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ORIGINAL ARTICLE

Evaluation of Dietary Quality Using Malaysian Healthy Eating Index and Its Relationships With Cardiometabolic Risk Factors in Malaysian Adolescents

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ABSTRACT

Introduction: This cross-sectional study aimed to investigate relationships between diet quality assessed by Malaysian Healthy Eating Index (HEI) and cardiometabolic risk factors in adolescents aged 13 years. **Methods:** 336 adolescents from various public secondary schools provided information on sociodemography and their anthropometric measurements including height (cm), weight (kg) and waist circumference (cm) were measured. Body mass index (BMI) was estimated thereafter. Dietary intakes assessed using a validated adolescent food frequency questionnaire (FFQ) was used to estimate Malaysian HEI. Biomarker parameters including lipid profile, fasting glucose, insulin and insulin resistance were also assessed. Associations of diet quality indicators to cardiometabolic risk factors were examined using regression models. **Results:** The overall diet quality of the adolescents was rather poor (49%), with a greater percentage of males were found to have low dietary quality score compared to females (56% vs. 39%; $p<0.05$). While males were more obese, a higher number of females (46.7%) were found to have at least one risk factors for cardiometabolic health compared to males (37.7%). After adjusting for covariates, no significant associations were observed among adolescents in the lowest quartile compared to those in the highest quartile of HEI score for obesity and abdominal obesity, as well as other cardiometabolic risk factors, in both males and females. **Conclusion:** Despite of poor dietary quality, no significant associations were observed between dietary quality assessed by Malaysia HEI and cardiometabolic risk factors in adolescents. Prospective studies are needed to establish a causal link between dietary patterns and cardiometabolic risk factors during adolescence.

Keywords: Diet quality, Malaysian Healthy Eating Index, Cardiometabolic risk factors, Adolescents, Cardiovascular disease

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INTRODUCTION

Although there are major enhancements in awareness and treatment of cardiovascular diseases (CVD) in the past decades, it still remains as the top cause of death, globally (1). A substantial evidence suggesting that risk factors for CVD namely obesity, insulin resistance, high blood pressure and dyslipidaemia develop early in life and tend to track between childhood and adulthood through the adolescence period (2, 3). Therefore, further understanding on these risk factors and the time period when they become very significant during the childhood period (including adolescence) are essential to plan for appropriate interventions.

Since diet is an important modifiable risk factor for CVD in adulthood, it is likely to be important as well for the prevention of early CVD risk factors in childhood (4). Several dietary factors such as dietary fats, dietary fibre and sodium have been linked as risk factors for CVD such as atherosclerosis, coronary heart disease (CHD) and myocardial infarction in adults. However, the recognition of the importance of a holistic dietary intake has guided many countries to develop their own dietary guidelines for maintaining health and preventing chronic diseases. Compared to the assessment of single nutrient or food group, these guidelines may facilitate a better informed overall food choice based on its variety and quality.

There is very limited information available on the role of diet in the development of early cardiometabolic risk factors in Malaysian children and adolescents. To date, only a few observational studies in the Western countries have evaluated empirical dietary patterns and their associations with adolescent cardiometabolic risk factors. For example, a dietary pattern characterised by foods high in energy dense and fat and low in fibre was previously identified using reduced rank regression (RRR) in two pregnancy cohort studies namely the Western Australian Pregnancy (Raine) Cohort Study and the UK Avon Longitudinal Study of Parents and Children (ALSPAC) study (5, 6). A higher adherence to the identified dietary pattern was associated with higher overall cardiometabolic risk factors and insulin resistance during adolescence in the Raine study and a greater fat mass between childhood and adolescence stage in the ALSPAC study (5, 6). On the other hand, an identification of a principal component analysis (PCA) derived dietary pattern in the Young Finns Study at ages between three and 18 years was positively associated with greater total cholesterol, LDL-C and an inflammatory marker namely C-reactive protein concentrations in women and men, 21 years later (7). The identified 'traditional' dietary pattern in the Young Finns Study was characterised by high intakes of potatoes, butter and sausages (7). Nonetheless these dietary patterns were derived either based on certain response variables i.e. energy density and percentage energy from total fat linked to cardiometabolic risk factors namely obesity or merely the dietary patterns a population exhibits at that point of time. These dietary patterns were not identified based on the certain dietary guidelines per se and therefore does not represent how well the population adheres to the set guidelines.

