ORIGINAL ARTICLE

A Dietary Pattern High in Sugar, Sodium and Saturated Fat Was Negatively Associated With Academic Performance in Malay Adolescents

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ABSTRACT

Introduction: Dietary patterns (DP) and its relationship with academic performance especially among schoolchildren have received significant attention in nutritional epidemiology studies. The objective of this cross-sectional study was to determine the determinants of academic success among Malay teenagers in Terengganu, Malaysia. **Methods:** Habitual dietary intakes were obtained using a semi-quantitative food frequency questionnaire, anthropometry data were measured by trained researchers and information on academic performance were gathered from the school registrar's office. The method of reduced rank regression was employed in order to determine the dietary patterns (DPs) and multivariable linear regression models were employed to examine the relationships between DP and academic performance. **Results:** Of the 375 study participants, half of the sample were female (50.1%), with 61.9% having a normal BMI. The main DP identified in this study was "high sugar, high sodium and high saturated fatty acid (SFA)". The models showed that there were significant inverse associations between the DP with Science marks (β=-1.87; 95%CI:-0.39,-3.36; p=0.013) and the combination of Mathematics and Science marks (β=-3.49; 95%CI:-0.45,6.52; p=0.024). Findings showed that a 'high sugar, sodium and SFA' DP could negatively impact the academic performance of adolescents, particularly in STEM-related subjects. **Conclusion:** These could serve as a basis for developing nutritional education among adolescents to enhance academic performance for a better future.
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INTRODUCTION

Adolescence is a period when significant physical, psychological and cognitive changes happen between childhood and adulthood. During this period, essential nutrients from foods are needed to catch up with the neural formation and brain development needs (1-2). According to Prado & Dewey (3), nutrient deficiencies during this developmental stage may have long-term detrimental impacts on cognitive function, compromising health and academic achievement. The academic performance of teenagers is a matter of worry for educators, parents, and children, as well as having broader public health concerns due to its potential impact on future educational achievements, which in turn affects socioeconomic status and health behaviours (4-5).

In recent years, there has been a growing scholarly focus on examining the correlation between dietary constituents and scholastic achievement among teenage individuals. The literature has shown that a child's physical development and academic performance depend on a healthy eating pattern that includes regular breakfast consumption, eating plenty of grains, consuming fruits and vegetables, moderate amounts of sugar and salt, calcium and iron-rich diet (6-7). Additionally, several studies identified a substantial correlation between eating breakfast frequently, eating fruits and vegetables, and performing well in school (8-9). In Sweden, higher fish consumption has been linked with better academic achievement in adolescents (10-11). In addition to food groups, previous studies also reported that providing folate and iron to adolescents was positively associated with academic achievement such as reading test, written and oral mathematics and English (12-13).

Despite growing awareness regarding healthy eating habits, numerous teenagers continue to consume unhealthy foods that could affect their academic results unfavourably (14). Unhealthy dietary habits such as skipping breakfast and other meals, excessive intake of sweets, salt, soft/ sugary drinks, and fried and refined food were found to be associated with poorer academic performance in adolescents (8,15). According to a study conducted in Australia, academic performance in adolescents worsened when they consumed more high-fat, high-sodium and added sugar snacks, sugary drinks and fried takeaway foods (16). As such, it is crucial to scrutinize how diet influences adolescents' learning outcomes while devising ways to improve young people's dietary behaviour. While it is well recognised that people do not eat nutrients or meals in isolation, a significant portion of past research has predominantly concentrated on examining individual nutrients or specific food items. The aforementioned phenomenon has sparked significant scholarly attention towards the field of dietary pattern analysis, which aims to elucidate the impact of dietary choices on overall health outcomes within a more comprehensive framework (17-18). However, studies on the association between DP and academic performance among adolescents, especially using reduced rank regression (RRR) method in a Malay population is notably lacking. This study focused to derive RRR-based DPs among 11-year-old adolescents in Terengganu, Malaysia and to investigate cross-sectional associations with academic performance. Adolescents with the age of 11 was chosen due to availability of data compared to other age groups and this age also marks a critical period in a child's development, both physically and cognitively.

MATERIALS AND METHODS

Ethical approval

The present study received approval from the UniSZA Human Research Ethics Committee (UHREC) with a protocol code UniSZA/UHREC/2018/72. The participants were provided with a verbal briefing explaining the study, and any inquiries they had were addressed. Prior to the enrolling of pupils, parental or guardian agreement was required in written form. Prior to any contact with schools, the researchers obtained permission to perform the study from the Ministry of Education Malaysia and the Terengganu State Education Department.

