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Abstract

Objective: Food environments are a major determinant of children's nutritional status. Scarce evidence on food environments exists in low and middle-income countries (LMICs). This study aims to fill this gap by documenting the obesogenicity of food environments around schools in Greater Tunis, Tunisia – an LMIC of the Middle East and North Africa region with an ongoing nutrition transition and increasing rates of childhood obesity.

Design: In this cross-sectional study, we assessed built food environments around 50 primary schools. Ground-truthing was performed to collect geographic coordinates and pictures of food retailers and food advertisement-sets within an 800-meter road-network buffer of each school. Retailers and advertisement-sets were categorized as healthy or unhealthy according to a NOVA-based classification. Associations between school characteristics and retailers or advertisement-sets were explored using multinomial regression models.
Setting: Greater Tunis, Tunisia.
Participants: Random sample of 50 (35 private and 15 public) primary schools.

Results: Overall, 3,621 food retailers and 2,098 advertisement-sets were mapped. About two thirds of retailers and advertisement-sets were labeled as unhealthy. Most retailers were traditional corner stores (22%) and only 6% were fruit and vegetable markets. The prevailing food group promoted was carbonated and sugar-sweetened beverages (22%). The proportion of unhealthy retailers was significantly higher in the richest vs. poorest areas.

Conclusions: School neighborhood food environments included predominantly unhealthy retailers and advertisements. Mapping of LMIC food environments is crucial to document the impact of the nutrition transition on children's nutritional status. This will inform policies and interventions to curb the emergent childhood obesity epidemic.

Keywords

School neighborhoods; Retail food environments; Food advertisements; Geographic Information System; Low- and middle-income.

Short title: Food environments around schools in Tunisia.

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Background

Over the last decades, childhood overweight and obesity have dramatically increased in low- and middle-income countries (LMICs), with the Middle East and North Africa (MENA) region experiencing one of the largest increases in childhood obesity rates, reaching around 20% in 2016 [1]. Complex and intertwined factors that span the socio-ecological model have been shown to influence children's diet and nutritional status [2]. Among these factors, the intermediate structures or meso-level factors, such as school neighborhood food environments, play a major role in shaping children's food choices and subsequently weight status [3].

Food environment is defined as "the interface within which people interact with the wider food system to acquire and consume foods" [4, p, 95]. As it includes the multitude of food options available to people in their environments, it can influence food choices, purchasing behaviors, and dietary intake – all of which have implications on the development of obesity and other diet-related non-communicable diseases (NCDs) at all stages of life [4, 5]. Promoting healthy food environments is a public health priority – it is among the objectives of the United Nations Decade of Action on Nutrition 2016-2025 in fighting malnutrition [6] and has implications on a wide range of nutrition-related Sustainable Development Goals (SDGs) including SDG 2 "Zero hunger" and SDG 3 "Good health and wellbeing" [7].

Food environments might influence food habits through direct access to foods or through food cues and desire [8, 9] – this influence is even more marked among schoolchildren. School and its neighborhood are key sites that influence food choices as children spend a large portion of their day in school and are more autonomous in their food choices [10, 11]. Beyond food provided within the school itself, children might buy snacks from outlets in the vicinity of schools during recess or on their way to and from school [12-14]. One study conducted in Scotland, showed that about 14% and 30% of children from primary and secondary schools, respectively, purchased food from outlets on their way to /from school [14] . Food advertisements can also influence children's food choices within school hours and after [15]. Some evidence shows that fast food restaurants and food advertisements tend to cluster around schools [16, 17] with sugar-sweetened beverages and high-fat foods being among the most advertised products [17, 18]. It has been hypothesized that school neighborhood food environments can facilitate exposure and access to low-cost, energy-dense, and ultra-processed foods – all of which might encourage children to choose, purchase, and consume

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unhealthy food. Conversely, food environments that mainly offer and promote healthy and nutritious food choices (such as fruits, vegetables, or unprocessed/minimally processed foods), might improve children's diet quality and weight status [19, 20].

Socio-economic patterning of built food environments has also been documented in several high-income countries (HICs). For instance, density of fast-food restaurants was higher around schools located in disadvantaged areas as compared to those in more advantaged ones [21, 22]. Similarly, advertisements promoting unhealthy foods were more frequent in areas with high levels of socio-economic deprivation as compared to those with lower levels [23, 24]. Other studies conducted in HICs found minor or no significant associations between area-level socio-economic status (SES) and type of food retailers or advertisements [25, 26].

The available literature on built food environments highlights the multitude of metrics (e.g., count, count per area, proximity, etc.), geographic boundaries (e.g., areal, person-centric, or buffer measures) and classification systems used in food environments research [27, 28]. Also, most food retailer constructs used in the literature (e.g., convenience stores, fast food restaurants, grocery stores) are designed for HICs and are often inappropriate for LMICs, where many traditional food retailers do not fit within these pre-defined constructs [28]. This hinders comparability across studies and might explain the inconsistent results observed in research looking at associations between food environments and children's nutritional status.

While there are considerable studies from HICs on school neighborhood food environments, less evidence exists in LMICs – with most studies being of low-quality [29]. To the best of our knowledge, few studies have assessed the neighborhood food environment in the MENA region [30, 31] and none have assessed it using geospatial methods [29]. This is a considerable research gap given that the last decades have been marked by substantial changes in food systems and dietary behaviors in the MENA region with multiple countries experiencing rapid nutrition and epidemiological transitions [32]. Tunisia is a lower-middle-income country of the MENA region having experienced rapid rates of economic development and urbanization. Childhood overweight rates in Tunisia have doubled over the past decades [1] with estimates reaching 29% in boys and 32% in girls among 6- to 9-year-old children living in Greater Tunis [33].

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This study aims to fill this important research gap by providing a comprehensive assessment on the quality of the built (i.e., external) food environment around Tunisian primary schools. The study objectives are to (1) map all types of food retailers and food advertisements present around primary schools in urban areas of Tunisia; (2) classify these food exposures as healthy, unhealthy, or mixed, using a typology derived from the NOVA classification [34]; (3) describe food retailers and advertisements using count, density, and proximity measures; and (4) investigate whether these food exposures differ by geographic and/or socio-economic characteristics.

Methods

Study site and sample

This study is part of a larger project entitled "School and community drivers of child diets in Arab cities; identifying levers for intervention (SCALE)", which aimed to investigate school and community-level drivers of children's food choices in two Arab cities: Greater Tunis in Tunisia, and Greater Beirut in Lebanon [35]. For the present study, we focus on the Tunisian part of the project. Tunisia has 11 million inhabitants with two thirds of the population living in urban areas. The study area is the "Greater Tunis" region, which includes the four "Governorates" of Ariana, Ben Arous, Manouba and Tunis (the capital city) [36]. A cross-sectional survey used a random sample of 50 primary schools proportionally stratified by type of schools (public (70%) vs. private (30%); 50 children were then randomly selected within each school. The sample size of 50 schools was based on the sample size calculation conducted for the SCALE project – further details can be found elsewhere [35] .

School neighborhood food environment

School neighborhood unit and mapping protocol

All food retailers and food advertisements present within an 800-meter road network of each school were mapped through ground-truthing; i.e., in-person mapping with direct observation and measurement/assessment on the ground of food exposures [37]. Ground-truthing was performed as (1) no commercial or governmental lists on food retailers are publicly available in Tunisia and (2) field observation is considered the gold standard to document all existing food exposures in neighborhoods [4]. We opted for an 800-meter road network buffer around schools as it corresponds to the distance that an average school-aged child can walk within 10 min [38] – which is a logical walking duration for children. To draw the buffers, a governmental open-source map of Greater Tunis main roads (n=812) was used as the base

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map. Manual drawing of street-level roads was conducted using both Google Earth and street map view base maps on ArcGIS (ArcGIS 10, ESRI Inc. CA); 7,357 streets were thus added to the map.

