Prospective associations between an empirically derived dietary pattern and life satisfaction in Malaysian adolescents

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Abstract

Background Little is known on the prospective associations between an empirically derived dietary pattern (DP) and life satisfaction among adolescents. This PUTRA-Adol follow-up study aimed to assess the prospective associations between the empirically derived DP and life satisfaction during adolescence.

Methods A total of 585 and 262 adolescents participated in the baseline PUTRA-Adol study in 2016 and PUTRA-Adol follow-up study in 2019–2020, respectively. These adolescents were recruited from three southern states in peninsular Malaysia, namely Negeri Sembilan, Melaka and Johor. Dietary assessments were estimated using a validated food frequency questionnaire (FFQ) while a Multidimensional Students' Life Satisfaction Scale (MSLSS) was used to measure life satisfaction at baseline in 2016 as well as at follow-up in 2019–2020. A DP characterised by foods high in free sugar and energy dense was identified using reduced rank regression (RRR), cross-sectionally at baseline and was reported elsewhere. Similar RRR analysis was used to find a DP that best explained the variation in response variables linked to poorer life satisfaction, including dietary energy density (DED), fiber density, and percentage of energy from total fat and sugar at the PUTRA-Adol follow-up study. Prospective relationship between adherence to the identified DPs and overall life satisfaction scores as well as its domains between 2016 and 2019–2020 were evaluated using generalized estimating equation models (GEE).

Results A DP characterized by high intakes of percentage energy from sugar, fibre and low in DED and percentage energy from total fat was identified at the 2019–2020 follow-up. The identified DP explained 11% of total variations in the response variables and was characterized by high intakes of sweets, sugar sweetened beverages (SSB) and fruits. Female adolescents [67.6(8.9)] had a mean (SD) of life satisfaction that was higher than male adolescents [67.5(10.8)] $p < 0.05$ in 2019–2020. Prospective analysis found a significant positive association between the identified DP and school domain, in male adolescents ($\beta = 0.117$; 95% CI 0.001, 0.234) and an inverse relationship between the DP z-score and self-domain in all adolescents ($\beta = -0.060$; 95% CI -0.115, -0.005) from 2016 to 2019–2020.

Conclusions An increasing score for the predominant 'High sugar and High fibre' DP was prospectively associated with increasing life satisfaction score for the school domain in male adolescents and decreasing score for self-domain in both male and females during adolescence. A lifestyle intervention targeting reduced dietary intakes, particularly

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Background

Life satisfaction can be defined as a person's cognitive judgment of their overall quality of life or its specific domains, and it is essential for good health [1]. Self-reported lower life satisfaction was strongly linked to anxiety, hopelessness, and concurrent depressive symptoms which are interrelated [2]. To put it another way, life satisfaction could be inversely correlated with perceptions of distress, low mood, hopelessness with anxiety and depression which are linked to poor state of psychological well-being [2]. In addition, psychological processes like a lack of positivity and the ability to manage emotions and stress can have a negative impact on one's overall life satisfaction and, as a result, may influence the onset of mental health conditions over time [3]. Although life satisfaction is adaptive and not a trait that lasts forever, many life circumstances often stay the same over time. As a result, early cognitive judgments about life satisfaction may carry over into adulthood to some extent [4]. DP rather than single nutrients or food groups have been largely used to elucidate better dietary connections with disease risk factors in the last decades and so. Rather than focusing on individual nutrients or specific foods, DPs take into account the overall combination of foods consumed, as well as the frequency and quantity of their intake [5].A systematic review has shown that healthy eating habits comprised of fruits, vegetables, whole grains, nuts, seeds, and fish can reduce the risk of depression and anxiety [6, 7]. Besides that, a systematic review of 12 epidemiological studies in the western countries highlighted that unhealthy eating habits such as diets high in saturated fats and refined carbohydrates have been linked to mental illnesses in children and adolescents [8]. In addition, an Australian study suggested that a "Western" DP was prospectively associated with increased mental health problems, including depressive symptoms, in adolescents through the obesity and inflammatory pathways, but "healthy" eating patterns appear to be protective through these similar pathways [9]. While psychological issues have been evaluated with specific dietary intakes, this was not extensively done in relation to life satisfaction, which could be used as a precursor for poor mental health in a long run. There is a dearth of evidence on the prospective associations between DP and life satisfaction among young people in Malaysia. Previously, we found that a diet high in free sugar and energy dense was cross-sectionally linked to lower levels of life satisfaction among adolescents, particularly among 13-year-old female adolescents [10]. This current study aimed to assess the prospective associations between DP characterised by high intakes of sugar, fibre and low in DED and fat, and life satisfaction during adolescence, specifically between the ages of 13 and 16 years old.

Methods

Study design

This was a prospective study known as PUTRA-Adol follow-up study conducted among Malaysian adolescents who were 13 years old at the time of their recruitment at baseline in 2016. Details of the baseline study in 2016 were previously described elsewhere [10–12].

