Original Article
PEDIATRIC OBESITY

Obesity

Differences in the Neighborhood Retail Food Environment and Obesity Among US Children and Adolescents by SNAP Participation

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Objective: The goal of this study was to understand the association between children's neighborhood food access and overweight/obesity in a national sample of US households, and whether this association differs by Supplemental Nutrition Assistance Program (SNAP) participation or household purchases.
Methods: Data were obtained from the National Household Food Acquisition and Purchase Survey (2012-2013; n = 3,748 children aged 2 to 18 years). Logistic regression was used to examine associations between neighborhood retail food access (≤1 mile from home), food purchases (including sugary beverages), and overweight/obesity, stratified by SNAP status (1,720 participants, 453 eligible nonparticipants, 1,575 SNAP ineligible). Store types included supermarkets/grocery, combination grocery/other (independent drug, dollar, and general stores), convenience, fast food, and non–fast food restaurants.
Results: Odds of childhood overweight/obesity (OR [95% CI]) were higher with greater access to combination grocery/other stores overall (1.10 [1.03-1.17]) and for children in SNAP (1.14 [1.05-1.24]). Eligible non-SNAP children had higher odds of overweight/obesity with greater access to convenience stores (1.11 [1.04-1.18]). The average child lived in a household with 6.3% of total spending at food outlets on sugary beverages (SNAP: 8.3%, eligible non-SNAP: 7.7%, SNAP ineligible: 5.5%).
Conclusions: Greater neighborhood access to combination grocery/other stores is associated with higher obesity prevalence for children overall and those in SNAP.

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Introduction

Overweight and obesity affect one in five children in the United States (1), disproportionately impacting racial and ethnic minorities, low-income children, and those living in southeastern states (2). Increasingly, public health and policy efforts have focused on the neighborhood food environment as a key contributor to poor diet and high BMI (3-5).

Prior research suggests that the food retail environment may contribute to obesity risk (3,6). The most consistent findings among children and adolescents are from studies in which the availability of convenience stores (7-10) and fast food restaurants (11,12) is associated with higher BMI and the availability of supermarkets is associated with lower BMI (7,12,13). However, several well-designed studies in both children and adults found no relationship between neighborhood food environment and BMI (14-17). In addition, a key limitation of past work is that few studies consider all types of food outlet access simultaneously (10). To our knowledge, there have been no national studies on the relationship between comprehensive neighborhood retail food access and obesity among all children aged 2 to 18 years.

The relationship between the food environment and obesity may be especially important for low-income children, who often have limited access to healthy, affordable food (6,18). Research among low-income

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children shows inconsistent relationships between access to food outlets and BMI (19,20). Other research shows some differences in households' food purchasing patterns by participation in the federal Supplemental Nutrition Assistance Program (SNAP), which is designed to support nutrition for low-income households through food assistance (21,22). SNAP households spend less per capita on food overall each week and have different food acquisition patterns than non-SNAP households (23), including a higher percentage of food spending on sugary beverages (22). In addition, the absolute dollar amount of sugary beverage spending using SNAP benefits is higher than spending on sugary beverages without SNAP benefits (24). Sugary beverages are a major source of empty calories in US children's diets (25), and children's consumption is consistently linked with excess calorie intake and weight gain (26,27). Because almost half of all SNAP recipients (47%) are children (21), we sought to determine whether SNAP eligibility and participation modify the relationship between children's food access and weight.

Our study addressed key gaps in the literature by examining the relationship between neighborhood retail food outlets (number and type) and childhood obesity prevalence, stratified by SNAP participation. We additionally examined whether household and adolescent (aged 11-18 years) spending at specific types of food outlets or on specific foods (sugary beverages) explained this relationship.

Methods

Data were obtained from the Food Acquisition and Purchase Survey (FoodAPS), collected by the United States Department of Agriculture (USDA) in 2012 to 2013 and released in 2015. FoodAPS is the first nationally representative data set of all households, SNAP households, and SNAP-eligible households in the United States that contains comprehensive data on food purchases and acquisitions (28). Data were collected from in-person interviews, telephone interviews, survey booklets, scanners, and receipts over a 7-day period for all individuals (N = 14,317) in 4,826 surveyed households. All household members 11 years and older were asked to report all weekly food purchases and free acquisitions, including events at home and away from home, by scanning bar codes for packaged foods, submitting receipts for stores and restaurants, and filling out daily food booklets. The primary respondent in each household reported food acquisitions for children under 11.