As Malaysia is undergoing a staggering level of both industrialisation and urbanisation in the recent times, it is therefore appropriate to investigate if dietary patterns common to that Western countries become widespread and established within the young population. Furthermore, as dietary habits carry over from childhood across adolescents' age to adulthood, establishing healthy dietary patterns at a younger age is of great importance for avoiding chronic diseases in later adult life. As such, recognising the relationships between dietary patterns and risk factors for CVD during childhood and adolescence may be useful in understanding the diet-disease pathway and in identifying potential programmes or interventions for future CVD prevention.

MATERIALS AND METHODS

Study sample

Details of this study and the number of eligible adolescents were previously described (8). In brief, a total of 933 adolescents aged 13 years were recruited and out of these 930, 793, 585 and 507 provided information on anthropometric, physical activity, valid dietary assessment data and biochemical measurements, respectively (8). Those who provided valid dietary (≥400 kcal and <8000 kcal), biochemical and anthropometric data (n=336) were included in this study (8). As adolescents in Malaysia enter secondary education at 13 years of age, it represents a period where major pubertal developments alongside with increasing autonomy from family and personal freedom takes place, both of which may affect food choices. The study adolescents were recruited from randomly selected national schools located in three states; Negeri Sembilan, Melaka and Johor. To ensure more ethnic and sex representatives, single ethnic group i.e. boarding, religious and vernacular schools were excluded from this study. Approvals were sought from the Ministry of Education, State Department of Education as well as the respective school head teachers prior to data collection. Ethical approval for the study was sought from the Ethics Committee for Research Involving Human Subjects (JKEUPM) of Universiti Putra Malaysia (IRB No: FPSK (EXP16) P031). Written informed consent was obtained from all adolescents and their parents or guardian prior to the study conduct.

Dietary assessment

A validated adolescent food frequency questionnaire (FFQ) was administered to estimate dietary intake over the previous year and it has been described elsewhere (9). In brief, the FFQ obtained information on usual frequency and serving sizes of 195 food and beverage items. Prior to the dietary assessment, detailed instructions on how to fill in the questionnaires were provided to all study adolescents by the study researchers. Adolescents in this study were also provided with a flipchart on household measurements to aid their food intake estimation. The average frequency of consumption for each food item was documented as 'never', '1-3 times per month', 'one time a week', '2-4 times per week', '5-6 times per week', 'one time a day', '2-3 times per day', '4-5 times per day', or '≥6 times per day'. These frequencies were manually converted to daily intakes using a standard conversion factor and linked with Malaysian Food Composition (10, 11). Subsequently, Nutritionist Pro software version 3.1 (Axxya Systems, USA) was used to estimate the daily nutrient intakes. Upon submission, all FFQs were checked by the study researchers to ensure no fields were left blank. Dietary misreporting was estimated using the Goldberg method as this is a common issue among adolescents (12, 13). Subsequently, dietary misreporting was included as a potential covariate in the regression models, in this study.

Malaysian Healthy Eating Index Scoring

The validated Malaysian Healthy Eating Index (14, 15) was used a measure of dietary quality in this study. Information on Malaysian HEI and its scoring method has been described elsewhere (16-18). In brief, the HEI comprised of nine components and out of these,

Table I: HEI component scores for adolescents aged 13 years from three southern states in Peninsular Malaysia