Study design and setting

The present investigation employed a cross-sectional design and was carried out within a sample of 10 elementary schools from four out of eight districts in Terengganu, Malaysia (i.e. Kuala Terengganu, Marang, Setiu and Kuala Nerus). The selection of schools was conducted in a random manner, utilising a comprehensive list of public elementary schools that are officially registered in the state of Terengganu as of 31st January 2019 (Ministry of Education Malaysia, 2019). The sample size determination was estimated using a single proportion formula, with 5% margin of error. Considering a 10% dropout rate, the sample size required wa 386 participants.

Study participants

Participation was entirely voluntary. The inclusion criteria included Year 5 students from the top and bottom class who understood and comprehended in Malay or English. Those who were reading-impaired, had physical disabilities or had neurological illnesses that impaired their academic performance were excluded from the study. These conditions included organ failure or haemodialysis, which require ongoing medication.

Data collection

Upon the commencement of the recruiting process, those who met the criteria for eligibility were provided with a comprehensive overview of the study, accompanied by the requirement of obtaining written consent. Guided by the trained researchers, they were requested to complete a self-administered sociodemographic form and a semi-quantitative food frequency questionnaire (FFQ) to record their dietary intake. Subsequently, the height and weight of the teenage participants were assessed by proficient researchers employing a standardised methodology on a day to day basis.

Measurements

Sociodemographic data

The survey gathered information pertaining to the demographic features of the participants, including age, gender, ethnicity, parents' monthly household income, and educational level.

Anthropometric measurements

Anthropometric measures were performed on participants while they were attired in lightweight clothes, without footwear, and in adherence to established protocols within the educational setting. The researchers obtained height and weight measurements from participants while they were in an upright standing posture. These measures were taken with a high level of precision, to the nearest 0.1 cm for height using the Seca 213 portable stadiometer manufactured by Seca in Germany, and to the nearest 0.1 kg for weight using the TANITA Model BC-583 digital weighing scale manufactured by TANITA in Japan. The BMI calculations were performed using the formula BMI = weight (kg) / height2 (m2), where body weight and height were utilised. The z-score for BMI-for-age was calculated using the World Health Organisation (WHO) AnthroPlus software and classified according to the WHO Growth Reference 2007 (19). The US Centre for Disease Control and Prevention (CDC) established specific thresholds in the year 2000 to classify individuals as underweight, overweight, or obese. These thresholds are determined based on body

mass index (BMI) percentiles, with the 5th, 85th, and 95th percentiles representing underweight, overweight, and obesity, respectively.

Food frequency questionnaire (FFQ)

The semi-quantitative FFQ utilised in this study was derived from the Malaysian Adults Nutrition Survey 2014 (20). It consists of a comprehensive list of 189 food items, with options for participants to indicate the frequency of consumption (e.g., times per day, daily, weekly, monthly) for each food item. Participants were instructed to estimate both the frequency and number of servings consumed per intake for each food item over the course of the previous month. To determine the daily energy, macronutrient, and micronutrient intakes, a database was developed using the Nutrient Composition of Malaysian Foods, United States Department of Agriculture (USDA) nutrient database, and the Singapore Food Database. This database was used to calculate the nutritional content of the food items based on the amount consumed by participants on a daily basis. Subsequently, the 189 food items were categorised into 30 major food groups, and the daily intake was measured in grammes.

Academic performance

Annual exam marks of four subjects (Bahasa Malaysia, English, Mathematics and Science) were used as the measure of academic performance since these subjects are common to each school participating in this study. In order to get the standardized exam marks from all of the involved schools, the scores from mid-year examination for Year 5 were obtained. Higher scores represent higher levels of achievement. Consent was asked from parents before obtaining the data from the school's registrar office.

Dietary pattern analysis

The determination of food pattern was conducted using RRR, a statistical technique that combines the benefits of both exploratory and hypothesis-oriented techniques to studying dietary patterns. The RRR approach utilised two sets of variables: independent variables or predictors, which mostly consisted of dietary components, and a set of response variables that were picked based on the a-priori premise that they had a relationship with the result of interest. The current investigation used the RRR model, which encompassed many dietary variables, including saturated fat (SFA), sugar, and salt. The selection of these dietary parameters was informed by prior research indicating that teenagers who exhibited greater intake of processed and salty foods, soft drinks, and sweets had worse academic performance (8, 15).

