Public Health Nutrition: 20(14), 2598–2607 doi:10.1017/S1368980016002123

Food swamps and food deserts in Baltimore City, MD, USA: associations with dietary behaviours among urban adolescent girls

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Submitted 4 February 2016: Final revision received 27 May 2016: Accepted 14 June 2016: First published online 22 September 2016

Abstract

Objective: To determine whether living in a food swamp (≥4 corner stores within 0·40 km (0·25 miles) of home) or a food desert (generally, no supermarket or access to healthy foods) is associated with consumption of snacks/desserts or fruits/vegetables, and if neighbourhood-level socio-economic status (SES) confounds relationships.

Design: Cross-sectional. Assessments included diet (Youth/Adolescent FFQ, skewed dietary variables normalized) and measured height/weight (BMI-for-age percentiles/*Z*-scores calculated). A geographic information system geocoded home addresses and mapped food deserts/food swamps. Associations examined using multiple linear regression (MLR) models adjusting for age and BMI-for-age *Z*-score.

Setting: Baltimore City, MD, USA.

Subjects: Early adolescent girls (6th/7th grade, *n* 634; mean age 12·1 years; 90·7 % African American; 52·4 % overweight/obese), recruited from twenty-two urban, low-income schools.

Results: Girls' consumption of fruit, vegetables and snacks/desserts: 1·2, 1·7 and 3·4 servings/d, respectively. Girls' food environment: 10·4 % food desert only, 19·1 % food swamp only, 16·1 % both food desert/swamp and 54·4 % neither food desert/swamp. Average median neighbourhood-level household income: $US 35 298. In MLR models, girls living in both food deserts/swamps consumed additional servings of snacks/desserts *v.* girls living in neither ($\beta = 0{\cdot}13$, $P = 0{\cdot}029$; 3·8 *v.* 3·2 servings/d). Specifically, girls living in food swamps consumed more snacks/desserts than girls who did not ($\beta = 0{\cdot}16$, $P = 0{\cdot}003$; 3·7 *v.* 3·1 servings/d), with no confounding effect of neighbourhood-level SES. No associations were identified with food deserts or consumption of fruits/vegetables.

Conclusions: Early adolescent girls living in food swamps consumed more snacks/desserts than girls not living in food swamps. Dietary interventions should consider the built environment/food access when addressing adolescent dietary behaviours.

Keywords
African American
Adolescents
Geographic information system
Snacks and desserts
Food desert/food swamp

Paediatric obesity is a public health problem that disproportionately affects African-American girls from low-income families[1–3]. African-American adolescent girls have a higher prevalence of obesity compared with Caucasian girls[3] and low-income children are 3·4 times more likely to be overweight compared with higher-income children[2]. Recent studies have shown that low-income, urban, African-American adolescent girls are consuming low-quality diets[4–6], putting them at an increased risk for obesity and chronic diseases later in life.

The built environment (all aspects of the surroundings, natural and man-made) may influence obesity and chronic disease risks by creating a food climate that does not support healthy eating[7]. Factors in the community food

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environment linked to healthy food consumption include food store access (presence of), availability (quality of food stores), accessibility (hours of operation), availability of healthy options and price/affordability of healthy foods[8–11]. African-American children are more likely to live near convenience stores than White or Hispanic children. The proximity to an abundance of convenience stores has a stronger association with BMI and overweight/obesity status among African-American children compared with White or Hispanic children[12]. Research is needed to determine how the food environment relates to food consumption among adolescents.

Disparities in the built environment put low-income, urban adolescents at increased risk for an unhealthy diet and obesity. Residents of low-income, non-White neighbourhoods have greater access to fast foods and energy-dense foods than residents in higher-income, White neighbourhoods[13,14]. In low-income neighbourhoods, distance between home and fast-food/convenience stores and the density of fast-food stores are each associated with increased risk for childhood obesity[15,16]. The definition of a food desert varies, but is generally considered an area without a supermarket and limited access to healthy foods[17]. Neighbourhoods with a majority non-White population are more likely to be considered 'food deserts', compared with predominantly White neighbourhoods[18,19]. Chain supermarket availability in African-American neighbourhoods is about half that of White neighbourhoods, with even fewer chain supermarkets available in urban African-American neighbourhoods[18]. Along with having low access to supermarkets and healthy food retailers, a majority of non-White neighbourhoods can have an abundance of food retailers that sell energy-dense, less healthy foods that 'swamp' out the healthy food choices that could be available, leading areas to be labelled as 'food swamps'[20,21]. Since the unhealthiest food environments (limited access to healthy foods and abundant unhealthy food outlets) are in areas with high proportions of low-income African-American residents[19], analyses of both food swamps and food deserts are needed to understand food consumption patterns in low-income, predominantly African-American communities[22]. Because food swamps and food deserts are disproportionately present in low-income, urban, African-American or Hispanic communities, there is debate as to the contribution of socio-economic status (SES; poverty, educational attainment, unemployment) in the association between dietary behaviours and food environment[23].

Theoretically meaningful constructs aid in conceptualizing how aspects of the neighbourhood environment relate to individual behaviours[24]. The Social Ecological Model describes the evolving interaction between developing children/adolescents and their environment[25]. Without health-promoting opportunities from higher-ranking systems (i.e. the neighbourhood), individuals (i.e. adolescents) have difficulty pursuing and maintaining healthy behaviours. The purpose of the present study was to examine how the food environment surrounding the home relates to food consumption among low-income, urban, African-American early adolescent girls. We hypothesize that living in a food desert is associated with lower consumption of fruits and vegetables (*v.* not living in a food desert) and that living in a food swamp is associated with a higher consumption of snacks and desserts (*v.* not living in a food swamp). Additionally, given the known association between neighbourhood SES and food environment, we sought to examine if neighbourhood-level SES confounds the association between the food environment and consumption within this exclusively low-income sample.