Children aged 2 to 18 years were included in this analysis, excluding those missing data on BMI or SNAP status (n = 413). The final analytic sample included 3,748 children from 1,942 households, including 1,720 children from 850 households participating in SNAP.

Dependent variable

Childhood overweight/obesity was the dependent variable, measured through self-reported height and weight of the child by each household's primary respondent and defined as BMI $\geq$ 85th percentile compared with age- and sex-specific Centers for Disease Control and Prevention 2000 growth charts. Because parent-reported child height and weight tend to result in an overestimation of childhood overweight/obesity prevalence for young children and overweight/obesity estimates were higher for children aged 2 to 5 years in FoodAPS compared with the National Health and Nutrition Examination Survey (NHANES) (29-31), we conducted sensitivity analyses to account for known biases, including adjusting estimates using NHANES measured height/weight data (29) and restricting analyses to only children aged 6 to 18 years (30).

Independent variable

The independent variable of primary interest was neighborhood food access, defined as the number of food outlets (stores and restaurants) within 1 mile (straight-line distance) of the child's home, approximating walking distance. This measure follows prior studies and the USDA's definition of "low access" neighborhoods (14,32,33). Access was reported for the following mutually exclusive food outlet types identified by the USDA: superstores, supermarkets, and large/medium grocery stores; combination grocery and other stores (including independent drug stores, dollar stores, and general stores); convenience stores; fast food restaurants; and non–fast food restaurants. Supporting Information Appendix A includes details on store types and definitions.

Alternate neighborhood food access measures tested in sensitivity analyses were food exposure (county-level density of different store types per 1,000 people), store type of closest SNAP retailer, number of household visits per week (by store type), and alternate access distances of 0.25, 0.5, and 2 miles.

Covariates

Analyses were stratified by SNAP participation, defined for each child as at least one household member reporting current participation in SNAP. For this analysis, we divided children in non-SNAP households into income-eligible ($\leq$130% of the federal poverty level [FPL]) and income-ineligible (>130% FPL) categories.

Household food purchases and acquisitions were a key covariate used in this analysis, measured through a combination of event-level food acquisition data (i.e., each recorded visit to a location where food was purchased or acquired for free is an "event") and item-level food acquisition data (i.e., an itemized list of every food and beverage item acquired at each event). We created several measures of food acquisitions and purchases, with full definitions in Supporting Information Appendix B. These include the mean number of weekly food acquisition events per household for each child, mean weekly spending at food outlets per household member, and the percent of weekly spending at food outlets by store type for each child. To capture a measure of spending on unhealthy items, we also examined the mean of each child's household sugary beverage spending as a percentage of total weekly food spending (mean of ratios). We also examined individual purchases of adolescents aged 11 to 18 years in order to understand their acquisitions separately from their households and to potentially account for behavioral effects.

Other demographic covariates included children's individual characteristics (age, gender, race/ethnicity), household characteristics (primary respondent's BMI, marital status, education, and work status; self-reported household income as a percent of the FPL; food security based on the USDA's 30-Day Adult Food Security Scale; household participation in the Special Supplemental Nutrition Program for Women, Infants, and Children [WIC]; urban or rural area of residence; household vehicle access), and neighborhood characteristics (closest SNAP-authorized retailer by store type, county-level poverty rate of households). Household income and county-level poverty

allowed examination of SNAP participants along the income gradient and of whether the income at the area of residence mattered.

Data analysis

First, we calculated group differences on demographic characteristics using χ^2 tests for categorical variables and regression for continuous variables, with post hoc pairwise comparison of means. We then calculated unadjusted differences in children's food access and household food purchases and acquisitions using the same methods. Then we estimated the association between food access and childhood obesity, overall and by SNAP status, with binary logit models that controlled for individual, household, and neighborhood covariates. All analyses included the use of sample weights provided by the USDA to account for unequal probability of selection from oversampling, nonresponse, and stratified multistage probability sample design. Standard errors have been estimated to account for the complex sample design of the survey. Data analysis was performed using Stata v.14 (StataCorp LP, College Station, Texas). As a secondary analysis, we examined child overweight/obesity by race/ethnicity, gender, and age (2-5 years, 6-10 years, 11-18 years) to understand heterogeneity among different subgroups.