HEI component score	Possible range of score	Criteria for minimum score of 0	Criteria for perfect score of 10	Respondents				p-value
				Range of score among respondents	**Male (n=98)**	**Female (n=239)**	**Total (n=337)**	
Cereals and grains*	0 to 10	0 serving	6-9 servings	0.0 – 10.0	10 (IQR=0.0)	10 (IQR=0.0)	10.0 (IQR=0.0)	0.889
Vegetables*	0 to 10	0 serving	3 servings	0.0 – 10.0	0.4 (IQR=2.7)	1.5 (IQR=4.7)	1.2 (IQR=4.1)	<0.001
Fruits∞	0 to 10	0 serving	2 servings	0.0 – 10.0	5.7 (SD=4.1)	6.2 (SD=3.7)	6.1 (SD=3.8)	0.258
Milk and milk products∞	0 to 10	0 serving	2-3 servings	0.0 – 10.0	3.2 (SD=3.9)	3.7 (SD=3.8)	3.5 (SD=3.8)	0.306
Poultry, meat and egg∞	0 to 10	0 serving	1-2 servings	0.0 – 10.0	7.6 (SD=3.7)	7.8 (SD=3.4)	7.8 (SD=3.5)	0.358
Fish∞	0 to 10	0 serving	1-2 servings	0.0 – 10.0	4.5 (SD=4.1)	5.7 (SD=4.2)	5.4 (SD=4.2)	0.011
Legumes*	0 to 10	0 serving	1 serving	0.0 – 10.0	0.3 (IQR=1.3)	0.3 (IQR=2.0)	0.3 (IQR=1.4)	0.107
% of energy from total fat∞	0 to 10	≥ 35% energy from fat	≤ 30% energy from fat	0.0 – 10.0	6.7 (SD=4.2)	7.0 (SD=4.1)	6.9 (SD=4.1)	0.627
Sodium*	0 to 10	≥ 2200-2300mg	≤ 2200mg	0.0 – 10.0	0.0 (IQR=0.0)	0.0 (IQR=0.0)	0.0 (IQR=0.0)	0.208
Malaysian HEI score*	0 to 100	-	-	15.5 – 85.8	46.3 (SD=14.0)	50.3 (SD=14.5)	49.1(SD=14.5)	0.02
Malaysian HEI, n=337 (%)								
Low risk (>46.0)	-	-	-	-	43 (43.9)	145 (60.7)	188 (55.8)	0.005
High risk (≤46.0)	-	-	-	-	55 (56.1)	94 (39.3)	149 (44.2)	

*Data presented as in median (IQR); ∞ Data presented as in mean (SD)

seven components were made up of food groups and the remaining two were nutrients i.e. percentage energy from total fat and sodium (mg) (Table I). The scoring of the HEI components were estimated using recommendations described in Malaysian Dietary Guidelines for Children and Adolescents (MDG). For instance, a HEI score for a female adolescent aged 13 years who consumed 4 servings of cereals and grains per day was estimated by dividing 4 with 7 servings (total serving per day according to MDG for female of this age) and multiplied by 10. The score for each component ranged between 0 (minimum) and 10 (maximum); scores for the in-between responses were proportionately calculated. Each component is scored such that a greater value indicates better adherence to MDG. The total HEI score was estimated by summing up scores from the nine components and subsequently, composite score in percentage were then calculated using the following formula: (total score from the nine components/ maximum score of 90) x 100%. Increasing HEI score indicate high diet quality. To allow for direct comparison, categories to indicate 'high' (≤46%) and 'low' (>46%) risk of poor diet quality as suggested by Fara Wahida et al. were adopted in this study (16). The study by Fara Wahida et al. was previously conducted among Malaysian adolescents in Kuala Lumpur in 2015 (16).

Cardiometabolic risk factors

Adolescents who agreed to participate in this study were measured for their weight and height using calibrated weighing scale (Tanita HD319, Japan) and bodymeter (SECA), respectively. Body weight was measured in light clothing and no shoes while height was measured from adolescents' head to toe in an upright standing position. BMI was calculated using weight (kg) over height squared (m)2. BMI z-scores were estimated using the WHO age and gender specific growth charts (19). The estimated BMI z-scores were further used to classify overweight and obesity; values of more than one and two standard deviations indicated overweight and obesity, accordingly. Waist circumference (cm) was measured at the midpoint between the lower border of the ribs and the upper border of the pelvis using SECA measuring tape (SECA, Germany). This was done with an average of two measurements for each adolescent. Participants were classified as having abdominal obesity if their waist circumference greater or equal to 90th percentile (20). Biochemical parameters were collected by a certified phlebotomist after an overnight fast (at least for 8 hours). Fasting glucose, serum insulin, triglycerides and HDL-C were analysed in Pantai Premier Pathology Laboratory using various standardised methods. For instance, fasting glucose was assessed by an automated Siemens Healthcare Diagnostics analyser using a hexokinase method. Insulin was measured using an automated ADVIA Centaur radioimmunoassay analyser (Siemens Healthcare Diagnostics Inc., Tarrytown NY, USA). Triglyceride levels were enzymatically determined using reagents from ADVIA Chemistry on Trinder analyser (Siemens Healthcare Diagnostics Inc., Tarrytown NY, USA). HDL-C and calculated LDL-C were measured using elimination/catalase method and Friedewald formula, respectively (21, 22) . Insulin resistance was estimated using Homeostasis model assessment (HOMA), calculated using a standard formula (23).