Methods

Sample description

The current study was conducted using baseline measures from a multilevel randomized controlled trial of health promotion/obesity prevention conducted among 6th and 7th grade girls attending schools in a large urban school district serving primarily low-income African-American communities. School inclusion criteria (*n* 22) were: (i) >75 % of students eligible for free/reduced-priced lunch; and (ii) >70 % of students African American. Girls in grade 6 or 7 with no chronic illness or health condition that would interfere with participation in a physical education class (*n* 789) were recruited to participate through mailings or in-person interviews during lunch periods and at school-sponsored events. Data collection occurred in four cohorts during the autumn semester, 2009–2013. All participants and their primary caregivers provided informed assent and consent. The study was approved by Institutional Review Boards at both the university and the public school system where the study took place.

Demographics

Girls reported on race/ethnicity and provided their birth date for calculation of chronological age.

Anthropometry

Overweight and obesity were determined using gender-specific BMI-for-age *Z*-scores and percentiles, with BMI-for-age *Z*-score ≥85th and <95th percentile considered as 'overweight' and ≥95th percentile as 'obese'[26]. BMI was calculated from weight and height measured by trained professionals using standardized procedures (three independent measurements). Weight was measured in kilograms to the nearest tenth using standard scales (TANITA Corp., Tokyo, Japan). Height was measured by a portable stadiometer (Shorr Productions, Olney, MD, USA) in centimetres to the nearest tenth.

Youth/Adolescent FFQ

Dietary patterns were measured with the Youth/Adolescent FFQ (YAQ), an instrument developed and validated for use with adolescents[27,28]. The YAQ was self-administered and girls reported foods consumed over the past 12 months. Based on responses on the YAQ, five daily consumption variables were created: (i) average daily energy consumption (values <2092 kJ/d (<500 kcal/d) or 20 920 kJ/d (>5000 kcal/d) were considered invalid and marked as missing)[4]; (ii) daily servings of fruits; (iii) daily servings of vegetables; and (iv) daily servings of snacks and desserts. In order to fully understand the role of French fries in the overall vegetable variable, we examined (v) daily servings of vegetables with and without French fries separately.

Each of the 'servings/d' variables is a summary score created from combining foods and their frequency of consumption included in the YAQ (131 foods are listed in the YAQ, including nine fruits, twenty-two vegetables and twenty-six snacks and desserts). These variables have been used in prior studies that rely on the YAQ for dietary data collection[29,30].

Neighbourhood-level socio-economic status

The Baltimore City Planning Department has identified fifty-five Community Statistical Areas which are clusters of Baltimore City's 278 recognizable city neighbourhoods. For these Community Statistical Areas, the Baltimore City Health Department prepares Neighborhood Health Profiles, outlining data on neighbourhood-level SES and health outcomes[31]. From these data, we exported SES variables specific to each participant's neighbourhood, including median income, percentage of unemployment, percentage of family poverty and percentage with a bachelor's degree or higher.

Food environment mapping

The home addresses from the 789 study participants were geocoded using the ArcGIS geographic information system (GIS) version 10.0. Geocoding is the process of determining the geographic coordinates of an address and placing location indicators on a map[32]. Using this procedure, 781 of the 789 girls' home addresses could be mapped; eight records did not geocode due to invalid addresses. The Baltimore City Food Policy Initiative in collaboration with the Johns Hopkins Center for a Livable Future has developed an official 'Baltimore City Food Environment Map'[33,34], which uses the 2012 food desert definition to define it as an area where: the distance to a supermarket is >0·4 km (>0·25 mile); the median household income is ≤185 % of the Federal Poverty Level; >30 % of households have no vehicle available; and the average Healthy Food Availability Index (HFAI) score (indicates the quality and quantity of healthy foods available[13]) for supermarkets and corner stores is between 0 and 8·7 (full range 0–26), which is classified as low. Shapefiles containing both designated food desert areas and food store locations concurrent with the data collection time period are publicly available[35]. The shapefiles show the boundary of food deserts (polygons) and the point location of convenience stores, corner stores, behind-glass corner stores and supermarkets. Convenience stores are typically chain stores that provide packaged and canned foods; some provide prepared foods or limited produce[26]. Corner stores are smaller stores that typically stock snacks, sodas and candy, and have a limited amount of fresh or frozen foods[26]. Behind-glass corner stores offer the same foods as regular corner stores, but all products are placed behind Plexiglas[26]. Supermarkets are large stores that sell all food types, including meat, seafood, produce, and canned and packaged foods[26]. Methods describing the store location data have been described elsewhere[13] and reflect data current as of 2006 (therefore temporally close to the dates of our individual data collection, which began in 2009). A purposeful sample of the stores included in this list was verified via ground truthing in order to generate the HFAI scores used in the food desert definition[13].

