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Is there a robust relationship between neighbourhood food environment and childhood obesity in the USA?

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SUMMARY

Objectives—To examine the robustness of the relationship between neighbourhood food environment and youth body mass index (BMI) percentile using alternative measures of food environment and model specifications.

Study design—Observational study using individual-level longitudinal survey data of children in fifth and eighth grades merged with food outlet data based on student residential census tracts.

Methods—The relationship between food environment and BMI was examined with two individual outcomes (BMI percentile in eighth grade and change in BMI percentile from fifth to eighth grade) and three alternative measures of food environment (per-capita counts of a particular outlet type, food environment indices, and indicators for specific combinations of outlet types).

Results—No consistent evidence was found across measures (counts of a particular type of food outlet per population, food environment indices, and indicators for the presence of specific combinations of types of food stores) and outcomes to support the hypothesis that improved access to large supermarkets results in lower youth BMI; or that greater exposure to fast food restaurants, convenience stores and small food stores increases BMI.

Conclusions—To the extent that there is an association between food environment and youth BMI, the existence of more types of food outlets in an area, including supermarkets, is associated with higher BMI.

Keywords

Childhood obesity; Neighbourhood food environment; Supermarket; Convenience store; Fast food restaurant

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Ethical approval
This study was reviewed by the RAND Human Subjects Protection Committee (HSPC) and determined to be exempt from HSPC review.

Competing interests
None declared.

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Introduction

Healthy People 2010 aimed to reduce the proportion of obese children and adolescents in the USA to 5% by 2010.[1] However, the actual rates are three times higher. The latest figures show 16.9% of those aged 2–19 years in the obese category [at or above the 95th percentile of the body mass index (BMI)-for-age growth chart] and 31.8% in the overweight category (at or above the 85th percentile).[2] This has led to a flurry of governmental activities in the past year, including a $400 million healthy food initiative,[3] the establishment of the White House Childhood Obesity Task Force,[4] and a new strategic plan that makes obesity prevention a priority in the Department of Health and Human Services.[5]

A recurring theme in these governmental activities is the role of the food environment, in particular the notion of 'food deserts', where access to healthy and affordable food is limited, especially in disadvantaged neighbourhoods.[6] 'Food deserts' are often identified by the absence of large supermarkets and the presence of a large number of fast food restaurants and/or small food outlets.[7,8] The hypothesis linking the food environment to obesity argues that greater access to fast food outlets, convenience stores and small grocery stores results in lower diet quality and overeating, whereas greater access to large supermarkets has a preventive effect due to its provision of various healthy products, mainly fruits and vegetables. This hypothesis is a central theme of the White House Childhood Obesity Task Force report[7] and the $400 million healthy food financing initiative.[3]

Evidence on how the food environment relates to obesity is still developing and, at this point, is more tentative than presented in the media and policy arguments.[9–11] The Task Force's recommendation on increasing the number of supermarkets in order to reduce childhood obesity only references a single study that associated nearby chain supermarkets with lower adolescent BMI and convenience stores with higher BMI.[12]

Reflecting the relatively early stage of this field, existing studies are heterogeneous with many unique measures and approaches that preclude meta-analyses.[9] In any new field of investigation, early results do not always hold up, or require some modification that is only detectable through replication, a central principle of the scientific method. The absence of reproducibility of original findings stems from factors such as lack of statistical power in individual studies, selection bias and publication bias.[13,14]

This study contributes to the literature on obesity epidemiology by examining the robustness of the relationship between neighbourhood food environment and youth BMI percentile in the USA using alternative environment measures and model specifications. Three commonly applied measures of the food environment are adopted, namely the per-capita counts of a particular type of food outlet in the neighbourhood,[12,15,16] the food environment indices (i.e. ratio of certain types of food outlets vs other or all outlets),[17–19] and indicators for the presence of specific combinations of types of food stores.[20] Alternative measures may reflect dissimilar assumptions on consumer behaviour and/or capture different characteristics of the food environment, so results can differ. However, if results are highly sensitive to the choice of measure, more caution should be placed on the interpretation of results and policy implications. Aside from replicating cross-sectional analyses with different food environment measures, changes in BMI over time were also studied. Almost all published studies have used cross-sectional outcomes (i.e. obesity or BMI at a point in time), and thus a longitudinal outcome measure should serve as an important complement. If certain environmental factors lead to obesity, results should hold when examining the change in BMI. As this study investigated youth, the outcome measures were BMI percentile (based on growth chart) and change in BMI percentile (from fifth to eighth grade).