Data collectors were given mobile phones with integrated Geographic Positioning system (GPS) and asked to collect geographic coordinates and pictures of all food retailers (including informal ones) and food advertisements present within the 800-meter road network buffers of each of the 50 schools using two applications: Collector Classic® and Survey123® (ESRI Inc., Redlands, CA). Pictures of food retailers and advertisements were taken as a verification step for quality assurance. The geographic coordinates of schools were also collected. The neighborhood mapping was conducted from September till October 2020 which coincides with the re-opening of schools after the COVID-19 lockdown lift in Tunisia. Mapping was also conducted during normal school hours to capture regular food environments on school days. Training of data collectors, piloting of the data collection tools, field monitoring, and verification of data entered after each field visit were all conducted to collect high-quality data. Reporting of this study-method is based on the GeoFERN framework [27].

Dimensions assessed

The definitions and terminology related to food environments that are used in this paper are mostly based on the conceptual framework developed by Turner et al (2018). We assessed availability (i.e., count, density, and proportion) of the different types of food retailers and advertisements, as well as accessibility or physical proximity of schools to the nearest food retailers [4].

Food retailers and food advertisements: Construct definitions and classification system

Given that there is no consensus on a classification system to categorize food environments as healthy vs. unhealthy, we opted for a typology derived from the NOVA classification system. The NOVA classification categorizes foods into four groups according to the extent of food processing level [34]. Foods in Group 1 are unprocessed and minimally processed foods such as fresh fruits and vegetables, and flours. Foods in Group 2 are processed culinary ingredients such as oils, honey, sugar and salt. Group 3 is for processed foods such as unpackaged breads, canned vegetables, and cheeses. Group 4 is for ultra-processed foods such as packaged snacks, chips, chocolates, and processed meat. We chose this NOVA-based typology given the evidence that food processing levels, rather than individual nutrients or food items, might be a major driver of childhood obesity with multiple studies associating

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intakes of ultra-processed foods with overconsumption and increased body weight [39, 40]. Below, a description of the NOVA-based constructs that we developed and used for this study.

1. *Food retailers*

This included all food or drink establishments within the 800-meter buffer zone (including side streets and building complexes) such as eating places, stores, markets, outlets, and mobile vendors. Food retailers were first categorized by type into 14 groups using a checklist adapted for the Tunisian foodscape. This checklist was developed by the research team after extensive discussions among team members; it included definitions, local examples, and sample pictures of each type of Tunisian food retailer (Supplementary figure 1, Additional file 1). The 13 categories were further grouped into six then three constructs (healthy, mixed, unhealthy) based on the processing-level of the prevalent foods sold within the retailer as shown in Table 1. For this, findings of a previous in-store audit conducted in Tunisia was used [41]. In the latter study, photos of all food products available in different types of food retailers were taken. Four trained nutritionists coded and classified all photographed food products into separate NOVA groups [34]. A list of 1436 unique varieties of these was established. The food retailers were then classified according to the relative abundance of NOVA food groups into unhealthy, neutral and healthy retailers.

2. *Outdoor food advertisements*

This encompassed all outdoor advertisements promoting food or drink products present within the 800m road-network buffer zone. We used a protocol derived from the International Network for Food and Obesity/NCDs Research, Monitoring and Action Support (INFORMAS) tools [42]. We included billboards, logos, signs, pictures, and storefronts advertisements as well as outdoor pictures or drawings of unbranded food or drink products as these also provide significant food cues. Temporary advertisements, such as those on stationary delivery vehicles, were excluded. For the remaining of the paper, the term food advertisements refer to any visual depiction of foods or drinks whether branded or not. All food and beverage advertisements available in one single geographic location (e.g., storefront of a food outlet) were considered as one set of advertisements (i.e., one exposure). Each advertisement set might include several food groups as it can promote more than one food or beverage product.

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Similar to food retailers, food advertisement-sets were grouped into three constructs (healthy, mixed, unhealthy) as shown in Table 1. For this, each food item included within the advertisement set was categorized into the four NOVA groups [34]. For comparability purposes, we additionally classified each food item into 21 groups using a checklist derived from the World Health Organization (WHO) nutrient profile model for the African region – the latter being a model that categorizes foods into permitted and not permitted to be marketed to children [43] (Supplementary table 1, Additional file 1). To avoid any misclassification, a rigorous protocol was implemented whereby two independent researchers reviewed all the geotagged pictures to assign the NOVA and WHO groups. As an example, an advertisement set which included breakfast cereals and apples would receive the following labels: (1) "NOVA group 4: breakfast cereals" and (2) "NOVA group 1: fresh fruits and vegetables". This advertisement set would be further categorized as "Mixed: Advertisement set including both unprocessed and processed foods".

Covariates

School-level measures including the type of school (private vs. public) and the departments (i.e. districts) and governorates where school are located were also collected during fieldwork. Poverty rate (as percentage per capita) and total population count (as total number of individuals) of each department of Greater Tunis were retrieved from a report produced by the National Institute of Statistics in Tunisia, in collaboration with the World Bank [36].

Data analysis

The geocoded locations of schools, food retailers and food advertisements were visualized using a Geographic Information System (GIS) software (ArcGIS Pro 3.0.0, ESRI Inc., Redlands, CA, USA). Analyses for food retailers and food advertisements were conducted separately.

Descriptive analyses were conducted in two ways:

- - First, we studied the frequency distribution of types of retailers and advertisement-sets pooled over the 50 schools, and this to provide an overall availability measure (i.e., GIS point data is the unit of analysis).
- - Second, we computed the count and density per school. Count was the number of each type of retailer and advertisement set in the 800-meter buffer around each school. For schools with overlapping buffers, food retailers and advertisement-sets were included in the count of each

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school. Density was calculated by dividing the count of each type of retailer and advertisement set by the surface area for each school: the surface area was the service area polygon of an 800-meter road network buffer (Supplementary figure 2, Additional file 1). For each school we also generated the shortest path (proximity) to the closest retailer by type. We used network distance, which accounts for the street network, rather than Euclidean distance as it better mimics the actual travel distances [44]. Median and inter-quartile range (IQR) across the 50 schools were computed for count, density and proximity data (as data was not normally distributed).

To explore potential factors associated with different types of food retailers or advertisement-sets (i.e., healthy, mixed, and unhealthy), multinomial regression models with type of retailer or advertisement set as response variables were conducted (using retailer or advertisement set as the unit of analysis, respectively). All models accounted for the school-level clustered sample, and included the following covariates: type of school (private vs. public), distance from school to food retailer or advertisement set within each buffer, governorate where school is located, poverty rate and population count of the departments where school is located. Crude and adjusted relative prevalence ratios (RPR) with 95% confidence intervals and using the "healthy" category as the response reference category were presented.

A sensitivity analysis using 400-meter and 200-meter road-network buffer zones was carried out as applying various buffer sizes is recommended to allow comparability across studies [9].

Descriptive geospatial analysis was conducted on ArcGIS Pro version 3.0.0 (ESRI Inc., Redlands, CA, USA). All statistical analyses were performed using STATA version 17 (STATA Corporation, College Station, Texas, USA) and a first type error rate of 0.05 was used.

Results

Overall, we collected data on 3168 food retailers and 1796 food advertisement-sets. As food retailers and advertisement-sets available in overlapping buffers were included in the count of each school, we ended up with a total of 3621 retailers and 2098 advertisement-sets across the 50 schools. Henceforth, all the analyses presented are based on the latter numbers.

School neighborhood food environments

The median counts were 64 (IQR=47-95) food retailers per school and 36 (IQR=25-53) food advertisement-sets per school (Table 2). Food retailers were more frequent in Tunis which is

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the capital and the most urbanized governorate of Tunisia as compared to other governorates (Table 2).

School neighborhood food environments in Greater Tunis included predominantly unhealthy retailers and advertisement-sets (Figure 1). According to the NOVA-based typology, around 60% of food retailers were classified as unhealthy (n=2172) and only 13% were classified as healthy (n=471) (Table 2). Similarly, the majority of food advertisement-sets included solely ultra-processed foods (around 60% of all food advertisement-sets) while only 18% included solely unprocessed and minimally processed foods (Table 2). In sensitivity analysis, this predominance of obesogenic food exposures was observed consistently regardless of the buffer size (i.e., 200, 400 and 800m) (Supplementary table 2, Additional file 1).

