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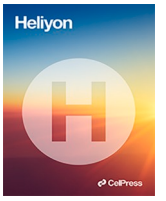

Research article

Association between neighbourhood food environment and dietary quality among adolescents in Kuala Lumpur, Malaysia

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ABSTRACT

The neighbourhood food environment has been found to influence the dietary quality of adolescents. Therefore, this study aims to investigate the association between neighbourhood food environment and dietary quality among adolescents that come from low-income families in Kuala Lumpur. This cross-sectional study involves 184 adolescents from six public secondary schools in Kuala Lumpur. The online self-administered questionnaire through Google Forms was used to obtain information regarding adolescents' sociodemographic characteristics, dietary quality, and perceived availability, accessibility, and affordability of the neighbourhood food environment. Food stores and home addresses were geocoded using Google Earth. Geographic Information System (GIS) was used to identify the status of neighbourhood food environment, map the food stores and home addresses, and determine 1000m buffer zones around respondents' addresses. Associations between neighbourhood food environment statuses and dietary quality were examined using Pearson correlation, Chi-Square Test and Multivariable Linear Regression (MLR). The most reported response for dietary quality status is it 'requires improvement' (62.0 %), compared to having a 'poor diet' (23.9 %) and 'good' (14.1 %). The majority (60.3 %) resided in a healthy food environment, while the minority lived in food swamps (37.0 %) and food deserts (2.7 %). Although the majority of respondents perceived While a higher number of them perceived high food availability (76.6 %) and affordability (64.7 %) of healthy food stores in their neighbourhood, over half (51.7 %) reported low accessibility to these stores. About 33.2 % of them never use food delivery services, followed by at least once per month (31.5 %), once every two weeks (16.3 %), and once per week (19.0 %). Age ($r_s = -0.19$), ethnicity ($X^2 = 5.75$), fathers' educational level ($r_s = 0.15$), non-fast-food restaurants (r = -0.16) and convenience stores (r_s = -0.20) were significantly correlated with adolescents' dietary quality ($p < 0.05$). However, after adjustment for covariates, ethnicity ($\beta = 0.180$, $t = 2.283$, $p = 0.020$), father's educational level ($\beta = 0.177$, $t = 2.113$, $p = 0.036$) and monthly household income ($\beta = -0.169$, $t = -2.160$, $p = 0.032$) were identified as significantly associated with dietary quality. The dietary quality of urban poor adolescents in Kuala Lumpur requires further improvement in terms of awareness and intervention. Interventions should focus on increasing fathers' awareness of healthy food choices

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and addressing ethnic dietary. Enhancing nutrition education in schools may also help improve dietary habits among low-income urban adolescents.

1. Introduction

Adolescence is a crucial period for growth and development. Nevertheless, global concerns about obesity are caused by poor dietary quality in adolescence continuing to increase among public health authorities [1,2]. Adolescents experience significant physical and social development, making them vulnerable to an unbalanced diet. Although obesity and chronic diseases are largely preventable through healthy lifestyles, adolescents worldwide consume fewer nutritious foods such as fruits and vegetables, whole grains, and dairy while eating more ultra-processed and energy-dense food [3]. Fast food and pre-packaged snacks are major sources of energy-dense food intake, with their consumption increased significantly in both high and low-to-middle-income countries, including Malaysia [4].

The complex socioecological factors affecting dietary behaviours, including demographic, genetic, socioeconomic, and cultural factors. Among these, the food environment has become a significant factor in dietary behavior in adolescence [5]. The food environment refers to collective physical, economic, policy, and sociocultural environments, opportunities, and conditions that affect people's food and beverage preferences and nutritional status [6]. The availability, acceptability, and affordability of food in a community's food outlets are all factors that contribute to the neighbourhood food environment, which is also referred to as the community food environment [7]. Examples of these outlets include convenience stores, supermarkets, and fast-food restaurants [8]. According to the Food Access Research Atlas, low-income and low-access census tracts are those with at least 500 residents, or 33 % of the total population, live more than one mile (in urban areas) or more than ten miles (in rural areas) away from the nearest supermarket, supercenter, or large grocery store. Adolescents often have easier access to local food outlets where they can visit, buy, and eat both healthy and unhealthy food [9].

In Malaysia, the food environment has drastically changed over the past ten years, and there are now significantly more options for unhealthy food than for healthy food [10]. Adolescents may be influenced by their neighbourhood food environment because they may have limited independent mobility compared to adults [11]. This developmental period is also when individuals begin to assert their independence in terms of eating habits and seek social recognition from peers [12]. Few studies that have examined adolescents' exposure to neighbourhood food outlets and dietary behaviours have been inconsistent. Other studies from Australia [13] and Denmark [14] found no associations between the proximity and availability of stores in the neighbourhood food environment and the purchase of fast food, snacks, and sugary beverages. Conversely, studies among adolescents from Malaysia and the Netherlands have found positive associations between the availability, proximity, or density of unhealthy food outlets near home, including fast food, convenience stores, and corner stores [15,16].

These inconsistencies may be due to varying methods used to measure food environment exposure including food swamps and food desert [17,18]. Evaluating the neighbourhood food environment requires a combination of measures, such as surveys or questionnaires and objective measures using GIS (geographic information system). GIS-based methods can assess food outlet density and proximity, while surveys capture individual perceptions of the food environment [19,20]. Both methods provide complementary insights into the availability, accessibility, and affordability of healthy food options [21,22]. However, using both methods are yet to be conducted in Malaysia.