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Methodology

Data

Individual-level data came from the Early Childhood Longitudinal Study-Kindergarten Class (ECLS-K), a multistage longitudinal survey of a nationally representative cohort of kindergarteners starting school in the 1998–1999 school year in the USA. Students were followed from kindergarten to eighth grade. Data used in this study were collected in the spring of fifth grade (2004) and eighth grade (2007). Height and weight were measured twice in each wave to reduce measurement error. Eighth-grade student residence was geocoded to census tract. Of the 9610 students in eighth grade with a home census tract identifier, 6260 (65%) had complete data for BMI percentile measured in both fifth and eighth grades, and other individual characteristics measured in eighth grade. These students lived in 2970 census tracks and attended 1900 schools in 45 US states.

The dependent variables were BMI percentile in eighth grade and change in BMI percentile from fifth to eighth grade. Age- and gender-specific BMI percentile (based on the 2000 BMI-for-age growth chart issued by the Centers for Disease Control and Prevention)[21] were used to account for the differential trends in body growth and fat change across age and sex. Individual covariates included age (i.e. age in months and age in months squared), gender, race/ethnicity (i.e. dichotomous variables for non-Hispanic black, non-Hispanic Asian, Hispanic, and other race or multirace, in comparison with non-Hispanic White), mother's education (i.e. dichotomous variables for high school graduate, some college, and college graduate or higher, in comparison with education less than high school), annual household income, total hours per week spent watching television, number of days per week spent undertaking vigorous physical activity (i.e. physical activity for at least 20 min that makes one sweat and breathe hard), and parent–child interactions (i.e. frequency of talking about friends and school, and frequency of helping with homework).

Three alternative measures of the neighbourhood food environment were constructed. The first was defined as the counts of a particular type of food outlet per 1000 population in the census tract where the student lived, allowing examination of the effect of outlet density on youth BMI. This is the most commonly used approach to measure food environment in published research, although some earlier studies did not have these finer geographical identifiers and had to resort to cruder or more arbitrary geographical units (e.g. counties or zip codes). The second measure was food environment indices, namely ratios of ‘unhealthy’ foods to ‘healthy’ or all sorts of foods. One such index is the Retail Food Environment Index (RFEI), constructed by the California Center for Public Health Advocacy,[17] which is the ratio of the counts of fast food outlets and convenience stores to supermarkets and produce vendors. Despite the considerable amount of attention that the RFEI has received, its definition suffers from a major problem. When analysing geographical units smaller than a county, a large number of areas are dropped out of the analysis because the RFEI is undefined if there is no supermarket or produce vendor in those areas.[19] In the present data, the RFEI was undefined for approximately 58% of youth, and studies using the RFEI are likely to suffer from severe selection bias. An alternative index, the Physical Food Environment Index (PFEI), which adds the counts of fast food outlets and convenience stores into the denominator of the RFEI, alleviates this problem in the present data.[19] Using PFEI, only about 13% of the individuals have their neighbourhood food environment undefined. Despite the limitations of the RFEI, this measure was used in this study to allow comparison with previous results. Besides RFEI and PFEI, two additional variables were constructed: the ratio of convenience stores to all food stores, and the ratio of fast food outlets to all restaurants. The third measure of the food environment was indicators for the presence of specific combinations of types of food stores, proposed by Morland et al.[20] Briefly, these indicators show whether a census tract contains: (1) supermarkets only; (2)

supermarkets and grocery stores; (3) supermarkets and convenience stores; (4) supermarkets, grocery stores and convenience stores; (5) grocery stores; (6) convenience stores; (7) grocery stores and convenience stores; and (8) no food stores.

Food outlet data came from InfoUSA, a compiler of business names, types, location/address, yellow page heading, number of employees and sales volume for approximately 14 million businesses in the USA. Various types of food outlets were selected based on the North American Industry Classification System (NAICS) codes. The categories were all restaurants (NAICS code 72211, 722211, and 722212), convenience stores and small food stores (44512 and 44511 with annual sales less than 1 million US$), grocery stores and medium-sized food stores (44511 with annual sales 1–5 million US$), and supermarkets (44511 with annual sales greater than 5 million US$). While there is no specific category for fast food in NAICS, fast food outlets are defined as limited-service (where patrons order or select items and pay before eating) restaurants and pizza establishments (NAICS codes 72221105 and 72211016).

