Parnell, Black, Skidmore, & Skidmore, 2012).

2.10 Summary on nutrient intake of the adolescent

From the studies done on adolescent diet around the globe, one can conclude that majority of nations around the world are in a period of nutrition transition, from a traditional diet high in fibre to a Western diet that is high in fats and sugar. Nutrition transition is strongly influenced by economic development. Nutrition transition was once believed to be a problem of industrialized nation, but from the studies discussed above, this appears not to be the case because the nutrition transition has been observed in low and middle income countries (Feeley, Musenge, Pettifor, & Norris, 2012; Misra et al., 2011). This nutrition transition has also been observed in Malaysia among adults since 2002; however, in relation to adolescents this issue did not receive much attention at that time (Noor, 2002).

As regards the effect of socio-economic factors, they can be determinants of good dietary practice in one area, but not in others. This can be seen in adolescents in Uruguay, where an inadequate intake fruit and vegetables coupled with an excessive consumption of soft drinks, fast food and added salt are mainly observed among those in a better economic situation (Ortiz & Pereyra, 2015). Similar findings have been reported among adolescents in Brazil, where an excessive intake of sugar was found among those with in better housing condition (Colucci et al., 2012). However, a study based in German shows that there is good micronutrient intake among adolescents with better socio-economic status (Finger, Varnaccia, Tylleskär, Lampert, & Mensink, 2015; Moore et al., 2014). Yet, there are inconsistencies in the findings with regard to adolescents' intake of nutrients when parental education status is taken into account.

Ethnicity, in most of the studies discussed above, is one of the factors that affects the macro- and micronutrient intake of adolescents. In the USA for example, whites have a high chance of having an adequate nutrient intake compared to blacks, Hispanics, and other ethnicities, and in Canada, a poor diet is prevalent among Aboriginal populations (Eicher-Miller, Fulgoni, & Keast, 2015; A. Gates et al., 2015). Increasing food prices and world economic crises have reduced access to nutritious food, making high-salt and high-sugar food cheaper and more accessible (Brinkman, de Pee, Sanogo, Subran, & Bloem, 2010). Accessibility of food also depends on economic status and on the residency. Rural adolescents in some countries have a nutrient intake that is below the recommended level, while the other countries showed no different in nutrient intake between the urban and rural areas and some shows the contrary (Berheto, Mikitie, & Argaw, 2015; Korkalo et al., 2015; Liu et al., 2012).

It should also be mentioned that snacking behaviour among adolescents is common in many countries, especially after school, while watching TV, and while hanging out with friends, which contributes to unhealthy food choices and eventually obesity, especially among low-income groups (Fatima, Fatima, & Mahmoodi, 2017; Larson, Miller, Watts, Story, & Neumark-Sztainer, 2016; Ranjana, Mahomoodally, & Ramasawmy, 2013).

While Malaysian adolescents have experienced a radical change in their diet, there is a lack of detail on the changes in their diet from a socio-economic, racial, and residency perspective. The identification of the diets of sub-populations of adolescents in Malaysia is therefore very important, so that a holistic approach can be developed and implemented to tackle the dual burden of under- and over-nutrition.

2.11 Summary of food frequency questionnaire in adolescent

It is important to explore the dietary intake and pattern of children and adolescents because it allows us to understand how diet affects their long-term or even short-term health. Currently, information on how the nutrient intake and diet pattern transitions from childhood to adulthood in Malaysia is lacking. The FFQ is one tool that can be used to explore the habitual intake of a population, thus it can be used in diet–disease relationship studies. However, the development, reproducibility, and validation of a FFQ need to be carefully planned because it depends on many variables, including the time frame of the methods, population group of the study, nutrient of interest, techniques to measure food and quantities consumed, between and within-subject variances, variability of portion sizes, adequacy of instruction given to the respondent, and even poor-quality control techniques such as typing errors and double recording (G. Block & Hartman, 1989; Gibson, 2005).

The second part in chapter 3 describes the details of the development and comparative validation of the multi-ethnic Malaysian Adolescent Food Frequency Questionnaire (MyUM Adolescent FFQ).

2.12 Research gaps

Statistics had shown that there are increasing prevalence of NCD with increasing age, and there is also evidence of type II diabetes in Malaysian population as early as 18 years old (Bakar et al., 2011). The prevalence of overweight and obesity among Malaysian primary school children is also on the rise, which generally known its relationship with diet and physical activities (Naidu et al., 2013). These evidence points to adolescent as a crucial period in development of adult NCDs.

From the literature review, noted that there is limited number of studies available on macro and micro nutrient intake among Asian and Malaysian Adolescent. While Malaysian adolescents have experienced a radical change in their diet, there is a lack of detail on the changes in their diet from a socio-economic, racial, and residency perspective. The identification of the diets of sub-populations of adolescents in Malaysia is therefore very important, so that a holistic approach can be developed and implemented to tackle the dual burden of under- and over-nutrition.

In the matter of dietary measurements, there is no simple and robust method of assessment. There are several methods which were discussed earlier with its pros and cons. Research takes time, thus need a simple and reliable method for dietary assessment, especially for large scale research. This point to the need for Malaysian Adolescent own FFQ that specific to its multi-ethnic population.

CHAPTER 3: METHODOLOGY

The steps taken in conducting this study will be described in detail in this methodology chapter.

In the first part of this chapter, the method for the part 1 study, which involved assessing Malaysian adolescents' dietary intake, will be described thoroughly. Secondary data from the 2014 MyHeART cohort study (Malaysian Health and Adolescents Longitudinal Research Team Study) were used for this assessment. The MyHeART study will be explained further in section 3.1.1.

The second part of the chapter presents the method for the part 2 study, which involved FFQ development and validation. Dietary data from the 2012 MyHeARTs cohort were used to develop the FFQ. The FFQ was then tested on randomly selected 2014 MyHeARTs cohort participants. Two existing dietary assessment tools, the 7-day diet history (7DDH) and blood biomarkers, were used as the validation tools.

3.1 Part 1 study: Assessment of Malaysian Adolescents' Dietary Intake derived from from MyHeART study data

The design of the part 1 study is a cross-sectional study design that uses data from the MyHeART study. Although the MyHeART study is a longitudinal cohort study design, data from 2014 were used to assess the adolescents' dietary intake and its socio-demographic variation.

3.1.1 MyHeART study

The MyHeART study is the acronym for the Malaysian Health and Adolescents Longitudinal Research Study. It is the first initiative in Malaysia to explore the risk factors for chronic NCDs among adolescents in Malaysia (M. A. Hazreen et al., 2014). It involves the collection of data from in-school adolescents and from their parents or guardians.

The main objective of the MyHeART study is to identify the trends of prevalence and the trends of the NCD risk factors among adolescent in Malaysia, and to determine how the lifestyle of adolescent in their early years will affect the development of NCD in early adulthood.

3.1.1.1 Study design

The MyHeART study is a dynamic prospective cohort study. There is ongoing recruitment of new adolescent participants in parallel with the follow-up of the participants from the previous waves of data collection. The participants of the study are being followed up every two years to assess the multiple exposures and multiple outcomes of NCDs. At the time of writing, the MyHeART study had completed data collection in years 2012, 2014 and 2016, and these adolescents will be followed up again when they reach early adulthood, at the age of 27 years old (M. A. Hazreen et al., 2014). The process of the three waves of data collection is outlined in the figure below.

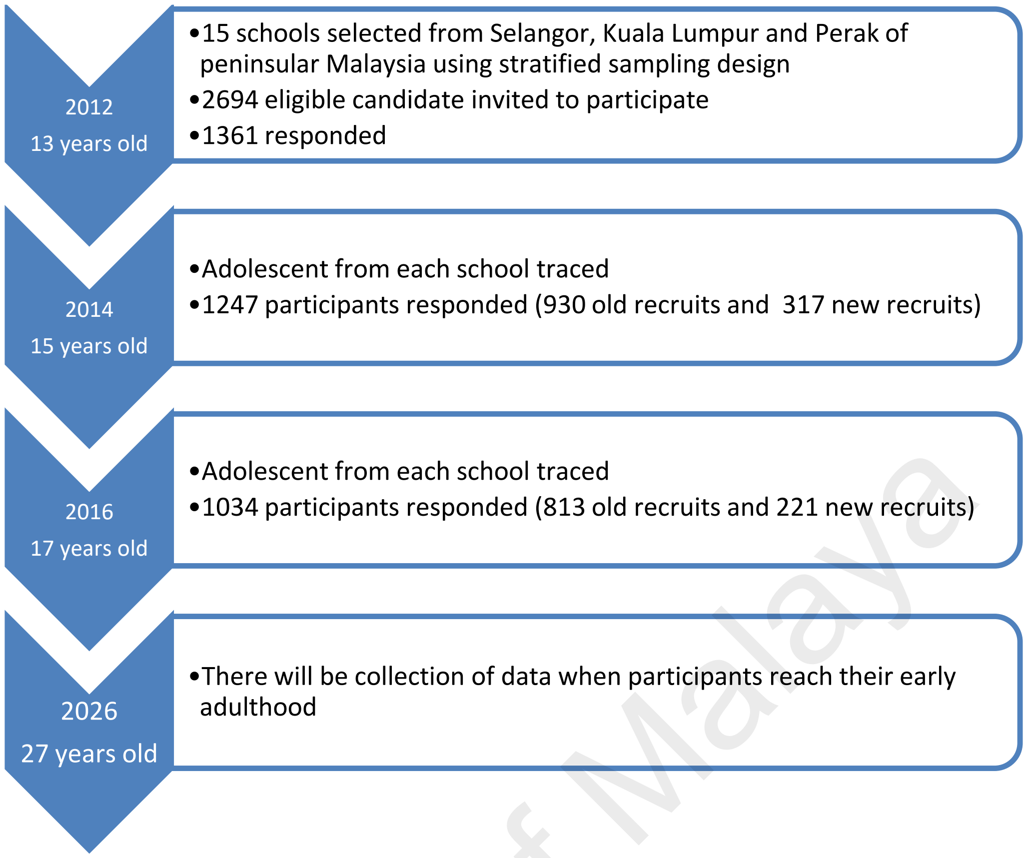

Figure 3.1: Flow chart of MyHeARTs dynamic cohort study

The MyHeART study was conducted in Selangor, Kuala Lumpur. and Perak, which are located in Peninsular Malaysia.

Malaysia is a country that is located in the Asian continent. The country consists of Peninsular Malaysia, Sabah, and Sarawak, which together cover 328,657 square kilometres of land and 1,190 square kilometres of water, making Malaysia the 67th largest nation in the world. Malaysia shares land borders with four other countries: Indonesia, Thailand, Singapore, and Brunei (Brys, Cribby, Nag, & Lee, 2015). The population of Malaysia is 32 million, of which 28.7 million are citizens and 3.3 million are non-citizens. Sixty-nine percent of the Malaysian population is Malay, while 23.2 percent, 7.0 percent, and 1.0 percent are Chinese, Indian, and others, respectively. There are 5.5 million adolescents in Malaysia; 2.8 million are male and 2.6 million are female (Mahidin, 2017).

According to Department of Statistic, Malaysia, the mean gross household monthly income in Malaysia as of 2014 is RM 6,141. Malaysians with a household income of <RM1500 account for 5.7 percent of the population, while those 49.2 percent and 45.1 percent have a household income of RM1500 – RM 5000 and >RM 5000 respectively (Unit, 2017). Only six percent of Malaysian citizens have never had any formal education. According to the 2010 Malaysian Population, Education and Social Characteristics Census, 22 percent of Malaysians have a primary school education, 42.7 percent have a secondary school education, and 16 percent have a tertiary level of education (Hassan, 2013).

A map of Peninsular Malaysia that shows the locations of Selangor, Kuala Lumpur. and Perak, the settings of the MyHeART study, is provided in Figure 3.2 below

Figure 3.2: Peninsular Malaysia map. Source: www.wikipedia.org

Selangor is one of the 14 states of Malaysia. The state of Selangor is bordered by Perak, Pahang, Negeri Sembilan, and the Straits of Malacca to the north, east, south, and west, respectively. The capital city of the state of Selangor is Shah Alam. Selangor is the largest state in Peninsular Malaysia with a total area of 8,104 km^2 and it is the most populous state in Malaysia and home to 6.4 million of the country's population. More than 89 percent of the population in Selangor are Malaysian citizens, while another 11 percent are foreigners. The Malay ethnicity is the dominant ethnicity in Selangor, accounting for 59 percent of total Malaysian citizens in the state, with Chinese, Indian, and others making up 27.2 percent, 12.6 percent, and 0.8 percent of the remainder, respectively. There are 933,800 adolescents in Selangor, of whom 478,800 are male and 455,000 are female (Mahidin, 2017).

The Federal Territory of Kuala Lumpur (Wilayah Persekutuan, Kuala Lumpur) is one of the three federal territories of Malaysia, and it is the capital city of Malaysia. It is an enclave within the state of Selangor, situated on the central west coast of Peninsular Malaysia. Although the total area of the Territory is just 243 km^2, the population in this area in 2017 stands at 1.8 million, making Kuala Lumpur the mostly dense populated area in Malaysia. Eighty-six percent of its population are Malaysian citizens while 14 percent are foreigners. Forty-seven percent of the Malaysian citizens in Kuala Lumpur are Malay, while 42.3 percent, 9.7 percent, and 1.1 percent are Chinese, Indian, and others, respectively. The adolescent population in Wilayah Persekutuan numbers 237,600, of whom 122,200 are male and 115,400 are female (Mahidin, 2017).

Perak is situated in the northern region of Peninsular Malaysia. Perak, which is comprised of 11 districts, covers an area of 21,035 km^2, making it the second largest state in the country. Perak is bordered by Kedah and Thailand to the north, Kelantan and

Pahang to the east, Penang to the northwest, and Selangor to the south, while the Straits of Malacca lie to its west. Ipoh is the capital city of Perak and is situated in the district of Kinta. Perak, with a population of 2.5 million, is the third largest state in terms of population size after Selangor and Johor. Ninety-six percent of the Perak population are Malaysian citizens, while the remaining four percent are non-Malaysians. As for the ethnic distribution of the population in Perak, the majority are Malay, with 58.8 percent, while Chinese, Indians, and others account for 29.1 percent, 11.7 percent, and 0.4 percent, respectively. The adolescent population in Perak is 442,400; 222,500 of them are male and 219,900 are female (Mahidin, 2017).

3.1.1.2 Study population – inclusion and exlusion criteria of MyHeART study

The study population of the MyHeART study in 2012 consisted of 13-year-old schoolchildren, who were attending the first year of government secondary school. The male and female participants were required to be able to understand and able to read in Bahasa Melayu, which is the national language of Malaysia. Adolescents studying in religious, boarding, and vernacular schools were excluded from the study. As the MyHeART study is a dynamic cohort study, in 2014 and 2016 new adolescents aged 15 and 17 years old, respectively, were recruited and followed up together with the previous 2012 cohort. Malay, Chinese and Indian were among major ethnic group that was included in the study. Minority ethnic groups such as Sikhs, Aborigine (also known as Orang Asli), and other races were grouped together as ‘Others’ and were also included in MyHeARTs study.

Students whose parents failed to give consent for the study were excluded from MyHeARTs study.

3.1.1.3 Sampling procedures

The sampling procedure for the MyHeART study followed a stratified sampling design. First, a complete list of public schools located in Selangor, Perak, and Wilayah Persekutuan was obtained from the Ministry of Education of Malaysia. The list contained 595 schools, 238 of the schools were in Perak, 261 were in Selangor, and 96 were in the Federal Territory of Kuala Lumpur. These listed schools were used as the sampling frame. Based on the criteria defined by Department of Statistics Malaysia, the schools were stratified into urban and rural (Mahidin et al., 2015). Then a computer-generated random number list was used to randomly select schools from urban and rural areas. Eight schools were selected from urban areas and seven from rural areas.

All the first-year secondary school students (age 13) from the selected schools were invited to participate in the MyHeART study in 2012. All the third-year secondary school students (age 15) from the selected schools were invited to participate in the MyHeART study in 2014, and all fifth-year secondary school students (age 17) from the selected schools were invited to participate in the MyHeART study in 2016. Each time during data collection, the participants and their parents were given a consent form and an information sheet about the MyHeART study. The information sheet contained clear information about the study to assist the parents in making a decision to participate or not to participate in the study. Participants and their parents who completed and submitted both the student and the parental consent forms were included in the study.

3.1.1.4 Sample size calculation

As the MyHeART study used stratified sampling, the following formula was used to calculate the sample size:

$$N = \frac{z^2pq}{re} \text{ x } \textit{Design effect}$$

where z = standard deviation, which was set at 1.96 and two-tailed, p = estimated prevalence, q = (1 – p), r = response rate, and e = precision level. The estimated prevalence of smoking in schools among 13 to 15-year-old adolescent students (33 percent) reported in the National Health Morbidity Survey 2011 was used as a reference in the MyHeARTs sample size calculation (Bakar et al., 2011). The calculated estimated sample for the MyHeART study was 1359 participants. A further 11 percent was added to the calculated sample size as a reserve to allow for dropping out and incomplete data, giving an expected study sample size of 1500 participants.

3.1.1.5 Data collection process

Before the MyHeART study was conducted, an official permission letter from the Ministry of Health and the Ministry of Education was obtained by the MyHeART study working group. An invitation letter regarding participation in the study was then sent to the headmaster/mistress of all the selected schools.

Enumerators who had a minimum educational qualification of an SPM certificate (UK GCSE level equivalent) were hired for the MyHeART study. Among the enumerators, qualified personnel with a Bachelor's degree in dietetics, a medical degree or Bachelor's degree in sports medicine were also recruited. The hired enumerators had a good command of English, Bahasa Melayu, and Mandarin, and also had strong reporting and documentation skills. They were given 2 days of intensive data collection and hands-on training. After completing the training, the enumerators were given assignments based on their working experience and their educational background. Enumerators with a medical degree background were assigned to measure the blood pressure of the participants. The dietitians were responsible for data on dietary intake, while those with a sport medicine or sports science degree were assigned to measure the physical activity and fitness level of the participants. The SPM certificate holders were responsible for the collection of other data such as weight and height using different tools and also for the administration of the questionnaires. All the activities during the MyHeART study data collection process were performed according to the study protocol and standard operating procedure.

3.1.1.6 Data collection tools

i) Student and parental questionnaires

The student and parental questionnaires for the MyHeART study were self-administered. These two questionnaires were adapted from an adolescent cohort study that was conducted in Northern Ireland, known as the Young Hearts project (Gallagher et al., 2002; Watkins et al., 2005). The questionnaires were translated into the Bahasa Melayu, and pilot tested on 30 subjects before the start of the MyHeART study.

The parental questionnaire collected information on the parent's socio-economic status and their family history of NCDs. Other information requested in the questionnaire included the student's birth weight and general health information.

The student questionnaire collected data on the pubertal stage, sleeping practices, life satisfaction, and behaviour. Questions to gather information on smoking, alcohol consumption, internet and gadget usage, drug abuse, and gambling were also included. Health information on breathing, airway, and skin problems was also collected. Some sensitive questions on sexual and reproductive health were also included in the student's questionnaire.

The self-administered parental questionnaire was given to the participant's parents to be completed at home and then later submitted to the MyHeART team. Missing information in the parental questionnaires was obtained through telephone interview. Although the parental data collection was initiated in 2012, due to the poor response the parental data collection was extended to 2013 to increase the response rate.

The student questionnaires were completed by the adolescent participants at school under the supervision of the research team to ensure that there was no information was missed during completion of the questionnaires.

ii) Dietary assessment

A 7DDH was chosen as the dietary assessment method in the MyHeART study because it has been shown to be a valid dietary estimate compared to other methods (Abdul Majid et al., 2016; M. B. Livingstone, P. J. Robson, & J. M. Wallace, 2004). This tool was adapted from the dietary history format used in the Young Heart Project that was conducted in Belfast, Northern Ireland, UK in 2000 (Gallagher et al., 2002; Watkins et al., 2005). The 7DDH was modified according to Malaysian setting, and pre-tested on 40 students from urban and rural school before been used in MyHeART study.

The dietitians conducted the 7DDH interview, which gathered information on the consumption of breakfast, mid-morning snack, lunch, afternoon tea, dinner, and supper on the preceding seven days. Flip-chart illustrations of local foods and common household measurements were used as supplementary tools to assist the participants during the interview in estimating the size and the portion of food and drink consumed

(Shahar, Safii, Manaf, & Haron, 2015). Each student needed about half an hour to complete the 7DDH.

iii) Physical evaluation

The height of the MyHeART study participants was measured using a calibrated vertical steadiometer (Seca Portable 217, Seca, UK). The measurement was taken without socks and shoes and was recorded to the nearest 0.1 cm.

The weight of the participants was taken using a digital electronic weighing scale (Seca 813, Seca, UK). The MyHeART study participants were weighed while wearing light clothing and the measurement was recorded to the nearest of 0.1 kg.

Body mass index was calculated by dividing the weight in kilograms by the height in square metres. Using the International Obesity Task Force (IOTF) criteria, with extrapolation to an adult BMI cut-off of 25 kg/m^2 for overweight and 30 kg/m^2 for obesity, in the MyHeART study the definition for overweight was 21.91 kg/m^2 and 22.58 kg/m^2 for male and female adolescents, respectively, while obesity was defined as 26.84 kg/m^2 and 27.76 kg/m^2 for males and females, respectively (Cole, Bellizzi, Flegal, & Dietz, 2000). All the tools used for the physical evaluation were calibrated and validated before the MyHeART study was conducted.

iv) Haematological and blood biochemical profile

The MyHeARTs participants were instructed to fast for at least 10 hours before the blood-taking procedure. The blood samples were taken by an experienced phlebotomist.

A total of 15 ml blood was withdrawn from each MyHeARTs participant and sent for analysis at a certified International Organization for Standardization (ISO) hospital pathology laboratory. The blood samples, after being withdrawn, were immediately stored in a cool box at a temperature of 4 degrees Celsius. This was to ensure that the samples taken preserved the level of markers that were sensitive to degradation if subjected to an increase in temperature. The use of a cool box was just a temporary measure because after the procedure, the samples were immediately transported to a field laboratory within each of the states. At the laboratory, the samples were spun and stored as serum. The serum was divided into several aliquots of 0.5 ml of serum. A full blood count test (Advia 2120 flow cytometry, Siemens, Germany), fasting blood glucose (Advia Chemistry, Siemens Germany) renal, lipid, and bone profiles (Advia Chemistry, Siemens, Germany), and a vitamin D and parathyroid hormone test (Advia Centaur XP immunoassay, Siemens, Germany) were performed at the field laboratory. In the field laboratory, all aliquots for future laboratory analysis were stored in freezers at a temperature of -80 degrees Celsius until ready to be transported back to the University of Malaya bio bank.