Using ArcGIS, a variable was generated that indicated whether a participant's home was located within a food desert polygon in the shapefile. Homes located within a food desert were assigned a binary designation, retained during the analysis, of being located within a food desert (1) or not located within a food desert (0). Because individuals are willing to walk for approximately 5 min to reach food stores[36,37] and it takes approximately 5 min to walk 0·4 km (0·25 miles), the number of food stores within 0·4 km (0·25 miles) of each girl's home address was calculated. We chose Euclidean distance both because it has been shown previously that similar food access patterns were found when using street network or Euclidean distances[38] and because of our interest in examining density of specific food stores within an area around the home. For each participant, a summation of the number of convenience stores, behind-glass corner stores and small grocery/corner stores within 0·4 km (0·25 miles) of home was calculated using ArcGIS. Living within 0·4 km (0·25 miles) of four or more of these stores was deemed as living in a 'food swamp'.

Data analysis

Data were analysed using the statistical software package IBM SPSS Statistics Version 22.0. Bivariate analyses, including Spearman correlations, t tests and ANOVA models (with *post hoc* testing via Fisher's Least Significant Difference), were conducted to identify unadjusted relationships and potential covariates. Significance was set at $\alpha = 0{\cdot}05$. Food desert/food swamp locations are not independent; thus participants could live in a food desert only, a food swamp only, both, or neither. Dummy variables were generated for food environment, with 'neither' chosen as the reference in regression models. Multiple linear regression models were employed to examine how dietary consumption (dependent variable) related to food environment (independent variable), with individual models tested for each dietary consumption hypothesis (fruits; vegetables; snacks and desserts). We chose standard regression over clustered modelling (adjusting for clustering within schools or neighbourhoods) because, in the case of schools, all schools were part of the same school system and served the same menu of foods daily, and, in the case of neighbourhoods, to reduce the possibility of over-adjusting for neighbourhood factors. The dietary consumption variables were tested for normality and skewed values were normalized by taking the natural log of (1 + variable). Although this approach is somewhat arbitrary, it enables the retention of the variability of the continuous variables while also retaining the zeros present in the data (few overall zeroes present). Covariates considered for inclusion in the models were age, BMI-for-age Z-score and total energy consumption, as these factors are commonly reported to be associated with dietary behaviours of adolescent girls[39]. Confounding was analysed by considering whether: (i) neighbourhood-level SES variables were associated with food consumption variables; (ii) neighbourhood-level SES variables were associated with food environment variables; and (iii) if (i) and (ii) were supported, whether the relationship between food consumption and food environment was attenuated when adjusting for neighbourhood-level SES. Because median household income is included in the definition of a food desert, we did not examine the confounding effect of neighbourhood SES in models that included food deserts. *A posteriori* power analyses using the sampsi command in the statistical software package Stata 12.0 were performed when hypotheses were not supported.

Results

Sample description

Among the sample with geocoded addresses (781/789), 634 had valid dietary data (forty-nine did not complete the YAQ, ninety-eight reported consuming >20 920 kJ/d (>5000 kcal/d)), representing 80·4 % of the original sample. The sample included in the analysis did not differ from the sample excluded based on age, race or weight status/BMI-for-age Z-score. The sample is described in Table 1. The girls ranged in age from 10·1 to 14·7 years, with a mean age of 12·1 years. The majority self-identified as African American or Black (90·7 %). Over half were overweight or obese (52·4 %). The girls in this sample lived in 134 unique neighbourhoods. Average median neighbourhood household income was approximately $US 35 000, with an average poverty rate of 17·6 % and an average unemployment rate of 14·3 %. On average, 16·3 % of adults in the neighbourhood had a bachelor's degree or higher. As seen in Table 1, the ranges for the neighbourhood-level SES variables were wide; however, only poverty rate and educational attainment were skewed (skewness >1·0). Neighbourhood-level SES variables were highly intercorrelated (correlation coefficients ranging from 0·44 to 0·85).

Dietary behaviours

YAQ data (Table 1) revealed that the girls were consuming an average of 1·2 servings fruits/d and 1·7 servings vegetables/d, representing a combined 2·9 daily servings of fruits and vegetables. French fries contributed minimally to the overall vegetables servings/d score, adding an average of 0·1 serving/d to the average; therefore French fries were incorporated into vegetables. Average snack and dessert consumption was 3·4 servings/d, with a wide range

Table 1 Description of the sample of urban, early adolescent girls (*n* 634), Baltimore, MD, USA, 2009–2013

	Mean or %	SD	Range
Age			
Years	12·1	0·7	10·1–14·7
Race/ethnicity			
% African American	90·7	–	–
Weight status			
% Overweight or obese	52·4	–	–
BMI-for-age *Z*-score	1·0	1·0	–0·4–2·9
Food consumption			
Fruits (servings/d)	1·2	1·1	0–6·6
Vegetables (servings/d)	1·7	1·4	0–10·9
Snacks and desserts (servings/d)	3·4	2·5	0–16·2
Energy intake (kJ/d)	10 088	4657	2188–20 882
Energy intake (kcal/d)	2411	1113	523–4991
Neighbourhood-level socio-economic status			
Median household income ($US)	35 298	10 335	13 388–75 248
% Unemployment	14·3	5·1	2·5–28·2
% Family poverty	17·6	10·3	0·6–48·8
% Bachelor's degree or higher	16·3	11·8	4·4–72·5

of 0–16·2. All dietary variables were skewed (skewness: fruits = 1·7; vegetables = 2·4; snacks/desserts = 1·4) and normalized by taking the natural log of (1 + variable) (skewness of normalized variables: fruits = 0·7; vegetables = 0·6; snacks/desserts = 0·1). Mean daily energy consumption was 10 088 kJ (2411 kcal).