For sensitivity analyses, we used multivariate ordinary least squares regression to analyze the relationship between food access and BMI percentile. To examine whether the 1-mile access measure was robust to alternate specifications, we conducted separate regressions for distances of 0.25, 0.5, and 2 miles, and we ran analyses restricted to children living in urban areas (a 1-mile radius may be inappropriate for rural children). We also included additional controls such as distance to the nearest store, county-level store density per 1,000 residents, county-level store totals, number of household events per week by store type, and month of the year to adjust for seasonal differences in purchasing patterns. We also ran analyses restricted to children in households where the primary respondent reported living at this address for 2 + years (since 2009), to examine the relationship between food access and childhood obesity only in a group with potentially more consistent recent neighborhood exposures and food access. To ensure that data were missing at random, we also examined whether children excluded from the sample because of missing BMI data differed from included children by demographic characteristics.

Results

Table 1 displays the key individual, household, and neighborhood demographic characteristics of children in the FoodAPS sample, by children's household SNAP participation. The study sample included 1,720 children living in households participating in SNAP (SNAP

TABLE 1 Children's (aged 2-18 years) individual, household, and neighborhood characteristics 2012-2013 FoodAPS Survey[a], by SNAP status

	SNAP	Eligible non-SNAP (≤130% FPL)	SNAP ineligible (>130% FPL)
Sample size, n			
Children ages 2-18 y	1,720	453	1,575
Households with children ages 2-18 y	850	217	875
Individual characteristics			
Child age, m	9.4[bc]	10.5[d]	10.3[d]
Child gender, n (%)			
Male	890 (51.5)	215 (46.0)	779 (49.7)
Female	830 (48.5)	238 (54.0)	796 (50.3)
Child race/ethnicity, n (%)			
White, non-Hispanic	646 (32.0)[bc]	168 (33.5)[cd]	888 (65.0)[bd]
Hispanic	598 (31.6)	176 (41.2)	395 (16.9)
Black, non-Hispanic	369 (29.7)	76 (19.6)	155 (9.8)
Other, non-Hispanic	107 (6.7)	33 (5.7)	137 (8.3)
Child BMI, n (%)[e]			
Healthy weight	940 (56.1)[bc]	237 (50.0)[d]	982 (66.2)[d]
Overweight/obesity	780 (43.9)	216 (50.0)	593 (33.8)
Household characteristics[f]			
Household size, m	4.9[c]	5.1[c]	4.4[bd]
Primary respondent BMI, m	30.5[c]	28.9	27.3[d]
Primary respondent marital status, n (%)			
Married	602 (30.7)[bc]	260 (56.9)[cd]	1,173 (75.6)[bd]
Not married	1,118 (69.3)	193 (43.1)	402 (24.4)
Primary respondent education, n (%)			
Less than high school	554 (32.1)[bc]	146 (36.2)[cd]	179 (4.9)[bd]
High school	486 (25.6)	138 (26.4)	364 (20.0)

TABLE 1. (continued).

	SNAP	Eligible non-SNAP (≤130% FPL)	SNAP ineligible (>130% FPL)
Some college	560 (34.8)	106 (26.1)	581 (37.7)
College or more	118 (7.5)	62 (11.4)	451 (37.4)
Primary respondent work status, n (%)			
Working	647 (40.4)[bc]	209 (50.0)[cd]	1,062 (70.1)[bd]
Not working[g]	1,073 (59.6)	244 (50.0)	513 (29.9)
Income (% FPL), m	111.8%[bc]	87.2%[cd]	385.2%[bd]
Food security, n (%)			
High (secure)	480 (32.3)[bc]	141 (32.9)[cd]	928 (69.0)[bd]
Marginal (secure)	452 (22.5)	90 (18.9)	364 (21.1)
Low/very low (insecure)	788 (45.1)	222 (48.2)	283 (9.9)
WIC participation	469 (26.8)[bc]	128 (22.8)[cd]	152 (5.4)[bd]
Area of residence, n (%)[h]			
Urban	1,309 (76.9)[c]	356 (80.6)[c]	1,098 (61.1)[bd]
Rural	411 (23.2)	97 (19.4)	477 (38.9)
Household vehicle access, n (%)[i]			
Owns/leases vehicle	1,303 (75.0)[bc]	407 (88.0)[cd]	1,534 (97.3)[bd]
Neighborhood characteristics			
Closest SNAP retailer, n (%)			
Convenience store	939 (53.5)[c]	234 (55.6)[c]	654 (37.7)[bd]
Superstore, supermarket, grocery store	400 (24.5)	106 (24.8)	473 (34.6)
Combo grocery or other store	282 (16.1)	92 (15.8)	362 (23.6)
Specialty store[j]	99 (6.0)	21 (3.7)	86 (4.1)
County-level poverty rate of households, m	15.5%[bc]	14.3%[cd]	12.8%[bd]