Retail food environment: typology, count, proximity, and socioeconomic disparities

The most common retailers available within the 800-meter buffers were corner stores or "attar" (21.8%) and desserts/coffee/tea places (20.9%), followed by kiosks (16.3%) and limited-service restaurants (16.2%) (Table 3). Only 6% of food retailers were fruit and vegetable markets. The limited-service restaurants category predominantly encompassed pizzerias and local sandwich shops (e.g., *mleoui, kabab, or chapati sandwich shops)* with less than 1% consisting of international fast-food chains. While around 22% of retailers comprised corner stores, hyper/super/mini markets were quite rare around schools (2.1%). As for proximity, corner stores were the closest to schools (median= 135m; IQR=58-215m) followed by dessert/coffee/tea places (median= 189m; IQR=88-295m) and kiosks (median= 208m; IQR=133-293m) (Table 3).

Table 4 explores the association between school socio-economic characteristics and types of food retailers. Analyses were performed with the GIS point data being the unit of analysis. The adjusted relative prevalence ratio of unhealthy to healthy food retailers was 1.9 times significantly higher in schools located in the richest areas (i.e., lowest poverty rates) as compared to the poorest areas (ARPR=1.9[1.3-2.7], p-value =0.001). The same analysis was performed on the six NOVA-based categories of food retailers to explore the difference in the sub-categories (Supplementary table 3, Additional file 1). Apart from corner stores, the adjusted relative prevalence ratios for all the remaining types of food retailers were significantly higher around schools located in the richest areas as compared to the poorest ones in the adjusted models (with the reference outcome being outlets selling mainly

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unprocessed foods). For corner stores, the opposite pattern was observed but without reaching statistical significance.

Food advertisements: typology, count, and socioeconomic disparities

Only 1% of advertisement-sets consisted of billboards (Supplementary table 4, Additional file 1). The remaining sets were located on storefronts and store signs of shops – mostly on corner stores (28% of all food advertisement-sets) and kiosks (23% of all food advertisement-sets) – and were predominantly promoting unhealthy food products (Supplementary table 4, Additional file 1).

Advertisement-sets present on fruit and vegetable shops/markets were mostly promoting solely unprocessed or minimally processed foods – although around 30% of these sets included ultra-processed food products. The latter consisted of promotional parasols for carbonated and sugar sweetened beverages which were used by vendors to protect their fruits and vegetables from the sun (Figure 2). A substantial number of store signs were also promotional products for a dairy brand. For billboards, around 86% included solely processed and/or ultra-processed foods (Supplementary table 4, Additional file 1).

As shown in table 5, the 2098 food advertisement-sets included 3622 different food groups as one food advertisement set might include several products. The prevailing food group promoted was carbonated beverages and sugar-sweetened beverages (22%); this was followed by sweet snacks (9.4% and 7.2%). Around 11% consisted of non-sweetened beverages and only 3% of fresh fruits and vegetables.

Distributions of the three NOVA-based types of food advertisement-sets (i.e., healthy, mixed, and unhealthy) did not significantly differ by distance from school nor by school characteristics (Supplementary table 5, Additional file 1).

Discussion

This study pertained to the Greater Tunis area, typical of a highly developed and urbanized area in the MENA region with an ongoing nutrition transition and increasing rates of childhood obesity. We studied the built food environment around primary schools using geospatial methods and a typology of food retailers and advertisements derived from the NOVA classification [34]. School neighborhood food environments included predominantly unhealthy food retailers and advertisements. Obesogenic food retailers were more prevalent around schools located in the richest areas.

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This study contributes to the scarce body of evidence on objectively measured food environments in LMICs. To the best of our knowledge, this is the first study to assess built food environments – specifically the availability of food retailers and advertisements around schools – in an Arab country using geospatial static methods.

Predominance of unhealthy food exposures

School neighborhoods included a substantial number of food retailers and advertisements; the majority of which were classified as unhealthy.

The most common food retailers consisted of small traditional shops including corner stores (*"attar*") and kiosks. The count of fast-food restaurants in school neighborhoods was higher than figures reported in Hong Kong [45], Mexico [46], and Berkshire, United Kingdom [47], but lower than those reported in New York City [48]. Yet, interpretation should be done with caution since the construct "fast food restaurants" might be defined differently across these studies.

As for food advertisements, the vast majority were promoting ultra-processed and high energy dense foods, including sweet snacks as well as carbonated and sugar-sweetened beverages; a finding which corroborates prior studies from other countries [18, 49]. Storefronts of corner stores and kiosks also included an overabundance of unhealthy food products located in one geographic place. This predominance of obesogenic food exposures is further exacerbated by the fact that we found healthy food retailers – such as fruit and vegetable markets – to be infiltrated by unhealthy promotional products, underlining the need to protect these sparse healthy spaces from unhealthy food marketing.

Disparities in food environments by school neighborhood SES

Unhealthy food retailers were more prevalent around schools located in the richest areas as compared to the poorest ones. This is consistent with early stage four of the nutrition transition model which posits that availability of unhealthy, processed, and high energy-dense foods – which contributes to obesogenic environments – increases as income rises. However, it is well-acknowledged that a wealth-gradient exists for overweight and obesity with evidence showing that overweight/obesity burdens – and thus obesogenic food environments – shift from wealthier to poorer sub-populations as a country develops [50]. We can conjecture that this shift has not occurred yet in Greater Tunis which explains why our finding contradicts reports from HICs [21, 22, 51] where unhealthy food environments tend to prevail in socioeconomically deprived areas.

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Challenges in assessing food environments in a LMIC

Our study adds to the body of knowledge on the challenges encountered when assessing food environments in LMICs. The main challenge pertained to the lack of valid, standardized, and cross-context equivalent metrics – as described by others [28].

Indeed, most of the literature on food retailers uses constructs such as "fast-food restaurants", "supermarkets", "grocery stores", or "convenience stores". However, these constructs are difficult to adapt to traditional Tunisian retailers. For example, traditional corner stores or *"attar"* are often labeled as convenience stores despite offering a relatively high proportion of healthy food options. This is why we developed a checklist adapted to the Tunisian foodscape.

Another challenge – albeit not specific to LMICs – pertained to the multiple definitions and scopes available in the literature for food retailer constructs which hinder comparability among studies. In their paper, Wilkins et al (2019) divided the constructs of "fast-food restaurants", "supermarkets" and "convenience stores" into narrow, moderate, and broad scopes [9]. In this context, our data showed that the frequency of the construct "supermarkets" changed from 2% to 25% (a 10-fold increase) when using the moderate vs. broad scopes (i.e., if we include corner stores within the "supermarkets" construct) (Supplementary figure 3, Additional file 1).

Apart from classifying food retailers into constructs, the lack of consensus on one classification system or index to categorize these constructs as healthy or unhealthy compelled us to adapt a NOVA-based classification system. Despite current debates surrounding the NOVA classification's lack of clear guidelines on how to classify foods based on ingredients [52], we opted for this system given the available evidence linking ultra-processed foods to adverse nutritional outcomes [40]. For food advertisements, we followed a thorough protocol to avoid any misclassification, whereby two independent researchers reviewed all the pictures and assigned food items into one of the four NOVA categories. Besides the intense logistics required to undertake a ground-truthing study, security concerns emerged during fieldwork. These largely related to the perception by food vendors (particularly informal vendors) that GIS mapping and pictures of their stores could negatively affect their business; e.g., shop closure; control from municipalities, and policy action.

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Strengths and limitations

Our study has several strengths. First, it is a representative study (through the sampling approach) of primary schools in Greater Tunis and therefore gives a solid description of the status-quo of school food environments of this middle-income Arab city. Additionally, an in-person mapping using Global Positioning System techniques along with a thorough protocol and rigorous training of fieldworkers was conducted to ensure high quality data collection. We collected data on all types of food retailers and did not restrict our research to fast-food restaurants or grocery stores; we also simultaneously collected data on food advertisements. We described our data using several metrics (count, proportion, density, proximity) and buffer sizes (200, 400, 800m road network buffers) to facilitate comparison across studies. Also, given that this is the first study to assess food environment in Greater Tunis using geospatial methods, the data that we generated can be used as a baseline data for future monitoring studies as well as in future research looking at associations between school neighborhood food environments and children's nutritional outcomes. Our study will also contribute to identifying policy and program levers for intervention, with the potential to improve children's nutritional status in Tunisia and countries with similar context.