Adolescents from low-income families reported prone to practice poor dietary habits, consuming less fruits and vegetables and higher intake of candies, snacks, fast food, and sugar-sweetened beverages [23,24]. Socioeconomic status is commonly assessed by educational level, occupation, and income, and it is related to health outcomes and life expectancy via a social gradient: the higher the position, the better the health [25]. The reasons are the low accessibility to healthy foods in low socioeconomic status neighbourhoods, family dynamics that do or do not promote the consumption of healthy food, lower nutritional knowledge, and a more sedentary lifestyle and less physical activity in adolescents contribute to the disparity in dietary behaviors between socioeconomic groups [26,27]. Tay et al. [28] found a significant association between food insecurity and poor dietary quality among Malaysian adolescents ($p < 0.01$).

The Adolescent Health Survey [29] revealed that 2.5 % of Malaysian adolescents reported feeling hungry most of the time or always because of not having enough food at home for the previous 30 days. Similarly, a UNICEF Malaysia study on urban poverty reported that more than 1 in 10 children in low cost flats in Kuala Lumpur consumed less than three meals a day and were undernourished. Adolescents who experienced poor dietary quality frequently reside in neighbourhoods with a higher prevalence of lack of access to food stores, poverty, and low-income populations [30]. Despite their vulnerability, studies on the association between neighbourhood food environment and dietary quality among adolescents in Malaysia are limited. While, national studies have focused on adults [31], research targeting adolescents mainly among those residing in urban areas with low socioeconomic backgrounds is lacking. Improved nutrition and food security are regarded as high-priority goals for many countries based on the Second Goal of Sustainable Development Goals (SG), under the theme "Zero Hunger". Therefore, this study aimed to identify associations between neighbourhood food environments and dietary quality among adolescents from the low-income families in Kuala Lumpur, Malaysia.

2. Methodology

2.1. Study area

Kuala Lumpur officially known as the Federal Territory of Kuala Lumpur, is the capital and the largest urban area in Malaysia with a covered area of 243 km^2 (94 sq mi). The Malaysian ringgit is the official currency of Malaysia (MYR) symbolized as RM (*Ringgit Malaysia*). Kuala Lumpur recorded a household consumption expenditure of RM6,913 which exceeds the national average of RM4,534 [32]. As of 2020, approximately 88,574 adolescents aged 13 to 18 resided in Kuala Lumpur [33]. Therefore, this study focusing on adolescents enrolled in public secondary schools in Kuala Lumpur. It involved schools in all three different District Education Offices (Pejabat Pendidikan Wilayah): Sentul, Keramat, and Bangsar Pudu. Overall, there are 89 public secondary schools in the Federal Territory of Kuala Lumpur, making it a representative location of the study.

2.2. Research design and sampling

This cross-sectional study was conducted from March to May 2021 among adolescents, i.e. students with a B40 family background. Three main income classifications are used to classify households in Malaysia which are Bottom 40 % (B40), Middle 40 % (M40), and Top 20 % (T20). B40 represents the bottom-tier households 40 % of income earners of below RM3,401, M40 the middle 40 % that have an income of below RM7,971, and T20 the top 20 % that have an income of below RM19,752 [32]. A total of 21 national secondary schools in Kuala Lumpur that are vernacular, single-gender, religious, and provide special education for students with special needs are excluded. Then, the 68 selected national secondary schools that include multiracial and a combination of male and female students from 13 to 16 years old were selected using Probability Proportionate to Size (PPS) sampling (Table 1). The method was selected to ensure that students from three District Education Offices of Wilayah Kuala Lumpur have the same probability of being sampled including Keramat Territory Education Offices, Bangsar Pudu Territory Education Offices, and Sentul Territory Education Offices.

Around 69, 984 students between the ages of 13 and 18 were registered in public secondary schools in Kuala Lumpur [33]. At least six secondary schools in Kuala Lumpur were chosen at random. The six National Secondary Schools represented by the clusters sampled were SMK Bandar Baru Seri Petaling, SMK Seri Tasik, SMK Seri Saujana, SMK Desa Tun Hussein Onn, SMK Sentul Utama, and SMK Kepong Baru. Therefore, 46 students from each school were estimated to participate in this study (Table 2).

The sample size was determined using correlation hypothesis testing sampling, as shown in equation (1). The correlation coefficient ($r = 0.224$) is based on Diana et al. [34] indicates that a minimum sample size 154 secondary school students are required to achieve statistical power for the study. According to a study conducted among school adolescents in Malaysia, about 81 % respond rate received by their respondents in their study [35]. For this reason, the expected proportion response rate for the present study was also recorded at 81 % with 90 % of the expected proportion eligible. After consideration of design effect, response rate, and expected proportion of eligibility, the final sample size required for this study was 275 respondents. Finally, a total of 184 students took part in this study with a response rate of 71.5 %. The reasons for some of the students not participating in this study were having internet connection problems, needing to be involved in other school activities, and not receiving permission from their parents.

$$\begin{aligned} N &= \left[\frac{Z_\alpha + Z_\beta}{c}\right]^2 + 3 \\ c &= 0.5x\,in\left[\frac{(1+r)}{(1-r)}\right] \\ n &= \left[\frac{(1.96+0.84)}{0.5xln\left[\frac{(1+0.22)}{(1-0.22)}\right]}\right]^2 + 3 \end{aligned} \tag{1}$$

where Z_α is the standard normal deviate for $\alpha = 1.96$, Z_β is the standard normal deviate for $\beta = 0.84(80\%)$, r is the expected correlation coefficient, and n = 154

An information sheet that explained the study was given to the students and their parents. During the data collection, the link to the digital consent form was distributed to facilitate obtaining consent from adolescents and their parents through their respective schools.

Table 1
Sampling with probability proportionate to size.

Steps	Calculations
Calculated sample size (n)	275
Total Population	69,984
Number of Clusters	6
Number of Individuals to be sampled from each cluster	275/6 = 45.8 ≈ 46
Sampling Interval (SI)	69,984/6 = 11,664
Random Start (RS)	5832

Table 2
Selected public secondary schools in Kuala Lumpur.