P value for difference based on χ^2 test for categorical variables and regression (P > F) for continuous variables with post hoc *t* tests; *P* values significant at $P < 0.05$ level. Column frequencies may not sum to full sample because of missingness. BMI measured in kg/m^2.
[a]Percentage of US population estimated with survey weights to adjust for unequal probability of sampling. All percentages shown are weighted column percentages.
[b]Significantly different from eligible non-SNAP ≤ 130% FPL, $P < 0.05$.
[c]Significantly different from SNAP ineligible > 130% FPL, $P < 0.05$.
[d]Significantly different from SNAP, $P < 0.05$.
[e]Weight categories based on BMI for sex and age, where healthy weight is < 85th percentile and overweight/obesity is ≥ 85th percentile.
[f]1,102 out of 1,942 households in this sample have at least two children between the ages of 2 and 18 years old; 80.5% of children in this sample live in households where the primary respondent is female; 19.5% live in households where the primary respondent is male.
[g]Not working includes those looking for work.
[h]The population-weighted centroid of a census tract is in an urban or rural area. Urban and rural are defined in the Census Bureau's urbanized area definitions, where rural areas are sparsely populated areas with fewer than 2,500 people, and urban areas are areas with more than 2,500 people. A census tract is urban if the geographic centroid of the tract is in an area with more than 2,500 people; all other tracts are rural. 77.3%, 81.8%, and 80.7% of SNAP, SNAP-eligible, and SNAP-ineligible children live in households in metropolitan areas (county-level metropolitan designation; metropolitan statistical areas have at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core measured by community ties).
[i]98.6% of children in this sample live in households that either own or lease a vehicle or have access to a car when one is needed for food shopping (only 1.5% of children live in households that reported issues accessing a vehicle).
[j]Specialty stores include fruit/vegetable, meat/poultry, bread/bakery, and seafood specialty stores; nonprofit cooperatives; delivery route services; and direct marketing and farmer's markets.
m, mean.

children hereafter), 453 children living in households eligible for but not participating in SNAP (non-SNAP children), and 1,575 children living in households ineligible for SNAP (SNAP-ineligible children). Children in SNAP had lower reported overweight/obesity prevalence (43.9%) than eligible non-SNAP children (50.0%, $P = 0.04$) but higher overweight/obesity prevalence than SNAP-ineligible children (33.8%, $P < 0.01$). Children in the three groups also differed in several household demographic characteristics, including the primary respondent's marital status, education, work status, income, and WIC participation. SNAP and eligible non-SNAP children were more likely to live in urban areas (76.9% and 80.6%) than SNAP-ineligible children (61.1%, $P < 0.01$), and they were more likely to have convenience stores as their closest neighborhood SNAP-authorized retailer ($P < 0.01$). SNAP children also lived in counties with higher household poverty rates (15.5%) than eligible non-SNAP children (14.3%, $P = 0.03$) and SNAP-ineligible (12.8%, $P < 0.01$) children.

Table 2 shows unadjusted measures of food access and acquisitions/purchases by household SNAP participation. SNAP-ineligible children had fewer retail food outlets of all types within 1 mile of their home compared with SNAP and eligible non-SNAP children. SNAP-ineligible children also had different household food purchasing and acquisition patterns than SNAP and eligible non-SNAP

TABLE 2 Children's food access and household food purchases and acquisitions, 2012-2013[a] FoodAPS survey, by SNAP status