All measures of the food environment use census tract as the neighbourhood unit. Census tracts in the USA typically include 2500–8000 individuals and represent areas with similar socio-economic characteristics of the population.[22] In large urban areas, a census tract usually covers an area within walking distance. These characteristics make census tracts a useful proxy of neighbourhoods, and widely used in health epidemiology literature.[23–25]

As well as individual covariates and measures of the neighbourhood food environment, census tract characteristics constructed using the 2000 Census data[26] were also controlled in the multivariate analyses, including median household income, percentage of non-Hispanic Whites, and an index for street connectivity (ratio of links in the network to maximum possible links between nodes; e.g. an index of 0.4 means that the street network is 40% connected).

Statistical methods

The relationship between neighbourhood food environment and youth BMI was examined using ordinary least squares with two dependent variables (BMI percentile in eighth grade and change in BMI percentile from fifth to eighth grade) and three alternative measures of the food environment [counts of a particular type of food outlet per 1000 population, food environment indices (e.g. RFEI and PFEI), and indicators for the presence of specific combinations of types of food stores]. For each combination of the dependent variable and food environment measures, two model specifications were performed. The first specification (Model 1) does not include any individual or census tract covariates, and the second specification (Model 2) includes both sets of controls. For models with change in BMI percentile as the dependent variable, the baseline BMI percentile in 2004 was also controlled. All models used the ECLS-K sampling weights to account for the differential probabilities for individual observations to be selected, and thus the population means are estimated. The Eicker-Huber-White sandwich estimator was used to calculate robust standard errors clustered at home census tract. All analyses were conducted using STATA Version 10.1 (StataCorp, College Station, TX, USA).

Results

Table 1 shows descriptive statistics for the ECLS-K sample. Half of the sample was female, and a variety of races/ethnicities were included (60% Caucasian, 15% African American, 18% Hispanic, 3% Asian and 4% other race or multirace). The average BMI in the spring of eighth grade was 23, and the average BMI percentile was 66.7. More than one-third (36%) of the sample was overweight (BMI percentile >85) and 19% were obese (BMI percentile

>95). On average, youth reported participating in vigorous physical exercise on 4.6 days/week and watching television for approximately 24 h/week. More than two-thirds of students (70%) lived in a census tract with one or more small food outlet or convenience stores, less than one-quarter (22%) had one or more medium-sized grocery stores, and more than one-third (36%) had at least one large supermarket. Most youth (81%) had at least one type of food outlet in their residential census tract, and over half of them (57%) had at least one fast food outlet in their neighbourhood.

The association between neighbourhood food environment and youth BMI was examined by two dependent variables (BMI percentile in eighth grade and change in BMI percentile from fifth to eighth grade) and three alternative measures of food environment [i.e. counts of a particular type of food outlet per 1000 population (Table 2), food environment indices (Table 3), and indicators for the presence of specific combinations of types of food stores (Table 4)].

In Table 2, the estimated coefficient of convenience stores ($\beta = 6.99$, $P<0.01$) in Model 1 was the only one that was significant at $P<0.05$ with the expected sign, but the effect size ($\beta = 1.33$, $P=0.52$) shrank substantially and became insignificant after controlling for covariates in Model 2. All point estimates in the cross-sectional models were positive, with supermarkets having the largest coefficient. Based on the point estimates, more of any one type of food outlet predicted higher BMI. In the longitudinal analysis, however, this relationship disappeared. Similar results were obtained when all food environment variables were included in the same model (results not shown in tables). In the cross-sectional model with no individual or census tract covariates, all except the coefficient of fast food outlets were significant at $P<0.05$, and the coefficient of supermarkets was the largest. When individual and tract variables were added, those food environment variables lost significance. In the longitudinal analysis, the joint significance of all food outlets was essentially zero, with and without the inclusion of individual and tract covariates.

Table 3 shows results with neighbourhood food environment measured by the food environment indices. Those indices were defined as the ratio of ‘unhealthy’ food stores to ‘healthy’ or all food stores, and thus the ‘food desert’ hypothesis implies significant positive coefficients. However, none of the estimated coefficients were significant either with BMI percentile or change in BMI percentile as the dependent variable. Some even reversed sign.

In Table 4, the reference group is ‘supermarkets only’ census tracts, and the coefficients are the effect of living in a census tract with a combination of food stores relative to living in a census tract that only has supermarkets on the individual outcome (i.e. BMI percentile or its change). Coefficients of all models were positive, implying the lowest BMI (or BMI gain) in census tracts that only had supermarkets. While most coefficients were highly significant in a simple model, most of the significance disappeared when including other covariates or in the longitudinal model.