Cluster	Total schools	Cumulative Sum	Clusters Sampled	Individuals per cluster
Keramat Territory Education Offices	35	34164	5832	46
			17496	46
			29160	46
Bangsar Pudu Territory Education Offices	17	48396	40824	46
Sentul Territory Education Offices	16	69984	52488	46
			64152	46

2.3. Study instrument

Data were collected using a structured questionnaire in the dual language of Bahasa Malaysia and English which consists of five parts as follows: A: sociodemographic; B: perceived neighbourhood food environment availability; C: perceived neighbourhood food environment accessibility; D: perceived neighbourhood food environment affordability; and E: food frequency. The respondents were given option to request feedback on their dietary quality scores. The questionnaires were pre-tested on 30 secondary school adolescents from the t.

2.4. Measures

2.4.1. Sociodemographic characteristics

The sociodemographic factors such as sex (male, female), age (13–15 years, 16–17 years), ethnicity (Malay, Chinese, Indian, others), father's educational level (no formal education, primary education, secondary education, tertiary education), mother's educational level (no formal education, primary education, secondary education, tertiary education), monthly household income (<RM2500, RM2500-RM3169, RM3170-RM3969, RM3970-RM4849), respondent's monthly allowance, as well respondent's address were identified in the questionnaires. Secondary education in Malaysia is a continuation of primary education. It is divided into lower secondary education and upper secondary education. Respondents are the students who are in the lower secondary education include Form One (13 years old), Form Two (14 years old), and Form Three (15 years old), while students who are in the upper secondary education including Form Four (16 years old) and Form Five (17 years old). The sociodemographic information helps to provide a better understanding of the background of the respondents.

2.4.2. Dietary quality

Food Frequency Questionnaires (FFQ) were used in this study, was adapted from the Adolescents Nutrition Survey (ANS) [36] and validated for use with the study's adolescents [37]. The FFQ was self-administered, and adolescents were required to report food consumed over the past one month. The form had listed 136 food items which were categorized into 12 food groups and a food conversion table was given to ease the portion estimation. Given the average frequency of consumption for each food item as "Never", "1–3 times/month", "2–4 times per week", "One time a week", "5–6 times per week", "One-time a day", "2–3 times per day", "4–5 times per day" and "≥6 times per day". The result was presented in both continuous (mean and standard deviation) and categorical variables (poor, need improvement, high dietary quality).

The FFQ included 136 food items, with 12 food groups. For the scoring calculation, seven out of the twelve food groups were analyzed in this study to calculate the Malaysian Healthy Eating Index (HEI) scoring, which are cereals and grains, vegetables, fruits, milk and milk products, poultry, meat and egg, fish, legumes, the remaining are two nutrients such as % of energy from total fat and sodium. The original ANS FFQ required adolescents to state their number frequency of intake by themself. To simplify and ease the process, the intake frequency categories in this study were adapted from Appanah et al. [38]. These frequencies were manually converted to daily intakes using a standard conversion factor and linked with Malaysian Food Composition [39,40]. The food group is attached to the Supplementary Table 1.

The scoring method was adopted from the Appannah et al. [38] and Razali et al. [41] studies. Their scoring of the HEI components was estimated using recommendations described in the Malaysian Dietary Guidelines for Children and Adolescents (MDG). The total

Table 3
The score of Malaysian Eating Index components among the adolescents.

HEI components	The possible range of score	Criteria for a minimum score of 0	Criteria for a perfect score of 10
Cereal and grain	0 to 10	0 serving	6-9 servings
Vegetables	0 to 10	0 serving	3 serving
Fruits	0 to 10	0 serving	2 servings
Milk and milk products	0 to 10	0 serving	2-3 serving
Poultry, meat, and egg	0 to 10	0 serving	1-2 servings
Fish	0 to 10	0 serving	1-2 servings
Legumes	0 to 10	0 serving	1 serving
% of energy from total fat	0 to 10	0 serving	≤30 % energy from fat
Sodium	0 to 10	0 serving	≤2000 mg

score of each HEI component ranged from 0 to 10, with a high score indicating a high tendency to achieve the recommended intake of HEI components. A score of '10' (full marks) was given for respondents who achieved the recommended number of servings while a score of '0' was assigned for those who did not consume any serving. For components eight and nine, a score of '0' was given for those who exceeded the recommendation and a score of '10' was given for those who met the recommendation. On the other hand, in components one to seven, scoring was based on a person's degree of compliance with the food groups' intake. The mean HEI composite score of the respondents was converted into a percentage by dividing the total score of respondents by the maximum score of 90 and then multiplied by 100, as shown in equation (2). The total score ranged was 0–90, and the composite score ranged was 0–100 (Table 3).

$$Composite\ score\ for\ HEI = \frac{Total\ score\ of\ 9\ componets}{9x10} x100\% \quad (2)$$

On the other hand, the dietary quality of the respondents was measured and classified using HEI composite scores in percentage [37] Based on the total score of HEI, the dietary quality of the respondents was categorized into poor (0–50), require improvement (51–80), and good (81–100) [42].

2.4.3. Neighbourhood food environment status

The status of the neighbourhood food environment was measured by estimating the proportion of healthy food stores versus unhealthy food stores using spatial analysis. Healthy food areas were defined as those with a higher proportion of healthy food stores, while unhealthy food areas included food deserts (areas with dense unhealthy food stores) and food swamps (areas with zero healthy food stores). The concepts of food deserts and swamps were established in the scientific literature to determine neighborhoods with limited access to healthy foods. Food deserts have been defined as neighbourhoods that have low access to some or all the foods that are needed for a balanced, nutritionally adequate diet [43]. Food swamps refer to areas where there is an excessive amount of unhealthy food choices compared to healthy food choices [44]. This study excluded contributions examining the organisational food environment that defined as environments and practices around schools, workplaces and homes. It was identified as separate and complex elements of the food environment where different mechanisms play a role in its effect on diets and obesity [45]. Hence, the neighbourhood food environment in the context of residential addresses was selected as the only exhibition site.