Percentage of adolescents having 1, 2 or greater than 3 cardiometabolic risk factors were estimated using cut-offs defined as high for every individual biochemical parameter assessed in this study including HDL-C (≤1.03 mmol/L), LDL-C (≥3.2 mmol/L), triglycerides (≤1.7 mmol/L), glucose (≥5.6 mmol/L), insulin (≥25.0 uIU/mL) and insulin resistance (HOMA-IR ≥4.0 unit) (24-27). Being obese and abdominally obese were also considered in this classification of cardiometabolic risk factors.

Covariates
Information on adolescents' and their parents' sociodemography were collected using self-administered questionnaires. These included adolescents' gender, parental income (low, moderate and high) and maternal education level (no formal education/primary, secondary and tertiary). A validated Physical Activity Questionnaire for older children (PAQ-C) was used to assess self-reported physical activity level among adolescents for the past 7 days (28, 29). A higher total score of PAQ-C indicated higher physical activity level.

Statistical analysis
As the variables for anthropometric were largely not normally distributed, median (IQR) was reported for these data and compared between girls and boys using Mann-Whitney U test. Similarly, data for biochemical parameters were not normally distributed and as such these variables were logged transformed and presented in geometric means. As sex dimorphism and puberty-related differences in growth are strongly related to the occurrence of cardiometabolic risk factors during adolescence, all the analyses were stratified by sex (30). Binary logistic regression analysis was conducted to determine the associations between diet quality (in tertile groups) and the odds of having cardiometabolic risk factors. Adjusted models were controlled for potential covariates including school location, maternal education level, dietary misreporting, physical activity, percentage of energy intake from dietary sugar and BMI (for blood biomarkers only). Dietary sugar included both monosaccharide and disaccharides (short-chained carbohydrates) that presented naturally in foods (fruits) or industrial products (refined sugar).

RESULTS

Sociodemography characteristics
Sociodemography characteristics in Table II indicating no significant differences between age, school location, ethnicity, parental income, maternal education level and gender (p>0.05). Nonetheless, there were higher number of adolescents recruited from schools in rural location (53.5%) and predominant of Malay ethnicity (87.2%). Similarly, majority of adolescents in this study were whose parents' income were below median (RM5, 228) and whose mothers attained secondary school education (73.8%). Males were observed to be more physically active compared to females (p<0.001).

Malaysian Healthy Eating Index
Females showed a significant (p=0.02) higher mean dietary quality score assessed by Malaysian HEI compared to males (Table I). A higher percentage of males showed high risk of having low dietary quality score compared to females (56.1% vs. 39.3%; p<0.05). The highest components of the Malaysian HEI score were contributed by cereals and grains followed by poultry, meat and eggs, percentage of energy from total fat, fruits and fish (Table II). A significant difference was observed for vegetable and fish components between the genders, whereby a higher consumption of these food groups was noted in females compared to males (p<0.05).

Table II: Sociodemographic characteristics of adolescents aged 13 years from three southern states in Peninsular Malaysia

Characteristics	n (%)			p-value
	Male (n=300)	**Female (n=633)**	**Total**	
Age (years), mean (±SD)	13.5 (±0.3)	13.5 (±0.3)	13.5 (±0.3)	0.982
School location				
Urban	147 (49.0)	287 (45.3)	434 (46.5)	0.29
Rural	153 (51.0)	346 (54.7)	499 (53.5)	
Ethnicity				
Malay	262 (87.3)	552 (87.2)	814 (87.2)	0.95
Chinese	21 (7.0)	42 (6.6)	63 (6.8)	
Indian	14 (4.7)	30 (4.7)	44 (4.7)	
Others	3 (1.0)	9 (1.4)	12 (1.3)	
Parental Income, n=599[a]				
Below median (<RM5, 228)	159 (88.3)	372 (88.8)	531 (88.6)	0.89
Above median (≥RM5, 228)	21 (11.7)	47 (11.2)	68 (11.4)	
Maternal education level, n=818				
No formal education/ Primary	23 (9.5)	68 (11.8)	91 (11.1)	0.58
Secondary school	179 (74.3)	425 (73.7)	604 (73.8)	
Higher institution	39 (16.2)	84 (14.6)	123 (15.0)	
Dietary misreporting, n=583	118 (68.6)	294 (71.5)	412 (70.8)	0.110
Adequate-reporters Misreporters, n=583	54 (31.4)	117 (28.5)	171 (29.2)	
	Mean (±SD)	Mean (SD)	Mean (±SD)	
Physical activity total score, n=793	2.77 (±0.7)	2.40 (±0.6)	2.52 (±0.6)	<0.001

p-value indicating differences between male and female
[a] Income groups were categorised based on a median level