3.1.1.7 Data management and data access

Before each MyHeARTs data collection, the field researchers involved in data assembly were given training to ensure standardized data management. All the questionnaires completed by the participants were checked by the field researcher to ensure completeness. For the purpose of confidentiality, a specific ID was given to each participant and other identification such as name, address, and national identification number were removed. Only authorized research members were allowed to access the confidential information. The data entry template was set by the principal researcher. The data from the questionnaires and the blood test results were entered into the template manually. Cross-checking of data between researchers was done regularly to reduce the number of errors during the manual data entry. The data administrator was notified about any inconsistencies. Ten percent of the data was randomly selected and checked by another researcher as a form of quality control of the data entry measures. All the data were stored in the University of Malaya server.

3.1.1.8 MyHeARTs 2012 cohort summary

There were 2694 eligible candidates within the 15 schools that were selected for the MyHeART study. However, only 1361 students agreed voluntarily to participate in the MyHeART study, giving an overall response rate of 51 percent. Urban schools had a lower response (22 to 53 percent) compared to rural schools (40 to 84 percent). There were more participants from urban schools compared to rural, and there was a higher numbers of female participants compared to male. More of the participants were of Malay ethnicity compared to other ethnic groups because Malay is the major ethnic group in Malaysia. Twenty-four percent of the adolescents were in the normal weight category, while 9 percent and 15 percent were obese and overweight, respectively (M. A. Hazreen et al., 2014).

3.1.2 Part 1 study instruments used to assess the Malaysian adolescent dietary intake

A huge amount of data was collected during the waves of the MyHeART cohort study. However, only the important data needed for the first part of this study were extracted from the MyHeARTs 2014 cohort data.

3.1.2.1 Seven-day diet history

As described in **Section 3.1.1,** diet data was among the enormous amount of data collected via the 7DDH interview during the MyHeART cohort study. All the diet data from the MyHeARTs 2014 cohort were extracted and analysed to describe the dietary intake of Malaysian adolescents as well as the socio-demographic variation in dietary intake. A 7DDH was used in this first phase of the study because a single 24-hour diet recall is unable to capture the details of the habitual diet and it is not representative of an individual's diet. A 7DDH can give a better picture of the dietary pattern, especially with regards to variation in macronutrient intake (Van Staveren, De Boer, & Burema, 1985). The guide for the 7DDH used in this study is included in Appendix B. Under-reporting of dietary intake by the participants was determined by a PAL calculation, which was based on the ratio between energy intake and predicted basal metabolic rate (EI:BMR). The Henry and Rees (1991) equation was used in the calculation of BMR because the equation is built on a database on tropical inhabitants and is therefore able to provide a better estimation of the BMR in Malaysian adolescents (B. Poh, Ismail, Zawiah, & Henry, 1999).

The formula used for BMR, using Henry and Rees (1991) equation was:

BMR for males = 80.4 x W + 2319

BMR for females = 54.4 x W + 2781

Where W = weight in kg

The calculation of the EI: BMR ratio was obtained by dividing the average energy intake of the adolescents in the 2014 MyHeART cohort study by the BMR of each participant of that cohort. Those participants with a EI:BMR ratio lower than the Kersting (W. Sichert-Hellert, Kersting, & Schoch, 1998) cut-off point, where EI:BMR is less than 1.44 for males and less than 1.25 for females, were excluded from the analysis. Those participants with an EI:BMR ratio of more than 2.5 were classified as over-reporters and also excluded from the analysis (A. E. Black, Coward, Cole, & Prentice, 1996).

3.1.2.2 Student and parental questionnaire

Data from the student and parental questionnaires contained a variety of information, as described earlier in Section 3.1.1. However, only the information needed for this particular analysis was selected. To answer the first research question of this study, only information on the gender, ethnicity, residency, and highest education level of the parent, as well as the gross income of the parent/caretaker were extracted.

The education of the parents was classified into four categories: Never schooled (never received any form of formal education), Primary education (formal education obtained between the age 7 to 12 years old), Secondary education (formal education obtained from the age of 13 to 17 years old, and Tertiary education (completion of A-level, college, or university education) (Hassan, 2013). The socio-economic status of the parents was categorized into low (<RM1500), middle (RM1501–RM5000) and high-income status (>RM5000) (Mahidin, 2017). The categorization of the level of education of the parents and household socio-economic status were based on the definitions of the Malaysian Government's Department of Statistics.

3.1.2.3 Physical measurement

Body mass index was calculated using formula,

BMI = Weight (in kg) / (Height x Height) (in meter)

Using IOTF criteria, underweight was defined as a BMI of less than 15.8 for males and less than 16.3 for females. An adolescent was judged to be of normal weight if the BMI was in the range of 15.8–<21.9 for males and 16.3–<22.6 for females. Overweight was characterized as a BMI of <21.9–<26.8 for males and 22.6–<27.8 for females. Adolescents were considered obese if their BMI was >26.8 for males and >27.8 for females (Cole et al., 2000). As the IOTF reference provides a smooth transition from the child/adolescent to adult definition of overweight and obesity, the IOTF criteria were used in this study (Must & Anderson, 2006). Another reason for the use of IOTF criteria was that they developed from the data of many nations including those in Asia such as Hong Kong and Singapore the latter of which is nearest to Malaysia in terms of geography and demographics. Furthermore, the BMI cut-offs in the IOTF criteria are linked to the adult cut-offs for overweight and obesity, which are good indicators of the risk of adverse health outcomes (Y. Wang, Monteiro, & Popkin, 2002). Some studies had showed no different in term of health correlations when comparing IOTF with other methods, including WHO method (Li et al., 2016; Rolland-Cachera, 2011; Tyson & Frank, 2017).

3.1.3 Sample size calculation for assessment of the Malaysian adolescent dietary intake study

Since the MyHeART study used a stratified sampling design, the sample size calculation for this dietary intake study was based on the same design. The prevalence of obesity among Malaysian adolescents (20.3 percent) in a study done in 2011 was used as reference for the calculation (Wahida, Nasir, & Hazizi, 2011).

$$n = \frac{z^2 . p . q}{r . e^2} \quad \text{X deff}$$

Where,

n = the desired sample size which would be sufficient to measure the different variables

z = the standard normal deviate, set at 1.96 at 5 percent level for a two-tailed test, which corresponds to 95 percent confidence level

p = estimated prevalence

q = 1 – p

deff = design effect for stratified sampling

r = response rate

e = the precision level or the distance from the prevalence estimate in either direction, which was set to ± 5 percentage points for a two-tailed equation or 0.05 (expressed in decimals).

The following information was used to calculate the sample size:

Estimation of prevalence: From a cross-sectional study conducted in Malaysia in 2011, the prevalence of obesity among adolescents is 20.3 percent (Wahida et al., 2011).

Response rate: The response rate assumed is 45 to 50 percent.

Z value: 1.96.

p (prevalence): 0.20

q (1-p): 0.8

e (effect size): 0.05

r (expected response rate): 0.5

Design effect: 2

$$n = \frac{z^2.p.q}{r.e^2} \text{ X deff}$$

$$= \frac{(1.96)^2 \text{x } 0.20 \text{ x } 0.8}{0.5 \text{ x } (0.05)^2} \text{ x } 2$$

$$= \frac{0.61}{1.25\ x\ 10^{-3}} \text{ X } 2$$

= 983

Thus, only 983 participants were required for the study of the socio-demographic variation in the dietary intake of Malaysian adolescents. However, the larger sample size of the 2014 MyHeARTs was used for the analysis in this study.

3.1.4 Study variables used in the Malaysian Adolescent Dietary Intake Study

Outcome variables: The outcome variables in this study were the various dietary intakes of in-school adolescents, particularly their energy, macro and micronutrient intakes.

Independence variables: The independent variables were the ethnicity, sex, parent's level of education, household economic status, and residence (urban or rural) of the participants.

Confounders: The confounding variables in this study were physical activity and sedentary lifestyle because these two components can also have effect on the dietary intake and pattern (Mesas et al., 2012).

3.1.5 Data cleaning

After the variables needed for the study had been extracted from main MyHeARTs database, data cleaning was conducted to detect any missing data. Corrections were made for any gross error detected in the data set. Variables such as blood nutritional indicators (Hb, total cholesterol, LDL, HDL etc.) had missing data that amounted to less than five percent, and no imputations were made. Among the variables, socio-economic indicators such as parental education and household income status had missing data amounting to as much as 33 percent. Little's MCAR test of these parental education and household income status showed p-value of <0.005, which indicated that data were missing not at random (MNAR). Thus, no imputations were made.

3.1.6 Data analysis process and statistical methods

The Statistical Package for the Social Sciences (SPSS) software version 20.0 (Chicago, IL, USA) for Windows was used for data analysis in this study. As the data for the Malaysian Adolescent Dietary Intake Study were extracted from the MyHeARTs, which is study that uses a complex sampling design, complex sampling data analysis procedures were practised. School weightage, student weightage, and final weightage were calculated and used in the complex sampling analysis.

The student weightage, school weightage, and final weightage were calculated using the following formulae:

$$\textbf{Student weight} = \frac{\textbf{Total student in school}}{\textbf{Student participated in that schools}}$$

$$\textbf{School weight} = \frac{\textbf{Total schools within residency}}{\textbf{selected schools}}$$

$$\textbf{Final weight} = \textbf{Student weight} \times \textbf{School weight}$$

Table 3.1 summarizes the school strata and Table 3.2 provides the final weightage of every school that participated in this study.

Table 3.1: Strata of the schools and school weight

	Perak		Selangor		Kuala Lumpur
	Urban	Rural	Urban	Rural	Urban
Total number of schools in the strata	108	99	170	57	92
Total number of selected schools	1	6	4	1	3
School weightage	108	16.5	42.5	57.0	30.7

Table 3.2: Final weightage summary

Schools	Participants	Total students	Student weight	School weight	Final weight
Datok Lokman	69	315	4.6	30.7	140.3
Desa Petaling	95	236	2.48	30.7	76.1
Seri Permaisuri	76	252	3.32	30.7	101.9
Bukit Jelutong	55	414	7.53	42.5	320.0
Dato' Abu Bakar Baginda	83	258	3.11	42.5	132.2
Sultan Abdul Aziz Shah	138	445	3.22	42.5	136.9
Tasek Permai	46	158	3.43	42.5	145.8
Bagan Terap	99	150	1.51	57	86.1
Pinji	69	224	3.25	108	351.0
M Shah	63	175	2.78	16.5	45.9
Raja Lope	107	240	2.24	16.5	37.0
Sayong	79	96	1.22	16.5	20.1
Sultan Tajul Ariffin	91	116	1.27	16.5	21.0
Tapah	43	49	1.14	16.5	18.8
Tun Perak	118	163	1.38	16.5	22.8

The data were then checked for outliers and normality. An informal method was used, where the mean and median every variable was compared and histogram, normal probability plot and box and whisker plot were constructed. After confirming the normality of each variable, independent sample t-test and analysis of variance (ANOVA) procedures were performed using the general linear model (GLM) in the SPSS complex samples menu.

Independent sample t-tests were used to compare the means of two groups of quantitative variables. Comparisons of gender (male and female adolescents) and of intake (urban and rural adolescents) were made.

In this study, ANOVA was used to compare the mean of the nutrient intake between ethnicity, parent's education, BMI, and also household socio-economic status. A post hoc test was performed whenever the ANOVA test showed significant results.

3.1.7 Ethical consideration

Ethical approval for the part 1 study (Assessment of Malaysian Adolescents' Dietary Intake) and the part 2 study (Development and Comparative Validation of a Malaysian Adolescent Food Frequency Questionnaire – MyUM Adolescent FFQ) was obtained from the Medical Ethics Committee of the University of Malaya Medical Centre (MEC Ref. No. 896.34) via the MyHeART study. The National Medical Research Register number is 14-376-20486.

3.2 Part 2 study: Development and Comparative Validation of a Malaysian Adolescent Food Frequency Questionnaire (MyUM Adolescent FFQ)

The second part of this study, which concerned the development of the MyUM Adolescent FFQ, is discussed in detail in this section. This section also includes a description of the comparative validation of the MyUM Adolescent FFQ with a 7DDH.

3.2.1 Study instrument of Development and Comparative Validation of MyUM Adolescent FFQ

The 7DDHs from the 2012 MyHeARTs cohort and 2014 MyHeARTs cohort were used in the second part of this study. The most commonly consumed foods in the 7DDH of the 2012 MyHeARTs cohort were used to construct the MyUM Adolescent FFQ. The validity of the FFQ was then tested by comparing its results with those of the 7DDH of the 2014 MyHeARTs cohort.

3.2.2 Construction of MyUM Adolescent FFQ

Four main steps need to be followed to develop a population-specific FFQ if scant data are available on the total food consumption of that particular population. The four main steps are 1) Food list compilation, 2) Portion size determination according to that specific population, 3) Categorization of consumption frequency, and 4) Food composition table development (J. Cade et al., 2002; W Willett & Lenart, 1998).

The MyUM Adolescent FFQ in this study was developed from the basic principle. Information on the food intake of the adolescents during weekdays and at the weekend was obtained through the 7DDH extracted from the 2012 MyHeARTs database.

Table 3.3: Seven days diet history of macro and micronutrient intake for adolescent age 13 years old from 2012 MyHeARTs cohort

Nutrients	Overall mean (95% CI)
Macronutrients	
Energy (kcal/day)	1659.0 (1634.6 – 1683.3)
Protein (g/day)	61.2 (60.1 – 62.2)
Carbohydrate (g/day)	229.0 (225.3 – 232.7)
Crude fibre (g/day)	2.9 (2.8 – 3.1)
Sugar (g/day)	24.3 (33.1 – 35.4)
Fat (g/day)	55.5 (54.4 – 756.5)
Cholesterol (mg/d)	223.3 (216.6 – 229.9)
Saturated fat (g/d)	10.9 (10.5 – 11.2)
Monounsaturated fat (g/d)	8.3 (8.0 – 8.5)
Polyunsaturated fat (g/d)	6.0 (5.9 – 6.2)
Micronutrients	
Vitamin D (µg/d)	0.6 (0.5 – 0.7)
Sodium (mg/d)	2289.5 (2239.9 – 2339.1)
Potassium (mg/d)	1033.22 (1012.3 – 1054.1)
Calcium (mg/d)	377.4 (365.1 – 389.7)
Magnesium (mg/d)	114.7 (110.9 – 118.5)
Phosphorus (mg/d)	842.3 (823.0 – 861.6)
Iron (mg/d)	14.2 (13.8 – 14.5)

(Abdul Majid et al., 2016)

Among the food data collected from the 1361 participants, 523 single foods were reported as being used on regular basis. However, foods were only included in the food item list in the questionnaire if they made an important contribution to the population's intake of energy and nutrients of interest (Gladys Block et al., 1986). From this list of 523 food items, the mean intake of each food item consumed by 2012 MyHeARTs participants was calculated. The nutrients contributed by each food item were then determined and the cumulative percentage of energy and macronutrients was calculated. A food item that contributed up to 90 percent of total energy and macronutrients, and any food items that appeared more than 20 times in the 7DDH, were selected for inclusion in the FFQ (Gladys Block et al., 1986; A. Norimah, Jr. & Margetts, 1997; A. F. Subar et al., 2000). Table 3.4, 3.5, 3.6 and 3.7 showed food items from 2012 MyHeARTs database that contributed 90 percent of energy, carbohydrate, protein, and fat intake.

Table 3.4: Food items that contributed up to 90 percent of total energy

No.	Food Item	Contribution to nutrient of interest (%)	Cumulative (%)
Energy			
1.	White rice	27.4	27.4
2.	Condensed milk	5.5	32.9
3.	Fried chicken	5.4	38.3
4.	Coconut rice	5.1	43.4
5.	Granulated sugar	5.1	48.5
6.	Fried rice	4.8	53.3
7.	White bread	2.9	56.2
8.	Fried chicken in chilli	2.8	59.0
9.	Fried mee	2.6	61.6
10.	Sunnyside egg	2.5	64.1
11.	Roti canai	1.9	66.0
12.	Malted milk powder	1.9	67.9
13.	Fried egg in chilli	1.8	69.7
14.	Instant noodles	1.6	71.3
15.	Sweetened flavoured drink	1.5	72.8
16.	Fried mee hoon	1.4	74.2
17.	Sausage bread	1.4	75.6
18.	Mee hoon soup	1.4	77.0
19.	Chicken curry	1.4	78.4
20.	Chicken rice	1.3	79.7
21.	Fried mackerel	1.3	81.0
22.	Fried chicken in soy sauce	1.2	82.2
23.	Curry sauce	1.1	83.3
24.	Curry puff	1.0	84.3
25.	Laksa	1.0	85.3
26.	Fried banana	1.0	86.3
27.	Cream bread	1.0	87.3
28.	Fried catfish in chilli	1.0	88.3
29.	Dhal gravy	1.0	89.3
30.	Chicken soup	1.0	90.3

Table 3.5: Food items that contributed up to 90 percent of carbohydrate intake

No.	Food Item	Contribution to nutrient of interest	Cumulative (%)
Carbohydrate			
1.	White rice	45.8	45.8
2.	Granulated sugar	9.2	55.0
3.	Fried rice	8.7	63.7
4.	Condensed milk	6.6	70.3
5.	Coconut rice	5.5	75.8
6.	White bread	4.3	80.1
7.	Fried mee	2.6	82.7
8.	Sweetened flavoured drink	2.4	85.1
9.	Malted milk powder	2.3	87.4
10.	Roti canai	2.1	89.5
11.	Instant noodle	1.6	91.1

Table 3.6: Food items that contributed up to 90 percent of protein intake

No.	Food Item	Contribution to nutrient of interest	Cumulative (%)
Protein			
1.	White rice	12.8	12.8
2.	Fried chicken	11.7	24.5
3.	Fried rice	6.8	31.3
4.	Fried chicken in chilli	5.4	36.7
5.	Condensed milk	3.9	40.6
6.	Fried mackerel	3.8	44.4
7.	Coconut rice	3.4	47.8
8.	Chicken curry	3.2	51.0
9.	White bread	3.1	54.1
10.	Sunnyside egg	2.5	56.6
11.	Fried mee	2.4	59.0
12.	Chicken soup	2.4	61.4
13.	Fried chicken in soy sauce	2.3	63.7
14.	Chicken rice	2.0	65.7
15.	Chicken burger	2.0	67.7
16.	Mee hoon soup	1.7	69.4
17.	Laksa	1.7	71.1
18.	Malted milk powder	1.6	72.7
19.	Sausage bread	1.5	74.2
20.	Fried catfish in chilli	1.5	75.7
21.	Fried catfish	1.1	76.8
22.	Roti canai	1.1	77.9
23.	Fried kuey teow	1.0	78.9
24.	Dhal gravy	1.0	79.9
25.	Chicken nugget	1.0	80.9
26.	Chicken tomyam	1.0	81.9
27.	Instant noodle	0.9	82.8
28.	Fried mee hoon	0.9	83.7
29.	Grill hardtail fish	0.8	84.5
30.	Mee soup	0.8	85.3
31.	Full cream milk	0.7	86.0
32.	Full cream milk powder	0.7	86.7
33.	Boiled egg	0.7	87.4
34.	Mackerel curry	0.7	88.1
35.	Fried anchovy in chilli	0.6	88.7
36.	Fried Tilapia	0.6	89.3
37.	Creamed bread	0.6	89.9
38.	Beef rendang	0.5	90.4

Table 3.7: Food items that contributed up to 90 percent of fat intake

No.	Food Item	Contribution to nutrient of interest	Cumulative (%)
Fat			
1.	Fried chicken	11.4	11.4
2.	Fried rice	10.0	21.4
3.	Sunnyside egg	7.1	28.5
4.	Fried chicken in chilli	5.7	34.2
5.	Coconut rice	5.2	39.4
6.	Condensed milk	4.3	43.7
7.	Chicken curry	3.0	46.7
8.	Mee hoon soup	3.0	49.7
9.	Curry gravy	2.7	52.7
10.	Fried mee	2.7	55.4
11.	Fried chicken in soy sauce	2.2	57.6
12.	Fried catfish in chilli	2.1	59.7
13.	Fried mackerel	2.0	61.7
14.	Sausage bread	2.0	63.7
15.	Roti canai	2.0	65.7
16.	Fried kuey teow	2.0	67.7
17.	Instant noodle	2.0	69.7
18.	Omelette	1.5	71.2
19.	Chicken nugget	1.4	72.6
20.	Curry puff	1.3	73.9
21.	Fried water spinach	1.3	75.2
22.	Malted milk powder	1.2	76.4
23.	Curry mee	1.2	77.6
24.	Chicken soup	1.1	78.7
25.	Creamed bread	1.1	79.8
26.	French fries	1.1	80.9
27.	Chicken burger	1.0	81.9
28.	Fried catfish	1.0	82.9
29.	Fried mee hoon	1.0	83.9
30.	Dhal gravy	1.0	84.9
31.	Full cream milk	1.0	85.9
32.	Full cream milk powder	1.0	86.9
33.	Fried tilapia	1.0	87.9
34.	Fried cabbage	1.0	88.9
35.	Sambal gravy	1.0	89.9
36.	Boiled egg	1.0	90.9

A total of 150 single foods were identified and organized into 14 main food categories: (1) cereal and cereal-based dishes; (2) meat and poultry; (3) seafood and shellfish; (4) milk and dairy products; (5) egg and egg dishes (6) vegetables; (7) fruit; (8) seasonal fruit; (9) traditional *kuih*; (10) non-alcoholic beverages; (11) alcoholic beverages; (12) sweets and spreads; (13) processed food; (14) fast food and snacks, as depicted in Table 3.8.