Study setting

In the 2016 baseline study, a total of 585 adolescents (63%) with 173 male adolescents (30%) and 412 female adolescents (70%) provided a complete and valid dietary intake data [12]. The subsequent PUTRA-Adol follow-up study was responded by a total of 262 adolescents (45%) with 79 male adolescents (30%) and 183 female adolescents (70%) and they provided a complete and valid dietary, life satisfaction and physical activity data [13]. A flow chart representing the total number of adolescents who have provided complete data in the 2016 baseline study and 2019–2020 PUTRA-Adol follow-up, and included in this study is shown in Fig. 1. The conduct of this study was fully approved by the Ethics Committee for Research Involving Human of Universiti Putra Malaysia [Reference No.: JKEUPM-2019-267]. Additional approvals were obtained from the Ministry of Education Malaysia, respective state education departments as well as the selected schools. Furthermore, informed consent was obtained from the parents or primary caregivers before any assessments were conducted.

Dietary assessment

Dietary assessment in the PUTRA-Adol follow-up study, was assessed using the 195-item MyUM Adolescent Food Frequency Questionnaire (MyUM FFQ). This MyUM FFQ was specifically designed for the Malaysian secondary school adolescents aged 13 to 18 years and was previously validated [14]. The study adolescents who participated in the follow-up study were asked to report their habitual dietary intake for the past 12 months.

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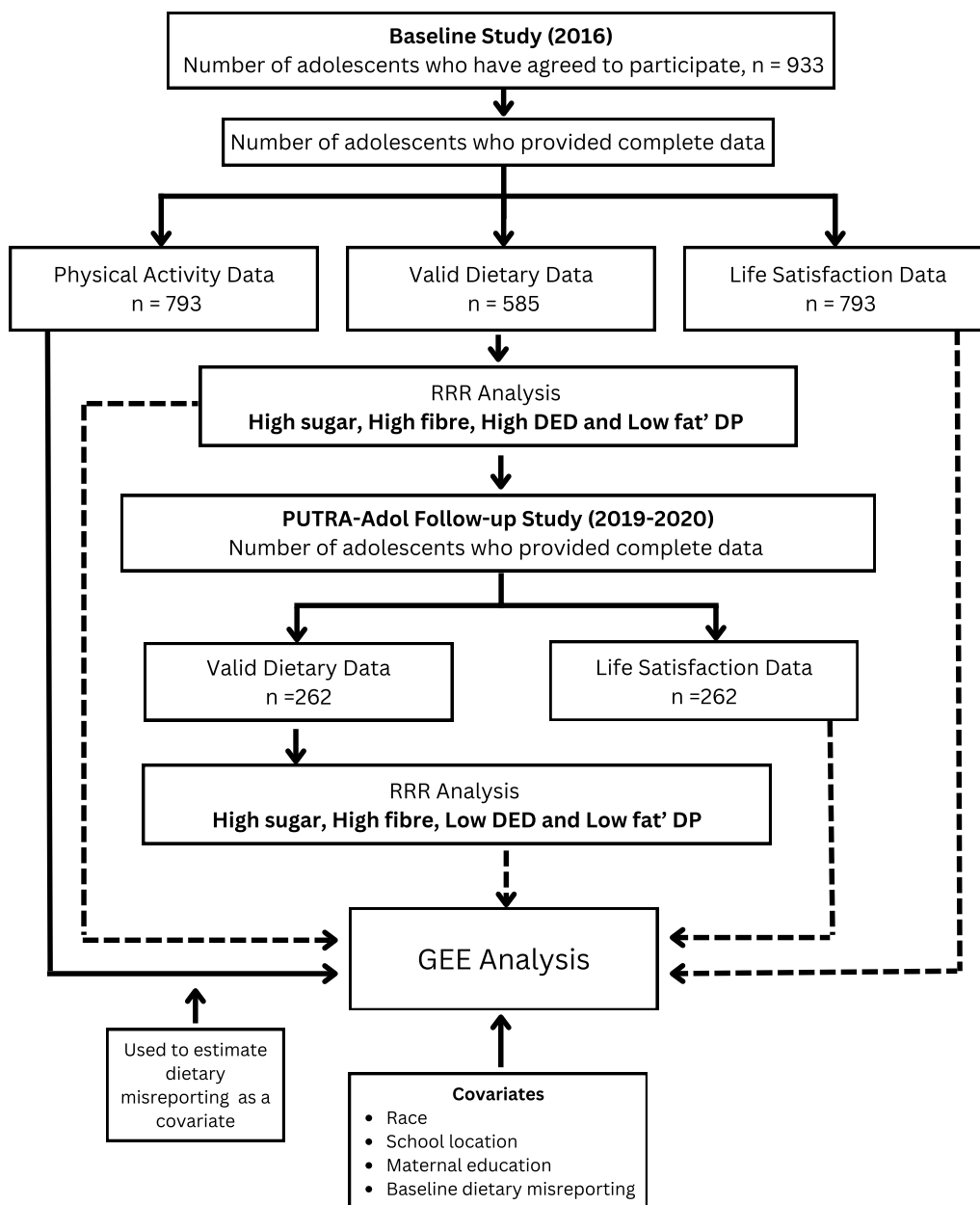
The dotted line highlights the variables included in the generalized estimating equation (GEE) analysis.