	SNAP, n = 1,720	Eligible non-SNAP (≤130% FPL), n = 453	SNAP ineligible (>130% FPL), n = 1,575
Mean number of stores within 1 mile of home			
Superstores, supermarkets, grocery stores	3.4[b]	3.2[b]	1.9[cd]
Combination grocery and other stores	2.4[b]	2.5[b]	1.5[cd]
Convenience stores	5.8[b]	5.5[b]	2.6[cd]
Fast food restaurants	5.6[b]	6.7[b]	4.1[cd]
Non-fast food restaurants	23.9[b]	24.2[b]	17.8[cd]
Mean number of food acquisition events per week per household[e]	14.7[b]	15.6	17.6[c]
Mean weekly spending at food outlets per household member[f]	$37.41[bd]	$31.51[bc]	$58.87[cd]
Percent of household weekly spending at food outlets for the average child, by store type[g]	n = 1,636 100%	n = 441 100%	n = 1,559 100%
Superstores, supermarkets, grocery stores	58.0%[b]	50.2%	49.3%[c]
Restaurants	24.4%[b]	26.7%	29.3%[c]
Combination grocery and other stores	4.9%[b]	5.3%	2.9%[c]
Other (miscellaneous)[h]	4.6%	4.7%	5.8%
Convenience stores	4.3%[bd]	2.1%[c]	2.2%[c]
Club stores	2.4%[b]	8.7%	6.4%[c]
Family/friends, school, work	1.4%[b]	2.2%	4.1%[c]

P value for difference based on regression (P > F) for continuous variables with post hoc *t* tests; *P* values significant at $P < 0.05$ level.
[a]Percentage of US population estimated with survey weights to adjust for unequal probability of sampling. All percentages shown are weighted column percentages.
[b]Significantly different from SNAP ineligible >130% FPL, $P < 0.05$.
[c]Significantly different from SNAP, $P < 0.05$.
[d]Significantly different from eligible non-SNAP ≤ 130% FPL, $P < 0.05$.
[e]Food acquisition events = number of visits to each place per week where food was purchased or acquired for free. See Supporting Information Appendix B for full details on how this measure was calculated.
[f]Event-level weekly spending may include spending on nonfood items for some events (e.g., supermarket spending may include nongrocery items); includes children living in households with $0 weekly spending. See Supporting Information Appendix B for full details on how this measure was calculated.
[g]Percent of weekly food spending excludes free events and excludes 112 children in households with $0 weekly spending. See Supporting Information Appendix B for full details on how this measure was calculated.
[h]Other (miscellaneous) includes several miscellaneous food outlets, including vending machines, nonfood retailers, travel places (airports, hotels, truck stops), gardens, hospitals and institutions, multiple places, and unknown.

children. SNAP-ineligible children had higher mean weekly household spending at food outlets per household member ($58.87) compared with SNAP children ($37.41, $P < 0.01$) and eligible non-SNAP children ($31.51, $P < 0.01$). SNAP-ineligible children also lived in households with different weekly food expenditures by store type than SNAP children (e.g., higher percentage of overall spending at restaurants and lower percentage of overall spending at supermarkets, combination grocery and other stores, and convenience stores). For adolescent spending, we found that among adolescents with any food spending (n = 800), there were not significant differences in mean weekly spending among SNAP, eligible non-SNAP, and SNAP-ineligible adolescents (see Supporting Information Table S2).

For sugary beverage spending, the average child lived in a household with 6.3% of total spending at food outlets on sugary beverages (SNAP: 8.3%, eligible non-SNAP: 7.7%, SNAP ineligible: 5.5%; see Supporting Information Table S1). At convenience stores, 26.1% of the average child's total household food spending was on sugary beverages (SNAP: 29.8%, eligible non-SNAP: 15.5%, SNAP ineligible: 25.6%). At combination grocery/other stores, 13.3% of the average child's total household food spending was on sugary beverages (SNAP: 18.4%, eligible non-SNAP: 17.7%, SNAP ineligible: 10.4%). Among adolescents with food spending, the average adolescent spent 10.0% of their individual weekly spending on sugary beverages (SNAP: 18.1%, eligible non-SNAP: 7.6%, SNAP ineligible: 8.9%). While the average child and adolescent in SNAP households spent a higher percentage of their food budget on sugary beverages than non-SNAP households, absolute dollars spent on sugary beverages was similar across groups (see Supporting Information Table S2).