Our research also includes some limitations. The main one pertains to the multitude of definitions and methods used by researchers to classify food retailers into types and/or constructs (e.g. healthy/unhealthy). This compelled us to develop our own NOVA-based typology which hinders comparability across studies. Additionally, food retailers were classified as healthy or unhealthy based on an in-store audit conducted on a subsample of retailers which might lead to some misclassification bias. We also only described school neighborhood food environments and did not include food environments of other places visited by children such as inside schools, home, or home neighborhoods. In-store audits might be essential to assertively assign a healthy or unhealthy label to retailers. Yet, they are costly, time consuming and difficult to conduct systematically on all retailers. While GIS mapping and in-store audits give us information on the quality of the external or built food environments, they should be complemented with qualitative interviews to explore how children's food choices are influenced by the density and types of food retailers and food advertisements. Finally, our study was conducted in the midst of the COVID-19 pandemic which caused significant disruptions to the global food system, including changes in food supply chain and consumer eating behaviors [53, 54] – all of this might have altered the Tunisian foodscape to some extent [53, 54].

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Future recommendations and policy implications

Food environments are one of the many entry points into food systems for improving children's dietary intakes. Intervening at the level of food environments might be more effective in modifying children's diets than individual-behavioral interventions which had limited success [55]. "This is all the more necessary since findings from the larger SCALE study [35] – of which the present study is part – revealed that about three quarters of children living in Greater Tunis tend to walk to school, and around 30% of them purchased food from stores available on their way to/from schools in the 24 hours prior to survey administration (unpublished data from SCALE study)". Considering the density of obesogenic food retailers and advertising in school neighborhoods, strategies used in other contexts and for other harmful behaviors, such as tobacco use [56, 57], could inform the development of effective interventions to enable healthy environments around schools in Greater Tunis. Our results call for regulation of the urban zoning area around schools to monitor and reduce the density of unhealthy food retailers and food advertisements in the vicinity of schools. As we expect the wealth-gradient shift to unfold in Tunisia, this policy should be put in action to protect schoolchildren from low SES neighborhoods from the expected proliferation of obesogenic food exposures. The number and type of advertisements on storefronts should be limited, especially those on corner stores and kiosks. Promotional products for ultra-processed foods should not be allowed to be used in healthy food spaces or as store signs. Similar to the one implemented in the United Kingdom [58], a law prohibiting advertisements within close distance of schools, such as 200-meter, might be considered – although the efficacy of such measure is yet to be confirmed. The quality and type of food products sold by food retailers around schools should also be controlled so that ultra-processed food products do not exceed a pre-defined threshold. Mandatory food labeling and warning labels for food items might be an additional strategy to limit demand for unhealthy products. The influence of school neighborhood food environment on children's purchasing behaviors and diets in this context should be further explored.

Conclusions

Our study collected monitoring data on the built (i.e., external) food environments in Greater Tunis and adds to the body of knowledge on the challenges encountered when assessing food environments in an LMIC. Overall, school neighborhood food environments in Greater Tunis included predominantly unhealthy food retailers and food advertisements underlining the

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need to promote healthy environments around Tunisian schools. On the other hand, unhealthy food retailers were more prevalent around schools located in the richest areas – which was not unexpected in this nutrition transition setting. Mapping of LMIC food environments is crucial to document the impact of these nutrition transitions on children's dietary intake and weight status. Therefore, our next step will be to study the association between school neighborhood food environments and children's nutritional status. This will help in identifying policy and program levers for intervention to improve children's diets and lessen the burden of obesity in Tunisia and countries with similar contexts.

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Conflict of Interest:

None.

Authorship:

CA (Akl) prepared the first draft of the manuscript and conducted data management, analysis, and interpretation. HG, JEA, AC, SEB, JC, ZJ, and AS conceptualized the SCALE study. HG, JEA, PT, CA (Akik) and CA (Akl) had primary responsibility for final content. CA (Akl), NEH, GS, SS, and TT trained data collectors and supervised fieldwork. CA (Akl), AES, TT, and HBJ manually screened all the geotagged pictures of food retailers and advertisements to assign correct categories. AS, CA (Akl), NEH, and GS developed the study protocol and research tools. All authors critically reviewed the paper, read and approved the final version.

Ethical Standards Disclosure:

In Tunisia, the SCALE 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 Ethics Committee on Human Research of the National Institute of Nutrition and Food Technology (INNTA) (Visa n° 03/2019) and by the National Council of Statistics in Tunisia (Visa n° 06/2019). For the neighborhood mapping component of the SCALE study, permission to map food retailers and advertisements around schools was granted from municipalities. Data collectors were requested to refrain from taking pictures if vendors did not want to have their shop photographed. This mapping component of the SCALE study did not involve human participants or human data.

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References

1. Abarca-Gómez L, Abdeen ZA, Hamid ZA *et al.* (2017) Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128· 9 million children, adolescents, and adults. *The lancet* 390, 2627-2642.
2. Harrison K, Bost KK, McBride BA *et al.* (2011) Toward a developmental conceptualization of contributors to overweight and obesity in childhood: The Six-Cs model. *Child development perspectives* 5, 50-58.
3. UNICEF and GAIN (2019) Food Systems for Children and Adolescents: Working together to secure nutritious diets. *UNICEF: New York, NY, USA*.
4. Turner C, Aggarwal A, Walls H *et al.* (2018) Concepts and critical perspectives for food environment research: a global framework with implications for action in low- and middle-income countries. *Global food security* 18, 93-101.
5. da Costa Peres CM, Gardone DS, Costa BVdL *et al.* (2020) Retail food environment around schools and overweight: a systematic review. *Nutrition Reviews* 78, 841-856.
6. World Health Organization (2018) Decade of action on nutrition—the April 2016 proclamation. https://www.who.int/news-room/events/detail/2016/04/01/default-calendar/decade-of-action-on-nutrition (accessed November 20 2022)
7. United Nations (2016) Transforming Our World: The 2030 Agenda for Sustainable Development., United Nations. https://sdgs.un.org/goals (accessed November 20 2022)
8. Clary C, Matthews SA Kestens Y (2017) Between exposure, access and use: Reconsidering foodscape influences on dietary behaviours. *Health & place* 44, 1-7.
9. Wilkins E, Morris M, Radley D *et al.* (2019) Methods of measuring associations between the retail food environment and weight status: importance of classifications and metrics. *SSM-population health* 8, 100404.
10. Briefel RR, Crepinsek MK, Cabili C *et al.* (2009) School food environments and practices affect dietary behaviors of US public school children. *Journal of the American Dietetic Association* 109, S91-S107.
11. Nestle M (2013) Food politics. In *Food Politics*: University of California Press.
12. Ogum-Alangea D, Aryeetey RN, Gray HL *et al.* (2020) Basic school pupils' food purchases during mid-morning break in urban Ghanaian schools. *Plos one* 15, e0238308.

https://doi.org/10.1017/S1368980023002860 Published online by Cambridge University Press

13. Crawford F, Mackison D, Mooney JD *et al.* (2017) Observation and assessment of the nutritional quality of 'out of school'foods popular with secondary school pupils at lunchtime. *BMC Public Health* 17, 1-9.
14. Wills WJ, Macdiarmid JI, Masson LF *et al.* (2013) Children's food and drink purchasing behaviour "Beyond the school gate": The development of a survey module. *International Scholarly Research Notices* 2013.
15. Smith R, Kelly B, Yeatman H *et al.* (2019) Food marketing influences children's attitudes, preferences and consumption: a systematic critical review. *Nutrients* 11, 875.
16. Austin SB, Melly SJ, Sanchez BN *et al.* (2005) Clustering of fast-food restaurants around schools: a novel application of spatial statistics to the study of food environments. *American journal of public health* 95, 1575-1581.
17. Kelly B, King L, Jamiyan B *et al.* (2015) Density of outdoor food and beverage advertising around schools in Ulaanbaatar (Mongolia) and Manila (The Philippines) and implications for policy. *Critical Public Health* 25, 280-290.
18. Vandevijvere S, Molloy J, Hassen de Medeiros N *et al.* (2018) Unhealthy food marketing around New Zealand schools: a national study. *International journal of public health* 63, 1099-1107.
19. Calvert S, Dempsey RC Povey R (2020) A qualitative study investigating food choices and perceived psychosocial influences on eating behaviours in secondary school students. *British Food Journal* 122, 1027-1039.
20. Watts AW, Lovato CY, Barr SI *et al.* (2015) A qualitative study exploring how school and community environments shape the food choices of adolescents with overweight/obesity. *Appetite* 95, 360-367.
21. Díez J, Cebrecos A, Rapela A *et al.* (2019) Socioeconomic inequalities in the retail food environment around schools in a Southern European context. *Nutrients* 11, 1511.
22. Maguire ER, Burgoine T Monsivais P (2015) Area deprivation and the food environment over time: A repeated cross-sectional study on takeaway outlet density and supermarket presence in Norfolk, UK, 1990–2008. *Health & Place* 33, 142-147.
23. D'silva K (2017) Outdoor Unhealthy Food Advertising Surrounding Schools in Auckland, New ZealandMaster's thesis, The University of Auckland, New Zealand.
24. Fagerberg P, Langlet B, Oravsky A *et al.* (2019) Ultra-processed food advertisements dominate the food advertising landscape in two Stockholm areas with low vs high socioeconomic status. Is it time for regulatory action? *BMC Public Health* 19, 1-10.