Fig. 1 Number of adolescents who have provided complete data in the 2016 baseline study and 2019–2020 PUTRA-Adol follow-up study

Before answering the FFQ, the study researchers gave step-by-step instructions to the participants on how to fill in the questionnaires. Moreover, a flipchart on household measurements was also given to the study adolescents to assist with the estimation and portion of their intakes. For each food item, the average frequency of consumption over the past year was recorded 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". The food intake frequency and portion size on each food item was recorded by the adolescents based on the household measurements provided. The study researchers checked the answers filled in by the adolescents to avoid any

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missing data before collecting the FFQ. The daily food intake estimation was assessed using the Nutritionist Pro diet Analysis software version 3.1. The food items in the MyUM FFQ were derived from the Malaysian Food Composition database freely available in the software of Nutritionist Pro Diet Analysis [15]. Using the standard reference, the nutrient composition of each unavailable food items was updated in the software database manually. Besides that, an overall reported dietary energy intake which is not in the range were excluded from the further DP analysis. The conversion of the data from the FFQ to daily energy and other nutrients was conducted using conversion factors manually to estimate the daily food intake. An overall dietary energy intake reported below or above the range of 400–8000 kcal were excluded from the DP analysis [16].

Dietary patterns

The identification of DP characterised by high intakes of sugar, fibre, DED and low intakes of fat using reduced rank regression analysis (RRR) in the baseline study in 2016 was previously described [12]. Following the identification of the above mentioned DP, a cross-sectional association between the identified 'High sugar, High fibre, DED and Low fat" DP and life satisfaction score was observed in the baseline study and published elsewhere [10]. The fact that most number of previous longitudinal studies in the Western countries have reported strong tracking of specific DPs during adolescence was one of the main reason for assessing prospective association of adhering to a specific DP and life satisfaction during adolescence in this current study [17, 18]. Hence similar to the baseline study, a total of 195 food items were categorized into 13 food groups (Supplementary Table 1) as predictors while DED, percentage of energy from total fat intake, percentage of energy from total sugar and fibre density was used as response variables in the current PUTRA-Adol follow-up study. DED was estimated by dividing total food energy (kJ) by total food weight (g), without beverages [19]. Fiber density was determined by absolute fiber intake (g/d) divided by total daily energy intake (MJ). Percentage of energy from total fat intake and free sugar was expressed by dividing total energy intake from fat (kJ) and free sugar (kJ), respectively, by total energy intake (kJ) and then multiplied by 100. Dietary sugar was defined as all short-chained carbohydrates known as monosaccharide and disaccharides presented naturally in foods such as fruits or in manufactured products such as refined sugar [20]. The degree to which each adolescent adhered to a DP was based on the z-score. When the intake of food with a positive factor loading increase, the adolescent's DP z-score increases

and when the intake of food with a negative factor loading increase, the adolescent's DP z-score decreases.

Life satisfaction

The adolescents' life satisfaction was assessed using the Multidimensional Students ' Life Satisfaction Scale (MSLSS) [21, 22]. There are 18-items with five domains namely as family, friends, school, living environment and self in MSLSS. Six-point response scale was used ranging from 1 = strongly disagree to 6 = strongly agree. The Likert scale was categorized into two groups; "agree" and "disagree". The selection of positive responses such as "strongly agree", "moderately agree" and "mildly agree" was classified as "agree" while the selection of negative responses including "strongly disagree", "moderately disagree" and "mildly disagree" was categorized as "disagree". A common method for calculating overall quality of life scores is to average subscale scores. High score corresponded to high level of overall satisfaction as well as high level of satisfaction to the corresponding domains of life satisfaction.

Potential covariates

Physical activity levels were assessed in the past seven days using a validated questionnaire known as Physical Activity Questionnaire for adolescent (PAQ-A) [23, 24]. The location of the selected schools was classified as either urban or rural based on the definition given by the Ministry of Education, Malaysia. Information on highest attained maternal education was obtained using a questionnaire sent to the parents or guardians. In light of the absence of BMI data in the current PUTRA-Adol follow-up study which impeded the estimation of dietary misreporting has led to the use of baseline dietary misreporting from the baseline study in 2016 [12]. A standardized equation based on energy intake (EI) to total energy expenditure ratio and its 95% confidence limit cut-offs was used to estimate the dietary misreporting [25]. Under-reporting, plausible reporting, and over-reporting are the category of dietary misreporting used.

Statistical analysis

For normally distributed continuous data, descriptive variables were reported as mean ± standard deviation (SD), and for irregularly distributed continuous data, this was described as median (interquartile range).Categorical data was reported as frequency (n) and percentage (%). An independent t-test, Mann–Whitney test, and chi-square test were used to compare sociodemographic characteristics between the sexes. Generalized Estimating Equations (GEE) was used to examine prospective associations between the identified DP z-scores and life satisfaction scores obtained in the baseline study in 2016

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and in the PUTRA-Adol follow-up study in 2019–2020. These GEE models regressed life satisfaction score on DP z-score at the previous follow-up by using DP z-scores and life satisfaction scores obtained in the baseline and in the follow-up, respectively (Fig. 1). In this repeated measure analysis, the first model was adjusted for race, school location and maternal education while second model included all of those in the first model as well as baseline dietary misreporting. All statistical tests were considered significant at a p-value of 0.05. The analyses were carried out using IBM SPSS Statistics version 28 [26] and STATA software [27].