Food deserts and food swamps

Over one-quarter (26·5 %) of the girls in this sample were living in a food desert (Table 2). Additionally, based on the definition of having four or more corner/convenience stores within 0·4 km (0·25 miles) of home, 35·2 % of the girls were living in a food swamp (32·3 % lived near no corner/convenience stores and 32·5 % lived near one to three such stores, together describing the 'non-food swamp' category, 64·8 %). Food deserts and swamps were not mutually exclusive, as shown in Table 2, where 16·1 % of the sample lived in an area designated as both a food swamp and a food desert, 10·4 % lived in a food desert only, 19·1 % lived in a food swamp only, and about half (54·4 %) lived in an area that is neither a food desert nor a food swamp.

Neighbourhood food environment and dietary behaviours

All analyses were conducted with normalized dietary variables; bivariate findings are presented with raw data to aid in interpretation. Initial bivariate models (*t* tests) demonstrated no association between living in a food desert and consumption of fruits, vegetables, or snacks and desserts (Table 2). Bivariate ANOVA models revealed a significant difference in mean snack and dessert consumption by food swamp designation, such that girls living near four or more corner/convenience stores consumed 3·71 servings of snacks and desserts daily compared with 3·07 servings/d ($F = 5·00$, $P = 0·007$) consumed by girls living near no corner/convenience stores (Table 2). When examining neighbourhood food environment as a four-category variable (food desert only; food swamp only; both desert and swamp; neither desert nor swamp), ANOVA models examining fruit and vegetable consumption were not significant, suggesting no overall mean difference in these behaviours by food environment (Table 2). The *F* value for the ANOVA model examining snack and dessert consumption by the four-category food environment variable was 2·44 ($P = 0·063$), with *post hoc* testing revealing that the mean daily servings of snacks and desserts among girls living in an area designated as both a food desert and a food swamp was significantly higher than that of girls living in an area designated as neither a food dessert nor a food swamp (3·81 *v.* 3·22 servings/d, $P = 0·019$).

Linear regression models adjusting for age and BMI-for-age *Z*-score supported the null bivariate findings with respect to dietary behaviours and living in a food

Table 2 Associations between the food environment and food consumption/neighbourhood-level socio-economic status among low-income, urban, predominantly African-American early adolescent girls (*n* 634), Baltimore, MD, USA, 2009–2013

	Food desert*				Food swamp† (number of stores)										
					No		Yes								
	No	Yes	t‡	P	(None)	(1–3)	(≥4)	F‡	P	Food desert only	Food swamp only	Both desert and swamp	Neither desert nor swamp	F‡	P
Sample size (*n*)	466	168	–	–	205	206	223	–	–	66	121	102	345	–	–
%	73·5	26·5	–	–	32·3	32·5	35·2	–	–	10·4	19·1	16·1	54·4	–	–
Daily servings of fruits	1·21	1·26	0·56	0·579	1·19	1·16	1·31	0·95	0·389	1·30	1·37	1·23	1·15	1·13	0·335
Daily servings of vegetables	1·69	1·82	0·72	0·471	1·60	1·73	1·84	1·48	0·228	1·68	1·78	1·91	1·67	1·06	0·365
Daily servings of snacks and desserts	3·33	3·64	1·54	0·124	3·07§	3·42	3·71	5·00	0·007	3·37	3·63	3·81§	3·22	2·44	0·063
Median household income ($US)	38 337	26 86	17·5	<0·001	39 760§	36 672§	30 085	57·0	<0·001	27 839§	33 137§	26 428§	40 209	90·6	<0·001
% Unemployment	12·82	18·21	13·2	<0·001	12·98§	13·52	16·09	24·2	<0·001	19·40§	14·96§	17·44§	12·05	78·4	<0·001
% Family poverty	14·72	25·33	12·8	<0·001	13·80§	16·66§	21·72	35·4	<0·001	25·44§	18·76§	25·26§	13·26	68·2	<0·001
% Bachelor's degree or higher	18·30	10·60	9·3	<0·001	17·58§	17·17	14·31	4·9	0·008	10·14§	17·09	10·98§	18·79		

*An area where: distance to a supermarket >0·4 km (>0·25 miles), median household income ≤185 % Federal Poverty Level, >30 % of households have no vehicle available and the average Healthy Food Availability Index score for supermarkets and corner stores is low.
†Four or more of the following stores within 0·4 km (0·25 miles) of home: convenience, small grocery/corner and behind-glass corner stores.
‡The *t* test and ANOVA statistics presented are based on normalized consumption variables.
§*Post hoc* testing (Fisher's Least Significant Difference) revealed significantly different from food swamp (≥4 stores) or neither desert nor swamp: $P < 0·05$.

https://doi.org/10.1017/S1368980016002123 Published online by Cambridge University Press

desert. *A posteriori* power analyses showed that the present study had enough power (≥80 %) to detect a small to medium relationship between food desert and dietary consumption (Cohen's $d=0{\cdot}26$). Based on the SD of the non-normalized consumption variables (Table 1), we could detect a difference of 0·29 servings fruits/d and 0·36 servings vegetables/d.

Table 3 displays findings from a multivariate linear regression model examining the association between daily snack and dessert consumption and food environment (four-category variable). In this model, living in a food swamp was associated with marginally greater consumption ($\beta=0{\cdot}11$, $P=0{\cdot}052$) of snacks and desserts, compared with living in a neighbourhood that is neither a food swamp nor a food desert. Girls living in both a food swamp and a food desert consumed more snacks and desserts than girls living in a neighbourhood considered neither a food swamp nor a food desert (based on normalized outcome; $\beta=0{\cdot}13$, $P=0{\cdot}029$).