Table 3.8: Description of food group

Food group	Description
Cereal and ceral based dishes	Rice, rice dishes, rice based noodles, bread, wheat, wheat based noodles, biscuits
Meat and poultry	White and red meat dishes, fish, squids, shrimps, shell
Milk and milk products	Milk, flavoured milk, milk powder, malted milk powder, ice creams, yogurt, cheese
Egg and egg dishes	Boiled egg, egg dishes
Vegetables	Green vegetables, leguminious vegetables, cruciferous vegetables, seeded vegetables, root vegetables, tuberous vegetables
Fruits	Fresh fruits, dried fruits, canned fruits, seasonal fruits
Traditional kuih/cakes	Malay, Chinese and Indian kuih/cakes
Non – alcoholic Beverages	Plain water, juices, carbonated drinks, cereal drinks
Alcoholic beverages	Alcoholic drinks
Sweets and spread	Extra granulated sugar, condensed milk, jam, chocolate
Processed food	Sausage, nugget, burger
Fast foods and snacks	Pizza, potato chips, French fries

A team of dietitians and public health professionals were then consulted concerning the list generated. The role of public health professional was to look at the relevance of the food item in term of health impact, while the dieticians focus on the nutrient component of the food items. Modifications and additions of important food items to the food list were made accordingly to avoid participant burden and at the same time to prevent underestimation of nutrient intake. A total of 200 listed close-ended food item questions were generated to cover all the food categories. The general format of the questionnaire was then addressed with respect to instructions, portion size options, and frequency of consumption options.

The nutrient composition of the food items in the MyUM Adolescent FFQ was based on the Malaysian Food Composition Database Programme (Siong, Noor, Azudin, & Idris, 1997).

Portion size options were included based on the common household instrument used for each food item to enable accurate quantification. A flip chart with colour illustrations of household measurement utensils and portions of commonly consumed food was also developed in order to explain the portion options for the food items to the participants. The portion options were based on the *Malaysian Atlas of Food Exchanges and Portion Sizes* (Shahar et al., 2015).

The frequency of food consumption was recorded in nine categories (none per month, one to three times per month, one time a week, two to four times per week, five to six times per week, one time per day, two to three times per day, four to five times per day, six and more times per day). In each category, there were options for how frequently each food item was consumed. For example, if a food item is consumed three times per week, the participants needs to enters 3 in the '2 to 4 times per week' category. Stated in the instruction, that all participants need to report their dietary intake for the past 12 months' duration.

The questionnaire instructions, frequency options and food list were presented in the Malay language. An extract of MyUM Adolescent FFQ is included in Appendix C.

3.2.3 Pre-testing

The questionnaire was then pilot tested on a sub-sample (n = 10) of 15-year-old adolescents, randomly picked from 2014 MyHeARTs participants. All the questions were answered during pilot testing. On average, the participants in the pilot test needed 30 minutes to complete the questionnaire. Qualitatively, the participants were asked to identify ambiguities and difficult questions, and to give overall feedback on the MyUM Adolescent FFQ. As result of the participants input, some final minor modifications were made to the language content to increase future participants' understanding of the questionnaire.

3.2.4 Reliability test

Using the convenience sampling method, 119 adolescents aged 13 to 15 years old, who were not participants in the MyHeART study, were invited to participate in the test-retest of the FFQ. The participants were from the Malacca, Perak, and Penang areas (Sekolah Menengah Kebangsaan Berapit, Penang, Sekolah Menengah Kebangsaan Seri Perak, Perak and Sekolah Menengah Kebangsaan Sultan Alaudin, Melaka) of Peninsular Malaysia. The participants were first given instructions and then asked to complete the FFQ with the assistance of the flip chart on household instruments and common portion sizes. The same adolescents were then followed up and asked to complete the same MyUM Adolescent FFQ 1 week later. A 1-week duration was chosen to avoid true changes in dietary habits among the adolescents, which may occur over longer periods of time (A. Nurul-Fadhilah, P. S. Teo, & L. H. Foo, 2012b; C. A. Vereecken et al., 2010; Carine Anna Vereecken, Rossi, Giacchi, & Maes, 2008).

3.2.5 Comparative Validation of MyUM Adolescent FFQ

3.2.5.1 Sample size calculation

Based on the Bland–Altman method, the sample size needed for the validation of the MyUM Adolescent FFQ had to consist of at least 50 participants, preferably more (J. Cade et al., 2002). However, a sample size larger than 200 subjects would only provide a small amount of additional precision to FFQ validation (W Willett & Lenart, 1998). Therefore, some correlation criteria were established in order to arrive at the sample size.

Previous studies have demonstrated that correlation coefficients for validation studies usually fall within the range of 0.3 to 0.7 (J. Cade et al., 2002; F. E. Thompson & Byers, 1994; W. C. Willett et al., 1985). Thus, the hypotheses HO: $r < 0.3$ and H_A: $r \geq 0.3$ were used to assess the correlation between the MyUM Adolescent FFQ and the 7DDH, which gave a minimal sample size of n = 85; for a desired lower limit of a two-sided 95 percent confidence interval, β of 0.2, and ***r*** of 0.3 (Hulley, Cummings, Browner, Grady, & Newman, 2013).

3.2.5.2 Sampling and data collection procedure

The data collection for the MyHeARTs 2014 cohort was conducted from April to July 2014. All 1247 MyHeARTs participants in 2014 were interviewed about their 7DDH by means of a face-to-face interview with a dietitian and assisted by tools such as flip charts and household measuring utensils such as cups, bowls, and spoons, as explained earlier in **Section 3.1.1.6**. After the diet history interview, and other data collection procedures such as those described in the MyHeARTs protocol (M. A. Hazreen et al., 2014), randomly selected participants from each school were invited to participate in MyUM Adolescent FFQ comparative validity study. Those who agreed were given verbal and written instruction on how to complete the MyUM Adolescent FFQ by a different researcher and subsequently asked to self-complete the MyUM Adolescent FFQ in the presence of the researcher. The MyUM Adolescent FFQ was then checked for completeness and the participants were asked to clarify any unclear or missing data whenever possible. The whole part 2 study process is depicted in Figure 3.3.

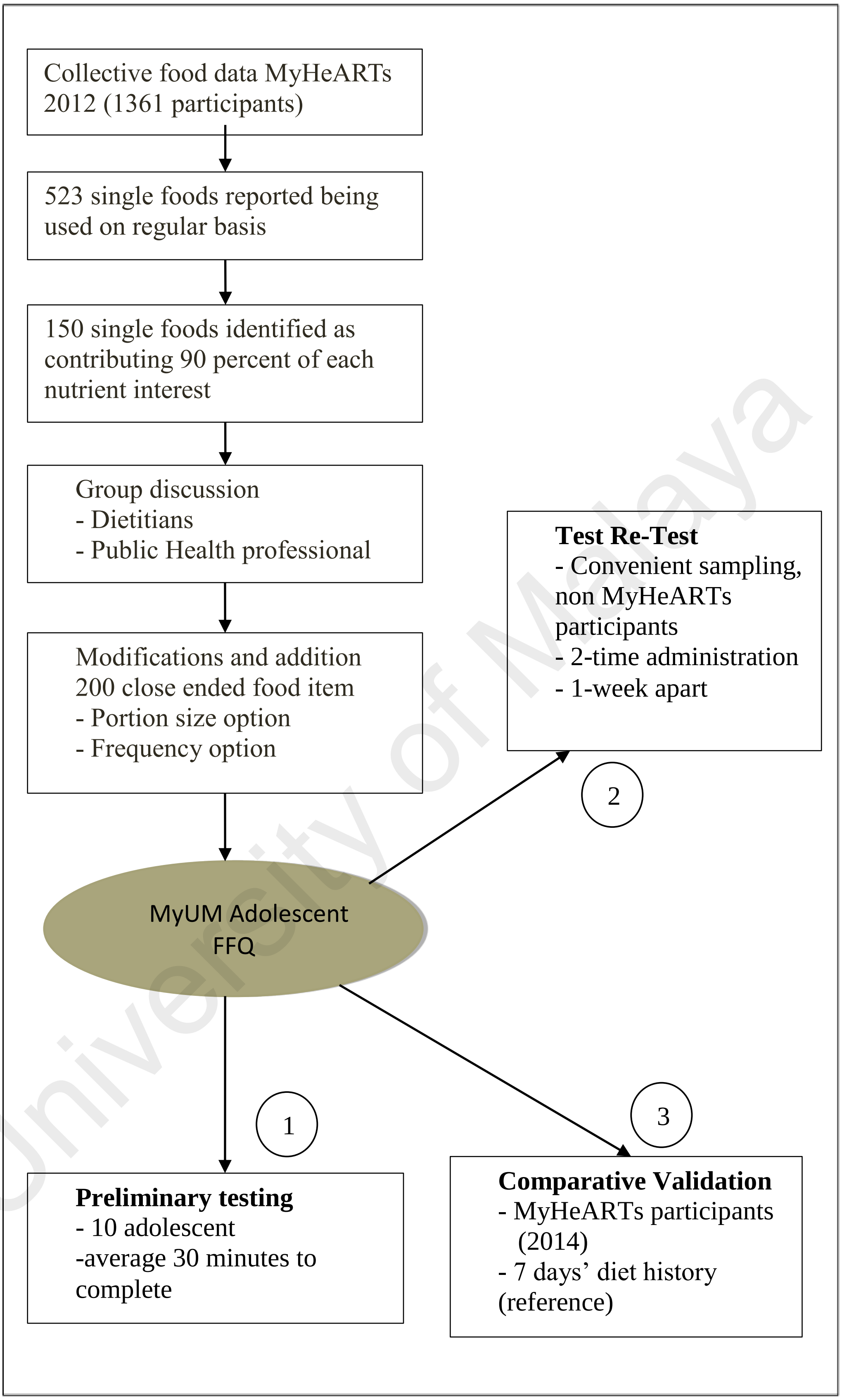

Figure 3.3: MyUM Adolescent FFQ development process and protocol

3.2.6 Statistical analysis

3.2.6.1 Data entry of nutrient intake

Information obtained from the 7DDH and MyUM Adolescent FFQ was input into Nutritionist Pro^{TM} Diet Analysis (Axxya System, USA) software in order to calculate the participants' nutrient intake. The nutrient composition data in the Nutritionist Pro^{TM} Diet Analysis database is compiled from a variety of sources, including the Nutrient Composition of Malaysian Food, which is the standard reference adopted by the current study (Siong et al., 1997). The average daily nutrient intake from the 7DDH was calculated as follows:

(Intake of nutrient from Monday to Sunday)/7.

The calculation of nutrient intake from the FFQ was based on the following formula:

Frequency of intake per day x serving size x total number of serving x weight of food in one serving.

To calculate the frequency of intake per day, foods taken one time per week, for example, were divided by 7 days, thus the frequency of intake per day = 0.14, while foods taken one time per month, for example, were divided by 30 days, thus the frequency of intake daily = 0.03 (W Willett & Lenart, 1998). Table 3.9 summarizes the frequency of intake of food items per day calculation based on the frequency of food intake in the FFQ.

Table 3.9: Frequencies of intake reported in MyUM Adolescent FFQ and the conversion to frequency of intake per day

Frequency of intake in FFQ	Frequency of intake per day (formula)
Per day	
Once a day	1.00 (1/1)
Two times per day	2.00 (2/1)
Three times per day	3.00 (3/1)
Four times per day	4.00 (4/1)
Five times per day	5.00 (5/1)
Six times per day	6.00 (6/1)
Per week	
Once a week	0.14 (1/7)
Two times per week	0.29 (2/7)
Three times per week	0.43 (3/7)
Four times per week	0.57 (4/7)
Five times per week	0.71 (5/7)
Six times per week	0.86 (6/7)
Per month	
Less than once a month	0.02 (0.5/30)
Once a month	0.03 (1/30)
Two times per month	0.07 (2/30)
Three times per month	0.10 (3/30)
Never	
Never in a year	0 (0/365)

3.2.6.2 Test-retest reliability statistical analysis

Using a ±2 SD reporting of energy intake cut-off criterion, subjects with a total energy intake that fell outside the range of 800 to 4000 kcal per day based on the MyUM Adolescent FFQ1 and MyUM Adolescent FFQ2 were excluded from the study (McCrory, Hajduk, & Roberts, 2002; Mendez et al., 2011).

The mean, SD, and t-test of energy and nutrients were calculated based on the data collected in the MyUM Adolescent FFQ1 (first administration) and MyUM Adolescent FFQ2 (second administration).

The data were checked for outliers and normality. As the data were not normally distributed for all the variables, a log transformation procedure was undertaken to improve normality.

Intra-class correlation was used to estimate the nutrient value relationship between MyUM Adolescent FFQ1 and MyUM Adolescent FFQ2, where a value less than 0.4 was interpreted as poor, 0.4 to 0.59 as fair, and 0.60 to 0.74 as good, while an ICC of more than 0.75 was interpreted as an excellent correlation (Leslie A. Lytle et al., 2002).

The agreement between the means of energy and nutrient intake of MyUM Adolescent FFQ1 and MyUM Adolescent FFQ2 was further assessed using the Bland-Altman method. The difference between the intake of the two administrations (MyUM Adolescent FFQ1 – MyUM Adolescent FFQ2) against the mean intake of the two administrations ([MyUM Adolescent FFQ+ MyUM Adolescent FFQ2]/2) were plotted (Giavarina, 2015). The limits of agreement (mean ± 1.96 SD) was used to assess the agreement between the two administrations (Bland & Altman, 1986).

3.2.6.3 Statistical analysis of comparative validation study

All the variables were checked for outliers and normality before further data analysis. Informal method was used, where the mean and median every variable was compared and histogram, normal probability plot and box and whisker plot were constructed. Not normally distributed variables were log transformed to improved normality.

Subjects with a total energy intake that fell outside the range of 800 to 4000 kcal per day based on the MyUM Adolescent FFQ and 7DDH were excluded from the study (McCrory et al., 2002; Mendez et al., 2011). In addition, participants whose questionnaires had missing information or who did not complete the questionnaire were also excluded.

The mean and SD of nutrient intakes assessed by the 7DDH and MyUM Adolescent FFQ were calculated. For the purpose of the current study, the nutrient intake data derived from the 7DDH and the MyUM Adolescent FFQ were compared using a signed-ranks test. Pearson's correlation coefficients were used to estimate the nutrient value relationship of the 7DDH and MyUM Adolescent FFQ, where $r < 0.3$ indicated a low correlation; $r > 0.3–0.5$ a moderate correlation, and $r > 0.5$ a good correlation (W Willett & Lenart, 1998). Nutrient intakes were adjusted for total energy by using regression analysis as per Willet-Lenart method (W Willett & Lenart, 1998).

The distributions of energy and nutrients were also categorized into quartiles, where the percentages of participants were classified by both methods (MyUM Adolescent FFQ and 7DDH) into 'same quartile', 'adjacent quartile', 'one quartile apart' and 'grossly misclassified' to assess agreement using cross-classification of nutrient intake (F. E. Thompson & Byers, 1994). A subject would be correctly classified using one assessment tool if the nutrient intakes of that particular subject were ranked into the same or adjacent quartile in the other assessment tool.

The agreement between the means of energy and nutrient intake of the 7DDH and MyUM Adolescent FFQ was assessed using the Bland–Altman method. The difference between the intake of the two methods (MyUM Adolescent FFQ – 7DDH) against the mean intake of the two studied measurement instruments ([MyUM Adolescent FFQ+7DDH]/2) were plotted (Giavarina, 2015). The limit of agreement (mean ± 1.96 SD) was used to assess the agreement between these two methods (Bland & Altman, 1986). All the statistical analyses in this study were done using SPSS for Windows 20.0 (SPSS Inc. USA).

CHAPTER 4: RESULTS

This chapter presents the results of the data analysis of the study. The first part of this chapter documents the findings on Malaysian adolescents' dietary intake and its socio-demographic variation. Then, the second part of this chapter presents the results of the comparative validation of the newly developed MyUM Adolescent FFQ.

4.1 Phase 1 study: Assessment of Malaysian Adolescents' Dietary Intake

Secondary data from the 2014 MyHeARTs database were extracted and analysed to study the dietary intake of the Malaysian adolescent population and to investigate whether there was variation in their intake based on socio-demographic characteristics.

A total of 1361 students participated in the 2012 MyHeART cohort study; however, only 930 students from the 2012 MyHeARTs cohort participated in the 2014 MyHeART study. Nevertheless, there were 317 new recruits in 2014, thus giving a total number of 1247 participants in the 2014 MyHeARTs cohort. However, as 98 students from 2014 MyHeARTs participants did not participate in dietary interview, thus, only 1149 participants in the 2014 MyHeART cohort study actually completed the dietary interview. Table 4.1 provides the characteristics of these 1149 participants by gender.

Table 4.1: Characteristics of 2014 MyHeARTs participants by gender

Characteristic	Male n=438 (38.1%) No (%)	Female, n=711 (61.9%) No (%)	Total n=1149 No (%)
Place of residence			
Urban	240 (20.9)	437 (38.0)	677 (58.9)
Rural	198 (17.2)	274 (23.8)	472 (41.1)
Ethnicity			
Malay	346 (30.1)	557 (48.5)	903 (78.6)
Chinese	29 (2.5)	56 (4.9)	85 (7.4)
Indian	36 (3.1)	63 (5.5)	99 (8.6)
Others	27 (2.3)	35 (3.0)	62 (5.4)
BMI (IOTF standards kg/m^2)			
Underweight	34 (3.0)	55 (4.8)	89 (7.7)
Normal	278 (24.2)	435 (37.9)	713 (62.1)
Overweight	76 (6.6)	140 (12.2)	216 (18.8)
Obesity	50 (18.8)	81 (7.0)	131(11.4)
Highest education of the parent			
Never schooled	4 (0.3)	3 (0.3)	7 (0.6)
Primary education	11 (1.0)	32 (2.8)	43 (3.7)
Secondary education	176 (15.3)	360 (31.3)	536 (46.6)
Tertiary education	77 (6.7)	122 (10.6)	199 (17.3)
Socio-economic status of the parent/caretaker			
Low	124 (10.8)	279 (24.3)	403 (35.1)
Middle	120 (10.4)	191 (16.6)	311 (27.1)
High	26 (2.3)	42 (3.7)	68 (5.9)

After excluding under-reporting participants (552; 48 percent), data from 597 dietary histories were analysed. The exclusion was made based on the 1998 Kirsting definition of Physical Activity level (PAL) cut off point, where EI:BMR is less than 1.44 for males and less than 1.25 for females, were excluded from the analysis (W. Sichert-Hellert et al., 1998). The socio-demographic characteristics of the 597 participants are presented in Table 4.2.

Table 4.2: Characteristic of 2014 MyHeARTs participants by gender after removal of under-reporters

Characteristic	Male n= 237 (39.7%) No (%)	Female, n=360 (60.3%) No (%)	Total n=597 No (%)
Place of residence			
Urban	122 (20.4)	207 (34.7)	329 (55.1)
Rural	115 (19.3)	153 (25.6)	268 (44.9)
Ethnicity			
Malay	192 (32.2)	286 (47.9)	478 (80.1)
Chinese	12 (2.0)	18 (3.0)	30 (5.0)
Indian	17 (2.8)	41 (6.9)	58 (9.7)
Others	16 (2.7)	15 (2.5)	31 (5.2)
BMI (IOTF standards kg/m^2)			
Underweight	23 (3.9)	34 (5.7)	57 (9.5)
Normal	180 (30.2)	239 (40.0)	419 (70.2)
Overweight	26 (4.4)	64 (10.7)	90 (15.1)
Obesity	8 (1.3)	23 (3.6)	31 (5.2)
Highest education of the parent			
Never schooled	1 (0.26)	2 (0.5)	3 (0.8)
Primary education	4 (1.0)	19 (4.9)	23 (5.9)
Secondary education	93 (49.5)	184 (47.4)	277 (71.4)
Tertiary education	63 (8.8)	51 (13.1)	85 (21.9)
Socio-economic status of the parent/caretaker			
Low	63 (16.4)	146 (38.0)	209 (54.0)
Middle	60 (15.6)	87 (22.7)	147 (38.0)
High	10 (2.5)	18 (4.7)	28 (7.2)

n=597

Of the 597 participants, 60 percent were female. Just over half of the participants (55.1 percent) were from the urban setting, while the ethnic majority of this study were Malay (80.1 percent), followed by Indian, Chinese and Others with 9.7 percent, 5.0 percent and 5.2 percent, respectively. The highest education level attained by 71.4 percent of the participants' parents was a secondary education. The majority of the participants were from low-income families, while only 7.2 percent of them were in a household that had a total income of more than RM5000 per month.

Table 4.3: Characteristic of 2014 MyHeARTs under-reporters

Characteristic	Male n= 201 (36.4%) No (%)	Female, n=351 (63.6%) No (%)	Total n=552 No (%)
Place of residence			
Urban	119 (21.6)	230 (41.7)	349 (63.2)
Rural	82 (14.9)	121 (21.9)	203 (36.8)
Ethnicity			
Malay	154 (27.9)	271 (49.1)	425 (77.0)
Chinese	17 (3.1)	38 (6.9)	55 (1.0)
Indian	19 (3.4)	22 (4.0)	41 (2.5)
Others	11 (2.0)	20 (3.6)	31 (5.6)
BMI (IOTF standards kg/m^2)			
Underweight	11 (2.0)	21 (3.8)	32 (5.8)
Normal	98 (17.9)	196 (35.5)	294 (53.3)
Overweight	50 (9.1)	76 (13.8)	126 (22.8)
Obese	41 (7.4)	59 (10.7)	100 (18.1)
Highest education of the parent			
Never schooled	3 (0.5)	1 (0.2)	4 (0.7)
Primary education	7 (1.3)	13 (2.4)	20 (3.6)
Secondary education	82 (14.9)	176 (31.9)	258 (46.7)
Tertiary education	44 (8.0)	71 (12.9)	115 (20.8)
Socio-economic status of the parent/caretaker			
Low	60 (10.9)	133 (24.1)	193 (35.0)
Middle	61 (11.1)	104 (18.8)	165 (29.9)
High	16 (2.9)	24 (4.3)	40 (7.2)

n=552

A total of 552 out of the 1149 participants were under-reporters, and more than half of them were female. Seventy-seven percent of the under-reporters were of Malay ethnicity. Majority of the under-reporters had a normal BMI. Students whose parents were secondary-school educated and whose family had low household income also featured notably among the under-reporters.

Table 4.4 summarizes the 2017 RNI for Malaysian adolescents (Noor et al., 2017), while Table 4.5 shows the overall nutrient intake of the male and female adolescents in this study.