Results

Characteristics of the study adolescents in the PUTRA-Adol follow-up study

In total, 262 adolescents participated in this study with 79 male adolescents and 183 female adolescents. Table 1 shows the sociodemographic and life satisfaction characteristics of the study adolescents by sex in the PUTRA-Adol follow-up study. Majority of the male (84.8%) and female (90.7%) adolescents were Malays and followed by Chinese with (10.1%) male and (6.6%) female adolescents. Subsequently, there were adolescents of (3.8%) Indian males, (1.3%) males of other races, (2.7%) Indian females, and no females of other races participated. A higher number of male adolescents (72.2%) and female adolescents (58.5%) from urban area participated compared to rural area with (27.8%) male adolescents and (41.5%) female adolescents. The majority of the adolescents' mothers attained their education at secondary school level for both male and female adolescents. There was a significant difference found in terms of school location between male and female adolescents ($p = 0.036$). Female adolescents reported a higher physical activity median score [2.19 (IQR = 0.57)] compared to male adolescents

Table 1 Sociodemographic, life satisfaction and DP z-score characteristics of the study adolescents by sex in the PUTRA-Adol follow-up study

Variables	Male		Female		*p*-value*
	n	%	n	%	
Race					
Malay	67	84.8	166	90.7	0.301
Chinese	8	10.1	12	6.6	
Indian	3	3.8	5	2.7	
Others	1	1.3	0	0	
School location					
Urban	57	72.2	107	58.5	0.036
Rural	22	27.8	76	41.5	
Maternal education					
No formal education/Primary school	12	15.2	32	17.5	0.621
Secondary school	56	70.9	116	63.4	
Higher institution	11	13.9	35	19.1	
	n	Median	IQR	n	Median	IQR	
Physical activity (PAQ-C score)	79	2.17	0.55	183	2.19	0.57	0.641
	n	Mean	SD	n	Mean	SD	
Life satisfaction domains							
Overall life satisfaction	79	67.5	10.8	183	67.6	8.9	**0.042**
Family		3.81	0.83		3.78	0.71	0.151
School		3.57	0.80		3.56	0.76	0.519
Self		3.40	0.79		3.41	0.77	0.661
Friends		4.00	0.78		4.08	0.65	
Living environment		4.16	0.98		4.12	0.92	0.187
DP z-score	79	− 0.05	1.31	183	0.02	0.98	0.616

Scores for overall life satisfaction and for each domain were assessed using MSLSS.

*p-value was estimated using independent t-test for continuous variables, chi-square for categorical variables and Mann-Whitney test was used to determine the significant difference between male and female adolescents. Significant findings were bolded

[2.17 (IQR = 0.55)], however this was not statistically significant.

Characteristics of the DP derived in the PUTRA-Adol follow-up study

Since a total of four response variables were included in the RRR analysis, an equivalent number of four DPs were identified in this study. The total percentage of variations in all response variables reported for DP1, DP2, DP3 and DP4 were 11%, 4%, 2% and 1% respectively (Supplementary Table 2). DP1 was selected in this study as it explained the maximum percentage variations of all the response variables compared to the other DPs. The percentage of variation mainly explained by percentage of energy from sugar (33%) and fibre density (11%) response variables compared to percentage energy from total fat and DED indicating their strong contributions to DP1. Similarly, strong to weak correlations were observed between the response variables to DP1; percentage of energy from sugar (r = 0.87). fibre density (r = 0.49), percentage of energy from total fat (r = 0.05) and DED (r = 0.01). Based on the correlations, DP1 was then labelled as the 'High Sugar, High Fibre, Low DED and Low Fat' DP. This DP was characterised by high intakes of sweets (r = 0.59), fruits (r = 0.41), SSB (r = 0.39) and low intakes of cereal and cereal-based dishes (r = − 0.42),

meat and meat-based dishes (r = − 0.19) and seafood and shellfish (r = − 0.10). A higher mean DP z-score was reported in female adolescents (Mean 0.02, SD 0.98) compared to male adolescents (Mean − 0.05, SD 1.31) in the PUTRA-Adol follow-up study in 2019–2020. The factor loadings for each food groups in 'High sugar, High fibre, High DED and Low fat' DP in 2016 baseline study and 'High sugar, High fibre, Low DED and Low fat' DP in the 2019–2020 PUTRA-Adol follow-up study are shown in Fig. 2. The combination of both magnitudes and directions of factor loadings for each food groups in both the identified DPs were largely similar and it was characterised by high consumption of SSB, sweets and fruits suggesting that these food groups are the most influential at both time points. A higher negative factor loadings for cereal and cereal-based dishes, meat and meat-based dishes and seafood and shellfish were reported. The large similarities found in the baseline and PUTRA-Adol follow-up study further allowed for the prospective association between these two time points in this study.