25. Adams J, Ganiti E White M (2011) Socio-economic differences in outdoor food advertising in a city in Northern England. *Public health nutrition* 14, 945-950.
26. Olsen JR, Patterson C, Caryl FM *et al.* (2021) Exposure to unhealthy product advertising: Spatial proximity analysis to schools and socio-economic inequalities in daily exposure measured using Scottish Children's individual-level GPS data. *Health & place* 68, 102535.
27. Wilkins E, Radley D, Morris M *et al.* (2019) A systematic review employing the GeoFERN framework to examine methods, reporting quality and associations between the retail food environment and obesity. *Health & place* 57, 186-199.
28. Carducci B, Oh C, Roth DE *et al.* (2021) Gaps and priorities in assessment of food environments for children and adolescents in low-and middle-income countries. *Nature Food* 2, 396-403.
29. Turner C, Kalamatianou S, Drewnowski A *et al.* (2020) Food environment research in low-and middle-income countries: a systematic scoping review. *Advances in Nutrition* 11, 387-397.
30. Tessier S, Traissac P, Bricas N *et al.* (2010) Food shopping transition: socio-economic characteristics and motivations associated with use of supermarkets in a North African urban environment. *Public health nutrition* 13, 1410-1418.
31. Miller V, Yusuf S, Chow CK *et al.* (2016) Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study. *The lancet global health* 4, e695-e703.
32. Popkin BM, Adair LS Ng SW (2012) Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition reviews* 70, 3-21.
33. Dogui D, Doggui R, El Ati J *et al.* (2021) Association between overweight and diet diversity score: A cross-sectional study conducted among tunisian children. *Children* 8, 536.
34. Monteiro CA, Cannon G, Levy R *et al.* (2016) NOVA. The star shines bright. *World Nutrition* 7, 28-38.
35. Ghattas H, Jamaluddine Z, Semaan A *et al.* (2022) School and community drivers of child diets in two Arab cities: The SCALE protocol and innovative tools to assess children's food environments. *Plos one* 17, e0264963.
36. National Institute of Statistics in Tunisia and World-Bank (2020) Carte de La Pauvreté En Tunisie.

https://doi.org/10.1017/S1368980023002860 Published online by Cambridge University Press

http://ins.tn/sites/default/files/publication/pdf/Carte%20de%20la%20pauvret%C3%A9%20en%20Tunisie_final_0.pdf (accessed 10 October 2022)

37. Sharkey JR & Horel S (2008) Neighborhood socioeconomic deprivation and minority composition are associated with better potential spatial access to the ground-truthed food environment in a large rural area. *The Journal of nutrition* 138, 620-627.
38. Jones AP, Coombes EG, Griffin SJ *et al.* (2009) Environmental supportiveness for physical activity in English schoolchildren: a study using Global Positioning Systems. *International Journal of Behavioral Nutrition and Physical Activity* 6, 1-8.
39. Monteiro CA (2009) Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public health nutrition* 12, 729-731.
40. Dicken SJ & Batterham RL (2021) The role of diet quality in mediating the association between ultra-processed food intake, obesity and health-related outcomes: a review of prospective cohort studies. *Nutrients* 14, 23.
41. FAO GAIN and WOF (2022) Assessment of retail food environments and green spaces for healthy cities – Methodological guidance based on the experiences in Dar es Salaam, Lima, Tunis. Rome.
42. Swinburn B, Sacks G, Vandevijvere S *et al.* (2013) INFORMAS (I nternational N etwork for F ood and O besity/non-communicable diseases R esearch, M onitoring and A ction S upport): overview and key principles. *Obesity reviews* 14, 1-12.
43. World Health Organization. Regional Office for Africa (2018) *Nutrient Profile Model for the WHO African Region: a tool for implementing WHO recommendations on the marketing of foods and non-alcoholic beverages to children*. no. Licence: CC BY-NC-SA 3.0 IGO. Brazzaville.
44. Smoyer-Tomic KE, Spence JC Amrhein C (2006) Food deserts in the prairies? Supermarket accessibility and neighborhood need in Edmonton, Canada. *The Professional Geographer* 58, 307-326.
45. Cheung JTH, Tang KC Koh K (2021) Geographic Clustering of Fast-Food Restaurants Around Secondary Schools in Hong Kong. *Prev Chronic Dis* 18, E56.
46. Soltero EG, Ortiz Hernandez L, Jauregui E *et al.* (2017) Characterization of the school neighborhood food environment in three Mexican cities. *Ecology of food and nutrition* 56, 139-151.
47. Williams J, Scarborough P, Townsend N *et al.* (2015) Associations between food outlets around schools and BMI among primary students in England: a cross-classified multi-level analysis. *PloS one* 10, e0132930.

48. Elbel B, Tamura K, McDermott ZT *et al.* (2019) Disparities in food access around homes and schools for New York City children. *PloS one* 14, e0217341.

49. Barquera S, Hernández-Barrera L, Rothenberg SJ *et al.* (2018) The obesogenic environment around elementary schools: food and beverage marketing to children in two Mexican cities. *BMC Public Health* 18, 1-9.

50. Templin T, Cravo Oliveira Hashiguchi T, Thomson B *et al.* (2019) The overweight and obesity transition from the wealthy to the poor in low-and middle-income countries: A survey of household data from 103 countries. *PLoS medicine* 16, e1002968.

51. Richardson AS, Boone-Heinonen J, Popkin BM *et al.* (2012) Are neighbourhood food resources distributed inequitably by income and race in the USA? Epidemiological findings across the urban spectrum. *BMJ open* 2, e000698.

52. Astrup A & Monteiro C (2022) Does the concept of "ultra-processed foods" help inform dietary guidelines, beyond conventional classification systems? NO. *The American Journal of Clinical Nutrition* 116, 1482-1488.

53. Sheth J (2020) Impact of Covid-19 on consumer behavior: Will the old habits return or die? *Journal of business research* 117, 280-283.

54. Harris J, Depenbusch L, Pal AA *et al.* (2020) Food system disruption: initial livelihood and dietary effects of COVID-19 on vegetable producers in India. *Food security* 12, 841-851.

55. Brambila-Macias J, Shankar B, Capacci S *et al.* (2011) Policy interventions to promote healthy eating: a review of what works, what does not, and what is promising. *Food and nutrition bulletin* 32, 365-375.

56. Ackerman A, Etow A, Bartel S *et al.* (2017) Reducing the density and number of tobacco retailers: policy solutions and legal issues. *Nicotine & Tobacco Research* 19, 133-140.

57. Siegel SD, Brooks M, Bourke J *et al.* (2021) Reducing exposure to tobacco retailers with residential zoning policy: insights from a geospatial analysis of Wilmington, Delaware. *Cities & health*, 1-13.