A second model examined the association between snack and dessert consumption and living in a food swamp using the three-category food swamp variable (no corner/convenience stores within 0·4 km (0·25 miles) of home as the reference, compared with one to three stores and four or more stores), not incorporating the food desert construct (Table 4, Model 1). This model revealed that living near one to three corner/convenience stores was marginally associated with an increase in consumption of snacks and desserts ($P=0{\cdot}087$) and living near four or more corner or convenience stores was associated with a statistically significant increase in consumption of snacks and desserts (based on normalized outcome; $\beta=0{\cdot}16$, $P=0{\cdot}003$), compared with no corner/convenience stores near home, when adjusting for age and BMI-for-age *Z*-score.

In both regression models (Tables 3 and 4) age and BMI-for-age *Z*-score were also associated with snack and dessert consumption, such that older girls and those with a lower BMI-for-age *Z*-score consumed more snacks and desserts than younger girls and those with a higher BMI-for-age *Z*-score.

Table 3 Linear regression model examining the relationships between neighbourhood food environment and daily consumption of snacks and desserts (dependent variable, normalized), adjusting for age and BMI-for-age *Z*-score, among low-income, urban, predominantly African-American early adolescent girls (*n* 634), Baltimore, MD, USA, 2009–2013

	β	P	95 % CI
Food environment*			
Food swamp	0·11	0·052	–0·001, 0·22
Food desert	0·05	0·458	–0·09, 0·19
Both food swamp and food desert	0·13	0·029	0·01, 0·12
Age			
Years	0·06	0·039	0·003, 0·12
BMI-for-age			
Z-score	–0·08	<0·001	–0·12, –0·42

*Reference category: neither food swamp nor food desert.

Confounding effect of neighbourhood socio-economic status

Girls living in either a food swamp or a food desert were also more likely to live in low-SES neighbourhoods, based on bivariate models (Table 2). Table 5 shows the bivariate associations (Spearman correlations) between neighbourhood SES variables and food consumption, demonstrating that living in a neighbourhood with a lower median income and a higher poverty rate was associated with higher snack/dessert consumption. There were no significant associations between neighbourhood-level SES and fruit or vegetable intake.

In Table 4, a second regression model (Model 2) is presented which includes median household income as a covariate. In this model, median household income was not associated with snack/desert consumption and, when comparing Model 1 with Model 2, the direction, magnitude and significance remained the same, with the R^2 value changing from 0·047 to 0·052. This model was repeated

Table 4 Linear regression model examining the relationships between living within 0·4 km (0·25 miles) of multiple corner/convenience stores and daily consumption of snacks and desserts (dependent variable, normalized), adjusting for age and BMI-for-age *Z*-score, among low-income, urban, predominantly African-American early adolescent girls (*n* 634), Baltimore, MD, USA, 2009–2013

	Model 1			Model 2		
	β	P	95 % CI	β	P	95 % CI
Number of corner/convenience stores within 0·4 km (0·25 miles) of home						
≥4*	0·16	0·003	0·06, 0·26	0·15	0·006	0·04, 0·26
1–3*	0·09	0·087	–0·01, 0·193	0·10	0·060	–0·004, 0·21
Age						
Years	0·06	0·035	0·004, 0·12	0·07	0·018	0·01, 0·13
BMI-for-age						
Z-score	–0·08	<0·001	–0·12, –0·04	–0·08	<0·001	–0·12, 0·04
Median household income						
$US	–	–	–	–0·000002	0·318	0, 0
R^2		0·047			0·052	

*Reference category: none.

https://doi.org/10.1017/S1368980016002123 Published online by Cambridge University Press

Table 5 Correlations (Spearman) between food consumption and neighbourhood-level socio-economic status among low-income, urban, predominantly African-American early adolescent girls (n 634), Baltimore, MD, USA, 2009–2013

	Median household income		% Unemployment		% Family poverty		% Bachelor's degree or higher	
	r	P	r	P	r	P	r	P
Daily servings of fruits	−0·03	0·402	0·02	0·572	0·02	0·558	−0·08	0·059
Daily servings of vegetables	−0·03	0·405	0·004	0·918	0·03	0·518	−0·04	0·274
Daily servings of snacks and desserts	−0·10	0·016	0·07	0·070	0·103	0·010	−0·057	0·158

using each of the neighbourhood-level SES variables of interest (percentage of unemployment, percentage of family poverty and percentage with a bachelor's degree or higher); in each case, similar outcomes were observed (data not shown).

Discussion

Using the Social Ecological Model as a framework, the current paper examined the association between the food environment around the homes of low-income, urban, early adolescent girls and their dietary consumption, focusing on access to food stores. Supporting our hypothesis, the study found that early adolescent girls living in food swamps consumed more snacks and desserts compared with girls living in areas that were not food swamps. Neighbourhood-level SES, although related to both snack and dessert consumption and food swamp status, did not confound this relationship. These results contribute to the body of literature showing an association between consumption of snacks/desserts and residence in a community with a large proportion of stores with unhealthy options[16,40]. Secondarily, we found that the girls in this sample consumed a large number of snacks and desserts, nearly three-and-a-half servings daily, compared with fewer than three daily servings of fruits and vegetables combined; and that girls with a lower BMI-for-age Z-score consumed more snacks and desserts than girls with a higher BMI-for-age Z-score, which may seem counter-intuitive but has been supported in other studies and may be related to variations in physical activity[41].