Table 4.4: Recommended Nutrient Intake (RNI) for 15 years old adolescent

Nutrient*	Male	Female
Energy (kcal)	2210	1810
Protein (g)	45	42
Carbohydrate	50-65% of kcal	50-65% of kcal
Fat (g)	61-86	50-70
Dietary fibre (g)	20-30	20-30
Sugar (g)	<10% of kcal	<10% of kcal
Vitamin D (ug)	15	15
Sodium (mg)	<2000 1500 (AI)‡ – 2300 (UL)±	<2000 1500 (AI)‡ – 2300 (UL)±
Potassium (mg)	4700	4700
Calcium (mg)	1300	1300
Magnesium (mg)	410	360
Phosphorus (mg)	1250	1250
Iron (mg)†	19	31

*RNI Malaysia – Male: 49.6kg, Female: 46.5kg; ‡Adequate Intake Level – goal for daily individual intake; ±Tolerable Upper Intake Level – maximum level daily intake that unlikely to pose risk; †10% bioavailability (Noor et al., 2017)

From Table 4.5 it can be seen that the mean energy intake of the male adolescents was significantly higher than that of the female adolescents. Also, compared to the RNI both genders exceeded the recommendation for total energy intake.

The protein intake among Malaysian male adolescents was also higher than among the female adolescents. However, both genders exceeded the daily protein intake recommendation by almost two times the amount recommended.

Similar to the total energy and protein intake, the intake of carbohydrate and sugar (both intrinsic and extrinsic) was also significantly higher in males than females. However, the intake of carbohydrate by both male and female adolescents was still within the recommended intake, which was 55 percent and 52.5 percent, respectively, of the total energy intake. The adolescents' sugar intake, which in this study consists of intrinsic and extrinsic sugar, was less than 10 percent of the daily kcal, as per the 2017 Malaysian RNI recommendation.

Malaysian male adolescents consumed significantly higher total fat compared to their female counterparts. The fat intake of both sexes was within recommendations. Also, both sexes consumed the same amount of fibre. However, the amount consumed was significantly low than the lower limit of the RNI.

As for micronutrient intake, the male adolescents had a higher intake of sodium, potassium, calcium, magnesium, phosphorus, and iron compared to the female adolescents. However, there was no significant difference in the intake of vitamin D between male and female adolescents. Sodium intake was 1.4 times and 1.2 times higher than the tolerable upper intake level for male and female adolescents, respectively. In contrast, the intake of potassium, calcium, magnesium, phosphorus, and iron, although significantly higher in males than females, was lower than the RNI in both male and female adolescents. Lastly, the intake of vitamin D was significantly lower than the RNI among both male and female adolescents.

Table 4.5: Nutrient intake for 15 years old adolescents attending the secondary schools by gender

	Overall Mean (95% CI) n=597	Male Mean (95% CI) n=237	Female Mean (95% CI) n=360	P-value
Macronutrient				
Energy (kcal/d)	2182.0 (2128.4-2235.5)	2431.8 (2341.2-2522.5)†	2027.1 (1969.2-2085.0)†	<0.001*
Protein (g/d)	82.0 (79.4-84.6)	89.3 (84.0-94.6)†	77.5 (74.9-80.2)†	<0.001*
Carbohydrate (g/d)	292.4 (284.1-300.7)	334.6 (320.8-348.4)	266.3 (257.7-274.8)	<0.001*
Total fat (g/d)	75.6 (73.3-78.0)	81.5 (77.5-85.5)	72.0 (69.2-74.8)	<0.001*
Cholesterol (mg/d)	269.1 (256.1-282.2)	296.5 (271.3-321.6)	252.2 (238.0-266.3)	0.003*
Crude fibre (g/d)	4.2 (3.9-4.5)	4.6 (4.0-5.3)†	4.0 (3.6-4.3)†	0.07
Sugar (g/d)	46.6 (42.9-50.2)	50.0 (44.4-55.5)	44.4 (39.6-49.3)	0.143
Micronutrient				
Vitamin D (µg/d)	1.8 (1.5-2.3)	2.2 (1.5-2.8)†	1.7 (1.2-2.2)†	0.281
Sodium (mg/d)	3004.5 (2886.2-3122.8)	3262.5 (3039.3-3485.7)†	2844.6 (2716.8-2972.3)†	0.001*
Potassium (mg/d)	1302.9 (1250.6-1355.3)	1418.0 (1304.6-1531.5)†	1231.6 (1185.7-1277.5)†	0.003*
Calcium (mg/d)	575.1 (547.6-602.7)	620.3 (573.6-666.9)†	547.2 (513.3 -581.0)†	0.013*
Magnesium (mg/d)	139.8 (134.3-145.3)	150.7(140.8-160.6)†	133.0 (126.7-139.4)†	0.003*
Phosphorus (mg/d)	768.5 (728.2-808.7)	872.7(805.0-940.5)†	703.8 (655.9-751.7)†	<0.001*
Iron (mg/d)	17.1(16.5-17.7)	18.8(17.8-19.9)	16.0 (15.2-16.8) †	<0.001*

†Statistically significant different from RNI * Statistically significant (independent sample t-test; Male vs. Female) -GLM

As shown in Table 4.6, which provides details of the macro- and micronutrient intake of the adolescents by place of residence, the adolescents who resided in rural areas consumed a significantly higher amount of cholesterol, sugar, potassium, and iron compared to those residing in urban areas. The other nutrients showed no significant difference between these two places of residence.

Table 4.6: Nutrient intake for 15 years old adolescents attending the secondary schools by place of residence

	Urban (n=329) Mean (95% CI)	Rural (n=268) Mean (95% CI)	*p*-value
Macronutrient			
Energy (kcal/d)	2164.5 (2101.6-2227.4)	2260.2 (2181.3-2339.2)	0.063
Protein (g/d)	81.4 (78.3-84.5)	84.7 (81.3-88.0)	0.164
Carbohydrate (g/d)	289.7 (280.1-299.5)	304.4 (291.9-316.9)	0.070
Total fat (g/d)	75.0 (72.3-77.8)	78.4 (75.2-81.5)	0.118
Cholesterol (mg/d)	263.5 (248.0-278.9)	294.5 (277.3-311.6)	0.009*
Crude fibre (g/d)	4.2 (3.9-4.6)	4.2 (3.5-4.8)	0.842
Sugar (g/d)	44.7 (40.4-49.0)	54.8 (48.9-60.8)	0.007*
Micronutrient			
Vitamin D (µg/d)	1.9 (1.4-2.3)	1.8 (0.9-2.8)	0.918
Sodium (mg/d)	3010.2 (2868.7-3151.8)	2978.8 (2843.3-3114.3)	0.753
Potassium (mg/d)	1277.6 (1215.7-1339.5)	1416.5 (1353.0 -1480.0)	0.002*
Calcium (mg/d)	583.3(550.9-615.7)	538.7 (497.9-579.5)	0.094
Magnesium (mg/d)	139.0 (132.5-145.6)	143.4 (136.0-150.8)	0.388
Phosphorus (mg/d)	757.5 (710.3-804.8)	817.4 (754.4-880.5)	0.136
Iron (mg/d)	16.7 (16.0-17.4)	18.9 (17.8-20.1)	0.001*

*Statistically significant (independent sample t-test)-GLM

Table 4.7 compares the dietary intake of male and female adolescents with urban and rural residency. The energy, protein, carbohydrate, total fat, and cholesterol intake were significantly higher in males than females for both urban and rural areas. The mean energy intake for males and females in both urban and rural areas was higher than the recommendation. Excessive protein intake compared to the RNI was observed in male and female adolescents, in both the urban and rural areas. The carbohydrate intake, although higher among males in both urban and rural areas, was still within the RNI. Rural female adolescents consumed fat in a quantity higher than the recommended level. The fibre intake was significantly lower than recommended for both males and females in urban and rural areas, and there were no significant differences between the sexes in both areas. No sex-difference in the intake of sugar was observed among urban adolescents. However, male rural adolescents consumed a significantly higher amount of sugar compared to their female counterparts.

The vitamin D intake was the same for both sexes among both urban and rural adolescents, although significantly lower than the RNI. Urban male adolescents consumed higher levels of sodium, potassium, and calcium than urban female adolescents. No significant difference in the sodium, potassium, and calcium intake was noted between the male and female rural adolescents. The sodium intake exceeded the RNI, while the potassium and calcium intakes were significantly below the RNI in male and female adolescents in both urban and rural areas. Urban and rural male adolescents' magnesium and phosphorus intakes were higher than those of their female counterparts, although compared to RNI, they were still significantly inadequate. Male urban and rural adolescents consumed enough iron, whereas the intake of iron among female urban and rural adolescents was inadequate.

Table 4.7: Nutrient intake for 15 years old adolescent attending the secondary schools by place of residence and gender

	Urban			Rural		
	Male (n=122) Mean (95%CI)	**Female (n=207) mean (95%CI)**	***p*-value**	**Male (n=115) Mean (95%CI)**	**Female (n=153) Mean (95%CI)**	***p*-value**
Macronutrient						
Energy (kcal/d)	2415.7 (2308.7-2522.7)†	2012.7 (1944.6-2080.8)†	<0.001*	2498.3 (2355.5-2641.0)†	2095.2 (2017.2-2173.2)†	<0.001*
Protein (g/d)	88.5 (82.0 -94.9)†	77.2 (74.1-80.3)†	0.002*	92.6 (87.2-98.1)†	79.1 (75.2-83.0)†	<0.001*
Carbohydrate (g/d)	331.6 (315.4-347.9)	264.4 (254.3-274.5)	<0.001*	346.9 (324.2-369.5)	275.0 (263.3-286.7)	<0.001*
Total fat (g/d)	81.2 (76.4-86.0)	71.3 (68.0-74.6)	0.001*	82.6 (77.2-87.9)	75.4 (71.7-79.2)†	0.034*
Cholesterol (mg/d)	290.1 (259.7-320.5)	247.4 (230.8-263.9)	0.016*	322.6 (295.0-350.1)	275.0 (253.5-296.4)	0.008*
Crude fibre (g/d)	4.6 (3.9-5.3)†	4.0 (3.6-4.4)†	0.116	4.6 (3.0-6.2)†	3.8 (3.5-4.2)†	0.351
Sugar (g/d)	46.3 (40.0-52.6)	43.7 (38.0-49.5)	0.557	65.0 (54.8-75.1)	47.8 (40.9-54.6)	0.006*
Micronutrient						
Vitamin D (µg/d)	2.0 (1.4-2.7)†	1.8 (1.3-2.4)†	0.556	2.7 (0.3-5.2)†	1.3 (0.9-1.6)†	0.240
Sodium (mg/d)	3310.7 (3037.7-3583.7)†	2828.7 (2678.0-2979.4)†	0.003*	3064.2 (2842.9-3285.6)†	2919.6 (2748.1-3091.1)†	0.310
Potassium (mg/d)	1406.7 (1268.2-1545.2)†	1199.6 (1147.3-1251.9)†	0.006*	1464.8 (1355.3-1574.2)†	1383.0 (1306.1-1460.0)†	0.230
Calcium (mg/d)	629.5 (574.5-684.5)†	555.3 (515.4-595.3)†	0.033*	582.2 (504.5-659.9)†	508.6 (466.0-551.1)†	0.103
Magnesium (mg/d)	149.2 (137.4-161.0)†	132.9 (125.3-140.5)†	0.023*	157.1 (142.4-171.8)†	133.8 (127.1-140.6)†	0.005*
Phosphorus (mg/d)	864.9 (785.4-944.4)†	692.7 (636.1-749.2)†	0.001*	905.2 (787.3-1023.1)†	756.6 (689.8-823.4)†	0.032*
Iron (mg/d)	18.3 (17.2-19.5)	15.7 (14.8-16.7)†	0.001*	21.0 (18.8-23.1)	17.5 (16.2-18.8)†	0.006*

†Statistically significant different from RNI * Statistically significant (independent sample t-test)-GLM

The intake of macronutrients and micronutrients was further analysed according to ethnicity and the results of that analysis are summarized in Table 4.8. Protein, cholesterol, and vitamin D intakes were high among Malay adolescents compared to their Indian counterparts. Malay adolescents also consumed the highest amount of sugar compared to Chinese, Indian, and Others. The Malay adolescent also consumed more potassium compared to Indian and Others adolescent. The calcium intake was higher among Indian and Malay participants. Indian adolescents had the highest intake of phosphorus compared to the three other ethnic categories.

Table 4.8: Nutrient intake for 15 years old adolescents attending the secondary schools by ethnicity

	Malay (n=478) Mean (95%CI)	Chinese (n=30) Mean (95%CI)	Indian (n=58) Mean (95%CI)	Others (n=31) Mean (95%CI)	*p*-value
Macronutrient					
Energy (kcal/d)	2215.6 (2152.1-2279.1)	2028.9 (1858.0-2199.8)	2104.6 (1974.5-2234.6)	2172.8 (1979.7-2365.9)	0.140
Protein (g/d)	84.3 (81.0-87.6)	78.4 (72.2-84.6)	75.7 (70.6-80.9)	78.3 (71.4-85.2)	0.026*
Carbohydrate (g/d)	296.4 (286.8-306.0)	267.1 (240.4-292.8)	282.5 (261.6-303.4)	303.4 (262.4-344.4)	0.156
Total fat (g/d)	76.6 (73.9-79.4)	72.1 (64.5-79.7)	74.0 (68.1-79.9)	71.5 (65.2-77.8)	0.369
Cholesterol (mg/d)	283.7 (268.5-298.9)	275.0 (225.2-324.9)	220.3 (194.0-246.6)	252.2 (182.6-321.7)	0.001*
Crude fibre (g/d)	4.4 (4.0-4.8)	4.5 (3.7-5.3)	3.7 (3.0-4.4)	3.8 (2.7-4.8)	0.250
Sugar (g/d)	51.2 (46.6-55.8)	34.3 (27.0-41.5)	37.0 (30.3-43.8)	29.4 (15.8-43.0)	<0.001*
Micronutrient					
Vitamin D (µg/d)	2.0 (1.5-2.5)	1.8 (0.9-2.6)	1.0 (0.5-1.4)	2.6 (0.7-4.5)	0.007*
Sodium (mg/d)	3081.4 (2944.8-3218.0)	3160.2 (2702.5-3617.9)	2801.4 (2509.9-3092.9)	2512.3 (2009.6-3014.9)	0.067
Potassium (mg/d)	1351.8 (1288.0-1415.5)	1263.6 (1134.0-1393.3)	1183.7 (1072.3-1295.1)	1107.1 (887.1-1327.0)	0.020*
Calcium (mg/d)	578.3 (546.5-610.0)	500.0 (455.1-544.9)	603.0 (527.4-678.5)	482.6 (395.8-569.4)	0.008*
Magnesium (mg/d)	137.5 (131.2-143.8)	136.6 (117.8-155.3)	152.5 (138.5-166.4)	122.1 (102.7-141.4)	0.081
Phosphorus (mg/d)	725.2 (683.9-766.4)	638.2 (504.6-771.9)	944.6 (838.5-1050.6)	807.5 (554.2-1060.9)	0.001*
Iron (mg/d)	17.4 (16.6-18.1)	15.0 (13.2-16.9)	17.1 (15.4-18.7)	15.9 (12.5-19.2)	0.128

*Statistically significant (ANOVA)-GLM

Table 4.9 shows the results of a comparison of the adolescents' macro and micronutrient intake according to their parent's highest education. Parent's education was noted to have no influence on the intake of macronutrients and no influence on the intake of some of the micronutrients. Adolescents with primary-school educated parents consumed a lower amount of sodium and phosphorus compared to adolescents whose parents had received a secondary or tertiary education.

Table 4.9: Nutrient intake for 15 years old adolescents attending the secondary school by parent's education

	Never (n=3) Schooled Mean (95%CI)	Primary (n=23) education Mean (95%CI)	Secondary (n=277) education Mean (95%CI)	Tertiary (n=85) education Mean (95%CI)	*p*-value
Macronutrient					
Energy (kcal/d)	2199.5 (1810.2-2588.9)	2016.8 (1816.5-2217.1)	2169.4 (2088.6-2250.2)	2194.7 (2073.6-2315.8)	0.500
Protein (g/d)	82.3 (77.5-87.0)	76.0 (67.0-85.0)	79.0 (75.8-82.1)	82.7 (77.8-87.5)	0.370
Carbohydrate (g/d)	275.4 (197.7-353.1)	266.4 (230.3-302.4)	293.2 (279.7-306.7)	293.8 (274.9-312.7)	0.546
Total fat (g/d)	84.4 (74.7-94.1)	71.9 (62.2-81.6)	75.3 (72.1-78.5)	76.2 (70.5-81.8)	0.292
Cholesterol (mg/d)	235.7 (138.5-332.9)	215.5 (178.9-252.0)	265.9 (247.7-284.2)	275.3 (246.0-304.6)	0.062
Crude fibre (g/d)	4.1 (2.0-6.2)	3.8 (2.4-5.3)	4.0 (3.6-4.4)	3.8 (3.3-4.3)	0.956
Sugar (g/d)	54.5 (20.4-88.7)	49.4 (23.6-75.2)	43.9 (39.5-48.3)	44.7 (38.1-51.2)	0.910
Micronutrient					
Vitamin D (µg/d)	3.8 (0.4-7.3)	1.4 (0.3-3.0)	1.8 (1.2-2.3)	1.7 (1.1-2.3)	0.640
Sodium (mg/d)	3232.7 (1735.5-4730.0)	2291.2 (1847.0-2735.3)	2972.1 (2807.3-3136.9)	3023.5 (2744.7-3302.3)	0.034*
Potassium (mg/d)	1313.4 (1197.7-1429.1)	1327.4 (1031.7-1623.2)	1279.7 (1212.0-1347.4)	1277.2 (1195.4-1359.0)	0.947
Calcium (mg/d)	610.7 (354.2-867.2)	500.6 (349.6-651.6)	550.5 (511.3-589.6)	588.8 (542.4-635.2)	0.501
Magnesium (mg/d)	157.2 (130.4-183.9)	146.4 (94.5-198.3)	146.8 (138.7-154.9)	137.3 (127.8-146.8)	0.350
Phosphorus (mg/d)	683.3 (318.5-1048.1)	567.9 (468.8-667.0)	765.5 (701.9-829.0)	825.2 (736.3-914.1)	0.001*
Iron (mg/d)	15.8 (11.9-19.6)	17.0 (12.1-21.9)	17.0 (16.0-18.0)	17.5 (15.9-19.1)	0.868

*Statistically significant (ANOVA) - GLM

Except for sodium, all the macro- and micronutrient intakes showed no difference between low, middle and high-income families, as depicted in Table 4.10. Adolescents from a middle-income family consumed higher sodium compared to those from a low-income family.

Table 4.10: Nutrient intake for15 years old adolescents attending the secondary schools by gross household income

	Low income (n=209) **Mean (95% CI)**	**Middle income (n=147)** **Mean (95% CI)**	**High income (n=28)** **Mean (95% CI)**	***p*-value**
Macronutrient				
Energy (kcal/d)	2109.7 (2025.9-2193.4)	2240.0 (2136.7-2343.4)	2150.5 (1922.4-2378.5)	0.158
Protein (g/d)	76.5 (72.8-80.2)	83.2 (79.3-87.2)	79.8 (72.8-86.7)	0.052
Carbohydrate (g/d)	285.0 (271.0-299.0)	300.6 (283.9-317.2)	289.2 (248.7-329.6)	0.372
Total fat (g/d)	73.5 (69.8-77.2)	77.8 (73.8-81.8)	74.8 (64.9-84.7)	0.297
Cholesterol (mg/d)	257.7 (237.7-277.8)	272.9 (249.3-296.5)	273.3 (222.4-324.1)	0.594
Crude fibre (g/d)	3.8 (3.4-4.2)	4.1 (3.6-4.6)	3.8 (3.1-4.4)	0.634
Sugar (g/d)	42.9 (37.2-48.6)	44.8 (39.5-50.0)	42.9 (32.7-53.1)	0.881
Micronutrient				
Vitamin D (µg/d)	1.6 (1.0-2.2)	1.8 (1.4-2.2)	2.4 (0.08-4.9)	0.768
Sodium (mg/d)	2746.9 (2584.0-2909.8)	3207.5 (2981.7-3433.3)	2968.5 (2505.6-3431.4)	0.005*
Potassium (mg/d)	1228.6 (1154.8-1302.3)	1039.7 (1226.9-1392.4)	1351.4 (1219.3-1483.4)	0.177
Calcium (mg/d)	525.2 (484.1-566.3)	597.3 (551.4-643.2)	535.3 (427.9-642.7)	0.068
Magnesium (mg/d)	140.8 (132.3-149.3)	149.4 (138.5-160.2)	136.9 (117.7-156.2)	0.372
Phosphorus (mg/d)	756.8 (685.6-828.1)	787.1 (709.1-865.0)	794.2 (649.8-938.5)	0.816
Iron (mg/d)	16.9 (15.6-18.1)	17.4 (16.2 -18.5)	17.3 (14.5-20.0)	0.843

Income category – Low: <RM1500, Middle: RM 1501 – RM 5000, High: >RM 5000 (Unit, 2017);*Statistically significant (ANOVA)-GLM

Table 4.11 shows the result of a comparison of the nutrient intake of the adolescents based on their BMI. The post hoc test showed that obese adolescents had a significantly higher energy intake as well as higher carbohydrate, sugar, and iron intakes compared to underweight, normal weight, and overweight adolescents. There was no significant difference in the other macro- and micronutrient intakes by BMI

Table 4.11: Nutrient intake of 15 years old adolescents by Body Mass Index (IOTF standards kg/m2)

Nutrient	Underweight (n=57) Mean (95% CI)	Normal (n=419) Mean (95% CI)	Overweight (n=90) Mean (95% CI)	Obesity (n=31) Mean (95% CI)	P-value
Macronutrient					
Energy (kcal/d)	2177.7 (1995.8 – 2359.6)	2163.8 (2102.4 – 2225.3)	2160.0 (2019.0 – 2301.0)	2621.4 (2344.1-2898.8)	0.019*
Protein (g/d)	81.4 (74.7-88.0)	81.0 (78.5-83.6)	85.3(80.4-99.8)	90.1(73.4-97.3)	0.318
Carbohydrate (g/d)	286.0 (257.5-314.5)	291.9 (281.8-302.0)	283.0 (266.5-299.5)	356.6 (320.3-392.8)	0.004*
Total fat (g/d)	78.4 (71.5-85.2)	74.3(71.7-76.9)	75.8 (68.8-82.8)	93.0 (77.1-108.9)	0.106
Cholesterol (mg/d)	310.8 (270.7-350.8)	259.1 (246.5-271.6)	282.5 (227.2-337.8)	288.8 (238.8-338.8)	0.069
Crude fibre (g/d)	3.7 (2.9-4.6)	4.3 (3.9-4.7)	4.0 (3.4-4.6)	4.7 (3.7-6.0)	0.450
Sugar (g/d)	43.2 (35.3-51.2)	46.9 (42.2-51.6)	41.0 (34.6-47.3)	70.5 (49.4-91.7)	0.047*
Micronutrient					
Vitamin D (µg/d)	2.8 (1.3-4.3)	1.8 (1.4-2.3)	1.5 (0.9-2.1)	1.2 (0.4-2.0)	0.236
Sodium (mg/d)	3275.9 (2867.5-3684.4)	2939.4 (2806.8-3072.0)	3002.3 (2655.1-3349.6)	3466.3 (2951.4-3981.2)	0.128
Potassium (mg/d)	1365.9 (1199.0-1532.7)	1266.2 (1219.2-1313.2)	1371.7 (1144.4-1599.1)	1553.7 (1197.8-1909.6)	0.237
Calcium (mg/d)	609.7 (531.9-687.6)	575.4 (540.4-610.4)	530.8 (484.5-577.0)	641.1 (531.7-750.5)	0.141
Magnesium (mg/d)	155.1 (136.5-173.8)	136.5 (130.4-142.6)	144.6 (127.0-162.2)	140.5 (123.2-157.8)	0.267
Phosphorus (mg/d)	748.5 (642.9-854.1)	758.9 (709.8-808.0)	830.6 (723.4-937.9)	767.6 (635.6-899.6)	0.666
Iron (mg/d)	17.6 (15.3-19.7)	16.7 (16.0-17.5)	17.7 (16.0-19.3)	20.9 (18.6-23.2)	0.008*

*Statistically significant (ANOVA)-GLM

The nutritional status indicators in Table 4.12 show that the MyHeARTs participants' Hb level was 13.5 g/dL. The mean Hb level of male adolescents was 14.6 g/dL, while the Hb level of female adolescents was 12.8 g/dL. However, HDL cholesterol was higher in females compared to males. The female adolescents also had higher total cholesterol and LDL cholesterol levels compared to the male adolescents. The triglycerides (TG), calcium and fasting blood sugar level was almost the same for male and female adolescents. Serum phosphate and vitamin D levels were higher in male than in female adolescents.