Characteristics of life satisfaction in the PUTRA-Adol follow-up study

The mean and SD of the overall life satisfaction score was 67.5 (10.8) in male adolescents and 67.6 (8.9) in female adolescents, $p < 0.05$, in the current
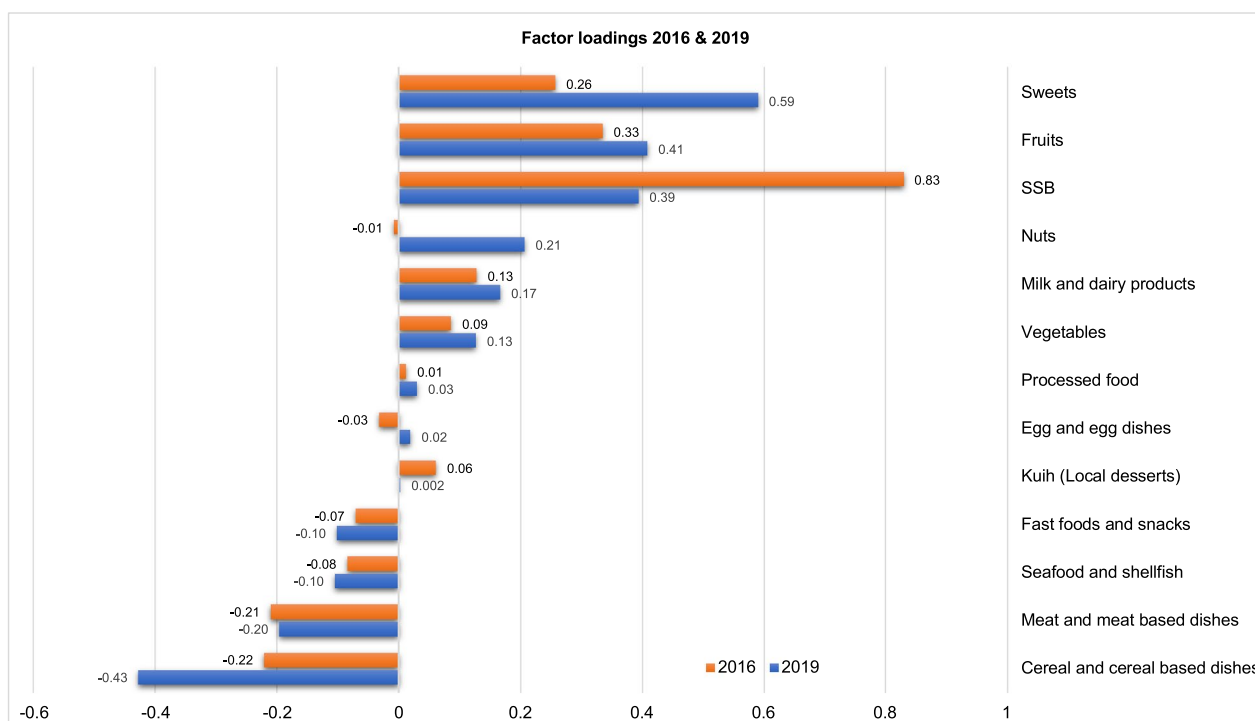
Fig. 2 Factor loadings for 'High sugar, High fibre, High DED and Low fat' DP in 2016 baseline study and 'High sugar, High fibre, Low DED and Low fat' DP in the PUTRA-Adol follow-up study

PUTRA-Adol follow-up study. These overall life satisfaction scores are largely unchanged between 2016 and 2019–2020. Meanwhile, male adolescents in 2019–2020 showed a higher score in the means and SD for the family domain, school domain and living environment domain compared to the female adolescents who only showed higher scores for friends and self-domains, however no significant differences reported in the distribution of domain of life satisfaction between male and female adolescents. Table 2 describes the study adolescents' responses to each item in the MSLSS. The 6-point Likert scale was categorized into two groups; "agree" and "disagree". The selection of positive responses such as "strongly agree", "moderately agree" and "mildly agree" was classified as "agree" while the selection of negative responses including "strongly disagree", "moderately disagree" and "mildly disagree" was categorized as "disagree". Almost all items in the questionnaire were agreed to (>80%) by most of the adolescents, except for three items in the domain of family, school and self. Specifically, item number 3 ("Members of my family talk nicely to one another.") was just agreed by 77.5%, while item number 5 ("Most people like me") was agreed by 68.7% and item number 10 ('I think I am good looking') was just agreed by 66.8%.