Prior studies have demonstrated that food swamps are likely to be located in low-income minority areas[42,43]. In the present study, neighbourhood-level SES (including median household income, percentage of unemployment, percentage of family poverty and percentage with a bachelor's degree or higher) was examined as a potential confounder and was not supported, suggesting that, regardless of neighbourhood-level SES, low-income adolescent girls living in food swamps consumed a greater number of snacks and deserts than girls living in neighbourhoods not considered a food swamp. Our findings support the need for more research to investigate the impact of transforming food swamps, via store-based interventions or a policy-based approach, on the dietary behaviours of at-risk populations, including African-American girls. A recent store-based intervention increased the availability of healthy foods in corner stores and found that promoting these foods through signage, taste tests and interactive activities led to a reduction of BMI-for-age percentile among girls with high exposure to the intervention[44,45]. Policy approaches, including zoning policies that focus on limiting the number of unhealthy food retailers to operate within specific areas, should also be considered and, if implemented, evaluated to determine the relationship with dietary consumption and weight.

We did not find support for our hypotheses that living in a food desert is associated with lower consumption of fruits and vegetables, compared with not living in a food desert. A systematic review of the local food environment and diet showed that several other studies have found null and non-meaningful results when investigating the built food environment and fruit/vegetable consumption[46] and publication bias may prevent the awareness of other studies with similar null findings. There are several possible reasons why our analysis did not support our hypothesis. First, the number of daily servings of fruits and vegetables was very low, below the daily recommendation, and had limited variability. This finding is consistent with other studies that have reported adolescents are not meeting the daily servings/d requirement of fruits and vegetables[46,47]. Second, studies that have reported relationships between fruit and vegetable consumption and the environment typically include parents and adolescents[46], or the home food environment as well as the community food environment[48]. Finally, proximal systems in the Social Ecological Model may be more influential than the environment on an adolescent's consumption of fruits and vegetables[20], including the home and school food environments.

Food swamps were common for girls living in neighbourhoods whose populations had a low median income, high unemployment rate, high family poverty rate and a low percentage of adults with a bachelor's degree or higher. Food deserts were also located in neighbourhoods characterized by low SES indicators; however, this was expected because Baltimore City's food desert definition includes median household income. The finding that lower-income areas are disproportionately affected by unhealthy food environments is widely supported in the literature[14,16–18]. The variability in the food environment and neighbourhood SES indicators in our sample of predominantly low-income African-American girls illustrates the value of considering neighbourhood SES when examining how the food environment relates to food consumption. As we consider policies and programmes to improve the quality of foods in food stores and access to healthy foods, neighbourhood-level SES should remain part of the conversation[23].

The current study had several strengths and limitations. Three major contributions are the inclusion of food swamps in addition to food deserts in relation to adolescent dietary behaviour, the inclusion of individual-level food consumption and the consideration of neighbourhood-level SES. The food desert definition used in the analysis incorporates not just access to supermarkets, but also a HFAI score for indicating the healthfulness of foods available within stores[13,33,34]. The use of GIS mapping is a strength in that it provides an objective measure of the built environment (*v.* self-report).

There are also limitations with the use of GIS. GIS-derived boundaries, including the use of a Euclidian distance of 0·4 km (0·25 miles) established in our food swamp calculations, are not always in line with residents' access. Euclidian distance does not account for street connectivity[48]. Our food swamp definition considered corner/convenience stores that may provide carryout, but not restaurants (fast foods, carryout or sit-down dining). We excluded restaurants because our primary interest was in snacking and, for the most part, restaurants serve meals. In addition, the Baltimore City food desert definition considers only food stores, which were, in part, ground-truthed; the restaurant data we obtained came from a similar yet unverified source. There are many factors that influence adolescent food consumption, including community, school, interpersonal and individual-level factors, as highlighted in the Social Ecological Model[20], which were outside the scope of our study and thus not included. Also, because the dietary consumption data were skewed, we relied on the natural log of (1 + variable) to normalize. Although this procedure is somewhat arbitrary, it allowed us to retain the zeros in the distribution and the variability of our continuous variables. Other limitations include the focus only on low-income, predominantly African-American early adolescent girls, which limits the generalizability of the findings, and the cross-sectional design, which does not allow for the examination of causal relationships or the role of residential self-selection.

Future studies should examine mechanisms explaining how living in a food desert, a food swamp or both may affect dietary choice and overweight/obesity status among populations at increased risk for obesity, including adolescent girls. Additionally, there are many definitions of food deserts and food swamps. The use of the Baltimore City definition of food deserts is a strength of our study because findings may inform local policy makers; however, the definition is unique to one city. The lack of uniformity in definitions among researchers and policy makers impedes progress, and consistent definitions are needed. An evaluation of the relationship between food swamps, food deserts and food consumption among other populations (children and adults of all ages and genders) should be conducted. Finally, an analysis that examines changes in food desert and food swamp locations and food consumption over time will inform causal relationships between the community food environment and food consumption.

Conclusion

In conclusion, the present study analysed the relationship between food deserts, food swamps and food consumption among urban, low-income, predominantly African-American early adolescent girls. The study adds to the literature by mapping food swamp locations and demonstrating a relationship between living in a food swamp and increased consumption of snacks and desserts among African-American early adolescent girls. This finding highlights the need to consider the built environment/food access when addressing adolescent dietary behaviours. It also highlights the need to consider food swamps, along with food deserts, when determining food access and food consumption behaviours. Policy makers and stakeholders should consider store-based interventions or policy approaches to increasing healthy food access in corner stores and limiting the number of unhealthy food retailers.