When we estimated the association between food access (the number of each type of food retail outlet within 1 mile of the child's home) and childhood overweight/obesity, controlling for individual, household, and neighborhood-level covariates, the odds of a child having overweight/obesity increased with each additional combination grocery/other store within 1 mile of a child's home (odds ratio [OR]: 1.10, 95% CI: 1.03-1.17; shown in Table 3). Access to other store types was not significantly associated with childhood obesity in overall models. Children in SNAP households had higher odds of

TABLE 3 Estimated odds of childhood overweight or obesity, by household food access and SNAP status, FoodAPS Survey, 2012-2013

Food access (number of stores within 1 mile of child's home), by outlet type	Overall (all children), N = 3,742		SNAP, n = 1,715		Eligible non-SNAP (≤130% FPL), n = 452		SNAP ineligible (>130% FPL), n = 1,575	
	OR	CI	OR	CI	OR	CI	OR	CI
Superstore, supermarket, grocery	0.98	0.95-1.02	0.99	0.95-1.04	1.00	0.92-1.10	0.98	0.92-1.04
Combination grocery store/other	1.10[a]	1.03-1.17	1.14[a]	1.05-1.24	0.99	0.76-1.29	1.10	0.99-1.24
Convenience stores	1.01	0.97-1.04	0.97	0.93-1.02	1.11[a]	1.04-1.18	1.02	0.97-1.07
Fast food restaurants	0.99	0.96-1.02	0.96	0.91-1.01	1.05	0.97-1.13	0.99	0.94-1.05
Non–fast food restaurants	1.00	0.99-1.00	1.00	1.00-1.01	0.98[a]	0.97-0.995	0.99	0.99-1.00

All models adjust for child's age, gender, race/ethnicity, primary respondent BMI, primary respondent marital status, primary respondent education, primary respondent work status, household income, food security, WIC participation, rural versus urban household location, vehicle access, closest SNAP retailer, county-level poverty rate, amount of weekly spending at food outlets per household member, number of weekly food acquisition visits to each store type, and percent of household spending by store type (includes children living in households with no spending). The Overall model also adjusts for SNAP participation. Models did not adjust for household size, as it is correlated with household income as a percent of the FPL.
[a]Statistically significant at $P < 0.05$.

overweight/obesity with greater access to combination grocery/other stores (OR: 1.14, 95% CI: 1.05-1.24). Eligible non-SNAP children had higher odds of overweight/obesity with greater access to convenience stores (OR: 1.11, 95% CI: 1.04-1.18). Supporting Information Table S3 shows the full overall model, including all covariates.

Results for combination grocery/other stores remained significant when BMI percentile was used as a continuous outcome measure (combination grocery/other store $\hat{\beta}=1.40$, 95% CI: 0.62-2.18). Combination grocery/other store access remained significant for children in SNAP (OR: 1.24, 95% CI: 1.04-1.48) within a 0.5-mile radius and for eligible non-SNAP children (OR: 2.30, 95% CI: 1.08-4.90) within a 0.25-mile radius. Results for convenience stores remained significant for eligible non-SNAP children (OR: 1.24, 95% CI: 1.05-1.50) within 0.5-mile radius. There were no other statistically significant relationships between any store types and overweight/obesity when access was set at 0.25 miles or 2 miles.

For adolescents aged 11 to 18 years, greater access to combination grocery/other stores was associated with higher overall odds for adolescent overweight/obesity, even after adjusting for adolescent spending at different food outlets and spending on sugary beverages (OR: 1.12, 95% CI: 1.02-1.22). Access to combination grocery/other stores within 1 mile was associated with obesity for children living in urban areas (OR: 1.11, 95% CI: 1.04-1.19) and for non-Hispanic black children (OR: 1.33, 95% CI: 1.04-1.70), but not for children living in rural areas (OR: 1.25, 95% CI: 0.76-2.07), non-Hispanic white children (1.07, 95% CI: 0.95-1.20), or Hispanic children (OR: 1.09, 95% CI: 0.97-1.21).

There was no significant relationship between any store type and overweight/obesity among children aged 2 to 5 years, the group most likely to be affected by errors in parent-reported BMI (29-31). The relationship between combination grocery/other stores and odds of overweight/obesity for all children remained significant after adjusting overweight/obesity prevalence for children aged 2 to 5 years using NHANES measured height/weight data (adjusted OR: 1.10, 95% CI: 1.02-1.18). Combination grocery/other store access also remained significant when children aged 2 to 5 years were excluded from analysis (n = 2,803 children aged 6-18 years; OR: 1.09, 95% CI: 1.02-1.18).