Prospective associations between the identified DPs and life satisfaction between 2016 and 2019–2020'

Prospective relationships between the both DPs identified in 2016 baseline study ('High sugar, High fibre, High DED and Low fat' DP) and 2019–2020 PUTRA-Adol follow-up study ('High sugar, High fibre, Low DED and Low fat' DP) and life satisfaction score between 2016 and 2019–2020 are presented in Table 3. An inverse associations were found for the self-domain score in all adolescents, where an increasing DP z-score was associated with a decreasing score for self-domain after adjusting for race, school location, maternal education, and baseline dietary misreporting, during the study period ($\beta = -0.060$, 95% CI -0.115, -0.005). On the other hand, there were no significant associations observed for overall life satisfaction score and other domains of life satisfaction including family, school, friends and living domains in all adolescents. In male adolescents alone, a significant over time association was found for school domain whereby an increase of 1 SD unit in the DP z-score was associated with 0.117 (95% CI 0.001, 0.234) higher school domain score after adjusting for covariates including race, school location, maternal education and baseline dietary misreporting. There were no significant associations observed for overall life satisfaction score, family, friends and living domains in both male and female adolescents.

Table 2 Adolescents' responses on MSLSS life satisfaction items in the PUTRA-Adol follow-up study

Domain	Item	Mean	SD	Disagree n (%)	Agree
Family	1. My family is better than most	3.99	1.05	26 (9.9)	236 (90.1)
	2. My parents treat me fairly	4.02	1.06	33 (12.6)	229 (87.4)
	3. Members of my family talk nicely to one another	**3.73**	**1.20**	**59 (22.5)**	**203 (77.5)**
	4. My parents and I do fun things together	3.43	0.98	32 (12.2)	230 (87.8)
School	**5. I look forward to going to school**	**3.13**	**1.30**	**82 (31.3)**	**180 (68.7)**
	6. School is interesting	3.59	0.95	19 (7.3)	243 (92.7)
	7. I learn a lot at school	3.80	1.12	40 (15.3)	222 (84.7)
	8. I enjoy school activities	3.74	1.15	43 (16.4)	219 (83.6)
Self	9. There are lots of things I can do well	3.47	1.02	45 (17.2)	217 (82.8)
	10. I think I am good looking	**3.13**	**1.16**	**87 (33.2)**	**175 (66.8)**
	11. I like myself	3.94	1.10	28 (10.7)	234 (89.3)
	12. Most people like me	3.10	0.90	46 (17.6)	216 (82.4)
Friend	13. My friends are nice to me	4.00	1.05	29 (11.1)	233 (88.9)
	14. My friends will help me if I need it	3.84	1.14	48 (18.3)	214 (81.7)
	15. I have a lot of fun with my friends	4.31	0.86	8 (3.1)	254 (96.9)
	16. I have enough friends	4.08	0.90	12 (4.6)	250 (95.4)
Living Environment	17. I like my neighbourhood	3.83	1.23	43 (16.4)	219 (83.6)
	18. I like where I live	4.43	0.89	11 (4.2)	251 (95.8)

Scores for each item in the domains were assessed using MSLSS. Bolded items in tables reflect low agreement (< 80%)

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Table 3 Prospective associations (β, 95% CI) between the DP z-scores in the 2016 baseline study and 2019–2020 PUTRA-Adol follow-up study and life satisfaction score in the 2016 baseline study and in the 2019–2020 PUTRA-Adol follow-up study

Life satisfaction	Male (n = 79)			Female (n = 183)			Total	
	Unadjusted Beta coefficient (95% CI)	Adjusted Beta coefficient (95% CI)		Unadjusted Beta coefficient (95% CI)	Adjusted Beta coefficient (95% CI)		Adjusted Beta coefficient (95% CI)	
		Model 1*	Model 2*		Model 1*	Model 2*	Model 1*	Model 2*
Overall score of life satisfaction	−0.009 (−0.036, 0.019)	0.270 (−1.306, 1.845)	0.271 (−1.525, 2.067)	0.011 (−0.005, 0.027)	−0.596 (−1.427, 0.235)	−0.927 (−1.874, 0.021)	−0.361 (−1.104, 0.382)	−0.358 (−1.010, 0.383)
Family	0.039 (−0.038, 0.115)	0.035 (−0.076, 0.145)	0.043 (−0.075, 0.161)	−0.009 (−0.022, 0.004)	−0.005 (−0.067, 0.057)	−0.008 (−0.076, 0.061)	0.001 (−0.048, 0.060)	0.006 (−0.048, 0.060)
School	0.113 (−0.036, 0.262)	**0.123 (0.013, 0.233)**	**0.117 (0.001, 0.234)**	−0.026 (−0.092, 0.041)	−0.021 (−0.085, 0.043)	−0.026 (−0.097, 0.045)	0.014 (−0.041, 0.070)	0.015 (−0.041, 0.071)
Self	**−0.075 (−0.126, −0.025)**	−0.068 (−0.169, 0.033)	−0.066 (−0.174, 0.041)	**−0.055 (−0.088, −0.022)**	−0.053 (−0.118, 0.013)	−0.043 (−0.115, 0.029)	**−0.060 (−0.012, −0.005)**	**−0.060 (−0.115, −0.005)**
Friends	−0.069 (−0.258, 0.119)	−0.073 (−0.189, 0.043)	−0.080 (−0.208, 0.049)	0.002 (−0.008, 0.013)	0.002 (−0.053, 0.057)	0.013 (−0.050, 0.075)	−0.014 (−0.066, 0.038)	−0.014 (−0.066, 0.038)
Living	0.052 (−0.064, 0.169)	−0.056 (−0.066, 0.178)	0.059 (−0.080, 0.198)	−0.021 (−0.122, 0.047)	−0.022 (−0.091, 0.047)	−0.039 (−0.117, 0.039)	−0.000 (−0.060, 0.059)	−0.000 (−0.061, 0.060)