Table 4.12: Nutritional status indicators of 15 years old adolescent by gender

	Total (n=597) Mean (95% CI)	Male (n=237) Mean (95% CI)	Female (n=360) Mean (95% CI)	p-value
Hb level g/dL	13.47 (13.30-13.64)	14.64 (14.44-14.84)	12.76 (12.56-12.95)	<0.001*
Total Cholesterol mmol/L	4.49 (4.41-4.58)	4.19 (4.08-4.31)	4.68 (4.58-4.78)	<0.001*
HDL Cholesterol mmol/L	1.43 (1.40-1.46)	1.35 (1.29-1.40)	1.48 (1.44-1.52)	<0.001*
LDL Cholesterol mmol/L	2.66 (2.59-2.73)	2.43 (2.33-2.53)	2.80 (2.71-2.89)	<0.001*
Triglycerides mmol/L	0.89 (0.83-0.96)	0.95 (0.80-1.09)	0.86 (0.81-0.91)	0.280
Calcium† mmol/L	2.30 (2.28-2.31)	2.30 (2.28-2.31)	2.30 (2.28-2.32)	0.736
Phosphate mmol/L	1.38 (1.36-1.40)	1.46 (1.42-1.50)	1.33 (1.31-1.35)	<0.001*
Fasting glucose mmol/L	4.8 (4.75-4.89)	4.90 (4.79-5.00)	4.78 (4.69-4.87)	0.084
Vitamin D ng/ml	59.16 (57.10-61.23)	69.18 (66.08-72.29)	53.01 (50.49-55.53)	<0.001*

*Statistically significant; †Corrected calcium with serum albumin level (Shane & Irani, 2006).

The nutritional status indicators of the 2014 MyHeARTs participants presented in Table 4.13 show that there is no significant difference by place of residence, except for phosphate consumption, which was higher among rural adolescents

Table 4.13: Nutritional indicators of `15 years' old adolescent by place of residence

	Total (n=597) Mean (95% CI)	Urban (n=329) Mean (95% CI)	Rural (n=268) Mean (95% CI)	p-value
Hb level g/dL	13.45 (13.30-13.64)	13.49 (13.29-13.69)	13.38 (13.11-13.65)	0.529
Total cholesterol mmol/L	4.49 (4.41-4.57)	4.48 (4.39-4.58)	4.55 (4.44-4.67)	0.336
HDL cholesterol mmol/L	1.43 (1.40-1.46)	1.44 (1.40-1.48)	1.39 (1.35-1.43)	0.105
LDL cholesterol mmol/L	2.66 (2.59-2.73)	2.64 (2.56-2.72)	2.76 (2.66-2.86)	0.068
Triglycerides mmol/L	0.89 (0.83-0.96)	0.90 (0.82-0.97)	0.88 (0.82-0.94)	0.730
Calcium mmol/L†	2.30 (2.28-2.31)	2.30 (2.28-2.31)	2.28 (2.27-2.30)	0.164
Phosphate mmol/L	1.38 (1.36-1.40)	1.37 (1.35-1.39)	1.43 (1.40-1.47)	0.002*
Fasting glucose mmol/L	4.82 (4.75-4.89)	4.82 (4.74-4.91)	4.83 (4.77-4.88)	0.941
Vitamin D ng/ml	59.14 (57.07-61.21)	59.00 (56.54-61.47)	59.76 (57.26-62.25)	0.674

*Statistically significant; † Corrected calcium with serum albumin level (Shane & Irani, 2006)

Table 4.14 depicts the nutritional status of the adolescents according to their ethnicity. The post hoc test result revealed that Malay adolescents had a higher triglycerides level compared to all the others ethnic categories. The corrected calcium level was also noted to be low among the Malay compared to the Chinese adolescents. Also, the serum phosphate level was higher among the Malay adolescents compared to the Chinese.

Table 4.14: Nutritional status indicators of 15 years' old adolescent by ethnicity

	Malay (n=478) Mean (95% CI)	Chinese (n=30) Mean (95% CI)	India (n=58) Mean (95% CI)	Others (31) Mean (95% CI)	p-Value
Hb level g/dL	13.58 (13.39-13.78)	13.55 (12.99-14.10)	13.18 (12.73-13.63)	12.96 (12.22-13.69)	0.190
Total cholesterol mmol/L	4.49 (4.40-4.58)	4.44 (4.21-4.68)	4.55 (4.34-4.76)	4.36 (3.98-4.74)	0.820
HDL cholesterol mmo/L	1.42 (1.39-1.45)	1.42 (1.33-1.52)	1.46 (1.36-1.57)	1.44 (1.34-1.54)	0.881
LDL cholesterol mmol/L	2.67 (2.59-2.75)	2.62 (2.39-2.85)	2.67 (2.48-2.85)	2.60 (2.25-2.96)	0.968
Triglycerides mmol/L	0.88 (0.83-0.92)	0.89 (0.75-1.02)	1.0 (0.73-1.26)	0.69 (0.58-0.80)	0.017*
Calcium† mmol/L	2.28 (2.27-2.29)	2.36 (2.32-2.40)	2.30 (2.28-2.33)	2.36 (2.14-2.58)	0.002*
Phosphate mmol/L	1.38 (1.36-1.40)	1.27 (1.21-1.32)	1.39 (1.33-1.44)	1.51 (1.37-1.64)	0.001*
Fasting glucose mmol/L	4.80 (4.73-4.88)	4.78 (4.58-4.97)	4.96 (4.77-5.16)	4.61 (4.22-4.99)	0.301
Vitamin D ng/ml	58.89 (57.43-62.35)	64.40 (58.14-70.67)	55.40 (50.50-60.31)	58.62 (52.23-65.01)	0.159

*Statistically significant; † Corrected calcium with serum albumin level (Shane & Irani, 2006)

Table 4.15 depicts the nutritional status of the adolescents according to parent's education.

The post hoc test showed that there was a statistically significant higher iron level among adolescents with tertiary-educated parent compared to the other categories of education level. The total cholesterol level was also noted to be higher among adolescents with secondary-school educated parents compared to adolescents with tertiary-educated parents. Those adolescents whose parents had never been schooled had a lower HDL cholesterol level, and a lower corrected serum calcium level compared to those with secondary-school educated parent. Adolescents with tertiary-educated parents had a lower LDL cholesterol and lower fasting glucose level compared to those with never-schooled and secondary-school educated parents. In contrast, adolescents with never-schooled parents had a lower triglycerides level compared to those with secondary-school- and tertiary-educated parents

Table 4.15: Nutritional status indicators of 15 years' old adolescent by highest education of the parent

	Never (n=3) schooled Mean (95% CI)	Primary (n=23) education Mean (95% CI)	Secondary (n=277) education Mean (95% CI)	Tertiary (n=85) education Mean (95% CI)	p-Value
Hb level g/dL	13.00 (12.24-13.76)	12.37 (11.72-13.03)	13.33 (13.07-13.60)	13.88 (13.51-14.25)	0.001*
Total cholesterol mmol/L	5.07 (4.23-5.90)	4.72 (4.26-5.18)	4.65 (4.52-4.78)	4.32 (4.15-4.49)	0.011*
HDL cholesterol mmol/L	1.23 (1.09-1.38)	1.43 (1.31-1.55)	1.43 (1.38-1.49)	1.47 (1.40-1.54)	0.034*
LDL cholesterol mmol/L	3.57 (2.88-4.25)	2.93 (2.51-3.35)	2.82 (2.71-2.93)	2.48 (2.33-2.62)	<0.001*
Triglycerides mmol/L	0.60 (0.44-0.76)	0.76 (0.68-0.84)	0.91 (0.78-1.04)	0.81 (0.71-0.91)	0.031*
Calcium† mmol/L	2.23 (2.21-2.26)	2.27 (2.23-2.31)	2.29 (2.27-2.30)	2.30 (2.24-2.36)	0.006*
Phosphate mmol/L	1.32 (1.17-1.47)	1.38 (1.30-1.45)	1.38 (1.35-1.41)	1.36 (1.31-1.41)	0.822
Fasting glucose mmol/L	5.03 (4.74-5.33)	4.64 (4.42-4.87)	4.94 (4.84-5.04)	4.67 (4.54-4.80)	0.002*
Vitamin D ng/ml	51.33 (38.87-63.80)	58.72 (51.25-66.19)	56.36 (53.97-58.75)	56.53 (51.96-61.09)	0.799

*statistically significant; † Corrected calcium with serum albumin level (Shane & Irani, 2006)

As regards the results presented in Table 4.16, the post hoc test showed that there was a significantly lower serum iron level among adolescents with low-income parents compared to those with middle- and high-income parents. Also, there was a significantly higher phosphate serum level among adolescents in the low-income group compared to those from the high-income group.

Table 4.16: Nutritional status indicators of 15 years' old adolescent by household income

	Low income (n=209) Mean (95% CI)	Middle income (n=147) Mean (95% CI)	High income (n=28) Mean (95% CI)	*p*- value
Hb level g/dL	13.11 (12.76-13.46)	13.73 (13.47-14.0)	13.9 (13.4-14.4)	0.008*
Total cholesterol mmol/L	4.64 (4.49-4.80)	4.46 (4.32-4.60)	4.54 (4.10-4.98)	0.223
HDL cholesterol mmol/L	1.45 (1.38-1.52)	1.44 (1.38-1.50)	1.42 (1.30-1.54)	0.904
LDL cholesterol mmol/L	2.81 (2.67-2.95)	2.62 (2.50-2.75)	2.75 (2.42-3.08)	0.156
Triglyceride mmol/L	0.90 (0.71-1.08)	0.87 (0.79-0.96)	0.79 (0.67-0.91)	0.446
Calcium† mmol/L	2.30 (2.26-2.34)	2.27 (2.26-2.29)	2.29 (2.25-2.33)	0.354
Phosphate mmol/L	1.38 (1.34-1.42)	1.39 (1.35-1.42)	1.27 (1.21-1.34)	0.010*
Fasting glucose mmol/L	4.90 (4.76-5.04)	4.81 (4.74-4.88)	4.87 (4.54-5.19)	0.490
Vitamin D ng/ml	56.99 (54.11-59.87)	55.27 (52.22-58.31)	58.75 (49.15-68.36)	0.633

*Statistically significant; † Corrected calcium with serum albumin level (Shane & Irani, 2006)

Post hoc analysis of Table 4.17 showed that the underweight and normal weight adolescents had a higher HDL serum level compared to the overweight and obese adolescents. On the other hand, the overweight and obese adolescents had higher LDL cholesterol and triglyceride levels compared to the normal and underweight adolescents. Obese adolescents had the lowest serum vitamin D level compared to underweight, normal weight, and overweight adolescents.

Table 4.17: Nutritional status indicators of 15 years' old adolescent by Body Mass Index (IOTF standards kg/m2)

Nutrient	Underweight (n=57) Mean (95% CI)	Normal (n=419) Mean (95% CI)	Overweight (n=90) Mean (95% CI)	Obesity (n=31) Mean (95% CI)	P-value
Hb level g/dL	13.50 (13.25-13.75)	13.49 (13.27-13.70)	13.33 (12.91-13.75)	13.69 (13.21-14.17)	0.749
Total cholesterol mmol/L	4.51 (4.22-4.79)	4.45 (4.36-4.55)	4.58 (4.38-4.78)	4.89 (4.52-5.25)	0.117
HDL cholesterol mmol/L	1.50 (1.39-1.62)	1.45 (1.41-1.48)	1.32 (1.24-1.40)	1.30 (1.20-1.41)	0.001*
LDL cholesterol mmol/L	2.63 (2.38-2.87)	2.62 (2.54-2.70)	2.80 (2.60-3.01)	3.01 (2.75-3.28)	0.022*
Triglycerides mmol/L	0.83 (0.72-0.94)	0.84 (0.79-0.89)	1.12 (0.77-1.46)	1.24 (1.01-1.47)	0.004*
Calcium mmol/L	2.34 (2.24-2.43)	2.29 (2.28-2.30)	2.30 (2.27-2.32)	2.29 (2.26-2.31)	0.715
Phosphate mmol/L	1.42 (1.36-1.50)	1.38 (1.36-1.41)	1.35 (1.30-1.39)	1.35 (1.28-1.43)	0.305
Fasting glucose mmol/L	4.84 (4.58-5.09)	4.79 (4.74-4.84)	4.89 (4.64-5.14)	5.17 (4.14-6.21)	0.746
Vitamin D ng/ml	57.03 (52.18-61.88)	60.45 (57.75-63.15)	57.91 (54.77-61.06)	45.81 (41.17-50.45)	<0.001*

*Statistically significant; † Corrected calcium with serum albumin level (Shane & Irani, 2006)

4.2 Phase 2 study: Deveopment and Comparative Validation of MyUM Adolescent FFQ

As mentioned in **Chapter 3: Methodology**, the developed MyUM Adolescent FFQ was pre-tested and then a test-retest was performed by a convenience sample of 78 adolescents. (Note: They were not MyHeART study participants.) Then the FFQ underwent validation, which involved 156 randomly selected 2014 MyHeART subjects and the use of the 2014 MyHeARTs 7DDH as the reference.

4.2.1 Test – retest reliability (MyUM Adolescent FFQ1 Vs MyUM Adolescent FFQ2)

Out of the original sample of 119 subjects that were recruited, three (2.5 percent) did not return the questionnaire and six (5 percent) did not complete the questionnaire. After excluding the questionnaires that contained unreliable data (n = 31) and had missing information (n = 1), a total of 78 subjects were included in the analysis (see Figure 4.1).

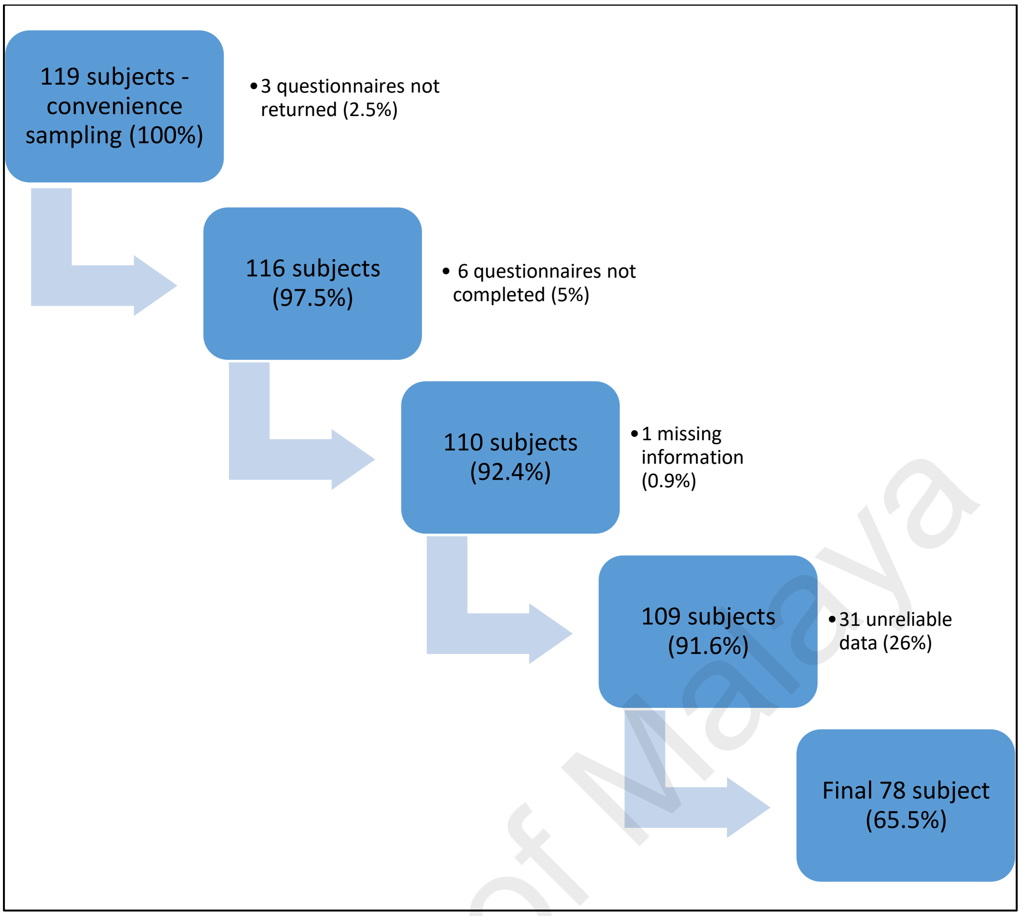

Figure 4.1: Flow diagram of sample selection for MyUM Adolescent FFQ reliability study

Table 4.18 shows the demographic characteristics of the convenience sample of the 78 non–MyHeARTs participants who completed the questionnaire. They consisted of 81 percent Malay, 14 percent Chinese, and 5 percent Indian adolescents. There were more female (60 percent) than male participants.

Table 4.18: Participants demographic characteristics of MyUM Adolescent FFQ test-retest reliability study

Demographic characteristics		n	Percentage
Sex	Male	31	39.7
	Female	47	60.3
Ethnicity	Malay	63	80.8
	Chinese	11	14.1
	Indian	4	5.1

n = 78, Mean age 14.4±0.77

The mean energy and nutrient intake from FFQ1 and FFQ2 are reported in Table 4.19. The intakes of total fat, vitamin B6, and sodium were significantly higher in FFQ1 compared to FFQ2, while the other nutrients showed no significant difference.

Table 4.19: Comparison of average mean daily nutrient intake and correlations between the FFQ1 and FFQ2

	Mean±SD		
Nutrient	FFQ1 (n=31)	FFQ2 (n=47)	p-value
Total Energy (kcal)	2001.9±714.6	1911.4±731.4	0.116
Total Carbohydrate (g)	304.7±109.1	296.8±106.3	0.383
Protein (g)	68±34.3	63.6±34.1	0.119
Total fat (g)	56.3±32.4	51.1±31.3	0.031*
Cholesterol (mg)	239.1±188.3	254.5±209.9	0.385
Crude dietary fibre (g)	4.0±2.9	3.9±3.8	0.746
Total sugar (g)	56.8±51.9	50.9±48.7	0.134
Vitamin A (IU)	530.7±390.0	467.5±371.5	0.079
Beta-carotene (µg)	360.4±498.4	322.1±548.9	0.608
Vitamin C (mg)	61.8±73.1	57.8±73.3	0.611
Vitamin E (IU)	2.2±1.9	2.1±1.4	0.601
Thiamine, B1 (mg)	0.5±0.3	0.5±0.4	0.447
Riboflavin, B2 (mg)	0.7±0.8	0.6±0.5	0.148
Niacin (mg)	5.7±4.1	4.9±3.5	0.050
Vitamin B6 (mg)	0.5±0.4	0.4±0.3	0.037*
Folate (µg)	36.4±28.6	33.1±24.8	0.152
Vitamin B12 (µg)	0.8±1.0	0.7±0.8	0.397
Sodium (mg)	2792.8±1721.7	2450.6±1641.0	0.017*
Potassium (mg)	1087.1±580.7	990.1±569.3	0.094
Calcium (mg)	522.7±366.5	478.7±347.3	0.233
Iron (mg)	18.4±33.2	13.9±7.6	0.249
Phosphorus (mg)	654.8±435.7	581.2±400.1	0.084
Magnesium (mg)	105.7±63.2	99.3±74.0	0.407
Zinc (mg)	2.2±1.8	2.1±1.7	0.160

*n=78, SD: Standard deviation, *Statistically significant at <0.05 (paired sample t-test)*

The ICC for the two administrations of the MyUM Adolescent FFQ ranged from 0.67 for vitamin E (good correlation) to 0.88 (excellent correlation) for total energy intake (see Table 4.20). All the macronutrient measurements gave ICCs of more than 0.7, and all the micronutrient measurements gave correlations of more than 0.6. This indicated that the proposed MyUM Adolescent FFQ had good to excellent reliability and reproducibility for macronutrients, and good reliability and reproducibility for micronutrients.