An alternative hypothesis more consistent with the results appears to be that ‘more varieties of food outlets, regardless of type, predict higher BMI’, although differences between types were not significant. The authors tested whether more types of food outlets predict higher BMI by creating an indicator for having grocery and convenience stores, supermarkets and convenience stores, supermarkets and grocery stores, or all three types of food stores. In the cross-sectional analysis (Models 1 and 2), the coefficient was positive and significant ($P=0.005$), suggesting that compared with living in a census tract where there is, at most, one type of food outlet (no food store, only supermarket, only convenience store or only grocery store), youth surrounded by more types of food outlets were associated with a higher BMI percentile. In the longitudinal analysis, the coefficient was negative but insignificant in the empty model (Model 1), and became positive but still insignificant when covariates were included (Model 2).

In contrast to the sensitivity of estimates across alternative measures of the neighbourhood food environment and BMI outcomes, the estimated coefficients of individual covariates were robust to different specifications. For example, spending an additional hour watching television each week was associated with a 0.04–0.06 higher BMI percentile with all different food environment measures (significant at $P<0.05$ in all models, except models with the ratio of convenience stores to all food stores, RFEI and PFEI), and a 0.04–0.05 higher gain in BMI percentile from fifth to eighth grade (significant at $P<0.05$ in all models except the model with RFEI). Compared with living in a low-income family (annual household income <$25,000), an adolescent raised in a high-income family (annual household income >$100,000) was associated with a 4–7 lower BMI percentile (significant at $P<0.05$ in all models except the model with RFEI) and a 4 smaller gain in BMI percentile (significant at $P<0.05$ in all models except the model with RFEI), conditional on neighbourhood food environments and all other covariates.

Discussion

This paper provides new data on the association between neighbourhood food environment and youth obesity using a nationally representative sample. To replicate and assess previous results that have received considerable attention, three types of measures were used to predict two individual outcomes: BMI percentile at eighth grade and change in BMI percentile from fifth to eighth grade. No consistent evidence was found across measures and outcomes to support the null hypothesis that greater exposure to fast food outlets, convenience stores and small food stores, and less access to large supermarkets results in higher BMI among youth. To the extent that there is any association between food environment and youth BMI at all, it would be a modification of the ‘food desert’ hypothesis in that more varieties of food outlets, regardless of type, are associated with higher BMI. Although specific estimates differ between urban and rural areas (results not shown), the conclusions are the same. For youth in this particular sample (which was nationally representative and had objective measures of BMI), no evidence for a protective effect from supermarkets was found, nor evidence for an adverse effect of fast food outlets and small food stores.

This study intentionally applied commonly adopted measures of the food environment (per-capita counts of a particular type of food outlet in the neighbourhood,[12,15,16] food environment indices,[17–19] and indicators for the presence of specific combinations of types of food stores[20]) in order to provide new results that can be compared with existing results. This type of research has several limitations and results should be interpreted with caution, regardless of whether they are a null finding (as in the present study) or significant associations (as in some previous studies[12,20]). The food environment measures are typically based on data from commercial vendors, such as InfoUSA (as in the present study) or Dun and Bradstreet, because only small localized studies use field work. Despite vendors’ claims about accuracy (InfoUSA claims that more than 99% of businesses are geocoded to census block groups), the actual accuracy of data is almost certainly lower. Research has found moderate agreement between field observations and secondary commercial data sources for food stores and restaurant outlets.[27,28] Business data are updated on a rotating basis, which means that a release date does not reflect the food environment at that date and it is not possible to construct short-term time series for the food environment. Census tracts are used as the geographical unit of analysis, which is the most commonly chosen administrative unit in previous research to proxy for neighbourhood, as this study focused on replicating previous analyses with new data for comparability. Census tracts may be the most manageable definition of neighbourhoods given data availability in most studies and are a reasonable first approximation, but census tracts do not reflect shopping environments and may not match perceived neighbourhoods.[29] Smaller geographical areas and individualized distance measures, as in recent alcohol studies,[30,31] may eventually prove to be a better approach, although this will not be possible for most studies given data availability.