58. Advertising Standards Authority (2018) Food: HFSS media placement. https://www.asa.org.uk/advice-online/food-hfss-media-placement.html (accessed November 20 2022)

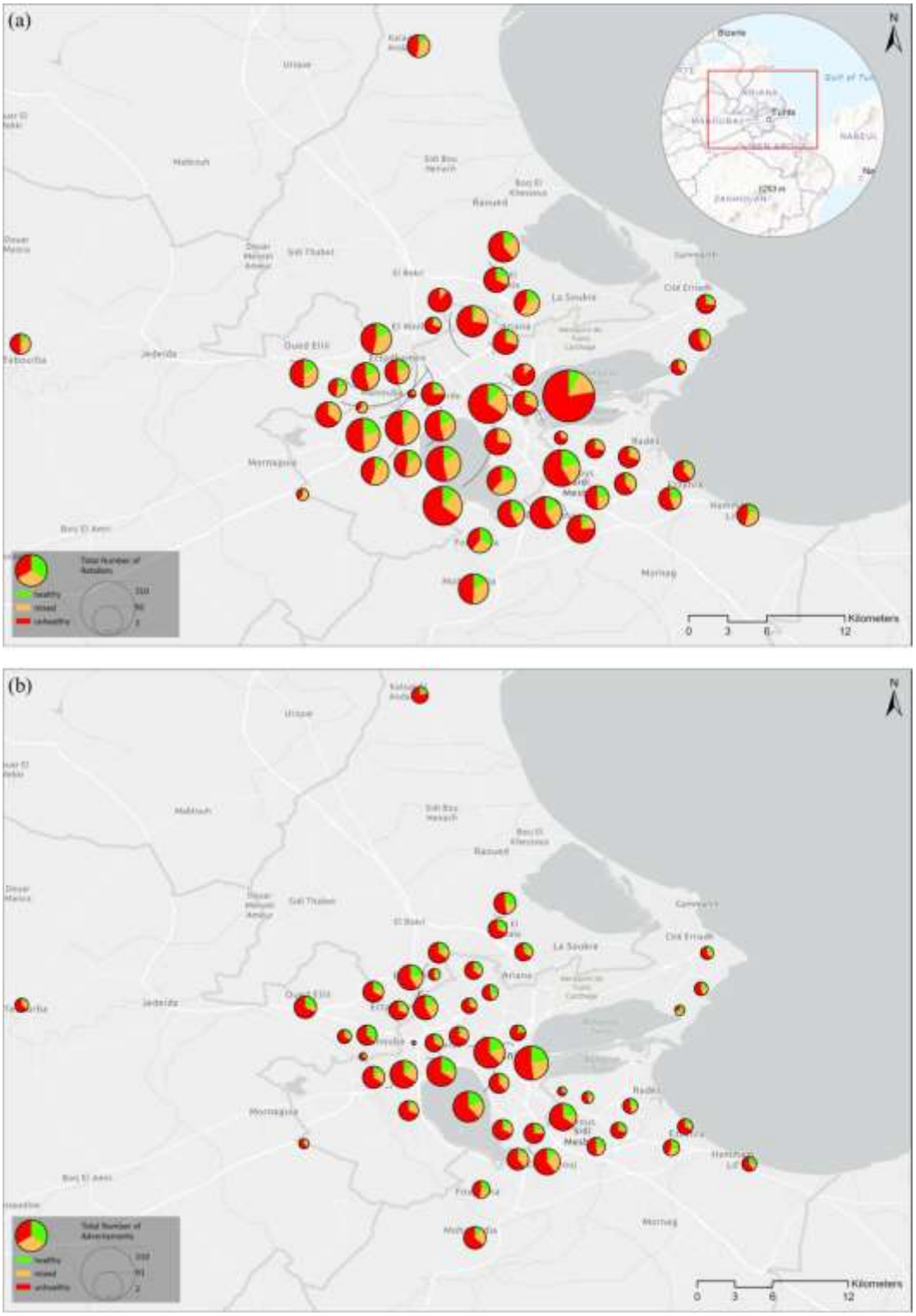

Figure 1. School neighborhoods in Greater Tunis: Availability of food retailers and food advertisement-sets by type.

Legend: Each pie represents a school. Availability of healthy, mixed, and unhealthy (a) food retailers and (b) food advertisement-sets in the Greater Tunis area (percentage of total). The size of the pie reflects the count of food retailers and food advertisement-sets. The size of each slice reflects the relative density.

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Figure 2. Sample pictures of fruit and vegetable markets/stores with parasols promoting ultra-processed foods.

Legend: Note: Pictures were taken by data collectors whose names are mentioned in the Acknowledgement section. Permission to use their pictures was granted.

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Table 1. Food retailers and advertisements in Greater Tunis: Detailed typology and NOVA-based typology.

<table>
<tr><td colspan="3">Food retailers [a]</td></tr>
<tr><td rowspan="2">Detailed typology (14 groups)</td><td colspan="2">NOVA-based typology [b]</td></tr>
<tr><td>6 groups</td><td>3 groups</td></tr>
<tr><td>Butcher, poultry, and fish stores/markets</td><td rowspan="3">Outlets selling mainly unprocessed or minimally processed foods or processed culinary ingredients
(> 60% of foods sold within the retailers are from NOVA groups 1 and 2).</td><td rowspan="3">Healthy</td></tr>
<tr><td>Fruit and vegetable stores and markets</td></tr>
<tr><td>Mobile vendors selling foods from NOVA groups 1 and 2 (e.g., fruits, vegetables).</td></tr>
<tr><td>Hyper/Supermarkets</td><td rowspan="2">Hyper/super/mini markets</td><td rowspan="4">Mixed
(outlets selling a wide range of products spanning across all four NOVA groups)</td></tr>
<tr><td>Mini markets (‘superette’, ‘maghaza’)</td></tr>
<tr><td>Corner shops (‘attar’)</td><td>Corner shops</td></tr>
<tr><td>Full-service restaurants</td><td rowspan="2">Outlets selling mainly unprocessed and processed/ultra-processed foods</td></tr>
<tr><td>Dairy stores</td><td rowspan="5">Unhealthy</td></tr>
<tr><td>Local limited-service restaurants</td><td rowspan="2">Limited-service restaurants and retailers</td></tr>
<tr><td>International fast-food chains</td></tr>
<tr><td>Mobile vendors selling foods from NOVA groups 3 and 4 (e.g., carbonated beverages, crepes, sandwiches).</td><td rowspan="4">Outlets selling mainly processed or ultra- processed foods
(> 60% of foods sold within the retailers are from NOVA groups 3 and 4).</td></tr>
<tr><td>Desserts, fruit cocktails, coffee, and tea places</td></tr>
<tr><td>Kiosks (‘kechk’)</td></tr>
<tr><td>Bakeries and pastries stores</td></tr>
<tr><td colspan="3">Food advertisement-sets [a,c]</td></tr>
<tr><td colspan="3">NOVA-based typology (3 groups)</td></tr>
</table>

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Healthy: *Advertisement set including solely unprocessed, minimally processed food items, or processed culinary ingredients.* *(Solely NOVA groups 1 and 2)*
Mixed: *Advertisement set including both unprocessed and processed/ultra-processed food items* *(all NOVA groups 1 to 4)*
Unhealthy: *Advertisement set including solely processed and ultra-processed food items* *(Solely NOVA groups 3 and 4)*
Unclear [d]

[a] Food includes beverages.

[b] Classification of food retailers into the three constructs was based on findings of a previous in-store and in-restaurant audit conducted in Tunisia [(41)].

[c] All food and beverage advertisements available in one single geographic location (e.g., storefront of a food outlet) were considered as one set of advertisements (i.e., one exposure). Each advertisement set might include several food groups as it can promote more than one food or beverage product.

[d] Unclear corresponds to food advertisement-sets that could not be categorized because (a) pictures were blurred or (b) it is not possible to deduce the NOVA-processing level [(34)] of the food items included in the pictures.

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Table 2. Availability of food retailers and advertisement-sets around 50 primary schools in Greater Tunis.