For children living in their current house for at least 2 years, odds of overweight/obesity were associated with access within 1 mile to combination grocery/other stores (n = 2,221; OR: 1.11, 95% CI: 1.03-1.20), but this was not the case for children living at their current address for less than 2 years. Alternate access measures of food exposure (county density, number of stores in county, and closest SNAP retailer) were not associated with child overweight/obesity. Results were robust when these variables were included as covariates and when we controlled for percent of free acquisitions and survey month (not included in final models).

Discussion

We analyzed a unique national sample of US children with rich information on their neighborhood retail food environment and household food spending to examine the relationship between food access and childhood obesity and whether it differed by SNAP participation and household purchases. We found that access to combination grocery/other stores (which includes independent drug stores, dollar stores, and general stores) is associated with higher childhood obesity prevalence overall, and this association is particularly strong for children living in households participating in SNAP. We also found that greater access to convenience stores was associated with higher overweight/obesity prevalence for eligible non-SNAP children. Main results were robust to alternate model specifications, and there was a stronger association between combination grocery/other store access and overweight/obesity for adolescents aged 11 to 18 years, children living in urban areas, and non-Hispanic black children.

To our knowledge, previous studies have not included combination grocery/other stores as a unique store type when examining the food

retail environment. Store type definitions, combined with the population studied (all children aged 2-18 years vs. restricted child ages), access boundaries set (0.25, 0.5, 1, and 2 miles vs. other radii), and children's household geographic location (nationally representative vs. concentrated in specific states or cities) are all plausible explanations for why our results do not replicate previous studies' findings of positive associations between fast food restaurants and BMI and negative associations between supermarkets and BMI. It is likely that our finding among combination grocery/other stores is most consistent with previous study findings on associations between convenience stores and higher BMI, as the definition of combination grocery/other stores includes some store types previous studies may have considered convenience (e.g., independent drug stores, dollar stores). Different classifications make comparisons difficult between studies, given the heterogeneity in store types. Distinguishing among different store types is important for future studies because combination grocery/other stores make up 22% of all SNAP-authorized retailers in the United States, while convenience stores make up 45% (34). Together, these two store types account for more than 10% of all redeemed SNAP benefits and 5% to 9% of all children's total household weekly spending at food outlets, making them a substantial contributor to the food environment. Other studies have examined these stores types as small grocery stores or nontraditional food stores (including corner/small grocery stores, gas stations, pharmacies, and dollar stores), working under the hypothesis that high availability of unhealthy food at the neighborhood level may lead to less healthy, higher-calorie diets in those neighborhoods (35,36). Consistent with our results, previous studies have found that small grocery store availability is associated with higher adult BMI (37,38) and that small grocery/nontraditional food retailers sell a high proportion of unhealthy options (e.g., in one sample, 0% of dollar stores and only 23% of pharmacies sold fresh vegetables) (36).

Our results also showed that among those who shopped at combination grocery/other stores and convenience stores, the average child's household spent 13% of weekly combination grocery store spending and 26% of weekly convenience store spending on sugary beverages. These results demonstrate significant household purchases of empty calories from these limited store types. Sugary beverage spending was also significant among all adolescents, and especially SNAP adolescents. Because there are often high amounts of sugar-sweetened beverages (39) and low amounts of fruits/vegetables or whole grains purchased at small grocery and nontraditional food stores (40), adolescents in particular may be incentivized to reduce sugary beverage purchases by providing easily understandable caloric information on prominent display at the point of purchase (e.g., signs on beverage cases with sugary beverage calories presented as physical activity equivalents) (41). In addition, practices such as offering a greater variety of and more shelf space for fruits/vegetables, having produce visible at the store entrance, and improving the ratio of shelf space for healthy versus less healthy items is associated with higher fruit/vegetable purchases at these store types (40). This suggests that modifying store practices and offerings without displacing these store types may have a positive impact on children's diets and BMI.