The Universal Transverse Mercator coordinates of the food stores and respondent's home addresses were geocoded using Google Earth™ version 7.15 (Alphabet Inc., Mountain View, CA, USA). A polygon shapefile of Kuala Lumpur with a scale of 1:4,000,000 was obtained from the Ministry of Agriculture and Agro-Based Industries. The coordinate system was projected into Kertau (RSO)/RSO Malaysia in meters and then, undergoes geo-referencing. Five types of food stores in Kuala Lumpur were imported into the attribute table and mapped. Using the buffer analysis, 1000m buffer zones around respondent's addresses were generated. A 1000m distance was chosen for the buffer radius as it is commonly used in accessibility studies to represent a 10–15-min walk [46]. Spatial analyses were performed using the Open Source QGIS 2.8.1 software. The number of each five supermarkets, grocery stores, non-fast-food restaurants, convenience stores, and fast-food restaurants within the buffer zones were identified. The Modified Retail Food Environment Index (mRFEI) from the total food stores listed was calculated using the following formula:

$$MRFEI = \frac{\text{Healthy food stores}}{\text{Healthy} + \text{Unhealthy food stores}} = \frac{\begin{array}{c} grocery\ stores + suprmarket + \\ non - fast - food\ restaurants \end{array}}{\begin{array}{c} fast - food\ restaurants + convenience\ stores\ grocery\ stores + \\ supermarket + non - fast - food\ restaurants \end{array}} \times 100$$

The modified Retail Food Environment Index (mRFEI) represents the healthy percentage. A zero score of mRFEI indicates a food desert area. mRFEI value is <50 %, classified as a food swamp area. mRFEI value is ≥ 50 %, classified as a healthy neighbourhood environment. We have adopted the cut-off points for the mRFEI from the National Center for Chronic Disease Prevention and Health Promotion [47].

2.4.4. Perceived availability of neighbourhood food environment

The availability of perceived healthy and unhealthy food stores was adapted from Lim and Majid's [48] study, which collects the number of food store types available within a stipulated radius (1000m). The number of stores was collected using data from the perceived type of neighbourhood food environment. The current study gathered respondent's perceptions, and they were asked to estimate the number of listed stores available in their housing area if they walked 10 min or took 5 min to get there. The three healthy food store types are given as follows; (i) supermarkets, e.g., Giant, Econsave, and AEON Jusco; (ii) grocery stores, e.g., neighbourhood marts and speciality stores; (iii) non-fast-food restaurants, e.g., local restaurants, "mamak" restaurants and cafes. Whereas two unhealthy food store types available will be as follows; (iv) convenience store, e.g., 7-eleven, Petronas Mesra Mart, and Shell Mart; as well as (v) fast-food restaurant, e.g., Mc Donald's, Pizza Hut, Domino's Pizza and KFC.

Perceptions oof unhealthy and healthy food store availability was obtained through six questions on 4-point scale ranging from 4 = strongly agree,3 = agree, 2 = disagree, and 1 = strongly disagree. The sub-scale scores were summed up with the average score of items for each subject calculated and subsequently categorized into dichotomous scales of higher and lower categories [48]. Respondent's perceived neighbourhood healthy food availability was categorized into two variables, higher healthy food availability (>19.2) and lower healthy food availability (≤19.2). The questions were "It is easy to buy fresh fruits and vegetables (local/imported) in my neighbourhood," "The fresh produce (Tempe, tofu, meat, seafood) in my neighbourhood is of high quality", "There is a large selection of fresh fruit and vegetables (local/imported) in my neighbourhood", "It is easy to buy low-fat products, such as low-fat milk and lean

meats, in my neighbourhood", "The low-fat products in my neighbourhood are of high quality" and "There is a large selection of low-fat products available in my neighbourhood".

2.4.5. Perceived accessibility of neighbourhood food environment

Five questions were asked to assess perceived geographical accessibility to food stores Each question offered four responses options: "strongly agree", "agree", "disagree", and "strongly disagree". The respondent was also asked the estimated minutes if they walked from their home to the five different food stores. Respondent's perceived geographical food store accessibility was categorized into two variables, higher healthy food store assessable (>14.4) and lower food store assessable (≤14.4) [48]. For the food delivery services' usage frequency, the questionnaire was adapted from Zao and Bacao [49]. The respondent was asked, "From the past six months, how many times have you reached or used food delivery services (e.g., Grabfood, Food Panda, Bungkusit, DahMakan, McD delivery, etc.)?". Frequency options were provided either "at least 1 time for every 3 days", "at least 1 time per week", "at least 1 time for every 2 weeks", "at least 1 time per month", or "never". The respondent was required to answer only one option.

2.4.6. Perceived neighbourhood food affordability

A total of six perceived neighbourhood food affordability questions 4-options ranging from strongly agree, agree, disagree, and strongly disagree were used. The questions are "The fresh fruits and vegetables (local/imported) in my neighbourhood are affordable to me", "the fresh produces (tempe, tofu, meat, seafood) in my neighbourhood are affordable to me", "the low-fat products, such as low-fat milk and lean meats, in my neighbourhood are affordable to me", "the sugar-sweetened beverages in my neighbourhood are affordable to me", "the snacks (sweets, candies, chocolates, cookies, ice creams, and others.) in my neighbourhood are affordable to me" and "the fast foods in my neighbourhood are affordable to me". The affordability level was categorized as higher food affordability (>9.6) or lower food affordability (≤9.6) [48].