Acknowledgements

Acknowledgements: The authors would like to acknowledge the Challenge! in Schools data collection team, especially Robyn Foreman, PhD (currently: Battelle Memorial Institute), Laura Latta (currently: Family League of Baltimore), Samantha Wilkes (currently: Family League of Baltimore) and Raquel Arbaiza. They are also grateful to the participants for their time. *Financial support:* This work was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD)–University of Maryland's Organized Research Effort in Women's Health BIRCWH K12 Scholar Program (grant number K12HD4489-8); the National Institutes of Health, NICHD (grant number R01HD054727); the Robert Wood Johnson Foundation, Active Living Research/New Connections (grant number 65631); and a State of Maryland MPower Initiative Grant awarded to the University of Maryland College Park Department of Geographical Sciences. The funders had no role in the design, analysis or writing of this article.

Conflict of interest: None. *Authorship:* E.R.H. conceived of this study. E.R.H., A.C. and D.H. conducted analyses for hypothesis testing. A.C., N.O. and J.H. gathered the spatial data and conducted the geocoding/spatial analyses. M.M.B., E.R.H., K.M.H. and N.O. gathered participant data. All authors participated in interpretation of findings and drafting and critically revising the manuscript for intellectual content. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the University of Maryland School of Medicine and public school system Institutional Review Boards. Written informed assent was obtained from all enrolled children and written informed consent was obtained from all parents/primary caregivers.

References

1. Ogden CL, Lamb MM, Carroll MD *et al.* (2010) Obesity and socioeconomic status in children and adolescents: United States, 2005–2008. *NCHS Data Brief* issue 51, 1–8.
2. Singh GK, Siahpush M & Kogan MD (2010) Rising social inequalities in US childhood obesity, 2003–2007. *Ann Epidemiol* **20**, 40–52.
3. Ogden CL, Carroll MD, Fryar CD *et al.* (2015) Prevalence of obesity among adults and youth: United States, 2011–2014. *NCHS Data Brief* issue 219, 1–8.
4. Hurley KM, Oberlander SE, Merry BC *et al.* (2009) The healthy eating index and youth healthy eating index are unique, nonredundant measures of diet quality among low-income, African American adolescents. *J Nutr* **139**, 359–364.
5. Wang Y, Jahns L, Tussing-Humphreys L *et al.* (2010) Dietary intake patterns of low-income urban African-American adolescents. *J Am Diet Assoc* **110**, 1340–1345.
6. Christiansen KM, Qureshi F, Schaible A *et al.* (2013) Environmental factors that impact the eating behaviors of low-income African American adolescents in Baltimore City. *J Nutr Educ Behav* **45**, 652–660.
7. Papas MA, Alberg AJ, Ewing R *et al.* (2007) The built environment and obesity. *Epidemiol Rev* **29**, 129–143.
8. Dunton GF, Kaplan J, Wolch J *et al.* (2009) Physical environmental correlates of childhood obesity: a systematic review. *Obes Rev* **10**, 393–402.
9. Glanz K, Sallis JF, Saelens BE *et al.* (2005) Healthy nutrition environments: concepts and measures. *Am J Health Promot* **19**, 330–333.
10. Engler-Stringer R, Le H, Gerrard A *et al.* (2014) The community and consumer food environment and children's diet: a systematic review. *BMC Public Health* **14**, 522.
11. McKinnon RA, Reedy J, Morrissette MA *et al.* (2009) Measures of the food environment: a compilation of the literature, 1990–2007. *Am J Prev Med* **36**, 4 Suppl., S124–S133.
12. Powell LM, Auld MC, Chaloupka FJ *et al.* (2007) Associations between access to food stores and adolescent body mass index. *Am J Prev Med* **33**, 4 Suppl., S301–S307.
13. Franco M, Diez Roux AV, Glass TA *et al.* (2008) Neighborhood characteristics and availability of healthy foods in Baltimore. *Am J Prev Med* **35**, 561–567.
14. Larson NI, Story MT & Nelson MC (2009) Neighborhood environments: disparities in access to healthy foods in the US. *Am J Prev Med* **36**, 74–81.
15. Galvez MP, Pearl M & Yen IH (2010) Childhood obesity and the built environment. *Curr Opin Pediatr* **22**, 202–207.
16. Hilmers A, Hilmers DC & Dave J (2012) Neighborhood disparities in access to healthy foods and their effects on environmental justice. *Am J Public Health* **102**, 1644–1654.
17. Walker RE, Keane CR & Burke JG (2010) Disparities and access to healthy food in the United States: a review of food deserts literature. *Health Place* **16**, 876–884.
18. Powell LM, Slater S, Mirtcheva D *et al.* (2007) Food store availability and neighborhood characteristics in the United States. *Prev Med* **44**, 189–195.
19. Gordon C, Purciel-Hill M, Ghai NR *et al.* (2011) Measuring food deserts in New York City's low-income neighborhoods. *Health Place* **17**, 696–700.
20. Rose D, Bodor NJ, Swalm CM *et al.* (2009) *Deserts in New Orleans? Illustrations of Urban Food Access and Implications for Policy Understanding the Economic Concepts and Characteristics of Food Access. Paper prepared for University of Michigan National Poverty Center/USDA Economic Research Service Research, 'Understanding the Economic Concepts and Characteristics of Food Access', February 2009*. New Orleans, LA: Tulane University; available at http://www.npc.umich.edu/news/events/food-access/rose_et_al.pdf
21. Ver Ploeg M (2009) *Access to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences: Report to Congress*. Washington, DC: US Department of Agriculture, Economic Research Service; available at http://www.ers.usda.gov/media/242675/ap036_1_.pdf
22. Saunders P, Saunders A & Middleton J (2015) Living in a 'fat swamp': exposure to multiple sources of accessible, cheap, energy-dense fast foods in a deprived community. *Br J Nutr* **113**, 1828–1834.
23. Brown DR & Brewster LG (2015) The food environment is a complex social network. *Soc Sci Med* **133**, 202–204.
24. Echeverria SE, Diez-Roux AV & Link BG (2004) Reliability of self-reported neighborhood characteristics. *J Urban Health* **81**, 682–701.
25. Bronfenbrenner U (1979) *The Ecology of Human Development*. Cambridge, MA: Harvard University Press.
26. Barlow SE & Expert Committee (2007) Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics* **120**, Suppl. 4, S164–S192.
27. Rockett HR, Breitenbach M, Frazier AL *et al.* (1997) Validation of a youth/adolescent food frequency questionnaire. *Prev Med* **26**, 808–816.
28. Rockett HR & Colditz GA (1997) Assessing diets of children and adolescents. *Am J Clin Nutr* **65**, 4 Suppl., 1116S–1122S.
29. Black MM, Hager ER, Le K *et al.* (2010) Challenge! Health promotion/obesity prevention mentorship model among urban, black adolescents. *Pediatrics* **126**, 280–288.
30. Papas MA, Hurley KM, Quigg AM *et al.* (2009) Low-income, African American adolescent mothers and their toddlers exhibit similar dietary variety patterns. *J Nutr Educ Behav* **41**, 87–94.
31. Baltimore City Health Department (2011) Baltimore City Neighborhood Health Profile Reports. http://healthbaltimorecitygov/neighborhood-health-profile-reports (accessed May 2016).
32. Cromley E & McLafferty S (2011) *GIS and Public Health*, 2nd ed. New York: The Guilford Press.
33. Johns Hopkins Center for a Livable Future: Maryland Food System Map (2015) The Baltimore City Food Environment Map. http://mdfoodsystemmap.org/2015-baltimore-city-food-access-map/ (accessed August 2016).
34. Baltimore City Department of Planning (2016) Baltimore Food Policy Initiative. http://planning.baltimorecity.gov/baltimore-food-policy-initiative (accessed August 2016).
35. Johns Hopkins Center for a Livable Future: Maryland Food System Map (2012) Baltimore City Food Deserts.