*Model 1 adjusted for race, school location and maternal education; *Model 2 adjusted for race, school location, maternal education and baseline dietary misreporting. Significant findings were bolded. GEE models were used to assess changes in life satisfaction scores by changes in DP z-scores between 2016 baseline study and 2019–2020 PUTRA-Adol follow-up study. The identified DPs in the 2016 baseline study and in 2019–2020 follow-up study was characterised by high intakes of percentage energy from total sugar, fibre density, DED and low in fat, and high intakes of percentage energy from total sugar, fibre density and low in DED and fat, respectively. Life satisfaction scores were assessed at both time points in this study

Discussion

An empirical DP predominated by foods high in sugar and fibre, and low in DED and fat was identified among the study adolescents in the PUTRA-Adol follow-up study in 2019–2020. Moreover, female adolescents showed significant higher overall life satisfaction score compared to male adolescents in the PUTRA-Adol follow-up study in 2019–2020. A significant prospective association between adherence to the identified DP z-scores and school domain, in male adolescents and an inverse relationship between the DP z-score and self-domain in all adolescents was observed over the study period. These associations were still apparent even after adjusting for a wide range of covariates including race, school location, maternal education and baseline dietary misreporting.

The identified 'High sugar and fibre, and Low DED and fat' DP in the 2019–2020 PUTRA-Adol follow-up study was slightly different to what we found in the baseline study in 2016 [12]. The main observed difference was of that correlation between DED and the identified DPs at both time points (r = 0.39 in 2016 vs. r = 0.01 in 2019–2020). Nonetheless, the low correlations between DED and the identified pattern in the current study was somewhat not surprising. This is mainly due to

the changes in the eating behaviour which were rather expected during adolescence and the fact that the follow-up study was conducted in the early stage of COVID-19 pandemic when access to foods high in DED might have been restricted. The consumption of foods low in DED were probably compensated by foods high in sugar such as SSB in the follow-up study. Having said that, the contributions of key food groups loaded on both DPs identified in the baseline study in 2016 and follow-up study in 2019–2020 were largely similar [10]. These key groups were including SSBs and sweets and were found to be similar to those in the UK ALSPAC study among children and adolescents aged between 7 and 15 years of age and in the Raine study in Australia among adolescents aged between 13 and 17 years of age [28, 29]. Higher adherence to DPs highly loaded on SSBs and sweets including chocolate and confectioneries were found to be prospectively associated with adiposity [28] and other cardiometabolic risk factors [12, 29]. Findings on life satisfaction in the follow-up PUTRA-Adol follow-up study were similar to that baseline study conducted in 2016 where female adolescents generally reported a higher overall life satisfaction score [10]. Female adolescents showed higher scores in all other domains including family, school, friends and living environment domains in the baseline

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study in 2016 compared to male adolescents who only had higher scores in the self-domain [10]. However, in the current PUTRA-Adol follow-up study male adolescents showed higher score in family, school and living environment compared to the female adolescents who only showed higher scores for friends and self-domains. This finding might indicate a potential difference in social connections for male and female adolescents, where male adolescents tend to find greater attachment and satisfaction within their home environment as they grow while female adolescents appeared to prioritize value on friendships.

A greater adherence to the identified dietary patterns was prospectively associated with increasing life satisfaction score for the school domain between 13 and 17 years of age could be due to the connections and interactions with like-minded peers as well as exposure and consumption to foods and drinks that are highly palatable and pleasurable may have contributed to adolescents' high levels of life satisfaction in the school vicinity. On the other hand, our study found an increasing dietary pattern score was associated with a decreasing score for self-domain for overall adolescents. In the current follow-up study, we found that one-third of the adolescents disagreed that they look good. Since life satisfaction with the overall appearance is linked to self-esteem, any dissatisfaction with oneself might have largely contributed to the low self-esteem and subsequently unhealthy eating behaviours particularly intakes of foods high in sugar and fat [30].