2.5. Statistical analysis

Data analysis was conducted using Microsoft Excel Worksheet and IBM SPSS Statistics version 25 software. Data distribution has been ensured by assessing normality using appropriate analyses before continuing with further analysis. The univariate analysis was used to analyze descriptive data. The results were presented in percentages and frequencies for categorical variables. Whereas continuous variables were presented in frequency, mean, and standard deviation. Pearson correlation was used to assess the relationship between continuous variables such as age, family monthly income, and adolescents' monthly allowance with dietary quality scores. The Chi-Square Test was used to evaluate the associations between categorical variables. Multiple Linear Regression (MLR) analysis was conducted to provides a more refined analysis by considering other influencing factors. R-squared (R^2) values were reported to indicate the proportion of variance in dietary quality explained by the predictors. A statistical level of $p < 0.05$ was considered as significant.

Table 4
Sociodemographic characteristics of adolescents in Kuala Lumpur during the year 2021 ($n = 184$).

Sociodemographic characteristics		*n* (%)	Mean ± SD
Age (years)			14.67 ± 1.02
	13–15	143 (77.7)	
	16–17	41 (22.3)	
Gender			
	Male	74 (40.2)	
	Female	110 (59.8)	
Ethnicity			
	Malay	75 (40.8)	
	Chinese	76 (41.3)	
	Indian	26 (14.1)	
	Others	7 (3.8)	
Father's educational level			
	No formal education	2 (1.1)	
	Primary education	14 (7.6)	
	Secondary education	121 (65.8)	
	Tertiary education	47 (25.5)	
Mother's educational level			
	No formal education	3 (1.6)	
	Primary education	17 (9.2)	
	Secondary education	99 (53.8)	
	Tertiary education	65 (35.3)	
Monthly household income (RM)			3426.60 ± 1274.15
	<2500	43 (23.4)	
	2500–3169	53 (28.8)	
	3170–3969	6 (3.3)	
	3970–4849	83 (44.6)	
Respondents' monthly money allowance (RM)			101.06 ± 97.40

3. Results

3.1. Sociodemographic characteristics

There are 184 students participating in this study, whereby 40.2 % are males and 59.8 % are females. Higher respondents were in the age group of 13–15 years old (77.7 %) compared to 16–17 years old (22.3 %), with their mean age was 14.67 ± 1.02 years. Most of the respondents were Chinese (41.3 %), followed by Malays (40.8 %), and Indians (14.1 %). The majority of the respondents' fathers (65.8 %) and mothers (53.8 %) completed secondary education at their highest educational level. The mean parental monthly income was RM3426.60 ± 1274.15, and the majority (44.6 %) of respondents had a household income of RM3970 per month. Meanwhile, the mean of students' monthly money allowance was RM 101.06 ± 97.404 (Table 4).

3.2. Dietary quality

The percentage energy from fat (10.0 ± 0.00) had the highest mean score followed by fruits (8.50 ± 3.41), fish (8.04 ± 3.98), poultry, meat, and egg (7.12 ± 4.54), legumes (6.85 ± 4.66), and cereal and grain (6.78 ± 3.93). Meanwhile, the sodium (1.52 ± 3.46), milk products (3.58 ± 4.50) and vegetable (4.95 ± 4.52) components had the lowest mean score among the respondents. The total mean score of the respondents was 57.3 ± 15.9, whereas the HEI per cent score of the respondents was 63.7 ± 17.6. Most of the respondents had a dietary quality that requires improvement (62.0 %), compared to 23.9 % who had a poor diet and 14.1 % were good (Table 5).

3.3. Sociodemographic factors, characteristics of the neighbourhood food environment and its correlation with dietary quality

Age displayed a significantly inverse association with the HEI score (r_s = -0.19, p = 0.01). Gender was not significantly correlated with the respondents' HEI scores (X^2 = 0.09 p = 0.66). Their ethnicity (X^2 = 5.74, p = 0.05) and their father's educational level (r_s = 0.15, p = 0.04) were positively correlated with HEI scores. The income among the B40 family background was categorized into four categories, yet it was not associated with the HEI scores of the respondents (r_s = -0.02, p = 0.83). On the other hand, respondents' monthly money allowance shows no significant correlation with respondents' HEI scores (r_s = 0.023, p = 0.759) (See Supplementary Table S2).

Most respondents lived in the healthy food area (60.3 %), followed by the food swamps area (37.0 %). Only 2.7 % of respondents were living in a food desert area. The most common food store available in the respondents' neighbourhoods was a non-fast-food restaurant (10.01 ± 6.20), then followed by fast-food restaurants (8.28 ± 5.51), convenience stores (3.43 ± 2.02), and supermarket and grocery stores (2.59 ± 2.01). The majority (81.5 %) of the respondents perceived the highly healthy food stores available in their neighbourhood area, compared to the low healthy food stores (18.5). The most common food store perceived available was a supermarket and grocery stores (5.28 ± 3.62), then followed by non-fast-food restaurant (3.37 ± 2.60), convenience stores (2.77 ± 1.95) and fast-food restaurants (2.70 ± 2.56). Most (76.7 %) of them said that their neighbourhood was available with many fresh and quality food products, which corresponds to high healthy food availability. However, slightly higher among them reported low accessibility to healthy food stores which is 51.6 %. About 33.2 % of them never use food delivery services, followed by at least once per month (31.5 %), once every two weeks (16.3 %), and once per week (19.0 %). Perceived higher food affordability accounted for 64.3 % which indicates that the majority of respondents felt their food affordability level was acceptable.