Table 4.20: Intra-class correlation (ICC) and 95% confidence interval (CI) between the 1st and 2nd administration of MyUM Adolescent FFQ

Variables	ICC	(95% CI)
Total energy (Kcal)	0.88	(0.80-0.92)
Protein (g)	0.87	(0.79-0.92)
Carbohydrate (g)	0.84	(0.76-0.90)
Total fat (g)	0.83	(0.73-0.89)
Cholesterol (mg)	0.71	(0.55-0.82)
Crude dietary fibre (g)	0.80	(0.69-0.88)
Total sugar (g)	0.79	(0.67-0.87)
Vitamin A (IU)	0.72	(0.56-0.82)
Beta-carotene (μg)	0.73	(0.57-0.83)
Vitamin C (mg)	0.78	(0.65-0.86)
Vitamin E (IU)	0.67	(0.47-0.79)
Thiamine, B1 (mg)	0.75	(0.61-0.84)
Riboflavin, B2 (mg)	0.78	(0.63-0.86)
Niacin (mg)	0.77	(0.71-0.88)
Vitamin B6 (mg)	0.72	(0.56-0.83)
Folate (μg)	0.72	(0.56-0.82)
Vitamin B12 (μg)	0.72	(0.55-0.82)
Sodium (mg)	0.85	(0.75-0.91)
Potassium (mg)	0.82	(0.71-0.88)
Calcium (mg)	0.83	(0.74-0.89)
Iron (mg)	0.68	(0.50-0.80)
Phosphorus (mg)	0.73	(0.57-0.83)
Magnesium (mg)	0.71	(0.54-0.82)
Zinc (mg)	0.75	(0.60-0.84)

n=78; All variables were log-transformed before analysis to improved normality; All nutrients were statistically significant with p-value less than 0.05 bibliography

Moreover, the Bland-Altman plot indicated that there was no serious systematic bias between the MyUM Adolescent FFQ1 and MyUM Adolescent FFQ2 range of mean nutrient intake (see Appendix D).

4.2.2 Comparative Validation of MyUM Adolescent FFQ with 7DDH

Out of the original sample of 230 adolescents recruited from MyHeARTs participants, five (2.2 percent) did not return the questionnaire and 44 (19 percent) did not complete the questionnaire. After excluding the questionnaires containing unreliable data (n = 23) and missing information (n= 2), 156 subjects were included in the analysis (Figure 4.2). The demographic and physical characteristics of the subjects of the validation study are shown in Table 4.21 and Table 4.22, respectively.

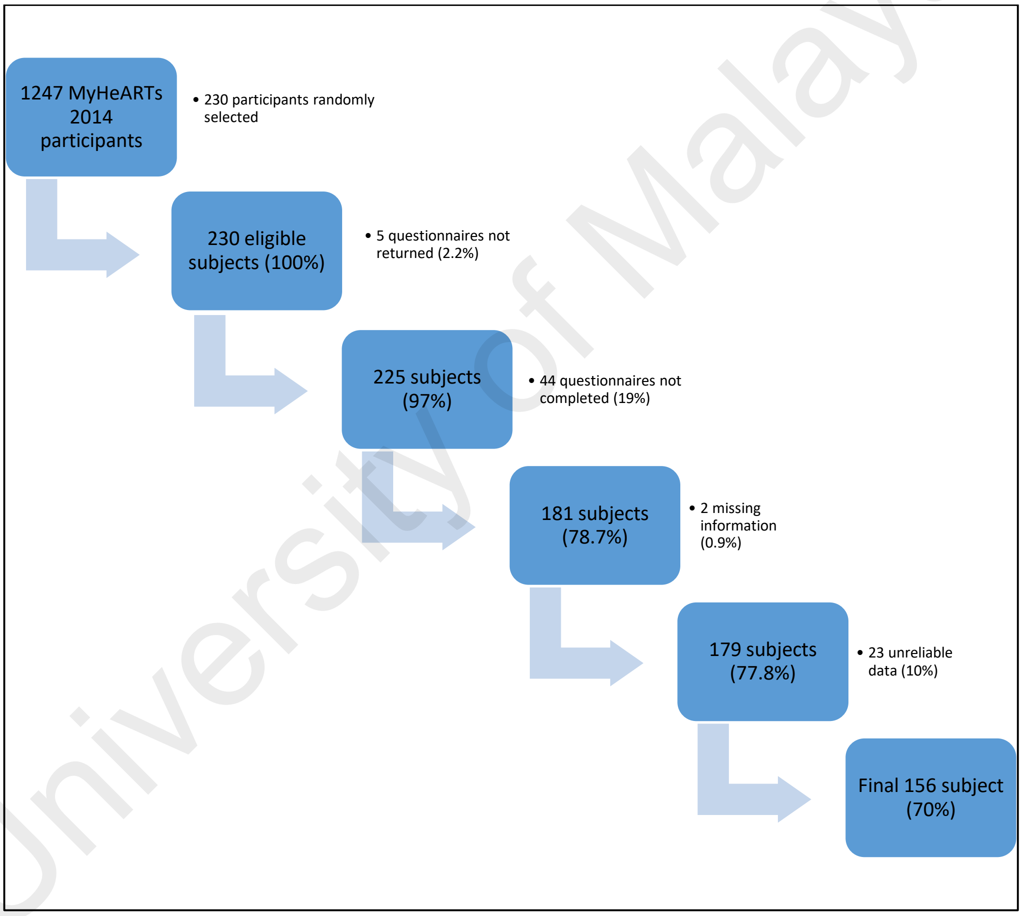

Figure 4.2: Flow diagram of sample selection for MyUM Adolescent FFQ comparative validity study

The demographic and physical characteristics of the subjects of the validation study are shown in Table 4.21 and Table 4.22.

Table 4.21: Demographic characteristics of the subjects in the validation study (156 MyHeARTs participants)

Characteristics		**n**	**Percentage**
Sex	Male	78	50.0
	Female	78	50.0
Ethnicity	Malay	102	65.8
	Chinese	24	15.5
	Indian	25	16.1
	Others	4	2.6
Residence	Urban	100	64.1
	Rural	56	35.9

n=156

Table 4.22: Physical characteristics of the subjects in the validation study (156 MyHeARTs participants)

Characteristics	Mean±SD		Total
	Male (n=78)	Female (n=78)	
Weight (kg)	56.3±17.1*	51.2±11.6	53.9±14.8
Height (cm)	163.4±7.3*	154.6±5.3	159.2±7.6
Body mass index (k/m2)	21.0±5.8	21.4±4.7	21.2±5.3
Waist circumference (cm)	73.4±14.0*	70.2±9.5	71.8±12.1
Hip circumference (cm)	89.6±10.9	92.6±8.7	91.1±10.0

*n=156; SD: standard deviation; *Independent sample t-test shows significant difference between the sexes*

Table 4.23 presents the comparison of the means and SD for macronutrients and micronutrients of the MyUM Adolescent FFQ and the 7DDH.

Table 4.23: Comparison of nutrient intakes per day by MyUM Adolescent FFQ and 7DDH

Nutrient	FFQ Mean±SD	7DDH Mean±SD	p-value†
Energy (kcal)	1965.4±565.7	1897.9±558.1	0.347
Protein (g)	72.1±27.5	72.4±22.2	0.921
Carbohydrate (g)	283.4±85.9	257.1±80.2	<0.001*
Total fat (g)	60.4±25.1	64.4±22.6	0.019*
Cholesterol (mg)	258.9±163.1	249.4±120.0	0.696
Crude dietary fibre (g)	4.4±3.0	3.7±2.0	0.013*
Total sugar (g)	44.5±30.4	38.0±22.4	0.039*
Vitamin A (IU)	541.0±302.5	439.9±319.9	0.001*
Beta-carotene (μg)	485.7±720.5	169.4±267.9	<0.001*
Vitamin C (mg)	72.1±58.6	59.8±37.7	0.026*
Vitamin E (IU)	2.7±1.7	2.3±1.5	0.108
Thiamine, B1 (mg)	0.5±0.3	0.4±0.2	<0.001*
Riboflavin, B2 (mg)	0.7±0.5	0.4±0.2	<0.001*
Niacin (mg)	6.0±3.1	5.1±3.2	0.003
Pyridoxine, B6 (mg)	0.5±0.3	0.3±0.2	<0.001*
Folate (μg)	40.4±22.2	27.9±19.9	<0.001*
Cobalamin, B12 (μg)	0.8±0.8	0.8±0.9	0.479
Sodium (mg)	2747.9±1381.0	2664.5±1018.7	0.340
Potassium (mg)	1218.7±505.7	1146.8±403.8	0.113
Calcium (mg)	498.6±277.4	485.7±244.4	0.578
Iron (mg)	16.2±7.6	15.3±7.4	0.175
Phosphorus (mg)	629.9±313.4	587.5±360.5	0.114
Magnesium (mg)	115.5±52.1	115.8±47.3	0.662
Zinc (mg)	1.2±1.2	2.0±1.3	0.078

*n = 156; SD – standard deviation; †Sign-rank test; *p-value <0.05*

Some of the macro and micronutrients estimated from the MyUM Adolescent FFQ were significantly different than those estimated from the 7DDH. However, total energy, protein, cholesterol, vitamin E, niacin, vitamin B12, sodium, potassium, calcium, iron, phosphorus, magnesium, and zinc showed no significant difference.

The Pearson's correlation for the nutrient intake derived from the MyUM Adolescent FFQ and from the 7DDH are shown in Table 4.24. The correlation coefficients for unadjusted data varied from 0.178 (total sugar) to 0.641 (carbohydrate) for macronutrients, and from 0.070 (betacarotene) to 0.474 (iron) for micronutrients and minerals. After adjusting for total energy intake, the correlation in some nutrients and minerals, such as protein, total fat, crude dietary fibre, total sugar, vitamin A, thiamine, riboflavin, niacin, pyridoxine, folate, sodium, potassium, iron, phosphorus and zinc was improved. All correlations for macronutrients were statistically significant with the p-value of <0.05. Except for beta-carotene and cobalamin (vitamin B12), other micronutrients and minerals also showed a statistically significant correlation with the p-value of <0.05.

Table 4.24: Pearson's correlation for MyUM Adolescent FFQ estimates and 7DDH estimates

Nutrient	Unadjusted Correlations	p-value	Energy-adjusted ¶ correlation	p-value
Energy (kcal)	0.719	<0.001*	-	-
Protein (g)	0.490	<0.001*	0.535	<0.001*
Carbohydrate (g)	0.641	<0.001*	0.628	<0.001*
Total fat (g)	0.480	<0.001*	0.486	<0.001*
Cholesterol (mg)	0.340	<0.001*	0.260	0.001*
Crude dietary fibre (g)	0.187	0.002*	0.247	0.002*
Total sugar (g)	0.178	0.026*	0.210	0.008*
Vitamin A (IU)	0.181	0.029*	0.403	<0.001*
Beta-carotene (μg)	0.070	0.402	0.013	0.881
Vitamin C (mg)	0.256	0.002*	0.110	0.188
Vitamin E (IU)	0.226	0.006*	0.220	0.008*
Thiamine, B1 (mg)	0.402	<0.001*	0.430	<0.001*
Riboflavin, B2 (mg)	0.273	0.001*	0.368	<0.001*
Niacin (mg)	0.363	<0.001*	0.397	<0.001*
Pyridoxine, B6 (mg)	0.237	0.004*	0.337	<0.001*
Folate (μg)	0.088	0.291	0.255	0.002*
Cobalamin, B12 (μg)	0.077	0.362	0.131	0.120
Sodium (mg)	0.257	0.001*	0.332	<0.001*
Potassium (mg)	0.352	<0.001*	0.413	<0.001*
Calcium (mg)	0.425	<0.001*	0.337	<0.001*
Iron (mg)	0.474	<0.001*	0.489	<0.001*
Phosphorus (mg)	0.367	<0.001*	0.499	<0.001*
Magnesium (mg)	0.394	<0.001*	0.314	<0.001*
Zinc (mg)	0.280	0.001*	0.386	<0.001*

*n = 156; All variables were log-transformed before analysis to improved normality; Nutrients intake were adjusted for total energy intake by residual method; *Correlation is significant at 0.05 level (2-tailed)*

The data on the nutrient intake estimated from the MyUM Adolescent FFQ and 7DDH were distributed into intake quartiles and these were then cross-classified. A subject was deemed to be correctly classified using one assessment tool if the nutrient intake of that particular subject was ranked into the same or adjacent quartile by the other assessment tool.

Table 4.25 presents a summary of the cross-classification analysis. The classification of the subjects into same and adjacent quartiles ranged from 70.5 percent for crude dietary fibre to 88.5 percent for carbohydrate in the case of macronutrients, while for micronutrients the classification ranged from 65.7 percent for beta-carotene to 80.2 percent for magnesium.

Moreover, the Bland-Altman plot indicated that there was no serious systematic bias between the MyUM Adolescent FFQ and 7DDH range of mean nutrient intake. (see Appendix E).

Table 4.25: Percentage of cross-classification in energy-adjusted nutrient intake into quartiles estimated from MyUM Adolescent FFQ and 7DDH†

Nutrient	Same Quartile (%)	Adjacent Quartile (%)	One Quartile Apart (%)	Grossly Misclassified (%)
Total energy (kcal)	54.5	37.8	5.8	1.9
Protein (g)	43.6	41.0	12.8	2.6
Carbohydrate (g)	50.0	38.5	10.3	1.2
Total fat (g)	39.1	41.7	16.0	3.2
Cholesterol (mg)	32.0	43.6	15.4	9.0
Crude dietary fibre (g)	32.0	38.5	21.8	7.7
Total sugar (g)	33.3	39.1	17.9	9.6
Vitamin A (IU)	36.3	39.0	17.1	7.5
Beta-carotene (µg)	26.0	39.7	23.3	11.0
Vitamin C (mg)	26.2	42.1	24.1	7.6
Vitamin E (IU)	32.2	35.6	25.3	6.8
Thiamine, B1 (mg)	30.1	47.3	19.2	3.4
Riboflavin, B2 (mg)	32.2	40.4	22.6	4.8
Niacin (mg)	34.9	40.4	19.9	4.8
Pyridoxine, B6 (mg)	30.1	42.5	19.2	8.2
Folate (µg)	26.0	40.4	24.7	8.9
Cobalamin, B12 (µg)	28.1	39.0	21.2	11.6
Sodium (mg)	37.2	32.7	24.4	5.8
Potassium (mg)	32.1	42.9	19.2	5.8
Calcium (mg)	36.5	39.7	18.6	5.1
Iron (mg)	35.3	43.6	17.3	3.8
Phosphorus (mg)	35.3	42.3	17.3	5.1
Magnesium (mg)	35.3	44.9	15.4	4.5
Zinc (mg)	31.5	45.9	16.4	6.2

n = 156, All data based on unadjusted values

4.2.3 Validation of MyUM Adolescent FFQ with biomarkers

Table 4.26 to Table 4.31 depict the correlation between selected nutrient intakes from the FFQ and 7DDH, with selected biomarkers. No significant associations were found between total iron intake from the MyUM Adolescent FFQ and the serum haemoglobin level. However, serum hemoglobin was significantly associated with the total iron intake in the 7DDH (r=0.230, *p*=0.004). The carbohydrate intake measured by the FFQ showed an inverse association with total cholesterol level (r = -0.244, *p* = 0.003), LDL cholesterol level (r = -0.246 *p* = 0.002), and serum triglyceride (r = -0.219, *p* = 0.007), while the carbohydrate intake measured by the 7DDH showed no association. In contrast, an inverse association was noted between the 7DDH intake of total fat and the triglyceride serum level (r = -0.182, *p* = 0.025), while no association was found when measured by the FFQ. The dietary zinc intake showed a positive correlation with the serum HDL cholesterol level when measured with the 7DDH (r = 0.243, *p* = 0.003), but not when measured by the FFQ. The other nutrient intakes showed no correlation for both the FFQ and 7DDH

.

Table 4.26: Pearson correlation with serum Hb level for selected nutrient estimates from MyUM Adolescent FFQ and 7DDH

Nutrient intake	Mean±SD (FFQ)	r	p-value	Mean±SD (7DDH)	r	p-value
Iron (mg)	16.2±7.6	0.040	0.623	15.3±7.4	0.230	0.004*
Vitamin C (mg)	72.1±58.6	-0.052	0.523	59.8±37.7	0.007	0.931

*n = 156; All variables were log-transformed before analysis to improved normality; *Correlation is significant at 0.05 level (2-tailed)*

Table 4.27: Pearson's correlation with serum total cholesterol level for selected nutrient estimates from MyUM Adolescent FFQ and 7DDH

Nutrient intake	Mean±SD (FFQ)	r	p-value	Mean±SD (7DDH)	r	p-value
Cholesterol (mg)	258.9±163.1	0.048	0.562	249.4±120.0	-0.045	0.585
Crude dietary fibre (g)	4.4±3.0	-0.086	0.296	3.7±2.0	-0.030	0.715
Total fat (g)	60.4±25.1	0.016	0.849	64.4±22.6	0.040	0.624
Carbohydrate (g)	283.4±85.9	-0.244	0.003*	257.1±80.2	-0.089	0.275
Zinc (mg)	1.2±1.2	0.067	0.412	2.0±1.3	0.038	0.647
Total sugar (g)	44.5±30.4	0.008	0.924	38.0±22.4	-0.111	0.175

*n = 156; All variables were log-transformed before analysis to improved normality; *Correlation is significant at 0.05 level (2-tailed)*

Table 4.28: Pearson's correlation with serum HDL cholesterol level for selected nutrient estimates from MyUM Adolescent FFQ and 7DDH

Nutrient intake	Mean±SD (FFQ)	r	p-value	Mean±SD (7DDH)	r	p-value
Cholesterol (mg)	258.9±163.1	-0.011	0.898	249.4±120.0	0.043	0.597
Crude dietary fibre (g)	4.4±3.0	-0.140	0.087	3.7±2.0	0.045	0.585
Total fat (g)	60.4±25.1	-0.017	0.838	64.4±22.6	0.121	0.137
Carbohydrate (g)	283.4±85.9	0.019	0.820	257.1±80.2	0.039	0.636
Zinc (mg)	1.2±1.2	-0.085	0.298	2.0±1.3	0.243	0.003*
Total sugar (g)	44.5±30.4	-0.013	0.877	38.0±22.4	0.006	0.942

*n = 156; All variables were log-transformed before analysis to improved normality; *Correlation is significant at 0.05 level (2-tailed)*

Table 4.29: Pearson's correlation with serum LDL cholesterol level for selected nutrient estimates from MyUM Adolescent FFQ and 7DDH

Nutrient intake	Mean±SD (FFQ)	r	p-value	Mean±SD (7DDH)	r	p-value
Cholesterol (mg)	258.9±163.1	0.053	0.517	249.4±120.0	-0.066	0.424
Crude dietary fibre (g)	4.4±3.0	-0.030	0.718	3.7±2.0	-0.034	0.680
Total fat (g)	60.4±25.1	0.020	0.810	64.4±22.6	0.046	0.580
Carbohydrate (g)	283.4±85.9	-0.246	0.002*	257.1±80.2	-0.112	0.171
Zinc (mg)	1.2±1.2	0.018	0.830	2.0±1.3	-0.045	0.589
Total sugar (g)	44.5±30.4	0.001	0.996	38.0±22.4	-0.105	0.201

*n = 156; All variables were log-transformed before analysis to improved normality; *Correlation is significant at 0.05 level (2-tailed)*

Table 4.30: Pearson's correlation with serum triglyceride level for selected nutrient estimates from MyUM Adolescent FFQ and 7DDH

Nutrient intake	Mean±SD (FFQ)	r	p-value	Mean±SD (7DDH)	r	p-value
Cholesterol (mg)	258.9±163.1	-0.021	0.799	249.4±120.0	-0.007	0.932
Crude dietary fibre (g)	4.4±3.0	-0.049	0.552	3.7±2.0	-0.007	0.936
Total fat (g)	60.4±25.1	-0.065	0.429	64.4±22.6	-0.182	0.025*
Carbohydrate (g)	283.4±85.9	-0.219	0.007*	257.1±80.2	-0.093	0.256
Total sugar (g)	44.5±30.4	0.044	0.596	38.0±22.4	-0.108	0.185

*n = 156; All variables were log-transformed before analysis to improved normality; *Correlation is significant at 0.05 level (2-tailed)*

Table 4.31: Pearson's correlation with serum fasting glucose level for selected nutrient estimates from MyUM Adolescent FFQ and 7DDH

Nutrient intake	Mean±SD (FFQ)	r	p-value	Mean±SD (7DDH)	r	p-value
Total sugar (g)	44.5±30.4	0.028	0.734	38.0±22.4	0.046	0.574
Carbohydrate (g)	283.4±85.9	0.141	0.084	257.1±80.2	0.038	0.645
Crude dietary fibre (g)	4.4±3.0	-0.017	0.835	3.7±2.0	0.142	0.081

*n = 156; All variables were log-transformed before analysis to improved normality; *Correlation is significant at 0.05 level (2-tailed)*

4.3 Results summary

From the dietary study, it is shown that the Malaysian adolescent consumed significantly high calories compared to the latest Malaysian RNI. The protein intake is two times higher than RNI for both male and female Malaysian adolescents. There's also alarmingly high sodium intake, where at 1.4 and 1.2 times the RNI for male and females respectively. Malaysian female adolescent consumed significantly low iron compared to Malaysian recommended intake with an average of 16mg/day, instead of 31mg/day recommendations. Fibre intake for both male and female adolescent is extremely low, which is an average of only 4g/day, when compare to RNI of 30g/day. Same goes with vitamin D, with an average intake of only 1.8ug/day. In residency perspective, those adolescent who resides in the rural area noted to consume higher cholesterol, sugar, potassium and iron compared to adolescent in urban areas. Malay ethnicity, had a higher sugar intake compared to all other races. Interesting to note, in this study, had shown that adolescent with primary educated parents, consumed less salt compared to those with secondary and tertiary educated parents. Also, adolescent from low income families, consumed less salt compared to middle and high income families.

For the development and validation of MyUM FFQ, ICC and Bland Altman plots was used for reliability study, while for reliability study, correlation coefficient, sign-rank test, cross classification and Bland Altman Plot were used. Reliability study showed that for most macronutrient, the ICC is > 0.8 and most of the micronutrient's ICC was more than 0.6. Pearson's correlation for validation study showed moderate to high correlation for macronutrient, while cross-classification showed more than 70 percent for same and adjacent quartile for MyUM adolescent FFQ and 7DDH

CHAPTER 5: DISCUSSIONS

This chapter presents a critical discussion of the findings of the study and compares those findings with the literature discussed in Chapter 2. The overall aim of the first part of the study was to assess the dietary intake of 15-year-old Malaysian adolescents. A 7-day diet history (7DDH) was used as the tool of assessment, and the results were described in Chapter 4. The 7DDH, as explained in previous chapters, is a good tool for the assessment of the habitual diet of the adolescent. However, the process involved in compiling the 7DDH is both tedious and time consuming. These drawbacks led to the development of the second part of the study, in which a FFQ was developed and validated in order to ease administration and improve the assessment of the dietary intake of Malaysian adolescents in future studies.