Cardiometabolic characteristics
The prevalence of both overweight and obesity was 35% and 31%, in males and females, accordingly. Table III shows that although the prevalence of overweight was lower in males compared to females (14% vs. 17%; p=0.340), a significant number of males were obese than females (21% vs. 15%; p=0.023). Similarly, males (12%) were more likely to be centrally obese compared to females (11%), p=0.003 (Table III).

Generally, males showed tendency to have more percentages of abnormal values for fasting glucose (p=0.039), LDL-cholesterol (p=0.021), triglycerides (p=0.629) and fasting insulin (p=0.309) compared to females. This was also similar for HDL-cholesterol in males (p=0.112). However, a significant higher number of females were insulin resistant compared to males (22.7% vs. 21.4%; p=0.037). In addition to that, approximately half of the females and 62% of males were found to have no cardiometabolic risk factors. Females showed higher percentages of having at least one risk factors compared to males (Table III).

Table III: Cardiometabolic characteristics of adolescents aged 13 years from three southern states in Peninsular Malaysia

Characteristics	Male (n=298)		Female (n=632)		p-value
	Median	IQR	Median	IQR	
Body mass index (kg/m^2)	20.5	6.7	19.2	5.5	0.242
Waist circumference (cm)	60.0	20.2	63.0	13.0	0.444
	n	%	n	%	
Overweight (%) [1]	42	14.1	104	16.5	0.340
Obesity (%) [1]	61	20.5	94	14.9	0.023
Abdominal obesity [2] (≥90th percentile)	35	11.8	73	11.6	0.003
	Male (n=154)		Female (n=353)		
High level of fasting blood glucose (≥5.6 mmol/L)	13	8.4	14	4.0	0.039
Low level of HDL-cholesterol (≤1.03 mmol/L)	13	8.4	17	4.8	0.112
High level of LDL-cholesterol (≥3.2 mmol/L)	13	8.4	57	16.1	0.021
High level of triglycerides (≤1.7 mmol/L)	9	5.8	17	4.8	0.629
Abnormal level of fasting insulin (≥25.0 mmol/L)	17	11.0	29	8.2	0.309
Abnormal level of HOMA (≥4.0 unit)	33	21.4	80	22.7	0.037
Number of risk cardiovascular risk factors					
No risk factor	96	62.3	188	53.3	0.058
At least 1 risk factor	58	37.7	165	46.7	

*Mean (SD); [1] Based on WHO Child Growth Charts 2007; [2] Based on Poh *et al.* (2011)(15)

Relationship between dietary quality and cardiometabolic risk factors

While there were tendencies of linear relationships between tertiles (comparing the first and third tertiles) of dietary quality as assessed by Malaysian HEI and individual cardiometabolic parameters, especially in females, these were not statistically significant (Table IV and V). Similar findings were also observed for those with at least one cardiometabolic risk factor and tertiles of Malaysian HEI in both males and females.

Adjustment for potential covariates did not yield any differences to the models and as such there were no significant relationships between any of the cardiometabolic risk factors and tertiles of Malaysian HEI (Table IV and V). This was similar to those with at least one risk factor and Malaysian HEI in both males and females.

DISCUSSION

To the best of our knowledge, this is the first study in Malaysia that has examined the association between Malaysian HEI and cardiometabolic risk factor among adolescents as well as the first study to conduct such analyses by gender. Despite the high prevalence of obesity and having at least one cardiometabolic risk factor as well as poor dietary quality, this study did not observe any significant associations between dietary quality as assessed by Malaysian HEI and cardiometabolic risk factors.