Dietary quality scores were not significantly correlated with the type of neighbourhood food environment (p = 0.61). In terms of

Table 5
The score of Malaysian Healthy Eating Index and dietary status of adolescents in Kuala Lumpur during the year 2021 (n = 184).

HEI and dietary status	Mean ± SD
HEI component score	
Cereal and grain	6.78 ± 3.93
Vegetable	4.95 ± 4.52
Fruits	8.50 ± 3.41
Milk and milk products	3.58 ± 4.50
Poultry, meat, and egg	7.12 ± 4.54
Fish	8.04 ± 3.98
Legumes	6.85 ± 4.66
% of energy from total fat	10.0 ± 0.00
Sodium	1.52 ± 3.46
Malaysian HEI	
Total score	57.3 ± 15.9
Composite score (%)	63.7 ± 17.6
Dietary quality status	
Poor	44 (23.9)
Require improvement	114 (62.0)
Good	26 (14.1)

the number of food stores available in the neighbourhood, there is a correlation ($p < 0.05$) between dietary quality score with non-fast-food restaurants and convenience stores, compared to supermarket and grocery stores ($p = 0.44$) and fast-food restaurants ($p = 0.16$). There is no significant correlation between dietary quality score with perceived type of neighbourhood food store availability, perceived number of food stores available in the neighbourhood, perceived neighbourhood healthy food availability, perceived geographical food store accessibility, and food delivery service frequency. The neighbourhood food environment characteristics of the respondents and their correction with the neighbourhood food environment was displayed in Supplementary Table S3.

After conducting multiple linear regression (MLR), ethnicity ($\beta = 0.180$, $t = 2.283$, $p = 0.020$) and father's educational level ($\beta = 0.177$, $t = 2.113$, $p = 0.036$) and monthly household income ($\beta = -0.169$, $t = -2.160$, $p = 0.032$) were identified as significant associated with dietary quality, indicating that higher values in these factors are associated with better dietary quality. In contrast, monthly household income reported a negative association with dietary quality, suggesting adolescents from higher income households had better dietary quality scores. Other variables, however, showed no significant association with dietary quality (Table 6). The regression model explained 18.6 % of the variance in dietary quality ($R^2 = 0.186$), showing that the factors accounted for nearly one-fifth of the variability in dietary quality. This underscores the importance of ethnicity, father's educational level, and household income while suggesting other factors may influence the remaining variance.

4. Discussion

To the best of our knowledge, this is the first study in Malaysia that examined the type of neighbourhood food environment dwelled among adolescents who had parents with household incomes classified as B40 in Kuala Lumpur, as well as the first study to conduct spatial analysis using the food swamps and food desert categorization. Despite most adolescents living in a healthy food environment, most of their dietary quality is recorded as poor and requires improvement. Looking back on the trends from previous studies, the HEI scores of adolescents from Kuala Lumpur were recorded at 37.9 ($n = 373$) in 2015 and increased to 49.1 ($n = 337$) in 2020 [38]. This study indicates that the dietary quality of the adolescents in Kuala Lumpur has shifted from the poor dietary quality status within a five-year period, which requires improvement on their diet.

Inadequacies in adolescents' diets (aged 11–18) are highlighted by the National Diet and Nutrition Survey, including high intakes of saturated fat (12.4 %) and sugars (14.1 %). Additionally, a large fraction of this population's intakes of iron (32 %), calcium (16 %), zinc (22 %), magnesium (38 %), potassium (28 %), iodine (20 %), and vitamin A (21 %) are below lower reference nutrient intakes [50]. The availability of food options in the school can significantly influence adolescents' dietary choices. However, most secondary school students still choose to not bring food to school [51]. Compared to school-prepared meals and packed lunches, students who purchase food from nearby outlets consume higher energy-dense, non-core foods and often results in lower fewer micronutrients intake which reduce the overall quality of their diets [52].

Table 6
Multiple linear regression result between sociodemographic characteristics and HEI scores of adolescents in Kuala Lumpur during the year 2021 ($n = 184$, $R^2 = 0.186$).

Socio-demographic characteristics	Unstandardized coefficient		Standardized coefficient	t	*p*-value
	B	Std.error	Beta		
Constant	24.709	17.028		1.451	0.149 ^{ns}
Age (years)	−3.310	3.236	−0.087	−1.023	0.308 ^{ns}
Gender	1.602	2.419	0.050	0.662	0.509 ^{ns}
Ethnicity	5.434	2.710	0.168	2.005	0.047*
Father's educational level	9.277	4.888	0.165	1.898	0.050*
Mother's educational level	4.244	4.127	0.083	1.028	0.305 ^{ns}
Monthly household income (RM)	−0.002	0.001	−0.169	−2.160	0.032*
Respondents' monthly pocket money (RM)	0.003	0.012	0.018	0.243	0.809 ^{ns}
Type of NHD food environment	5.240	2.941	0.180	1.781	0.077 ^{ns}
Number of food stores available in NHD					
Supermarket and grocery stores	0.034	0.684	0.004	0.049	0.961 ^{ns}
Non-fast-food restaurant	−0.557	0.414	−0.218	−1.346	0.180 ^{ns}
Convenience stores	−0.981	0.723	−0.127	−1.357	0.177 ^{ns}
Fast-food restaurants	0.368	0.410	0.128	0.897	0.371 ^{ns}
Perceived type of NHD food store availability	−1.510	3.371	−0.037	−0.448	0.655 ^{ns}
Perceived number of food stores available in NHD					
Supermarket and grocery stores	−0.132	0.427	−0.030	−0.310	0.757 ^{ns}
Non-fast-food restaurant	0.791	0.597	0.129	1.323	0.188 ^{ns}
Convenience stores	−0.198	0.805	−0.024	−0.247	0.806 ^{ns}
Fast-food restaurants	−0.257	0.634	−0.042	−0.406	0.685 ^{ns}
Perceived NHD healthy food availability	2.342	3.137	0.062	0.746	0.456 ^{ns}
Perceived geographical food store accessibility	−3.550	2.395	−0.112	−1.482	0.140 ^{ns}
Food delivery service frequency	−1.457	0.951	−0.114	−1.533	0.127 ^{ns}
Perceived NHD food affordability	3.181	2.886	0.096	1.102	0.272 ^{ns}

*Significant at <0.05.
^{ns} not significant.
NHD = Neighbourhood.