In this study, a comprehensive set of 31 food groups (g/d) was classified based on their nutritional profiles and categorised into several food group categories. These categories included white bread, green leafy vegetables, cruciferous vegetables, fruits, sugar sweetened beverages and fizzy drinks, and the meat group. These food groups were utilised as predictors in the RRR analysis. This study identified three dietary patterns (DPs) as factors for analysis. Only the factors that accounted for the highest amount of variance in all response variables were selected for further investigation in relation to academic performance in the current study. The consumption of food items that exhibited a positive factor loading was shown to be associated with an increase in the dietary pattern (DP) z-score. Conversely, the consumption of food items with a negative factor loading was found to be associated with a drop in the DP z-score. Food categories with factor loadings more than or equal to 0.20 and less than or equal to -0.20 were deemed significant and regarded as the most substantial positive or negative contributors to the z-scores of the dietary pattern (15,21).

Data analysis

The data were subjected to analysis using IBM SPSS Statistics version 23.0 (Armonk, NY: IBM Corp), while the RRR was computed using SAS on Demand for Academics software (SAS Institute, Cary, NC) to derive the dietary pattern (DP). Descriptive statistics were utilised to provide a summary of the demographic characteristics, whereas anthropometric measures were reported in frequencies (n) and percentages (%), as well as mean and standard deviation (SD). The use of simple linear regression was employed in order to ascertain the potential independent variables that are associated with academic achievement. A multivariate regression analysis was performed in order to ascertain the correlation between the average DP z-scores of adolescents and their academic achievement. Besides, Fisher Exact Test was used to assess the differences in categorical characteristics according to the DP quartiles. The level of significance for this study was established at a p-value threshold of less than 0.05.

RESULTS

Participants' characteristics

As summarised in Table I, 375 adolescents participated in the study, of which 50.1% were girls. Majority of them were from Kuala Terengganu (30.7%), whilst least number was from Kuala Nerus (18.1%). Most of their fathers (51.2%) and mothers (47.7%) attained secondary education. The majority of participants had normal BMI for their ages (61.6%), with monthly household incomes ranging from RM1,000.00 to RM5,000.00 (35.7%). Regarding academic performance, the mean score for total marks was 306.9 (standard deviation (SD) = 100.9). Bahasa Malaysia had the highest mean score (mean = 59.3, SD = 18.2) and Mathematics had the lowest mean score (mean = 45.4, SD = 20.1).

Dietary pattern

The RRR analysis identified one primary DP, called 'high sugar, sodium and SFA' with 21.46% of variation explained in habitual dietary intakes. This DP was

Table I: Study characteristics of the adolescents (n=375).

Characteristics	n (%)
Districts	
Kuala Terengganu	115 (30.7)
Marang	110 (29.3)
Setiu	82 (21.9)
Kuala Nerus	68 (18.1)
Gender, n (%)	
Male	187 (49.9)
Female	188 (50.1)
Mother's education level‡	
No formal education	2 (0.5)
Primary education	15 (4.0)
Secondary education	179 (47.7)
Tertiary education	91 (24.3)
Father's education level‡	
No formal education	3 (0.8)
Primary education	24 (6.4)
Secondary education	192 (51.2)
Tertiary education	68 (18.1)
Monthly household income§	
<RM1,000	96 (25.6)
RM1,000 – RM5,000	134 (35.7)
RM5,001- RM10,000	40 (10.7)
>RM10,000	6 (1.6)
Anthropometric measures; Mean SD	
Weight (kg)	36.5 ± 17.8
Height (cm)	138.2 ± 6.9
BMI-for-age, %ile	
Underweight (<5th %ile)	41 (10.9)
Normal (5th – 85th %ile)	232 (61.9)
Overweight (≥ 85th %ile)	48 (12.8)
Obesity (≥ 95th %ile)	54 (14.4)
Academic performance; Mean SD	
Total marks	306.9 ± 100.9
Mathematics + Science	94.6 ± 36.4
Bahasa Malaysia	59.3 ± 18.2
English	46.9 ± 17.3
Mathematics	45.4 ± 20.1
Science	49.2 ± 17.9

Data are presented as n (%) or mean ± standard deviation (SD); RM, Ringgit Malaysia; BMI, body mass index
‡Mother's education level, n=287; ɪFather's education level, n=287; §Monthly household income, n=276