5.1 Assessment of Malaysian Adolescents' Dietary Intake

As noted in the literature review discussed in Chapter 2, there are a lot of studies worldwide that demonstrate nutrient transition among the adolescent population, where there is a shift from traditional, low-fat, high-fibre food, to energy-dense, low-fibre food. According to Popkin (2001), this phenomenon of nutrition transition occurs simultaneously with two other historic change processes, namely demographic transition and epidemiologic transition (Omran, 2005; Barry M. Popkin, 2001; B. M. Popkin & Gordon-Larsen, 2004). A nutrition transition from a healthy to unhealthy diet intake among adolescents in Malaysia was described in 2002 (Noor, 2002), and was also described by another later study in 2014 (Soon & Tee, 2014). Previous studies on the diet of Malaysian adolescents have identified a high intake of fat, sugar, and salt, as well as a low intake of fibre, which in the long term can be detrimental to their health (Abdullah et al., 2016; Loh et al., 2017; A. Norimah et al., 2015; Zalilah et al., 2006).

While looking into the determination of nutrient intake among the adolescent, based on the socio-ecological model, there are complex factors at multilevel of influence that determine the adolescent's dietary intake and BMI (Leslie A Lytle, 2009; Reicks et al., 2015). According to this theory, the dietary intake of the adolescent is influenced by personal factors, such as biology, the food choice the adolescent made, with whom the goods are consumed, also the place and the time the foods were consumed. This, in turn, affected by multi layers of influence such as beliefs, values and practices of the parents and family members (Birch & Davison, 2001; Scaglioni, Salvioni, & Galimberti, 2008), settings in which the food and beverages available for consumption (Neumark-Sztainer et al., 1999; Tilles-Tirkkonen et al., 2011), and social environment, such as peer support, school and public health policies (Baker, Little, & Brownell, 2003; Mary Story, Neumark-Sztainer, & French, 2002; Verstraeten et al., 2014). Additionally, household organization, the role of the parents, ethnicity upbringing, acculturation and socio-economic position (Reicks et al., 2015), which was partly addressed in this study may perhaps mediate the influence of dietary intake among the adolescent.

5.1.1 Dietary profile of adolescents

As discussed in the literature review, male adolescents require more energy and other nutrients compared to female adolescents. In the sample of 597 participants analysed in this study, the mean reported energy intake was 2182.0 kcal/day, with male adolescents consuming approximately 400 kcal more per day in comparison to female adolescents (2431.8 kcal vs. 2027.1 kcal). Moreover, both sexes exceeded the 2017 Malaysian RNI, with female adolescents having a higher energy intake than their male counterparts (112 percent for females vs. 110 percent for males). A high energy intake among adolescents was prevalent in the current study, regardless of residency, ethnicity, parent's education, and household income. Cross-sectional studies around the world have reported conflicting results among children and adolescents. Some of the studies identified a significant relationship between dietary intake and obesity, while others found a negative relationship, and there were also some studies that reported a non-significant relationship (Gazzaniga & Burns, 1993; Gillis, Kennedy, Gillis, & Bar-Or, 2002; Guillaume, Lapidus, & Lambert, 1998; McGloin et al., 2002). In line with some studies in Malaysia, the current study found that obese adolescents reported a higher mean energy intake compared to normal weight and overweight adolescents (Abdul Majid et al., 2016; Soo et al., 2011).

On the subject of macronutrients, there was a significant difference in protein intake between the two genders, where the male adolescents consumed 11.8 g more protein per day than the female adolescents (89.3 g vs. 77.5 g). Both genders exceeded the recommended protein intake by 198 percent for males and 184.5 percent for females. A previous study on Malaysian adolescents showed that girls had a protein consumption of 72 g, 70 g and 80 g and boys 89 g, 80 g and 86 g in the underweight, normal weight, and overweight categories, respectively (Zalilah et al., 2006). The same pattern of excessive intake of protein has also been described in other adolescent studies outside Malaysia (Aeberli et al., 2007; Gharib & Rasheed, 2011; Stefanska et al., 2012; Toselli et al., 2010). In fact, the current study, which had a larger sample size than a 2007 Canadian study, showed a higher intake of protein (Hanning et al., 2007). Same finding noted when compared to Pakistani adolescent (Aziz & Hosain, 2014). Moreover, protein consumption was excessive among both urban and rural adolescents, across all levels of parent's education, or across all categories of household income and body weight. The intake was also high across ethnicities although the Malay adolescents consumed a higher amount of protein compared to Indians. This pattern of high protein consumption was also described among Malaysian adults in 2008 (A. K. Norimah, Jr. et al., 2008). The increasing livestock industries in Malaysia might be one of factors contributing to increasing meat availability and subsequently consumption among Malaysians (Kei, 2017), as taking plant based protein diet were not encourage in Malaysian traditional diet. Long-term excess protein intake can result in disorders of the bone and calcium homeostasis, renal function and liver function disorders, and also precipitate the progression of coronary artery disease, as well as increase the cancer risks (Barzel & Massey, 1998; Delimaris, 2013).

In the current study, carbohydrate consumption for both sexes was within the recommended intake of 50–65 percent of total energy, although there was a significantly higher intake in males compared to females. The mean carbohydrate intake was 292.4 g per/day, with male and female intakes of 334.6 g and 266 g per/day, respectively. There were no differences in carbohydrate consumption between urban and rural adolescents, across all levels of parent's education, or across all categories of household income and ethnicity. However, it was noted that carbohydrate consumption was highest among obese adolescents compared to underweight, normal weight and overweight adolescents. A previous study on Malaysian adolescents also showed a carbohydrate intake of less 55 percent of total energy intake (Zalilah et al., 2006). The same trend is also seen in Europe, where the intake of carbohydrate is low, while the total energy intake is higher than the recommendation (Martone et al., 2010).

The mean recorded fat intake in the current study was 75.6 g per/day, with male and female intakes of 81.5 g and 72.0 g per day, respectively. Male adolescents exceeded female adolescents' fat intake by 9.5 g per day. Although statistically there was no significant difference from the upper limit of the 2017 Malaysian RNI, the mean fat intake of the female adolescents exceeded the upper limit of 2017 Malaysian RNI by 3 percent. Subgroup analysis showed that female adolescents in rural areas consumed a higher amount of fat than upper limit of recommendation, compared to urban adolescents that consumed amount of fat that within the recommendations. There were no differences in fat intake across ethnicity, parent's education, household income, and even BMI. At the time of writing, the most recent study on primary school children in Malaysia recorded a high fat intake of 58 g per/day, suggesting that there is a high-fat diet intake among Malaysians even at an early age (W. Y. Yang et al., 2017). The same phenomenon was also reported in other parts of the world (Aeberli et al., 2007; Ali et al., 2013; Gupta et al., 2010; Leal et al., 2010; Moreno et al., 2014; Toselli et al., 2010). According to Department of Statistic 2016 Malaysia, the rural population spends 25.7 percent of their income on food, compared to urban population with 16.7 percent. The rural community's expenditure on meat, fat and oils, also food product higher compared to their urban counterparts (Mahidin, 2016). This may contribute to higher fat intake among rural adolescent in Malaysia.

In the current study, the adolescents' sugar intake, although still within the limit of the recommendation, accounted for almost 10 percent of the total energy intake (8.2 percent and 8.8 percent, respectively). Moreover, male adolescents in rural schools consumed a significantly higher amount of sugar than female adolescents in rural schools with a mean intake of 65.0 g per/day. The Malay adolescents' sugar intake was the highest compared to the other ethnicity categories with a mean intake of 51.2 g per/day. Also, obese adolescents were noted to consume the highest amount of sugar compared to the other BMI categories with a mean intake of 70.5 g per/day. Parent's education and household income had no influence on the sugar intake of the adolescents. There are limited studies available in regards to sugar intake among adolescents in Malaysia. The few published papers available on adolescents dietary intake have recorded items such as bread, biscuits, chocolate malt drink, tea, and *kuih* (traditional cakes) are the most consumed by adolescents and contribute a high extrinsic amount of sugar to their daily diet (Boon, Sedek, & Kasim, 2012; Huat et al., 2006). Another study among 13-year-old adolescents reported a high consumption of sugar-sweetened beverages among the Malay participants, which might be the reason for the overall high sugar intake among Malay adolescents (Loh et al., 2017). Studies on adults using a small sample size reported a mean sugar intake of more than 10 percent of total energy intake. Among foods most consumed by adults that contribute to a high intake of sugar are cordial, syrup, coffee, chocolate flavoured beverages, condensed milk, and traditional rice-based cakes known as *kuih* (Amarra et al., 2016). The current study finding regarding total sugar intake is consistent with other studies conducted on adolescents outside Malaysia (Fidler Mis et al., 2012; A. Gates et al., 2015; Zhang et al., 2015). Research showed that sugar-rich foods are the most preferred foods among children and adolescents (Cooke & Wardle, 2005). Eating is a social behaviour, in which, children and adolescent observed the behaviour of others, especially their parent, and subsequently influence their own preference and behaviour (van Brug, Lenthe, & Kremers, 2006). Since, Malaysian's adult, preferred sugary food as reported in a 2016 study, thus this, influence the sugar intake of the adolescents (Amarra et al., 2016). This also explained the contrary finding in Japanese children and adolescents that have a reported sugar intake that is within the range of FAO and WHO recommended limits (Takeichi et al., 2012). Clear restrictive rules about high sugary foods during childhood, through parents influence and education system were associated with healthier food choice in adolescent, which was shown in a study in Belgium (De Bourdeaudhuij & Van Oost, 1996).

On the other hand, the current study found that fibre consumption was below the recommended intake of 20–30 g per day among both males and females, with only 4.6 g and 4.0 g consumed daily, respectively. This contrasts with the intake of fibre among aboriginal Canadian adolescents, which is much higher than the fibre intake of Malaysian adolescents (Allison Gates et al., 2012; C. Ng, Young, & Corey, 2010). However, adolescents in Mexico, Bahrain, Libya, Nigeria and Iran for example, have also been reported to have a low fibre intake, which is consistent with the finding of the current study (A.Elhisadi, 2013; Doustmohammadian, Keshavarz, Doustmohammadian, Abtahi, & Shahani, 2013; Flores et al., 2009; Gharib & Rasheed, 2011; Yunusa & Ezeanyika, 2013). The low fibre intake in the current study was seen among males in females residing in urban and rural areas, in all ethnicities, in all levels of parent's education and household income, and also in all BMI categories. This is contrary to a quite a number of previous studies that reported high fibre intake in adolescents from high-income families (Minaker et al., 2006; M. Storey & Anderson, 2014). A study among Australian adults and adolescents showed that socio-economic differences in fibre consumption were more apparent in adults rather than in adolescents (Giskes, Turrell, Patterson, & Newman, 2002). A study among adults in the USA showed that there is an inverse relationship between the socio-economic status of white Americans and their fibre intake (Beydoun & Wang, 2007). A few barriers to the adequate intake of fruit, vegetables and fibre have been discussed in the literature. One of the obstacles seems be the price of fruit and vegetables, which can be expensive, which offers a reasonable explanation for low intake among those of low socio-economic status, as mentioned in a previous study (Drewnowski, Darmon, & Briend, 2004). However, in the current study, even among the high-income group, fibre consumption was low, which indicates that socio-economic status is not a guarantee of healthy diet, particularly in regards to fibre intake in the Malaysia context. This may be because eating out of the home is an important aspect of many diets worldwide and, although often not healthy, such activity is common among those of higher socio-economic status (Lachat et al., 2012). Palatability is another factor that needs to be explored in future adolescent diet studies because highly energy-dense and low-fibre foods are tastier compared to healthy food (Darmon & Drewnowski, 2008). The rapid growth of the fast-food industries in Malaysia, as well as the presence of local food stalls that sell energy-dense, low-fibre and yet tasty food might be among the possible reasons for the low fibre intake among Malaysian adolescents because a previous study has shown that the higher the income, the more frequent the purchase of fast food (Habib, Dardak, & Zakaria, 2011; Heng & Guan, 2007). This explanation can also be extended to adolescents of low socio-economic status because fast food is available everywhere, sold by multiple restaurants and vendors at cheap prices, and developed communication and transportation systems enable marketing campaigns and allow Malaysians to get access to these food products (Heng & Guan, 2007; Muhammad, Othman, Ghazali, & Karim, 2013; Nik Mustapha, Rahman, Zubaidi, & Radam, 2001). Also, modern methods of food processing that minimize the germs of the crops, which contains high amount of fibre, may be one of the factors contributing to the low dietary fibre intake among adolescents (Dhingra, Michael, Rajput, & Patil, 2012). Long-term low dietary fibre intake has been associated with a high risk of CVD, haemorrhoids, diverticular disease, and colonic cancer (Aune et al., 2011; McDonald, Pirhonen, & Rangam, 1983; Murphy et al., 2012; Satija & Hu, 2012). This is important because colorectal cancer is the second most common cancer in males and third most common in females in Malaysia (Veettil, Lim, Chaiyakunapruk, Ching, & Abu Hassan, 2016). A recent study published in 2016 has also even suggested that a high dietary fibre intake in young adults can reduced the risk of breast cancer (Farvid et al., 2016). With the incidence of breast cancer in Malaysia as high as 38.7 per 100,000 of the population in 2012 (Yip, Bhoo Pathy, & Teo, 2014), hopefully the promotion of a high-fibre diet among adolescents will not only reduce the incidence of colonic cancer in the community, but breast cancer as well. More studies are needed to find the cause of low fibre consumption, which may be due to factors additional to those mentioned above. Appropriate education and suitable intervention also needs to be planned to encourage fibre intake among adolescents, which subsequently can reduce the risks in Malaysian adolescents.

The combination of a low-carbohydrate, high-fat, and low-fibre diet in adolescents can produce undesirable effects in the future. A previous study has shown that a combination of low starch, high fat, and low fibre is associated with hyperinsulinaemia in the non-diabetic population, which results in insulin resistance. This can open up the possibility of adolescents suffering from insulin-resistant diabetes mellitus later in life (Marshall, Bessesen, & Hamman, 1997). A more recent study in 2011 demonstrated that a very-high-protein, high-fat, low-carbohydrate, and low-fibre diet intake may, in the long term also pose a colonic disease risk (Russell et al., 2011). The combination of high protein, inadequate carbohydrate, and low fibre is a recipe of disaster for the Malaysian adolescent population because it is harmful to their health as future adults. Three quarters of premature deaths in Malaysia result from NCDs (Yusoff et al., 2013). The economic burden of NCDs in developing nations is increasing (Ibrahim, Aljunid, & Ismail, 2010). A modification of the diet of adolescents is needed so that they have a healthy diet in order to ensure the health of Malaysians and to reduce the economic burden of chronic diseases on society.

As evidenced in the current study, both male and female Malaysian adolescents tend to consume an excessive amount of sodium, in quantities that are significantly higher than the Malaysian RNI. The male is at greater risk because sodium intake is significantly higher in male compared to female adolescents. In the current study, there is no difference in the sodium intake between urban and rural residency because both sub-categories of participants reported a high sodium intake that is above the recommendation. The same high sodium intake pattern was also seen in all ethnicities and all levels of BMI. Surprisingly, in the current study, the adolescents with primary-school educated parent consumed less salt compared to adolescents with secondary school and tertiary-educated parent. As mentioned above, eating out of the home has become an important part of the diet among high-income families, and this factor may have contributed to the above findings (Lachat et al., 2012). Little is known regarding salt intake among adolescents in Malaysia. A previous study in 2016 on the diet intake of 13-year-old adolescents reported a sodium intake averaging 2289.5 ± 920.9 mg per day, which already exceeded the recommended intake level (Abdul Majid et al., 2016). The current study found that there was an even higher average intake of sodium of 3004.5 mg per day. Local snacks, such as fish crackers called *keropok* were described by previous studies in 2006 as the most common, high-sodium content snack consumed by adolescents (Huat et al., 2006; Moy, Ying, & Kassim, 2006). Further research on the types of food that adolescents are consuming and that might be contributing to this problem is needed because the diet of adolescents might undergo changes in the next 10 years in line with economic and social changes that influence the food choices of adolescents. At present, there is not enough research available in Malaysia that addresses the influence of parent's educational background on adolescent dietary intake. One study with a small sample size (n = 100) that was conducted in Kuantan found that the knowledge of parents does not guarantee good diet practices among their adolescent offspring (Hatta, Rahman, Rahman, & Haque, 2017). The same conclusion can be drawn from the current study. Even outside Malaysia, research on the parent's role in an adolescent's diet is scanty (Khandpur, Blaine, Fisher, & Davison, 2014; Tornaritis et al., 2014). Thus further studies on the role of the parent in the dietary intake and food choices of Malaysian adolescent would be beneficial. Then proper interventions can be planned and implemented to curb this problem of excessive sodium intake in the adolescent diet. Besides the enforcement of legislation on mandatory labelling of sodium content in all food products according to Food Act 1983, working with stakeholders such as the media, Ministry of Education, food operators, hawkers, and the food and beverages industries is another strategy that could be undertaken to provide education on the danger of excessive salt intake, and also empowering individuals and communities to make behavioural changes towards achieving a healthy lifestyle (MacGregor, Jenner, & Brown, 2017).

On the other hand, the intake of potassium salt was below the recommended intake for both male and female adolescents in this study, although it was higher among males compared to females. The intake was higher among rural adolescents compared to urban.

The Malay ethnicity had a higher intake compared to Indians and Others. Parent's education, household income, and BMI had no influence on potassium intake among adolescents. Not many studies are available on potassium intake among adolescents. Outside Malaysia, Polish and Kenyan adolescents have also been reported to have a low intake of potassium, below the recommended value (Seidler et al., 2013; Semproli et al., 2011).

Vitamin D is one of the important micronutrients for the human body; however, there is an inadequate intake of this vitamin in Malaysian adolescents' diet. The mean intake of vitamin D in the current study was only 1.8 µg/day, and was significantly lower than the recommended 2.2 µg/day. There was no significant difference in vitamin D intake in the current study by sex, residency, parent's education, household income, and BMI. A previous study among 13-year-old adolescents also showed no significant difference between the urban and rural intake of vitamin D (Majid et al., 2017). Vitamin D consumption was low in all ethnicities in this study; however, it was noted that the intake among Indian adolescents was significantly lower compared to Malay adolescents.

Similar to vitamin D, the calcium intake among adolescents in the current study was also inadequate. The mean intake of calcium was only 575.1 mg/day, with male and female intakes of 620.3 mg/day and 547.2 mg/day, respectively, significantly lower than the recommended intake of 1300 mg/day. The same finding of low calcium intake was also documented in the above-mentioned study on 13-year-old adolescents (Abdul Majid et al., 2016). In the current study, the intake was significantly lower in female adolescents in urban schools. Also, Chinese adolescents consumed less calcium compared to Malay adolescents. There was no statistically significant difference in the intake of calcium by parent's education, household income, and BMI.

The adolescents in the current study were also noted to be deficient in phosphorus intake. The mean intake of phosphorus was only 768.5 mg/day, with 872.7 mg/day and 703.8 mg/day for males and females, respectively. Both the male and female intakes were significantly lower than recommendation of 1250 mg/day, and the female intake was significantly lower than the male adolescent intake. Adolescents of Indian ethnicity had highest intake of phosphorus compared to Chinese and Malay adolescents. Also, those adolescents with parents who had received a primary-school education consumed a diet containing less phosphorus compared to adolescents with parents who had received a secondary-school or tertiary education. There was no difference in the intake of phosphorus across residency, household income, and BMI.

Not many studies are available on the dietary intake of vitamin D, calcium, and phosphorus among adolescents in Malaysia. In the 2012 Malaysian National Health and Morbidity Survey, the dietary intake of calcium among subjects aged 13 to 17 years old was assessed, but not vitamin D (Zainuddin et al., 2013). Outside Malaysia, a study that was conducted on a large sample of European adolescents reported inadequate intake of vitamin D (Diethelm et al., 2014). Studies among Canadian Aboriginal and Kuwaiti adolescents also recorded a low intake of vitamin D, and also a low intake of calcium (A. Gates et al., 2015; Zaghloul et al., 2013). A low intake of calcium has also been reported among adolescents in India, the UAE and Kenya (Ali et al., 2013; Semproli et al., 2011; Shafiee et al., 2015). In the USA, the intake of vitamin D is higher among male compared to female children and adolescents. The vitamin D obtained from the diet and from supplementation was also noted to be higher among those from high-income families and those of white ethnicity (Moore et al., 2014).

The mean vitamin D serum levels in the current study were higher among male compared to female adolescents (69.18 ng/ml vs 53.01 ng/ml; $p < 0.001$). Obese adolescents had the lowest mean vitamin D level compared to the other BMI categories (45.81 ng/ml; $p < 0.001$). There was no significant difference in mean serum vitamin D level among adolescents in urban and rural schools. There was also no significant difference by ethnicity, highest education of the parent, and household income status. The uptake of vitamin D depends not only on diet, but on many other factors such as sun exposure, skin colour, gut vitamin D absorption, vitamin D metabolism, physical activity, and few other factors that were not measured in the current study (Tsiaras & Weinstock, 2011). The lower vitamin D level among female Malaysian adolescents is probably due to the different dress code among females, which results in less sun exposure compared to males in Malaysia, in addition to the avoidance of sun exposure due to cosmetic reasons and lack of physical activity under the sun (Al-Sadat et al., 2016).

The mean serum corrected calcium level was 2.30 mmol/L. There were no significant differences in mean serum corrected calcium level by sex, residency, household income, and BMI. Adolescents of Malay ethnicity had a lower mean serum corrected calcium compared to Chinese and Others. The corrected serum calcium level was also noted to be lower in adolescents with never-schooled parents compared to adolescent with secondary-school- and tertiary-educated parents. The mean phosphate level among adolescents in the current study was 1.38 mmol/L, with the male level being higher compared to the female at 1.46 mmol/L and 1.33 mmol/L, respectively. The mean phosphate level was also noted to be higher among rural compared to urban adolescents. It was also noted to be lower among adolescents who were Chinese and also in those with a high household income.