Furthermore, many students favour quick, grab-and-go foods, frequently picking options that are high in calories and low in micronutrients [53]. Other factors that affect students' food choices at schools include price, length of queues, the availability of food, and the presence of competitive food outlets close by Refs. [54,55]. Adolescents also frequently skip their breakfast, snack in front of a screen, and eat less frequently with their families, which have been linked to unhealthy diets [56].

It is known that people who are overweight as adolescents have a greater probability of developing obesity, chronic diseases such as cardiovascular diseases and diabetes mellitus, and premature death in later years [57]. One main contributing factor is an unhealthy diet, especially one low in fruits and grains, and high in sodium [58]. An unhealthy diet also leads to physiological changes associated with obesity and overweight through imbalances between calories consumed and calories expended [59]. It is well established that improving dietary quality is essential to address the rising obesity rates [60]. The differences in dietary quality between ethnic groups may be a result of cultural differences in the types of foods consumed and food preparation methods [41,61]. Malay ethnic groups were found to consume more Western and convenience products compared to other ethnicities due to the "Halal" status, food safety, and rapidity of service [62].

Father's education could influence the awareness of choosing healthy food choice through good food parenting practices such as preparing healthy foods, suggesting the mother to use healthier cooking methods, making sure there is healthy food at home, and buying nutritious food together with their children [63]. Liu et al. [64] found that the fast-food intake among adolescents was lower when adolescents perceived that their fathers set limits for fast-food intake for them. Their consumption of sweets or salty snacks was lower when they perceived that their fathers modelled intake of sweets or salty snacks less frequently and brought sweets or salty snacks available at home less often. Fathers' knowledge and involvement in parenting practices may be an important intervention goal to minimize intake of energy-dense and consumption of nutrient-poor foods as snacks.

The significant negative relationship between monthly household income and dietary quality with existing literature, which highlights the challenges faced by low-income households in accessing healthier food options. Studies have shown that individuals in lower socioeconomic neighbourhoods often face limited availability of healthy food and tend to rely more on affordable, less nutritious options [65,66]. This pattern is consistent with findings in Malaysia, where lower-income households (B40) spend a larger proportion of their income on food but still struggle to afford healthier choices [67]. International studies further support the perception that income constraints negatively impact dietary quality, particularly among adolescents in low-income urban areas [68,69]. Therefore, this study highlights how important household income is when it comes to dietary habits, especially for those with lower incomes.

Primarily, non-fast-food restaurants are considered healthy food stores because they serve a balanced diet of good and unhealthy foods and use raw, fresh products in their cooking [70]. However, this study found that the availability of non-fast-food restaurants and dietary quality among adolescents were not significant.

Similarly, low-income adolescents' dietary quality was correlated to neighbourhood convenience stores availability [18,71]. Convenience stores are categorized as unhealthy food stores and are often stocked with fewer healthful grains, fruits, and veggies than supermarkets [72]. Thus, the increased presence of these stores results in unhealthy item purchases and consequently low dietary quality among the residents. Although the negative relationship suggests that increased availability of convenience stores may lead to a decrease in dietary quality, the evidence is not sufficient to conclude that these factors significantly affect dietary quality. More research is needed to examine the specific types of foods offered in these stores and how they directly affect adolescents' dietary quality.

High percentage of perceived healthy food availability and affordability were found in this study. Denoting that many adolescents who had parents with household incomes classified as B40 in Kuala Lumpur believe their neighbourhoods have a variety of food stores which offer fresh products and that the prices are also affordable for them. Despite that, lower perceived geographical food store accessibility was also recorded, denoting that many adolescents find it harder to reach those healthy food stores by walking. Moreover, most policies aimed to decrease food deserts by expanding supermarkets to low-income areas, and thus, residents will demand more healthy food [73,74]. However, contrary to popular belief, those living in areas with ample nutritious food do not inevitably eat healthy [75].

Food accessibility and diet quality are not significantly correlated, possibly due to adolescents' travel capacity. Adolescents can travel longer distances independently and use public transportation more than adults [76]. Due to Kuala Lumpur's advanced transportation systems, adolescents may have chosen food places outside their residential buffer zone. Besides, the availability of personal transportation may also allow them to access food destinations outside their immediate walksheds [65]. Future research should look at other levels of influence on the neighbourhood food environment in adolescents' lives, including school, to get a more comprehensive view of the multiple levels of influence that contribute to adolescent dietary quality. Furthermore, studies that compare interventions that focus on the residential food environment only, the school food environment only, or both together would be important to carry out to confirm results from the current study. It is suggested to expand this study in future to include more schools enabling more comprehensive analyses. Given the importance of social factors in school food choices, there are significant opportunities for policy and health promotion interventions that involve adolescents in education, food systems, health, social welfare, and digital media [77,78]. Besides, measuring the totality of places the teens visit on a routine basis – activity space – should be considered in future studies. This may offer additional insight into how their dietary behaviours are associated with specific types of food environments encountered during daily activities. For example, exposure to healthy food options in an individual's activity space might promote better dietary habits, while frequenting areas with predominantly unhealthy food options could have the opposite effect [79,80].