The reported dietary quality score using the Malaysian HEI in this study was somewhat higher to that published previously by Fara Wahida et al. in 2015 among adolescents aged between 13 and 16 years in Kuala Lumpur (16). As such, the prevalence of adolescents reported to be at higher risk of poor diet quality in the current study was lower (44.2%) than to that reported in adolescents from Kuala Lumpur in 2015 (80.7%) (16). However, the inconsistencies observed in the dietary quality score between these studies could be due to the differences in the age group of the adolescents, sample size, location of the study setting and dietary assessment method. Having said that, a significant lower dietary quality score in males was similar to that observed in Fara Wahida et al. (16). This is not surprising as females showed higher tendency to consume more vegetable and fruit intakes compared to males in the present study as well as in a study by Fara Wahida et al., particularly for vegetable intakes (16). Males were also observed to have a lower HEI score compared to females in two randomized controlled trials conducted in low-income, predominant by African American adolescents in urban and rural setting, respectively (31, 32).

Since there is lack of studies on HEI among Malaysian adolescents as well as their associations with cardiometabolic risk factors, we have attempted to compare our results to those published from other countries, particularly the US (33, 34). Therefore, direct comparisons should be cautiously interpreted due to the inherent binational differences between the populations being assessed. The reported dietary quality score in this study is lower than a dietary quality score observed among American adolescents (overall mean score of 61; 95%CI 60.2, 61.8) between 1999 and 2002 (35). The HEI dietary quality score from the US study was estimated from a total of 4450 adolescents aged between 12 and 19 years using a 4-year combined data of the National Health and Nutrition Examination Survey (35). On the other hand, another findings from the National Health and Nutrition Examination Survey (NHANES) among American adolescents reported a lower dietary quality score as assessed by Healthy Eating Index 2010 to that observed in the current study (36). The reported mean dietary quality score ranged from 43.6 to 46.9 among adolescents aged between 14 and 18 years in this study (36). Having said that, this study identified that four out of 10 young people are at risk of poor dietary intakes and that raised an important public health implications in this country.

Although the prevalence of overweight and obesity and

Table IV: Associations [odd ratios (95% CI)] between the tertiles of HEI scores and cardiometabolic risk factors in males

Cardiometabolic risk factors[a]	n		1st tertile (Low M-HEI score)	2nd tertile (Medium M-HEI score)	3rd tertile (High M-HEI score)
Overweight/Obesity	98	Unadjusted OR	0.867 (0.297,2.525)	0.480 (0.140,1.643)	1 (ref)
	80	Adjusted OR	0.937 (0.228,3.847)	0.600 (0.136,2.649)	
Abdominal Obesity	98	Unadjusted OR	0.921 (0.200,4.242)	0.233 (0.023,2.400)	1 (ref)
	80	Adjusted OR	0.245 (0.007,8.927)	0.000 (0.000,0.000)	
Elevated FBG (≥5.60 mmol/L)	98	Unadjusted OR	2.359 (0.248,22.405)	3.407 (0.355,32.679)	1 (ref)
	80	Adjusted OR	3.374 (0.109,104.882)	1.920(0.084,43.676)	
Lower HDL-C level (≤1.03 mmol/L)	98	Unadjusted OR	0.718 (0.147,3.514)	0.000 (0.000,0.000)	1 (ref)
	80	Adjusted OR	2.899 (0.106,79.455)	0.000 (0.000,0.000)	
Abnormal LDL-C (≥2.90 mmol/L)	98	Unadjusted OR	0.718 (0.147,3.514)	0.483 (0.074,3.149)	1 (ref)
	80	Adjusted OR	0.192 (0.015,2.439)	0.411 (0.041,4.125)	
Elevated triglycerides (≥1.70 mmol/L)	98	Unadjusted OR	1.122 (0.096,13.056)	0.767 (0.045,12.921)	1 (ref)
	80	Adjusted OR	0.000 (0.000,0.000)	0.000 (0.000,0.000)	
Elevated serum insulin (≥20.0 uIU/mL)	98	Unadjusted OR	0.739 (0.206,2.645)	0.407 (0.087,1.909)	1 (ref)
	80	Adjusted OR	0.796 (0.087,7.241)	0.259 (0.025,2.708)	
Abnormal HOMA-IR level (≥3.0 unit)	98	Unadjusted OR	1.583 (0.559,4.482)	0.952 (0.306,2.962)	1 (ref)
	80	Adjusted OR	1.297 (0.246,6.838)	0.358 (0.059,2.163)	
Has at least one cardiometabolic risk factors	98	Unadjusted OR	0.988 (0.352,2.772)	0.580 (0.183,1.837)	1 (ref)
	80	Adjusted OR	1.168 (0.259,5.266)	0.310 (0.064,1.508)	

Model adjusted for school location, maternal education level, dietary misreporting, physical activity, energy intake from sugar-sweetened beverages and BMI (for blood biomarkers only).
[a]Third tertile of Malaysian HEI was used as reference for all cardiometabolic risk factors.