http://mdfoodsystemmap.org/glossary/baltimore-city-food-deserts-2/ (accessed August 2016).
36. Atash F (1994) Redesigning suburbia for walking and transit: emerging concepts. *J Urban Plan Dev* **120**, 48–57.
37. Pushkarev B & Zupan J (1975) *Urban Space for Pedestrians: A Report of the Regional Plan Association*. Cambridge, MA: MIT Press.
38. Sparks AL, Bania N & Leete L (2011) Comparative approaches to measuring food access in urban areas: the case of Portland, Oregon. *Urban Stud* **48**, 1715–1737.
39. Laska MN, Murray DM, Lytle LA *et al*. (2012) Longitudinal associations between key dietary behaviors and weight gain over time: transitions through the adolescent years. *Obesity (Silver Spring)* **20**, 118–125.
40. Larson N, Story M, Eisenberg ME *et al*. (2015) Secular trends in meal and snack patterns among adolescents from 1999 to 2010. *J Acad Nutr Diet* **116**, 240.e2–250.e2.
41. Larson N & Story M (2013) A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status? *Child Obes* **9**, 104–115.
42. Boone-Heinonen J, Gordon-Larsen P, Kiefe CI *et al*. (2011) Fast food restaurants and food stores: longitudinal associations with diet in young to middle-aged adults: the CARDIA study. *Arch Intern Med* **171**, 1162–1170.
43. Fielding JE & Simon PA (2011) Food deserts or food swamps?: comment on 'Fast food restaurants and food stores'. *Arch Intern Med* **171**, 1171–1172.
44. Gittelsohn J, Dennisuk LA, Christiansen K *et al*. (2013) Development and implementation of Baltimore Healthy Eating Zones: a youth-targeted intervention to improve the urban food environment. *Health Educ Res* **28**, 732–744.
45. Shin A, Surkan PJ, Coutinho AJ *et al*. (2015) Impact of Baltimore Healthy Eating Zones: an environmental intervention to improve diet among African American youth. *Health Educ Behav* **42**, 1 Suppl., 97S–105S.
46. Caspi CE, Sorensen G, Subramanian SV *et al*. (2012) The local food environment and diet: a systematic review. *Health Place* **18**, 1172–1187.
47. Watts AW, Masse LC, Barr SI *et al*. (2014) Parent–child associations in selected food group and nutrient intakes among overweight and obese adolescents. *J Acad Nutr Diet* **114**, 1580–1586.
48. Ding D, Sallis JF, Norman GJ *et al*. (2012) Community food environment, home food environment, and fruit and vegetable intake of children and adolescents. *J Nutr Educ Behav* **44**, 634–638.