Food [a] environment within 800m [b] of schools	Availability					
	Food retailers [c]			Food advertisement-sets [c]		
	Unit of analysis: GIS point data, n=3621	Unit of analysis: School, n=50		Unit of analysis: GIS point data, n=2098	Unit of analysis: School, n=50	
	Total count, n (%) [d]	Median count per school (IQR) [f]	Median density (count/km^2) [e] per school (IQR) [f]	Total count, n (%) [d]	Median count per school (IQR) [f]	Median density (count/km^2) [e] per school (IQR) [f]
Total	3621	64 (47-95)	59 (43-79)	2098	36 (25-53)	33 (24-49)
Type of food exposure						
Healthy	471 (13.0)	8 (3-14)	7 (3-12)	371 (17.7) [g]	6 (4-8)	6 (3-7)
Mixed	978 (27.0)	18 (10-28)	17 (10-22)	383 (18.3) [g]	5 (4-10)	5 (3-9)
Unhealthy	2172 (60.0)	39 (28-52)	34 (23-45)	1255 (59.8) [g]	23 (13-32)	19 (12-31)
Type of school						
Public	2690 (74.3)	67 (49-95)	59 (45-81)	1538 (73.3)	41 (25-53)	34 (25-49)
Private	931 (25.7)	59 (28-96)	48 (29-74)	560 (26.7)	35 (17-66)	27 (14-51)
Poverty rate of the departments where school are located [h] (tertiles)						
High poverty rate	1449 (40.0)	56 (39-99)	58 (35-83)	815 (38.8)	28 (20-59)	26 (17-55)

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Medium poverty rate	1509 (41.7)	76 (55-96)	62 (51-87)	900 (42.9)	45 (29-58)	36 (29-60)
Low poverty rate	663 (18.3)	61 (36-77)	50 (32-66)	383 (18.3)	35 (20-43)	28 (19-38)
Total population count of the departments where schools are located [h] (quintiles)						
q1	444 (12.3)	53 (39-72)	42 (38-63)	263 (12.5)	32 (16-47)	26 (17-44)
q2	731 (20.2)	97 (50-159)	79 (45-132)	392 (18.7)	54 (27-101)	43 (25-84)
q3	499 (13.8)	50 (24-63)	53 (32-69)	287 (13.7)	26 (11-41)	31 (14-38)
q4	844 (23.3)	63 (47-82)	60 (45-75)	524 (25.0)	35 (25-55)	39 (24-49)
q5	1103 (30.5)	78 (65-99)	67 (54-81)	632 (30.1)	45 (34-53)	35 (27-58)
Governorates where schools are located						
Tunis	1781 (49.2)	74 (55-123)	74 (51-112)	1068 (50.9)	47 (27-85)	47 (32-61)
Ariana	637 (17.6)	65 (63-96)	59 (46-69)	329 (15.7)	36 (32-41)	28 (26-37)
Ben Arous	926 (25.6)	57 (47-83)	54 (45-81)	538 (25.6)	32 (25-52)	29 (24-49)
Manouba	277 (7.6)	25 (10-62)	24 (14-59)	163 (7.8)	17 (5-33)	15 (6-32)

Note. GIS: Geographic Information System; IQR: interquartile range; km: kilometers, m:meters; q: quintile.

[a] Food including beverages.

[b] Road-network distance in meters.

[c] Retailers that display storefront advertisements were included in the count of both retailers and advertisement-sets.

[d] Non-standardized counts were generated by summing the GIS data points within the 800m buffers across the 50 schools. For schools with overlapping buffers, GIS data points were included in the count of each school. Column percentages were computed.

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[e] For each of the 50 schools, the 800m road-network buffer yielded a different surface area. The surface area ranged from 0.4 to 1.5 km^2 with a median of 1.2 km^2. Density was calculated for each school by dividing the count of retailers or advertisement-sets by the surface area of the 800m buffer (in km^2).

[f] Medians and IQRs were generated across the 50 schools.

[g] Column percentages do not add up to 100 as n=89 advertisement-sets could not be categorized because (a) pictures were blurred or (b) it is not possible to deduce the NOVA-processing level of the food items included in the pictures [(34)].

[h] Poverty rate (as percentage per capita) and population count (as total number of individuals) of each department of Greater Tunis were retrieved from a report produced by the National Office of Statistics of Tunisia, in collaboration with the World Bank [(36)]. Poverty rates were categorized into tertiles as follows: High poverty rate (7.3-15.2%); Medium poverty rate (4.1-7.1%) and Low poverty rate (0.2-3.8%). Total population count was categorized into quintiles as follows: q1 (17,408-27,749 individuals); q2 (29,185-40,101); q3 (41,830-57,194); q4 (58,792-84,312) and q5 (86,024-129,693). Each school was matched to its corresponding department's poverty rate tertile and population quintile.

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Table 3. The retail food environments around 50 primary schools in Greater Tunis: Proximity and availability.

Retail food [a] environment within 800 m [b] buffer of schools					
Typology			**Proximity (m) [c]**	**Availability**	
NOVA-based typology [d]		**Detailed typology**	**Unit of analysis: School, n=50**	**Unit of analysis: GIS point data, n=3621**	**Unit of analysis: School, n=50**
			Median distance per school (IQR) [e]	**Total count, n(%) [f]**	**Median count per school (IQR) [e]**
Healthy	Outlets selling mainly UNP foods	Butcher, poultry, and fish stores/markets	304 (155-440)	243 (6.7)	4 (2-8)
		Fruit and vegetable stores and markets	291 (200-419)	216 (6.0)	3.5 (2-6)
		Mobile vendors [g]	--	12 (0.3)	0
Mixed	Hyper/super/mini markets	Hyper/Supermarkets	409 (265-554)	77 (2.1)	1 (1-2)
		Mini markets *('superette', 'maghaza'*)	400 (227-641)	35 (1.0)	0 (0-1)
	Corner shops	Corner shops *('attar')*	135 (58-215)	788 (21.8)	14 (6-24)
	Outlets selling mainly UNP & P foods	Full-service restaurants	435 (305-685)	47 (1.3)	0 (0-1)
		Dairy stores	294 (145-481)	31 (0.9)	0 (0-1)

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Unhealthy	Limited-service restaurants and retailers	Local limited-service restaurants	217 (150-325)	586 (16.2)	9 (5-13)
		International fast-food chains	537 (369-695)	3 (0.1)	0
		Mobile vendors [g]	--	17 (0.5)	0
	Outlets selling mainly P foods	Desserts, fruit cocktails, coffee, and tea places	189 (88-295)	755 (20.9)	12 (9-19)
		Kiosks *('kechk')*	208 (133-293)	590 (16.3)	12 (7-15)
		Bakeries and pastries stores	339 (192-496)	221 (6.1)	4 (2-6)

Note. GIS: Geographic Information System; IQR: interquartile range; m: meters; P: processed food; UNP: unprocessed food.

[a] Food including beverages.

[b] Road-network distance in meters.

[c] For each of the 50 schools, road-network distance (in meters) from the school to the nearest retailer, by type, was generated. Median and IQR across the 50 schools are presented in the table.

[d] NOVA classification [(34)]. In this table, unprocessed foods refer to unprocessed/minimally processed foods and processed culinary ingredients (NOVA groups 1 and 2). Processed foods refer to processed and ultra-processed foods (NOVA groups 3 and 4).

[e] Medians and IQR were generated across the 50 schools.

[f] Non-standardized counts were generated by summing the GIS data points within the 800m buffers across the 50 schools. For schools with overlapping buffers, GIS data points were included in the count of each school. Column percentages were computed.

[g] Mobile vendors include (a) vendors selling unprocessed/minimally processed foods such as vegetables, fruits, and popcorn and (b) vendors selling processed/ultra-processed foods such as sandwiches, carbonated beverages, and crepes. The median distance from schools to nearest mobile vendors was not generated.

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Table 4. Association between type of food retailers and school characteristics across primary schools in Greater Tunis.