The role of transportation is important for shopping and dining patterns. This idea was highlighted in the recent report by the US Department of Agriculture on food deserts,[8] which alters the definition of the shopping environment both across areas and individuals. Finally, the large majority analysed residential neighbourhoods, and a few considered work or school neighbourhoods. However, a recent study examining the food environment around residences and schools found no association between the food environment and dietary behaviours of children and adolescents in California.[32]

Despite the many limitations in this type of research, initial significant results have received an extraordinary amount of attention. Some of those results on food environment appear to have been intended for advocacy to begin with (e.g. the RFEI was developed by the California Center for Public Health Advocacy), but selected early research is also used to justify policy. The Childhood Obesity Task Force's recommendation to increase the number of supermarkets in order to reduce childhood obesity is based on a single study that associated chain supermarkets in a postal zip code with lower BMI among adolescents. Improving the range of foods available, particularly fresh produce, may be a laudable goal from a number of perspectives, including diet quality and consumer choice. It is less clear that it would prevent obesity because much of the revenue in supermarkets comes from the wider selection of soft drinks, sweets, salty snacks or frozen dinners, which are available at lower prices and larger package sizes. Excess consumption of foods that should only be eaten as part of discretionary calories, rather than underconsumption of fruits and vegetables, is the main discrepancy to dietary guidelines and a reliable predictor of obesity among adults.[33,34] Variety tends to be a consistent predictor of higher consumption.[35] Food offerings at fast food outlets are often criticized for contributing to obesity, but fast food could be a prudent choice compared with sit-down restaurants given that items can be ordered individually, and sit-down restaurants often offer very high calorie meals.[36,37] Measuring the neighbourhood food environment may be important, but understanding the true association between the food environment and obesity requires integration of this community nutrition environment with school[38–40] and consumer nutrition environments.[41]

This study did not find consistent evidence across measures and outcomes to support the ‘food desert’ hypothesis that improved access to large supermarkets could prevent obesity among youth, nor that fast food restaurants or small food stores and convenience stores have adverse effects. Robustness testing and systematic replication of results in many different settings are key for this type of exploratory research, and prerequisite in providing reliable policy implications.

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Table 1

Descriptive statistics of Early Childhood Longitudinal Study-Kindergarten Class (ECLS-K) sample in eighth grade and the neighbourhood environment.

Variable	% or Mean (SD)
Gender	
Male	50.0%
Female	50.0%
Race/ethnicity	
White (Non-Hispanic)	60.2%
Black (Non-Hispanic)	15.1%
Asian (Non-Hispanic)	2.9%
Hispanic	17.8%
Other race or multi-race	3.9%
Age (months)	171 (4.58)
BMI status	
Overweight	36.0%
Obese	19.2%
BMI	23.0 (5.3)
BMI percentile	66.7 (28.3)
Mother's education	
Less than high school	9.8%
High school graduate	22.4%
Some college	36.6%
College graduate or higher	31.2%
Annual household income	
$0–25,000	18.3%
$25,001–40,000	17.8%
$40,001–75,000	26.6%
$75,001–100,000	17.4%
≥$100,001	19.9%
Activity level	
Weekly days of vigorous physical activity	4.6 (2.0)
Weekly hours spent watching television	24.1 (20.6)
Parent–child interactions	
Frequency parents talk with their child about friends and school	7.2 (1.0)
Frequency parents help their child with homework	7.2 (2.7)
Census tract characteristics	
Median household income	$49,022 ($21,728)
Percentage of non-Hispanic White	70.5%
Index for street connectivity	0.4 (0.5)

BMI, body mass index; SD, standard deviation.

Sample size = 6260.

Statistics have been adjusted using ECLS-K sampling weights.

Table 2

Estimated associations for count of outlets per 1000 population and youth body mass index (BMI).

	BMI Percentile in eighth grade		Change in BMI percentile between fifth and eighth grade	
Measure	**Model 1[a]**	**Model 2[b]**	**Model 1[a]**	**Model 2[b]**
Fast food outlets per 1000 population	1.74 (1.28)	1.09 (1.26)	-0.55 (0.60)	-0.75 (0.55)
Convenience stores per 1000 population	6.99 (1.88)**	1.31 (2.02)	-0.64 (0.89)	-1.86 (0.97)
Grocery stores per 1000 population	7.43 (5.39)	2.39 (4.46)	1.13 (2.08)	0.12 (1.80)
Supermarkets per 1000 population	8.82 (5.24)	9.15 (5.06)	0.21 (2.74)	1.74 (2.45)

Sample size = 6260.

Models were estimated using ordinary least squares.

Standard errors are in parentheses.

Statistics have been weighted by Early Childhood Longitudinal Study-Kindergarten Class sampling weights.