To the best of knowledge, no studies have assessed associations between empirically derived adolescent DPs and life satisfaction per se except to that published in the baseline study in 2016 [10]. Previously, we found a significant cross-sectional association between adherence to the 'High sugar, High fibre, High DED and Low fat' DP and overall life satisfaction and living environment domain, in female adolescents, in the baseline study [10]. The fact that a slightly different DP ('High sugar, High fibre, Low DED and Low fat') was observed in the current PUTRA-Adol follow-up study, this would have led to the differences in findings between the DPs and overall life satisfaction. Secondly, SSBs was highly correspond to the identified DP in the baseline study in 2016 and that has changed to sweets in 2019–2020. Since liquid SSBs are high in added-sugar content this could have led to low satiety and incomplete compensatory reduction in energy intake at subsequent meals after consuming them, as opposed to sweets as in solid food form. Nonetheless, the contribution of free sugar in the PUTRA-Adol follow-up study is mainly from the sweets and SSB which represents the characteristic of a 'western' DP and is most likely linked to the observed connection between DPs

and lower life satisfaction. Correspondingly, a review in 2011 reported that 'Western' DP characterised by foods and beverages with high glycemic loads such as SSB, sweets, candies, and confectionaries were found to have raised plasma C-reactive protein (CRP) which is a marker for inflammation and subsequently depression, anxiety, fatigue, and social withdrawal in young people [28, 29, 31]. Furthermore, a Western Australian study found a prospective association between adherence to a "Western" DP characterised by confectionaries and mental illnesses during adolescence [9]. Moreover, a prospective study of Australian adolescents found that a lower Paediatric Quality of Life Inventory (PedsQL) score was associated with lower diet quality, which was measured as lower adherence to the Dietary Guidelines for Children and Adolescents in Australia and a greater consumption of processed food including those confectionaries [31]. Besides that, Supplémentation en Vitamines et Minéraux Antioxydants (SU.VI.MAX) cohort study among children found an association between junk food in early childhood and emotional problems that may reflect a long term nutritional imbalance [33]. Declines in psychological functioning were also linked to lower diet quality characterised by high glycemic load (GL) diets over the course of a follow-up period among Australian adolescents [32]. Whereas, Mediterranean diet which includes high number of healthy foods such as whole grains, fruits, vegetables, seafood, and nuts showed a lower risk for mental health among adolescents in the SU.VI.MAX cohort study [33].

The strength of this study included the ability to track dietary habits during adolescence, an age group that was often overlooked in the previous years. It is also important to note that this was the first study to investigate the prospective association between DP and life satisfaction level among Malaysian adolescents. There are several limitations worth mentioning. Firstly, the large reduction in the response rate in the present follow-up study compared to the baseline study. This was mainly due to the Covid-19 pandemic issue, when all schools in Malaysia were closed and travels were hindered for data collection. While we attempted for online data collection, a prevalent issue in the majority of households stemmed from a lack of internet access, consequently posing further hurdles to the data collection process. Furthermore, the potential for reporting bias was acknowledged due to the self-administration of the FFQ and MSLSS. To mitigate this bias, researchers offered illustrative examples and meticulously reviewed the questionnaires for any discrepancies. Moreover, the associations observed in this study could be a result of reverse causation. In this case, low life satisfaction may be linked to increased sugar intake as mental health problems such as depression

could negatively impact dietary choices. Additionally, regression models were also adjusted to accommodate dietary misreporting, a prevalent concern within the field of nutrition research. Although adjustment for a few confounders was done, residual confounding cannot be fully ruled out as there were important additional confounding factors such as BMI and physical activity that were not considered in this study. Furthermore, the study participants only came from three southern states in Malaysia, therefore the findings may not be generalisable to the entire country.

Conclusions

To our knowledge, there have been no studies to date that have examined prospective associations between empirically derived DPs and life satisfaction among Malaysian adolescents. The implications of this study result may indicate that improvements in dietary intakes particularly limitations of foods high in sugar within the framework of lifestyle intervention may improve life satisfaction, especially the self-satisfaction for a healthier future among adolescents. While school settings present a unique place for improved life satisfaction, this does not need to be in the expense of healthy dietary intakes which are known to have strong linkages with prevention of non-communicable diseases in later life.

Abbreviations

BMI	Body mass index
COVID-19	Coronavirus disease
CRP	C-reactive protein
DED	Dietary energy density
DP	Dietary pattern
FFQ	Food Frequency Questionnaire
IQR	Interquartile range
JKEUPM	UPM's Ethics Committee for Research Involving Human Subjects
MSLSS	Multidimensional Students Life Satisfaction Scale
PAL	Physical activity level
PAQ-A	Physical Activity Questionnaire for Adolescent
PAQ-C	Physical Activity Questionnaire for Older Children
PEDSQL	Paediatric Quality of Life Inventory
RRR	Reduced rank regression
STATA	Statistical software for data science
SD	Standard deviation
SPSS	Statistical package for the social sciences
SSB	Sugar sweetened beverages
SU.VI.MAX	Supplémentation en Vitamines et Minéraux Antioxydants
UPM	Universiti Putra Malaysia
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12986-024-00832-w.

Supplementary Material 1.

Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available due the raw information gathered in this research were kept strictly confidential as stated in respondents' consent agreement but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Universiti Putra Malaysia's Ethics Committee for Research Involving Human Subjects (JKEUPM) (Reference number: JKEUPM-2019-267). Written informed consent was obtained from all study respondents and their parents.

Consent for publication
All respondents and their parents or guardian provided consent for publication. However, researchers disclosed no names or other identifying information related to respondents and their parents or guardian in this manuscript.

Competing interests
The authors declare no competing interests.

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