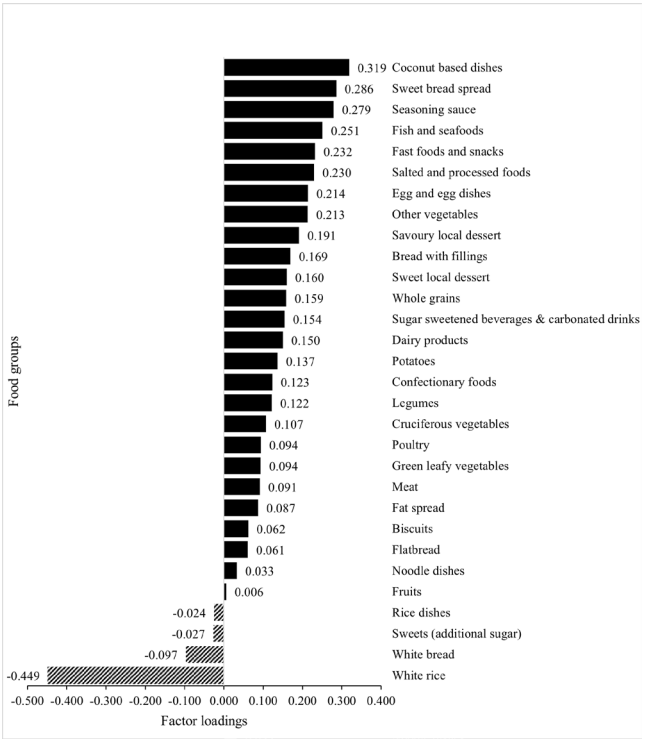

Figure 1: Factor loadings for DP 'high sugar, sodium and SFA'

characterised by coconut-based dishes, sweet bread spread, fast foods and snacks and salted and processed foods groups. The factor loading for the DP is presented in Figure 1. This DP showed a moderate and strong correlation of sugar (r=0.341), SFA (r=0.765) and sodium (r=0.546). The characteristics of DP 'high sugar, sodium and SFA' derived from RRR are summarised in Table II.

Associations between DP and academic performance

Table III presents the results of the multiple linear regression analysis, which examines the association between the DP z-scores and the academic performance of adolescents. There was a significant negative association between DP 'high sugar, sodium and SFA' with Science marks (β = -1.87; 95% CI: -0.39, -3.36; p = 0.013) and combination of Mathematics and Science marks (β = -3.49; 95% CI: -0.45, 6.52; p = 0.024) after adjusting for gender, mother and father education level, monthly household income, physical activity level and BMI-for-age. However, there was no significant association with total marks, Bahasa Malaysia and English.

Characteristics of adolescents according to quartile of dietary pattern z-scores

The characteristics of 11-year-old adolescents by quartile of the dietary patterns are described in Table IV. Results show that the father's education level was significantly decreased across the increased quartile of DP 'high sugar, high sodium and high SFA' z-scores (p = 0.045). No significant association was found between other factors with the quartile of DP.

Table II: Characteristics of DP 'high sugar, high sodium and high SFA' by RRR (n=375)

Dietary pattern (DP)	Explained variation (%)					Correlation coefficient		
	Food intakes (current)	Responses (current)	Sugar (%E)	SFA (%E)	Sodium (mg/1000 kcal)	Sugar (%E)	SFA (%E)	Sodium (mg/1000 kcal)
DP 1*	7.18	21.46	7.47	37.69	19.22	0.341	0.765	0.546
DP 2	3.48	13.58	7.55	50.82	46.77	-0.044	-0.568	0.822
DP 3	4.44	7.72	27.98	52.96	47.36	0.939	-0.304	-0.160

*DP chosen for further analysis; %E: percentage of energy intake; SFA: saturated fatty acid.

Table III: Multivariate regression models between academic performance and DP 'high sugar, high sodium and high SFA' (n=375)