Ninety-nine percent of total body calcium can be found in the skeleton. A person's calcium metabolism depends on sets of interacting hormones, including parathyroid hormones, vitamin D, phosphorus, ionized calcium, and other corresponding receptors in the gut, bone, and kidney (Fukumoto, 2014). Since only 0.03 percent of the total body calcium is in the plasma, it is not a good indicator of calcium and phosphorus nutritional status. Bone mineral density is the best surrogate marker of calcium status (Almeida Paz & Bruno, 2006). Studies have shown that an adequate intake of vitamin D and calcium is associated with a lower risk osteoporotic fracture (Cumming et al., 1997; Sunyecz, 2008). With their low intake of calcium and low calcium serum level, Malaysian adolescents are at risk of developing osteoporosis later in life. Carbonated beverages contain a high concentration of phosphate, which can further reduce the blood calcium level and result in demineralization of bone (K. L. Tucker et al., 2006). In 1996 to 1997, hip fractures among the elderly was 90 per 100,000 individuals, where the incidence was highest among those of Chinese ethnicity followed by those of Indian descent (J.-K. Lee & Khir, 2007). The latest study on the elderly conducted in 2016 reported a 10.6 percent prevalence of osteoporosis among males and 8.0 percent among females, with no significant ethnic difference in prevalence (K.-Y. Chin, Kamaruddin, Low, & Ima-Nirwana, 2016).

The lack of knowledge about the benefit of dairy/calcium to health, probably one of the reasons of low calcium and vitamin D intake among Malaysian adolescent population in Malaysia. The consumption of healthy diet has been associated with higher nutritional knowledge (Dickson-Spillmann & Siegrist, 2011). In previous research overseas, habits and routine have also been found to affect adolescent's dairy intake (Neumark-Sztainer et al., 1999; Novotny, Han, & Biernacke, 1999), as it has shown that food choices thought during childhood and adolescent will also persist into adulthood. Taste preference also had shown as one of utmost stimulus of food choices and dairy product consumption

(Larson, Story, Wall, & Neumark-Sztainer, 2006; S. Lee & Reicks, 2003; Neumark-Sztainer et al., 1999; Novotny et al., 1999). This could be the case in Malaysian adolescent, as a study among adult Malaysian had shown consumption of dairy product below the recommended serving per day, at only 73.6 percent, which could influence the dietary habit of the Malaysian adolescent (Mohamad Hasnan, Khoo, Yusuf, & Foo, 2015).

The intake of iron among adolescents in the current study was adequate among males, but significantly below the recommendation among females. The mean intake of iron was noted to be higher among rural adolescents compared to urban. The same was also noted among obese adolescents compared to other weight categories. There was no significant difference in mean iron intake across ethnicity, parent’s education and household income status. Low iron intake and anaemia have been observed among adolescents in previous studies (Cynthia et al., 2013; Foo, Khor, Tee, & Prabakaran, 2004). In India, and even high-income countries like Canada and Poland, iron intake among adolescents has been reported to be below the recommended level (Broniecka et al., 2014; Shafiee et al., 2015; Wadsworth et al., 2012).

While most countries need to deal with a low nutrient intake among the rural adolescent population compared to the urban (Herrador et al., 2014; Rodriguez-Ramirez et al., 2009), in Malaysia, we seem to be facing a phenomenon where the nutrient intake among rural adolescents, especially of cholesterol, sugar, potassium and iron, is higher compared to their urban counterparts. However, Malaysia is not alone because a 2013 study in Bangladesh reported that the intake of macronutrients is significantly lower in urban compared to rural adolescents (Akhter & Sondhya, 2013). Besides the parent’s education and household income, factors such as food availability, culture, and even adolescent knowledge about nutrients are worth investigating in future research because these factors also influence the food choices and food intake of adolescents (Alam, Roy, Ahmed, & Ahmed, 2010). Mother's employment is another interesting factor that can contribute to the nutrient intake of the adolescent because a study has shown that adolescents whose mother is in full-time employment have an unhealthy dietary intake compared those with a stay-at-home mother (Bauer, Hearst, Escoto, Berge, & Neumark-Sztainer, 2012). According to the 2015 statistics for Malaysia, of the 5.3 million working females in Malaysia, 1.1 million of them are in rural areas, while 4.2 million are in urban areas (DOSM, 2017). However, no statistics are available on working mothers in Malaysia. Understanding how the factors of food accessibility, food choices and the nutrient intake of adolescents interact is imperative so that effective strategies can be developed and implemented. While employment for parents is beneficial, a proper policy and programme strategies to reduce work-life-related stress need to be implemented to give positive support to the family food environment and ultimately the diet of adolescents. One of the strategy would be to improve positive involvement of parents to create a supportive educational environment for adolescents in schools (Sadegholvad, Yeatman, Parrish, & Worsley, 2017).

The current study showed that the Malay ethnicity consumed a high amount of cholesterol compared to Indian adolescents. The Indian participants had a lower intake of protein compared to the Malay and Chinese. The Malay adolescents also had a significantly high sugar intake compared to the Chinese, Indian and Other categories of participants. A study in Kelantan district in Malaysia showed that Chinese adolescents tend to consume healthier food compared to Malay adolescents (Abdullah et al., 2016). The finding in the current study shows that ethnicity is one of the many factors that play role in food choices, in addition to other factors such as education. Identifying the processes underlying ethnic food choices is important, especially for nutrition educators whether they be nutritionists or dietitians, because it will help them to promote healthy food choices in a multicultural society (Devine, Sobal, Bisogni, & Connors, 1999). With the increasing prevalence of diabetes in Malaysia, from 2 percent in 1985 to 17.5 percent in 2015, a serious systematic implementation of action plans is needed to combat diabetes and its associated risk factors, which include high sugar intake and obesity (Mustaffa, 1985; Tee & Yap, 2017).

5.1.2 Limitation of the dietary assessment study

The current study is a cross-sectional study; therefore, causality cannot be determined. Similar to any study using multiple 24-hour recall as a diet record method, the current study may also have been affected by recall bias. This is because only a few subjects are able to accurately remember the amounts and types of food taken in the last 24 hours (Shim et al., 2014; Todd, Hudes, & Calloway, 1983). However, the 7DDH interview in the current study was conducted by a trained dietician who interviewed each adolescent on a one to one basis. The interviewers used household measurement tools, such as a plate, glass, cup, bowl, spoon and ladle, to quantify the food intake. Also, a flip chart that depicted the common Malay, Chinese and Indian dishes was used to assist the diet history data collection (Shahar et al., 2015). This is because children and adolescents will remember better if given something that can trigger their diet recall memory, such as visual images of the food, probing on usual practices, enquiring about the association with a preferred food or preferred activity during the day, and also their food preferences (Baranowski & Domel, 1994; Baxter, Thompson, Davis, & Johnson, 1997; Warren et al., 2003).

Nutrition studies tend also to be affected by self-report bias. This is a condition where the participants respond in a way that makes them look as good as possible in terms of their food consumption habits. Thus, participants tend to over-report food intake that is deemed to be appropriate and under-report food intake that is not viewed to be appropriate (Donaldson & Grant-Vallone, 2002). In the current study, appropriate action was taken to mitigate this bias; using the Kersting criteria, where the under-reporters were excluded from the analysis (W Sichert-Hellert, Kersting, & Schöch, 1998).

It should also be noted that insulin was not measured in the current study. Thus, the relationship between dietary intake and hyper/hypoinsulinaemia cannot be determined. Also, the food compositions used for the dietary assessment in the current study were based on a 1997 food composition book (Siong et al., 1997). There was no later version of a Malaysian food composition book. However, for food that had no composition information, such as foods from manufacturers, this information was added individually into the software. A Singaporean nutrition database was also used to ensure that all the nutritional values of the foods consumed by the adolescents were available for the data analyses ("Energy and Nutrient Composition of Food Singapore," 2011).

Lastly, a multivariate analysis was not done in this study because the objective of the study was to examine individually the gender, residency, BMI, and socio-economic differences in the dietary intake of the Malaysian adolescent population.

5.1.3 Strength of the study

The current study, using MyHeARTs database, is one of the few studies to use a large sample size to investigate adolescent dietary intake in Malaysia. Single 24-hour diet recall alone is not able to capture the true dietary intake of the adolescent. In this study, the 7DDH were used, thus enabling the near to precise capture of the dietary intake and pattern of the Malaysian adolescent(Van Staveren et al., 1985). It has also been shown that the diet history method can estimate energy intake at the group level in a younger population, better than the weighed record method (Van Staveren et al., 1985), and most importantly, the 7DDH is better at overcoming the age-related bias that is common in the reporting of food intake (M. B. Livingstone et al., 1992).

5.2 Development and Comparative Validation of MyUM Adolescent FFQ

In the second part of the discussion chapter, the steps of FFQ construction were described. Statistical analyses were performed to demonstrate the ability of constructed FFQ to reproduce and to measure the dietary intake of the Malaysian adolescent population, which is known as 'reproducibility and validity'.

5.2.1 MyUM Adolescent FFQ construction

A systematic review by Cade in 2002 found that the number of food items in FFQs ranges from 5 to 350 food items (J. Cade et al., 2002). However, where there are more than 273 food items in an FFQ, this will result in a decreasing marginal gain of information and also increase the participant burden (W Willet, 1998). Accordingly, the MyUM Adolescent FFQ food item list contained 200 items, which is within the acceptable range of food items that can maximize gain of information on the dietary intake of the Malaysian adolescent population.

5.2.2 Reproducibility and comparative validity of MyUM Adolescent FFQ

The results demonstrated that the 200-item self-administered MyUM Adolescent FFQ proposed in the current study is a relatively valid tool for dietary assessment of the adolescent population in Malaysia. Statistical tests and analysis showed that the MyUM Adolescent FFQ has moderate to good reproducibility and strength in terms of diet estimation.

In the current study, the difference between the first and second MyUM Adolescent FFQs (FFQ1 and FFQ2) completed by 78 participants was analysed using ICC, reliability, and reproducibility. The results of the analysis showed a higher correlation (0.67 to 0.88) than that reported in other previous studies which reported a correlation of 0.53 to 0.65 and 0.31 to 0.73, respectively (Marchioni, Voci, Lima, Fisberg, & Slater, 2007;

Moghames et al., 2015). However, the test-retest study duration was longer in those studies compared to that of MyUM Adolescent FFQ test-retest study.

The mean nutrient intake value derived from the MyUM Adolescent FFQ was noted to be higher than that from the 7DDH. This was expected because this is a common issue that has also been reported by other studies; adolescents tend to overestimate the nutrient intake in their recall for a FFQ compared to their recall for a multiple 24-hour diet record (W. C. Willet et al., 1985; W Willett & Lenart, 1998). The signed-ranks test showed no significant difference in most macronutrients, micronutrients, and minerals, which indicates that there is agreement between the two methods of diet estimation investigated in the current study.

The comparative validity of this newly developed FFQ was further examined by correlation coefficient analysis, where the 7DDH was used as a reference. A significantly moderate to high correlation for macronutrients such as total energy, protein, carbohydrate, and total fat, proved that the MyUM Adolescent FFQ was able to deliver a good evaluation of the macronutrient intake compared to the reference method. This was also the case for micronutrients because the correlation for most of the micronutrients was found to be moderate. This is consistent with other studies on adolescent populations (Araujo et al., 2010; A. Nurul-Fadhilah et al., 2012a; Papadopoulou et al., 2008). Although there was a decrease in the correlation after energy adjustment in carbohydrate, vitamin C, vitamin E, calcium and magnesium intake, which may indicate a systematic error of overestimation or underestimation (Walter Willet & Stampfer, 1986), most of the nutrients, such as protein, cholesterol, crude dietary fibre and other micronutrients had an improved correlation with energy adjustment. This could be due to the wide range of food items listed in the MyUM Adolescent FFQ that took into account multi-ethnic common food consumption and seasonal fruit as well as the use of household measurement utensils, frequency and serving size options in the MyUM Adolescent FFQ that enabled the near-precise estimation of nutrient intake among adolescents (Shahar et al., 2015).

The use of correlation analysis in assessing the validity of a questionnaire is often questioned because it measures the strength of association rather than agreement (Bland & Altman, 1986; J. Cade et al., 2002). Hence, multiple statistical analyses (Bland–Altman plot and cross-classification) were used in the current study to show the strength of agreement of the proposed FFQ rather than using correlation analysis alone. The use of cross-classification and Bland–Altman plots showed that there was minimal systematic bias for most of the macro- and micronutrient, which indicates good agreement, and shows that the MyUM Adolescent FFQ is comparable with other FFQs (Araujo et al., 2010; Henn, Fuchs, Moreira, & Fuchs, 2010; Kobayashi et al., 2011; A. Nurul-Fadhilah et al., 2012a).

5.2.3 Limitation of MyUM Adolescent FFQ study

It should be noted that the current study has some limitations. First, a general limitation that needs to be acknowledged is that tools of dietary assessment that rely on memory, such as the MyUM Adolescent FFQ and 7DDH, may be subject to bias due to over- and underestimation. However, the 7DDH is one tool that has managed to capture the foods that are commonly consumed by Malaysian adolescents and it was based on this that the MyUM Adolescent FFQ was constructed. Furthermore, this limitation was minimized in the current study by the use of face-to-face interviews conducted by dietitians, assisted by colourful flip charts and household measurement utensils to overcome bias (Baranowski & Domel, 1994). Additionally, to capture more representative data on nutrient intake, the allocation of a greater number of days for a diet recall or a diet record would be required, especially for micronutrients. A longer period of assessment is required for micronutrients because some of them are only present in certain food (S. A.

Bingham, 1987). At least eight repeated 24-hour recalls are recommended to capture the variation in micronutrient intake (Jackson, Byrne, Magarey, & Hills, 2008). In the case of some micronutrients, several weeks of 24-hour recalls are needed to measure the intake accurately (Amoutzopoulos et al., 2015a). However, an FFQ can be used as a complementary dietary assessment tool and is able to capture the micronutrient intake and day-to-day variation while reducing the burden on the subject (P. Emmett, 2009). Thus, the MyUM Adolescent FFQ is a suitable tool to use to capture not only the habitual diet of Malaysian adolescents, but also to assess their micronutrient intake, which usually takes a greater number of days when using a traditional diet record or diet recall methods. This FFQ can also minimize the cost of interviewers compared to other diet assessment methods.

According to Cade (2004), the shortest time interval to repeat a questionnaire is 2 hours apart, while the longest duration is 15 years (J. E. Cade et al., 2004). In the current study, the time interval between the first FFQ and the second FFQ in the test-retest analysis was a 1-week period. A duration of 1 week between the first and second administration of the FFQ was chosen to avoid true changes in the dietary habits of the adolescents, which may occur over longer periods of time. At the same time, 1 week was considered long enough for participants not to remember their responses in the first FFQ administration. There are quite a number of studies in which the test-retest of the first and second FFQ is conducted 1 week apart (Braakhuis A J, Hopkins W G, Lowe T E, & EC, 2011; Hebden L, Kostan E, O'Leary F, Hodge A, & Allman-Farinelli M, 2013; A. Nurul-Fadhilah et al., 2012a; Psoter WJ, Gebrian B, & Katz RV, 2008).

From the psychological point of view, when participants are asked about episodes of eating and drinking, *specific dietary information* or *generic dietary information* is used. In the case of a FFQ with a short reference period (e.g. participants need to recall food intake for the past 2 weeks) *specific dietary information* is used and the accuracy of reporting the diet decreases as the amount of time between the dietary intake and dietary interview increases. However, *generic dietary information* is used when the participant is asked to report their diet intake over a longer duration (e.g. participants need to recall food intake for the past 1 year). A study by Smith and colleagues in 1991 showed that the longer the reference period is, the more accurate subjects can be, not because they remember better, but because their report will better match what they are supposed to remember (Smith, Jobe, & Mingay, 1991). There may be a possibility of the influence of learning experience coming into play when the same individual is asked the same questions twice during a test-retest study. However, because the current FFQ measured the habitual nutrient intake for the past 1 year, the participants were required to report their 1-year food intake in the FFQ using the network of general knowledge of *generic dietary information*, rather than *specific dietary information*. Thus, the reported diet for the 1-year period actually reports the habitual diet of the participants, rather than the learning experience.

The current FFQ showed weak, and no correlation with biomarkers, as reported in Chapter 4. Although biomarkers can provide an objective measure of intake (J. Cade et al., 2002; Jenab, Slimani, Bictash, Ferrari, & Bingham, 2009), they have several drawbacks. Undeniably, while the FFQ measures intake, the biomarkers measure circulating concentrations that are influenced by not only the dietary intake, but also a number of environmental and physiological factors (Walter Willet & Lenart, 2013). The effects of physiology, lifestyle, genetics, and other dietary factors may also affect the relationship between the amount ingested and the biochemical measurement (Hunter, 1998; Jenab et al., 2009). The weak and no correlation observed between biomarkers and FFQ-estimated values would be due to these effects.

Another limitation in this validation study is lack of second 7-days diet recall. This is a standard design of validation studies to measure day to day variability, where the second, and other repeated 7-days diet recalls measurements should have accounted for mid-term drifts and seasonal changes over this one-year period of time (Walter Willet & Lenart, 2013).

CHAPTER 6: CONCLUSION

Different populations have their unique nutrition problems. In the Malaysian adolescent population context, there is a difference in nutrient intake between gender, residency, ethnicity, parent's education, household income and BMI. The current study found that male adolescents had a higher intake of macro- and micronutrients compared to female adolescents. Rural adolescents consumed more cholesterol, sugar, potassium, and iron compared to those in urban areas. Sugar intake was highest among Malays compared to other races. Sodium intake was higher among adolescents whose parents were tertiary educated, and among those who were in middle- and high-income households. Similar to other studies, this study also found that obese adolescents have high energy, carbohydrate, sugar, and iron intakes compared to other BMI categories. Therefore, the null hypothesis formulated in the first part of this study is rejected. Identification of these factors that affect the nutrient intake of the Malaysian adolescent population is important as it related to the current's adolescent unhealthy intake behaviour and it warrant urgent intervention for prevention. A comprehensive national strategy based on socio-ecological framework, is required to deal with this long-term hazard of chronic disease in Malaysia. Based on the results, the excessive intakes of energy, protein and salt, low intakes of fibre, potassium, calcium, magnesium, phosphorus, and iron need appropriate attention.

Currently in schools, topic of nutrition was incorporated into science, and physical and health education syllabus. There was no specific subject of nutrition in schools in Malaysia. Thus, an educational intervention programme in secondary schools to educate adolescents on a balanced healthy diet, focusing on the factors determining nutrient intakes, should be a public health priority. KOSPEN activities, which currently only focused in community, should also be expanded to schools. Adolescents in 'Doktor

Muda' program should be the health promoter, in promoting health and healthy diet in schools using KOSPEN concept. This empowering the adolescent in making healthy diet decision in their everyday life, until they reach their adulthood. In Malaysia, there are two policies that support the environment that conducive to healthy eating habit at schools. The two policies are Healthy School Canteen Management Guide and Enforcement Guidelines on Prohibition of Food and Beverage Sales Outside the School Fence. These guidelines that implemented in every school need to be continued and strengthened as it able restrict unhealthy food from entering school canteen and school compound areas. As in the guidelines, the nutrient content of the food in the school canteen must be displayed so that children and adolescents can make healthier diet choices while at school, and continue to do so when they are outside the school compound. School Health Team, which currently run by the District Health Office, needs to include dietary assessment of the adolescent, using this newly developed FFQ, besides other basic health assessment such as weight and height measurement. This to ensure that the unhealthy diet among adolescent can be picked up early, and educational intervention can be planned and implemented. The establishment of a social support system comprised of other agencies such as non-governmental organizations (NGOs), the Social Welfare Department, Ministry of Education, as well as media and social marketing to increase awareness and help to engender a healthy dietary habit among Malaysian adolescents, is very important.

One area of future work is the design of an intervention programme that is tailored to promote healthy eating among adolescents that takes into account different ethnicities, residencies and even different socio-economic backgrounds. The incorporation of a NCD prevention strategic plan, particularly one that addresses the issues of obesity prevention and healthy diet promotion in all school programmes, is urgently needed in Malaysia. Nutritionist and dietitians should be part of a strategic working team to develop a public health strategic plan. The introduction of a nutrition subject, together with a qualified nutrition educator, into primary and secondary school education, as in Japan, would be a good avenue through which to expose children and adolescents to nutrition knowledge and reverse the worsening crisis of overweight and obesity among this population. Moreover, the enforcement of the law on the maximum salt content in food is needed to curb the problem of excessive salt intake among Malaysian adolescents. Government support for controlling the prices of the fruit and vegetables would be a great step towards encouraging healthy food choices among both the adolescent and adult Malaysian population. A public–private partnership, with other agencies and NGOs, as well as the food industries, would be another big step that could be taken by the Malaysian government. All sectors, including the private sector, need to work together to address the multiple issues related to healthy eating and obesity prevention. This includes increasing the availability of and ease of access to healthy and nutritious food among children and adolescents, diminishing the marketing of foods containing a high fat, salt, and sugar content to the population, and also improving the physical environment to promote children's and adolescents' physical activities.

There is no perfect dietary assessment tool to measure the habitual dietary intake of the adolescent. The use of the 7-day diet history in the first part of the study, although able to assess the habitual diet of the adolescent, would be costly for a large-scale study because quite a number of dietitians are needed to get the details of the dietary intake of the adolescents during the assessment. Thus, the development and validation of the MyUM Adolescent FFQ, which is self-administered, will aid in the dietary assessment of adolescents in the future because it can be conducted easily in a population study and requires less guidance from dietitians. The results showed that this 200-item FFQ developed specifically for the Malaysian adolescent population has moderate to good comparative validity for the assessment of energy, protein, carbohydrate, fat, vitamin A, vitamin B1, vitamin B2, vitamin B6, sodium, potassium, calcium, iron, phosphorus, magnesium, and zinc intakes, and therefore can be used to assess the diet of multi-ethnic adolescents in Malaysia. The macronutrient intake of the adolescent that captured using this FFQ is important as it can be used to investigate its relationship with NCDs and obesity. However, this FFQ cannot be generalized to the whole Malaysian adolescent population, as an adolescent from Borneo for example, has their own different ethnic composition as well as different food and dietary intake. Thus, validation study of this FFQ among Borneo adolescent is a need in the future. As noted in the first part of the study, the promotion of healthy nutrition and a proper diet intervention is needed among Malaysian adolescents. Although there are national nutrition programs tailored to tackle adolescent issues in Malaysia, most of them have not been evaluated. The effectiveness of School Canteen Management Guidelines, for example, have not been evaluated since its implementation in 2011. Lack of political commitment in tackling obesity has led to financial shortfall and subsequently had led to lack of capacity in running effective nutritional programs which then resulted in a lack of monitoring and evaluation. This quick and easily administered tool could be used to measure the effectiveness of diet promotions and interventions in future adolescent diet studies. In addition, a future study on the effect of the stay-at-home mother on the nutrition of the adolescent, using this newly developed FFQ, would be beneficial in facilitating a better understanding of the environmental influence on the dietary intake of Malaysian adolescent. It could also be used to examine the diet–disease relationship in future Malaysian adolescent epidemiological studies.

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