Additionally, to our knowledge, this is the first study to examine the relationship between the use of online food delivery and B40 adolescents' dietary quality, however, it is not significant. The insignificant associations could be explained by the affordability of online food delivery services. Ali Othman [81] reported that food prices offered by online food delivery services are comparable higher than retail pricing, particularly during the pandemic (23.0 % higher), leading to a reduction in purchasing especially by teens. Besides,

it is possible that delivery purchases were made by someone other than the respondents, which was not recorded in this study and may influence respondents' dietary intake.

The strength of this study is it was one of the first studies that assessed the relationship between the neighbourhood food environment and dietary quality among a representative Malaysian adolescent population sample who came from low-income family. Another strength is this study uses a GIS technique for mapping several types of neighbourhood food stores and home addresses and determining 1000m buffer zones around respondents' addresses, integrated with sociodemographic data. Furthermore, focus groups with adolescents aged 13–17 years old were considered valuable when topics addressed their own experiences [82], and most of them spoke passionately and had more to say than time allowed. This study also included diverse backgrounds among respondents and the educational level of their parents. Education is a frequently employed indicator of socioeconomic status, as it is thought to show a person's cognitive knowledge and ability to remember health information. It is also likely to affect both occupation and income [83]. Occupation and income can change during a person's lifetime, but education appears to be consistent [84]. Considering the adolescents and their parents' educational level reflects the dietary habits in the area where they lived. Moreover, the use of MLR to analyze complex relationships between sociodemographic factors and dietary quality added rigor to the study by controlling for confounding variables and providing more robust conclusions [85].

Despite these strengths, this review has several limitations. Firstly, it is impossible to make causal inferences regarding the effect of the neighbourhood food environment on dietary quality due to the cross-sectional nature of the study. Secondly, the dietary intake assessment was self-reported, it may be that the data obtained was not accurate due to the recall and systematic biases. Third, this study did not investigate the under and over-reporting of energy intake by respondents due to the unavailability data on physical activity. Fourth, the stores available and the type of neighbourhood food environment were manually counted via GIS, which means that there might be stores in the neighbourhood food environment which are not included in the database and human error is possible. The current study also did not include questions about the type of vehicle respondents own or their frequency of use of public transportation. This may contribute to the inability to demonstrate a clear relationship between neighbourhood walking distance and dietary quality among adolescents. The exclusion of the food environment around and within schools also presents study's limitation. These environments play a crucial role in shaping dietary behaviours, especially for adolescents who spend a significant portion of their day in school settings. Finally, it is important to note that the concept of activity space was not measured in the current study, capturing detailed movement patterns and providing a richer dataset to explore complex relationships between the food environment and dietary behaviours.

5. Conclusion

Age, ethnicity, father's educational level, and the presence of non-fast-food restaurants and convenience stores were all found to be associated with dietary quality. However, further analysis revealed that ethnicity, father's educational level, and total household income were the main factors significantly predicting dietary quality. This suggests that while factors like age, non-fast-food restaurants, and convenience stores may initially seem important, their influence on dietary quality is likely influenced by other sociodemographic variables. Strategies to improve dietary habits among adolescents should focus more on socio-demographic factors such as ethnicity and parental education. Despite the findings that a minority of them lived in food swamps and food deserts, their dietary quality status must be improved, as they perceived low accessibility to healthy food stores in their neighbourhood. These findings imply that the neighbourhood accessibility to healthy food stores may influence the intake of foods high in nutrients, and thereby, the potential nutrient adequacy of diet and the risk of micronutrient deficiencies. The variety and abundance of all types of food stores may potentially reduce the propensity to visit fast-food restaurants. Their purchasing choices may be influenced by their exposure to a large number of potentially "healthy" and "unhealthy" food stores in their area, with healthy food options probably competing with unhealthy food options. Local government could emphasize an overall balance of healthy food stores when designing neighbourhoods to reduce the propensity for unhealthy food store visitation. Another study implication is for the local government, planners and stakeholders to include dieticians in the regulation, modification and management of adolescents' food environments. Macro-level regulations and policies should be implemented, such as regulating the distribution and density of food stores in improving the health-impeding neighbourhood food environment surrounding adolescents' residential areas. Hence, multi-component interventions including educational, policy, parent participation, food environmental components, and behavioural components, could be beneficial in promoting healthy eating habits when planning for the residential development. A nutrition education program that is community-based, multi-level, and multi-components needs to collaborate with grocery shops, supermarkets, non-fast-food restaurants, and convenience stores to successfully enhance the availability of healthy foods and improve the availability of healthy menu alternatives. Future research should incorporate the neighbourhood food environment in schools, compare it with residential areas, examine interventions targeting both settings, and use multivariate analyses to further investigate the relationships between both residential and school neighbourhood food environments with dietary quality to better enhance the dietary quality among children.

CRediT authorship contribution statement

Nurfarhana Norddin: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nik Norasma Che'Ya:** Writing – original draft, Visualization, Supervision, Conceptualization. **Nur Adibah Mohidem:** Writing – original draft, Visualization, Conceptualization. **Nurzalinda Zalbahar:** Writing – original draft, Visualization, Project administration, Funding acquisition, Conceptualization.

Data availability statement

The dataset includes sensitive personal information and sharing it openly would conflict with privacy laws and commitment to ethical standards that prioritize participant confidentiality. The data will be included as results tabulated and presented as it is.

Ethics declaration

The ethic approvals were obtained from the Ethics Committee for Research involving Human Subjects Universiti Putra Malaysia (JKEUPM) (Reference number: JKEUPM-2021-464), Ministry of Education Malaysia, and State Education Department of Kuala Lumpur. All participants provided informed consent to participate in the study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2025.e42247.

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