Academic performance	Unadjusted		Model 1[a]		Model 2[b]		Model 3[c]	
	β (95% CI)	*p*-value	β (95% CI)	*p*-value	β (95% CI)	*p*-value	β (95% CI)	*p*-value
Total marks	-7.71 (-1.09, -16.51)	0.086	-8.60 (-0.17, 17.36)	0.054	-7.37 (-1.16, 15.89)	0.090	-7.20 (-1.28, 15.69)	0.096
Mathematics + Science	-3.72 (-0.55, -6.89)	0.021*	-4.00 (-0.84, -7.16)	0.013*	-3.56 (-0.48, 6.63)	0.024*	-3.49 (-0.45, 6.52)	0.024*
Bahasa Malaysia	-0.08 (-0.25, -2.92)	0.098	-0.10 (-0.10, -3.06)	0.066	-0.08 (-0.26, -2.84)	0.104	-0.08 (-0.29, -2.81)	0.110
English	-0.04 (-0.86, 2.17)	0.394	-0.06 (-0.69, 2.32)	0.286	-0.04 (-0.85, 2.09)	0.406	-0.04 (-0.87, 2.06)	0.425
Mathematics	-1.71 (-0.04, 3.46)	0.050*	-1.86 (-0.54, 8.65)	0.026*	-1.65 (-0.07, -3.36)	0.060	-1.61 (-0.08, -3.31)	0.062
Science	-2.01 (0.46, 3.56)	0.011*	-2.14 (-0.59, -0.37)	0.007*	-1.90 (-0.40, -3.40)	0.013*	-1.87 (-0.39, -3.36)	0.013*

[a]Model 1: adjusted for gender. [b]Model 2: adjusted for gender, mother and father education level and monthly household income level. [c]Model 3: adjusted for, gender, mother and father education level, monthly household income level, physical activity level and BMI-for-age.

Table IV: Characteristics of adolescents according to quartile of DP z-scores (n=375).

Variable (s)	DP 'high sugar, high sodium and high SFA'				
	Q1 (≤-0.76)	Q2 (-0.75 – 0.28)	Q3 (-0.27 – 0.63)	Q4 (≥0.65)	p-value[a]
Gender					
Male	40 (42.6)	44 (48.4)	51 (54.8)	51 (54.3)	0.291
Female	54 (57.4)	47 (51.6)	42 (45.2)	43 (45.7)	
Mother's education level[ǂ]					
No formal education	0	1 (1.4)	1 (1.5)	0	0.491
Primary education	2 (2.7)	2 (2.8)	7 (10.3)	4 (5.7)	
Secondary education	51 (68.0)	45 (63.4)	40 (58.8)	41 (58.6)	
Tertiary education	22 (29.3)	23 (32.4)	20 (29.4)	25 (35.7)	
Father's education level[ǂ]					
No formal education	1 (1.3)	1 (1.4)	1 (1.5)	0	0.045*
Primary education	4 (5.3)	2 (2.8)	10 (14.7)	8 (11.4)	
Secondary education	52 (69.3)	52 (73.2)	48 (70.6)	38 (54.3)	
Tertiary education	18 (24.0)	16 (22.5)	9 (13.2)	24 (34.3)	
Monthly household income[§]					
<RM1,000	27 (38.6)	27 (38.0)	20 (31.3)	21 (30.9)	0.973
RM1,000 – RM5,000	34 (48.6)	32 (45.1)	32 (50.0)	34 (50.0)	
RM5,001- RM10,000	8 (11.4)	11 (15.5)	10 (15.6)	11 (16.2)	
>RM10,000	1 (1.4)	1 (1.4)	2 (3.1)	2 (2.9)	
BMI-for-age, %ile					
Underweight	10 (10.6)	14 (15.4)	8 (8.6)	8 (8.5)	0.251
Normal	62 (66.0)	49 (53.8)	64 (68.8)	55 (58.5)	
Overweight	10 (10.6)	11 (12.1)	14 (15.1)	13 (13.8)	
Obese	12 (12.8)	17 918.7)	7 (7.5)	18 (19.1)	

Data are presented in n (%), [a]Fisher's Exact test was applied, *Significant level was set at p-value ≤ 0.05. SD, standard deviation; RM, Ringgit Malaysia; BMI, body mass index; df, degree of freedom; Q1, quartile 1; Q2, quartile 2; Q3, quartile 3; Q4, quartile 4.
[ǂ]Mother's and father's education level, n=287
[§]Monthly household income, n=276