This study makes several contributions to existing literature on food access and childhood obesity. Our results indicate a consistent association between some measures of the food environment (access to combination grocery/other stores) and children's weight, even after controlling for important covariates. We also found an association between convenience store access and overweight/obesity for eligible non-SNAP children. However, it is unclear which specific food outlets drive these relationships, as SNAP-authorized combination grocery/other stores and convenience stores are heterogeneous in their availability and stock of food items. For example, grocery stores and stores in higher-income neighborhoods tend to offer a greater variety of healthful foods, while convenience/small food stores and stores in lower-income neighborhoods tend to offer less healthful options (42). Our robust finding of the positive relationship between number of combination grocery/other stores and childhood obesity may also reflect the types of neighborhoods that are characterized by these types of outlets (e.g., lower-income SNAP and eligible non-SNAP children are more likely to live in urban environments with a greater number of food outlets of all types compared with higher-income SNAP-ineligible children). In other words, combination grocery/other stores may serve as a proxy for other unmeasured factors in the neighborhood environment that contribute to obesity risk. Consistent with this, previous research has found that socioeconomically disadvantaged and minority neighborhoods may draw less healthy food outlets—including fast food restaurants and smaller grocery stores—over time (43). Future research should explore this possibility. In addition, our results suggest that further research is needed to better understand observed patterns in sugary beverage purchases among SNAP participants.

There are several important limitations of this study, including the cross-sectional nature of the data, which limits our ability to draw causal conclusions about the food environment and childhood obesity. Access measures tested may not account for children's neighborhood food environments in all settings (e.g., sprawling or rural areas). Specifically, our sensitivity analysis found that the 1-mile access measure was significant for urban but not rural children, which may reduce the generalizability of our results to children living in rural areas. In addition, there are known biases using parent-reported child height and weight, particularly for height of young children (aged 2-5 years). However, our results were robust to sensitivity analyses that adjusted for these biases. In addition, 411 children were excluded because of missing BMI data. Excluded children were not statistically different from included children on most demographic variables (e.g., race/ethnicity, SNAP participation, income, food access). However, excluded children were statistically more likely to be younger, female, have the primary respondent report a lower BMI, and have a different SNAP-authorized retailer closest to their home compared with included children.

Data were limited to household purchases and acquisitions and did not include individual purchases of children under 11 years of age, children's overall diet patterns, or children's actual consumption of the acquired foods; these factors are likely important unobserved variables in the relationship between the food environment and childhood obesity. This data also does not include children's physical activity levels or sedentary behaviors, which are other important correlates of obesity. As a proxy, we examined adolescent food purchases and acquisitions to investigate whether detailed individual-level food acquisitions attenuated the relationship between food access and obesity prevalence, and results remained robust to their inclusion.

This analysis is also subject to measurement error, as exposure and access measures may not be complex enough to account for how food purchasing decisions (and, subsequently, consumption patterns) are

made. Although the USDA excluded nonfood items when possible, calculations using only event-level acquisitions may include spending on nonfood items for some events (e.g., supermarket spending may include nongrocery items), resulting in a likely overestimate of actual food spending. Calculations using item-level acquisitions (e.g., reported sugary beverage spending) are likely to underestimate actual food spending, as some event-level acquisitions were missing item-level product information. In addition, there may be unobservable variables that account both for increased childhood obesity prevalence and changes to the neighborhood food environment. This analysis also does not address the impact of relative food prices or policies on childhood obesity prevalence, and future research should examine their effects while accounting for neighborhood characteristics.

Conclusion

This study found a positive and consistent relationship between combination grocery/other store access and overweight/obesity prevalence in a national sample of children, particularly for low-income children living in households participating in SNAP. The findings were stronger among adolescent children and non-Hispanic black children. Higher-income children living in SNAP-ineligible households live in different retail food environments than SNAP and eligible non-SNAP children, and they have different household food and sugary beverage purchasing and acquisition patterns. The presence of some types of food outlets (i.e., those with limited healthy grocery options) may serve as a proxy for obesity-promoting environments for some children. They also raise questions of whether policies aiming to improve healthy food availability in retail food outlets may improve dietary choices or health outcomes for disadvantaged children and families. For example, the USDA recently developed new rules to increase the availability of healthy options for SNAP participants by requiring SNAP-authorized retailers to stock a larger inventory and variety of healthy foods (44). However, the implementation of these rules has been delayed indefinitely. Longitudinal and experimental research is needed to examine how these types of changes in food access, both at the neighborhood level and within certain store types, influence BMI in children over time. O

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