Eicker-Huber-White sandwich estimator was used to calculate robust standard errors clustered as census tract.

*$P<0.05$

[a]Model 1 includes the food environment measure as the only independent variable.

[b]Model 2 includes the food environment measure, individual covariates (age, age squared, gender, race/ethnicity, mother's education, family income, weekly hours spent watching television, weekly days of vigorous physical activity, and parent–child interactions) and census tract characteristics (median income, percentage non-Hispanic White population, and street connectivity index).

**$P<0.01$.

Table 3

Estimated associations for the food environment indices and youth body mass index (BMI).

	BMI Percentile in eighth grade		Change in BMI percentile between fifth and eighth grade	
Measures	**Model 1[a]**	**Model 2[b]**	**Model 1[a]**	**Model 2[b]**
RFEI[c]	0.37 (0.25)	0.08 (0.23)	-0.04 (0.12)	-0.13 (0.11)
PFEI[d]	3.27 (2.59)	1.26 (2.44)	0.90 (1.49)	0.48 (1.31)
Ratio of convenience stores to all food stores	2.88 (2.11)	-0.09 (1.98)	0.58 (1.21)	-0.06 (1.05)
Ratio of fast food outlets to all restaurants	3.73 (2.88)	2.40 (2.68)	0.43 (1.47)	0.55 (1.34)

RFEI, Retail Food Environment Index; PFEI, Physical Food Environment Index.

Sample size = 2610 for RFEI; 5450 for PFEI; 5690 for the ratio of convenience stores to all food stores; and 5010 for the ratio of fast food outlets to all restaurants.

Models were estimated using ordinary least squares.

Standard errors are in parentheses.

Statistics have been weighted by Early Childhood Longitudinal Study-Kindergarten Class sampling weights.

Eicker-Huber-White sandwich estimator was used to calculate robust standard errors clustered as census tract.

*$P<0.05$, **$P<0.01$.

[a]Model 1 includes the food environment measure as the only independent variable.

[b]Model 2 includes the food environment measure, individual covariates (age, age squared, gender, race/ethnicity, mother's education, family income, weekly hours spent watching television, weekly days of vigorous physical activity, and parent–child interactions) and census tract characteristics (median income, percentage non-Hispanic White population, and street connectivity index).

[c]RFEI is the ratio of the counts of fast food outlets and convenience stores to supermarkets and produce vendors.

[d]PFEI is the ratio of the counts of fast food outlets and convenience stores to all types of food outlets (including fast food outlets, convenience stores, supermarkets and produce vendors).

Table 4

Estimated associations for indicators for the presence of specific combinations of types of food stores and youth body mass index (BMI).

	BMI Percentile in eighth grade		Change in BMI percentile between fifth and eighth grade	
Measures	**Model 1[a]**	**Model 2[b]**	**Model 1[a]**	**Model 2[b]**
Supermarkets and grocery stores	9.64 (4.13)*	8.38 (3.77)*	1.02 (3.12)	1.67 (2.57)
Supermarkets and convenience stores	11.96 (3.09)**	8.90 (2.98)**	1.60 (1.74)	2.14 (1.56)
Supermarkets, grocery, and convenience stores	14.61 (3.52)**	9.54 (3.59)**	4.13 (1.98)*	4.05 (1.69)*
Grocery stores only	9.17 (4.72)	4.57 (4.41)	3.80 (2.76)	2.52 (2.46)
Convenience stores only	9.11 (3.01)**	5.00 (2.89)	2.36 (1.72)	1.83 (1.51)
Grocery and convenience stores	8.78 (3.33)**	4.40 (3.29)	2.04 (1.93)	1.70 (1.68)
No food stores	6.60 (3.15)*	5.32 (3.01)	4.39 (1.90)*	3.98 (1.67)*

Sample size = 6260.

Models were estimated using ordinary least squares.

Standard errors are in parentheses.

Statistics have been weighted by Early Childhood Longitudinal Study-Kindergarten Class sampling weights.

Eicker-Huber-White sandwich estimator was used to calculate robust standard errors clustered as census tract.

[a]Model 1 includes the food environment indicator variables as the only independent variables.

[b]Model 2 includes the food environment indicators, individual covariates (age, age squared, gender, race/ethnicity, mother's education, family income, weekly hours spent watching television, weekly days of vigorous physical activity, and parent–child interactions) and census tract characteristics (median income, percentage non-Hispanic White population, and street connectivity index).

*$P<0.05$

**$P<0.01$.