DISCUSSION

Healthy lifestyles, which include good eating habits, have been linked to greater academic attainment in teenagers (8, 22-23). Therefore, the present study looked at the associations between adherence to an unhealthy dietary pattern in 11-year-old adolescents in Terengganu and their academic performance. The DP 'high sugar, sodium and SFA' was identified by RRR and found to be inversely associated with academic performance among adolescents. This DP was distinguished by food groups such as coconut-based dishes, sweet bread spread, fast foods and snacks and salted and processed foods. Similar characteristics of the DP was found in a previous study by Nyaradi et al. (15) that was referred as a 'Western' pattern. This study concluded that an increased adherence to the 'Western' DP was associated with poorer academic performance among adolescents

in Australia. Nonetheless, Pearce et al. (16) found that the 'noncore' DP was negatively associated across academic performance domains reading, numeracy and language. The present finding was also in line with others which indicate that unhealthy DP have been allied with poor academic performance in school (4,9). Furthermore, the food groups included in the DP 'high sugar, sodium and SFA' consisted of foods frequently found in school cafeterias/canteens, which increased the amount of unhealthy intake among school-aged adolescents. Due to their easy preparation and high demand from students, energy-dense foods and beverages are commonly available at school canteens (24-25). In accordance with the present results, other research has linked students' access to and availability of less-healthy food and beverages in schools to low nutritional status, which in turn affects their academic performance (8, 24-26). These results offer important insights on how to improve adolescents' dietary patterns by making more nutritious food alternatives available and limiting the availability of low-nutrient food products, especially in school settings. This was supported by other studies, which found that eating a diet rich in fruits, vegetables and whole grains improved scholastic performance at school (6,22).

The DP identified in this study was statistically significant and inversely associated to Science and a combination of Mathematics and Science marks after adjusting for the potential confounding factors. This inverse relationship between the 'Poor' and 'Western' patterns and academic achievement was also shown in other studies (9,15). In contrast to the DP examined in this study, all detected patterns had comparable attributes characterised by elevated levels of harmful food consumption, such as fast food, fried food and sugars, and low consumptions of fruits, vegetables and wholegrains. The observed inverse correlation might perhaps be elucidated by considering the influence of nutrients in the regulating cognitive function which affects academic achievement. According to a systematic and meta-analysis review by Taylor et al. (27), a consumption of meals high in saturated fat and refined carbohydrates is linked to deficiencies in spatial learning and memory tasks through impairments in hippocampal-dependent forms of cognition. These impairments may be caused by neuroinflammation, oxidative stress, and abnormal brain lipid metabolism (28-31). It is interesting to note that diets high in SFA and added sugars have been shown to decrease hippocampal-dependent learning and memory after four or eight days of intervention (30, 32). Hence, it could conceivably be hypothesised that an unhealthy dietary pattern lowers the cognitive function among adolescents.

On the other hand, adolescents with higher DP 'high sugar, sodium and SFA' z-scores were linked with their father's education level. The present finding was supported by Jang & Kim (33), who found that highly educated parents are more likely to engage in healthy lifestyle and encourage their children to maintain healthy eating habits. For instance, the parent's food choices and intake may influence the eating habits of the adolescents throughout their life. In addition, the dietary habits of adolescents are also greatly influenced by various factors, including family/peer influences, food advertisements, accessibility and availability of foods (34,35). Physiological and personal factors including hunger, taste preferences and lack of awareness about healthy eating also contribute to eating habits in adolescents (36,37). Therefore, comprehensive actions to promote healthy eating habits are essential to improve scholastic performance as well as preventing health issues.

It is essential to address some limitations inherent in this study. The participation of a limited number of ten educational institutions originating from a single state and limited sampling to standard five school adolescents during recruitment may not represent adolescents in other age groups. One additional constraint of this research was to the teenagers' capacity to precisely recollect their dietary consumption using the Food Frequency Questionnaire (FFQ), thereby heightening the likelihood of bias, underestimation, or misrepresentation. Nevertheless, the potential for recollection bias and underreporting has been mitigated by conducting interview sessions administered by researchers who have received appropriate training. The cross-sectional nature of this analysis may have biased the results due to reversed causality, and the observational design limits our ability to draw firm conclusions. Furthermore, this research contributed to the existing body of information about the relationship between dietary habits and academic performance in teenagers residing in the local area. Further longitudinal research is necessary to ascertain the precise food pattern prevalent among the Malaysian population and its potential influence on academic performance as a whole.

CONCLUSION

This study identified a 'high sugar, sodium and SFA' DP among 11-year-old adolescents in Terengganu. This DP was negatively associated with Science and the combination of Science and Mathematics scores. Enhancing public awareness and providing education on the significance of adopting a healthy diet are crucial factors in enhancing academic performance among teenagers. Nevertheless, the results obtained from this study might potentially function as preliminary indications for the development of more comprehensive and long-term investigations aimed at validating the influence of DP on academic performance.

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