Retail food [a] environment within 800 m [b] of schools	**Unit of analysis: GIS point data [c]**			**Multinomial regression [d]** (Reference category: Healthy)			
	Healthy (n=471)	**Mixed (n=978)**	**Unhealthy (n=2172)**	**Mixed**		**Unhealthy**	
	n(%)			**RPR [95% CI]**	**ARPR[e] [95% CI]**	**RPR [95% CI]**	**ARPR [e] [95% CI]**
Type of school							
Public	337 (71.5)	752 (76.9)	1601 (73.7)	ref	ref	ref	ref
Private	134 (28.5)	226 (23.1)	571 (26.3)	0.8 [0.6-1.0]	**0.7 [0.5-0.9]****	1.0 [0.7-1.4]	0.9 [0.7-1.4]
Distance from school to food retailers within buffers (m) [f]							
=< 200	52 (11.0)	109 (11.1)	201 (9.3)	ref	ref	ref	ref
>200 to =<400	107 (22.7)	244 (24.9)	479 (22.1)	1.1 [0.7-1.7]	1.1 [0.7-1.7]	1.2 [0.8-2.0]	1.3 [0.9-2.0]
>400 to =< 800	312 (66.2)	625 (63.9)	1492 (68.7)	1.0 [0.7-1.7]	1.0 [0.7-1.6]	1.4 [0.9-2.1]	**1.5 [1.0-2.1]***
Poverty rate of the departments where schools are located [g] (tertiles)							
High poverty rate	113 (24.0)	223 (22.8)	327 (15.1)	ref	ref	ref	ref
Medium poverty rate	197 (41.8)	423 (43.3)	889 (40.9)	1.0 [0.7-1.5]	1.0 [0.8-1.4]	**1.5 [1.1-2.1]***	1.2 [0.8-1.8]
Low poverty rate	161 (34.2)	332 (33.9)	956 (44.0)	1.1 [0.8-1.5]	1.2 [0.9-1.5]	**2.2 [1.5-3.3]*****	**1.9 [1.3-2.7]****
Total population count of the							

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departments where schools are located [g] (quintiles)							
q1	41 (8.7)	121 (12.4)	282 (13.0)	ref	ref	ref	ref
q2	84 (17.8)	141 (14.4)	506 (23.3)	**0.5 [0.3-0.9]***	**0.5 [0.3-0.9]***	0.9 [0.4-1.9]	0.9 [0.5-1.7]
q3	50 (10.6)	131 (13.4)	318 (14.6)	0.9 [0.5-1.6]	1.1 [0.7-1.9]	1.0 [0.5-2.0]	1.2 [0.5-2.6]
q4	147 (31.2)	249 (25.5)	448 (20.6)	**0.6 [0.3-0.9]***	0.7 [0.4-1.1]	**0.4 [0.2-0.7]****	**0.5 [0.3-0.9]***
q5	149 (31.6)	336 (34.4)	618 (28.5)	0.7 [0.5-1.2]	0.9 [0.5-1.5]	0.6 [0.3-1.1]	0.6 [0.3-1.1]
Governorates where schools are located							
Tunis	194 (41.2)	468 (47.9)	1119 (51.5)	ref	ref	ref	ref
Ariana	83 (17.6)	181 (18.5)	373 (17.2)	0.9 [0.7-1.2]	0.9 [0.6-1.2]	0.8 [0.5-1.2]	1.1 [0.8-1.7]
Ben Arous	150 (31.8)	235 (24.0)	541 (24.9)	**0.7 [0.5-0.9]***	**0.8 [0.6-1.0]***	0.6 [0.4-1.0]	0.8 [0.6-1.1]
Manouba	44 (9.3)	94 (9.6)	139 (6.4)	0.9 [0.6-1.3]	1.0 [0.7-1.4]	**0.5 [0.4-0.8]****	1.0 [0.6-1.6]

Note: ARPR: adjusted relative prevalence ratio; CI: confidence interval; GIS: Geographic Information System; IQR: interquartile range; m: meters; q: quintile; ref: reference category; RPR: relative prevalence ratio.

[a] Food including beverages.

[b] Road-network distance in meters.

[c] Non-standardized counts were generated by summing the GIS data points within the 800m buffers across the 50 schools. For schools with overlapping buffers, GIS data points were included in the count of each school. Column percentages were computed.

[d] Multinomial regressions were conducted with the reference category being 'Healthy' food retailers.

[e] Models adjusted for all the variables presented in column one (i.e., type of school, poverty rates and total population count of the areas where schools are located, governorates where schools are located, and distance from school to food exposures).

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[f] Distance (road-network) in meters from school to food retailers within each buffer.

[g] Poverty rate (as percentage per capita) and population count (as total number of individuals) of each department of Greater Tunis were retrieved from a report produced by the National Office of Statistics of Tunisia, in collaboration with the World Bank [(36)]. Poverty rates were categorized into tertiles as follows: High poverty rate (7.3-15.2%); Medium poverty rate (4.1-7.1%) and Low poverty rate (0.2-3.8%). Total population count was categorized into quintiles as follows: q1 (17408-27749 individuals); q2 (29185-40101); q3 (41830-57194); q4 (58792-84312) and q5 (86024-129693). Each school was matched to its corresponding department's poverty rate tertile and population quintile.

Numbers in **bold** indicate statistical significance: * p<.05; **p<.01; *** p<.001

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Table 5. Food groups promoted around primary schools in Greater Tunis, by type and distance from school.

Food group type [a]	**Count across the 50 schools n(%)** [b]			
	=<200 m [c]	***200-400 m*** [c]	***400-800 m*** [c]	***Total***
NOVA Groups 3 and 4 [d]				
Carbonated beverages and sugar-sweetened beverages [e]	82 (19.9)	185 (23.0)	529 (22.0)	796 (22.0)
Cakes, sweet biscuits and pastries, and other sweet bakery products [e]	48 (11.7)	77 (9.6)	216 (9.0)	341 (9.4)
Chocolate and sugar confectionery, energy bars, sweet topping, ice cream, and sorbets [e]	23 (5.6)	55 (6.8)	183 (7.6)	261 (7.2)
Flavored yoghurt, sweetened milk, and dairy products	47 (11.4)	87 (10.8)	245 (10.2)	379 (10.5)
Food restaurant items (dishes and sandwiches), ready-made and convenience foods and composite dishes	27 (6.6)	59 (7.3)	204 (8.5)	290 (8.0)
Savory/salty snacks (including salted nuts)	13 (3.2)	27 (3.3)	77 (3.2)	117 (3.2)
Processed meat, poultry, and similar [e]	8 (1.9)	18 (2.2)	55 (2.3)	81 (2.2)
Bread, bread types and breakfast cereals	2 (0.5)	8 (1.0)	42 (1.7)	52 (1.4)
Miscellaneous including canned fish, processed fruits and vegetables, and processed sauces and dressings.	8 (2.1)	7 (0.9)	28 (1.2)	43 (1.3)
NOVA Groups 1 and 2 [d]				
Non-sweetened beverages (water, coffee, tea, etc.)	43 (10.4)	100 (12.4)	247 (10.3)	390 (10.8)
Fresh and frozen meat, poultry, fish, and eggs	21 (5.1)	38 (4.7)	126 (5.2)	185 (5.1)
Fresh and frozen fruits and	11 (2.7)	16 (2.0)	76 (3.2)	103 (2.8)

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vegetables				
Fresh, dried or cooked pasta, rice and grains	7 (1.7)	9 (1.1)	41 (1.7)	57 (1.6)
Milk and unflavored yoghurt	6 (1.5)	11 (1.4)	36 (1.5)	53 (1.5)
Butter, and other fats and oils	4 (1.0)	4 (0.5)	21 (0.9)	29 (0.8)
Miscellaneous including honey, spices, and herbs	6 (1.5)	10 (1.2)	23 (1.0)	39 (1.1)
Unclear [f]	56 (13.6)	95 (11.8)	255 (10.6)	406 (11.2)
Total number of promoted food groups	**412**	**806**	**2404**	**3622**
Total number of food advertisement-sets [g]	**220**	**489**	**1389**	**2098**

Note: m: meters

[a] Food including beverages.

[b] Non-standardized counts were generated by summing food groups promoted (and not food advertisement-sets) within the 800m buffers and across the 50 schools, by type and distance from school. For schools with overlapping buffers, food groups were included in the count of each school. Column percentages of total number of promoted food groups were computed.

[c] Distance (road-network) in meters from school to advertisement-sets within each buffer.

[d] NOVA classification [(34)].

[e] Food groups for which marketing is prohibited or not permitted to children based on the nutrient profile model in the WHO Eastern Mediterranean Region [(43)] .

[f] Unclear corresponds to food items that could not be categorized because (a) pictures were blurred or (b) it is not possible to deduce the NOVA-processing level of the food items included in the pictures [(34)].

[g] All food and beverage advertisements available in one single geographic location (e.g., storefront of a food outlet) were considered as one set of advertisements. Each advertisement set might include several food groups because it is promoting more than one food or beverage product.

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