Table V: Associations [odd ratios (95% CI)] between the tertiles of HEI scores and cardiometabolic risk factors in females

Cardiometabolic risk factors[a]	n		1st tertile (Low M-HEI score)	2nd tertile (Medium M-HEI score)	3rd tertile (High M-HEI score)
Overweight/Obesity	238	Unadjusted OR	0.814 (0.407,1.628)	1.261 (0.667,2.381)	1 (ref)
	204	Adjusted OR	0.589 (0.234,1.481)	1.270 (0.603,2.677)	
Abdominal Obesity	238	Unadjusted OR	1.488 (0.569,3.892)	1.236 (0.475,3.216)	1 (ref)
	204	Adjusted OR	0.415 (0.104,1.662)	0.724 (0.238,2.205)	
Elevated FBG (≥5.60 mmol/L)	238	Unadjusted OR	0.846 (0.137,5.208)	1.076 (0.211,5.488)	1 (ref)
	204	Adjusted OR	3.855 (0.168,88.427)	1.801 (0.137,23.653)	
Lower HDL-C level (≤1.03 mmol/L)	238	Unadjusted OR	5.354 (0.585,49.036)	6.868 (0.809,58.334)	1 (ref)
	204	Adjusted OR	0.000 (0.000,0.000)	0.000 (0.000,0.000)	
Abnormal LDL-C (≥2.90 mmol/L)	238	Unadjusted OR	0.879 (0.388,1.990)	0.580 (0.249,1.353)	1 (ref)
	204	Adjusted OR	0.784 (0.249,2.467)	0.615 (0.225,1.683)	
Elevated triglycerides (≥1.70 mmol/L)	238	Unadjusted OR	2.646 (0.470,14.891)	1.633 (0.266,10.029)	1 (ref)
	204	Adjusted OR	17.942 (0.904,356.118)	2.590 (0.182,36.848)	
Elevated serum insulin (≥20.0 uIU/mL)	238	Unadjusted OR	2.167 (0.906,5.183)	2.194 (0.946,5.085)	1 (ref)
	204	Adjusted OR	1.769 (0.500,6.267)	2.067 (0.693,6.161)	
Abnormal HOMA-IR level (≥3.0 unit)	238	Unadjusted OR	1.685 (0.885,3.209)	1.177 (0.631,2.194)	1 (ref)
	204	Adjusted OR	1.459 (0.556,3.826)	0.907 (0.395,2.084)	
Has at least one cardiometabolic risk factors	238	Unadjusted OR	1.325 (0.705,2.493)	0.990 (0.542,1.810)	1 (ref)
	204	Adjusted OR	1.097 (0.463,2.598)	0.850 (0.404,1.791)	

Model adjusted for school location, maternal education level, dietary misreporting, physical activity, energy intake from sugar-sweetened beverages and BMI (for blood biomarkers only).
[a]Third tertile of Malaysian HEI was used as reference for all cardiometabolic risk factors.

abdominal obesity was somewhat similar in both males and females, a greater number of female adolescents were found to have at least one cardiometabolic risk factors compared to males. One of the reason that could explain such differences is early menarche in females compared to those in males. Early menarche was positively associated with unfavourable cardiometabolic risk factors, independent of BMI and chronological age during adolescence (37, 38). Furthermore, a local study by Lee et al. in 2006 indicated 10 years old as the earliest age for menarche among female children in their study (39). Therefore, it could be that female adolescents in this study have had early menarche and maturation, and subsequently higher risks of having greater number of cardiometabolic risk factors at the age when this study was conducted. In line with that, a large UK population-based the Million Women Study in 2014 reported that early menarche (≤10 years of age) was significantly associated with increased risk of developing CHD in women without any history of heart disease (40). Although elevated insulin resistance is rather typical during the onset of puberty, it was suggested that female adolescents whose pubertal timing were earlier tended to retain high levels of insulin and/or insulin resistance throughout puberty (41).

Despite the major role of diet to cardiometabolic health and the findings on poor dietary quality among adolescents in this study, there was lack of significant association between dietary quality score and cardiometabolic risk factors. This finding is consistent to that observed in a study by Williams et al. in 2019 among college students in the US (42). This is rather unsurprising as even in adults no significant associations or weak associations were reported between dietary quality as assessed by HEI, cardiovascular diseases incidence and mortality, and cancer in both men and women (43-45). The lack of significant associations between dietary quality as assessed by Malaysian HEI and various cardiometabolic risk factors including obesity in this study could be due to limitation of HEI as it was developed to assess how well the adolescents' diets conform to the Malaysian Dietary Guidelines and not merely for the prevention of cardiometabolic risk factors. In that context, a-posteriori empirical dietary patterns are probably more meaningful in evaluating relationships between dietary intakes and outcomes of interest.

Another limitation of Malaysian HEI is the fact that the HEI did not measure consumption of added sugars i.e. in sugar-sweetened beverages, candies and chocolates in its score. The intakes of these food groups were found to be high among Malaysian adolescents and often associated with cardiometabolic risk factors including overweight and obesity through the excessive energy intake pathway (46-49). Furthermore, a recent identification of an empirical dietary pattern using RRR was positively associated with cardiometabolic risk factors, particularly dyslipidaemia among adolescents in the current study (8). The identified dietary pattern was characterised by foods high in added sugar and energy density such as sugar-sweetened beverages and sweets (8). Additionally, it is possible that some individuals get the same total score but have somewhat different scores for individual components on the index. This might be true in this study whereby despite the fact that most adolescents in this study showed poor dietary quality score, the intakes of fruit, particularly, were found to be generally adequate. The synergistic effect of fruit and vegetable component may have benefited in preventing cardiometabolic risk factors in the current study. A cross-sectional study among adolescents aged between 13 and 17 years in the US found that a higher fruit consumption (1.5 serving) was inversely associated with an inflammatory marker namely C-reactive protein (CRP) ($r=-0.19$; $p<0.05$) (50).

The lack of significant associations in this study could be also due to the use of self-report dietary assessment method. While the use of FFQ is feasible in large number of population, it is often subjected to energy misreporting. A study among 630 Caucasian children aged 8 to 10 years in Canada found that energy under-reporters were more likely to be older, had higher BMI-z score and poorer cardiometabolic health indicators compared to adequate-reporters (51). Although we have attempted to control for dietary misreporting in the regression models, residual confounding cannot be completely ruled out.

While the contribution of diet to the development of cardiovascular diseases is quite established, other lifestyle behaviours such as screen time, smoking, stress may be much more important factors associated with cardiometabolic risk factors in adolescents in this study at least. Nonetheless, none of this information was collected in this study and therefore suggests that more work needs to be done in this field. Similar to the adult's populations, findings between dietary indices and cardiometabolic risk factors, specifically obesity from cross-sectional studies have been mixed in adolescents as well (52-54). The process of developing obesity is rather gradual and complex and often influenced by the presence of multiple factors, therefore a longitudinal assessment between adherence to a specific dietary guideline and cardiometabolic risk factors is warranted.

There are obvious limitations for the current study. Firstly, it is impossible to make causal inferences regarding the effect of diet on cardiometabolic risk factors due to the cross-sectional nature of the study. Second, since the dietary intake assessment was self-reported, it may be that the data obtained was not accurate due to the recall and systematic biases. However, we have attempted to adjust for dietary misreporting in this study. Third, although adjustments for a few potential covariates were taken into consideration in the current study, it might have not fully controlled the effect of confounding factors. Forth, the location of this study was focused on three southern states in Peninsular Malaysia and as such the generalisation of the findings observed may be limited. The strengths on this study included the objectively measured biochemical parameters and to the best of our knowledge, this is the first study in Malaysia that has attempted to evaluate the contribution of dietary intakes on various cardiometabolic risk factors among young people.

CONCLUSION

Despite of overall poor dietary quality and high prevalence of overweight and obesity, no significant associations were observed between dietary quality assessed by Malaysia HEI and cardiometabolic risk factors including overweight or obesity and abdominal obesity in adolescents. Prospective studies are needed to establish a causal link between dietary patterns derived using a-posteriori method and cardiometabolic risk factors during adolescence.

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