Original Contribution

Differential Associations Between the Food Environment Near Schools and Childhood Overweight Across Race/Ethnicity, Gender, and Grade

Brisa N. Sánchez*, Emma V. Sanchez-Vaznaugh, Ali Uscilka, Jonggyu Baek, and Lindy Zhang

* Correspondence to Dr. Brisa N. Sánchez, Department of Biostatistics, School of Public Health, University of Michigan, 1415 Washington Heights, Ann Arbor, MI 48109 (e-mail: brisa@umich.edu).

Initially submitted July 22, 2011; accepted for publication November 9, 2011.

Epidemiologic studies have observed influences of the food environment near schools on children’s overweight status but have not systematically assessed the associations by race, sex, and grade. The authors examined whether the associations between franchised fast food restaurant or convenience store density near schools and overweight varied by these factors using data for 926,018 children (31.3% white, 55.1% Hispanic, 5.7% black, and 8% Asian) in fifth, seventh, or ninth grade, nested in 6,362 schools. Cross-sectional data were from the 2007 California physical fitness test (also known as “Fitnessgram”), InfoUSA, the California Department of Education, and the 2000 US Census. In adjusted models, the overweight prevalence ratio comparing children in schools with 1 or more versus 0 fast food restaurants was 1.02 (95% confidence interval (CI): 1.01, 1.03), with a higher prevalence ratio among girls compared with boys. The association varied by student’s race/ethnicity ($P = 0.003$): Among Hispanics, the prevalence ratio = 1.02 (95% CI: 1.01, 1.03); among blacks, the prevalence ratio = 1.03 (95% CI: 1.00, 1.06), but among Asians the prevalence ratio = 0.94 (95% CI: 0.91, 0.97). For each additional convenience store, the prevalence ratio was 1.01 (95% CI: 1.00, 1.01), with a higher prevalence ratio among fifth grade children. Nuanced understanding of the impact of food environments near schools by race/ethnicity, sex, and grade may help to elucidate the etiology of childhood overweight and related race/ethnic disparities.

childhood obesity; food environment; health disparities; log-binomial models; schools

Abbreviation: CI, confidence interval.

In the past decade, concern has been growing over the retail food environment because of its potential influence on children’s diet and body weight (1–7) and the need for interventions to reverse the childhood obesity epidemic (8–10). Although influences of the food environment on children’s weight have been observed, little research has systematically assessed whether the associations differ across race/ethnic groups (8), by sex or grade level, or whether there are threshold effects.

Because children spend a large proportion of their time in schools (11) and are exposed to the environments surrounding schools (e.g., on their way to school), food types available near or around schools may be particularly important for children’s weight. The presence of fast food restaurants and convenience stores near schools may shape children’s diet and body weight directly through availability (12–14) and consumption (15) of energy-dense foods and beverages or indirectly via advertising (16–18). One-third of all US public middle and high schools have at least 1 fast food restaurant or convenience store within walking distance, with higher rates around schools attended by Hispanic and black children (5, 12, 19–22).

Using data pertaining to children in the fifth, seventh, and ninth grades attending public California schools, we examined 1) the association of fast food restaurants and convenience store availability within a half-mile (0.81-km) radius of schools with childhood overweight; 2) differences in the association across 4 major race/ethnic groups—Asian, black, Hispanic, and white children, by gender or grade levels; and 3) the possibility of nonlinearity in these associations.
MATERIALS AND METHODS

Data sources

We utilized data for children who participated in the 2007 California physical fitness test (also known as “Fitnessgram”), collected between February and May of 2007 (23). Obtained through a special request from the California Department of Education, Fitnessgram data contain direct measures of children’s weight, height, and physical fitness among all children attending fifth, seventh, and ninth grades, as well as their age, sex, race/ethnicity, and a school identifier indicating the school attended by each child at the time of the test.

The locations of fast food restaurants and convenience stores in California were purchased from InfoUSA, a commercial source (24), in January 2009. To select food outlets, Standard Industry Classification codes were used in conjunction with a list of national and local food outlet franchises generated by InfoUSA. Any businesses opened after 2007 were removed. Fast food places were selected if their primary, secondary, or tertiary Standard Industry Classification code was 581208 (restaurant) and the food outlet was a known franchise (refer to Web Table 1 for the list used) (Web Table 1, along with the Web Appendix and Web Figures 1–5, is posted on the Journal’s Web site (http://www.aje.oxfordjournals.org/)). Convenience stores were those establishments with a primary, secondary, or tertiary Standard Industry Classification code of 541103 (convenience store) regardless of their franchise status. Geocodes (latitude and longitude) for all locations were provided by InfoUSA, with a reported 90% accuracy in code to the business street address (24).

We obtained school-level data from California Department of Education databases (25) and the 2000 US Census (26). Information on enrollment by grade and race/ethnicity and percentage of students eligible for free or reduced price meals during the 2006–2007 school year, as well as school open and close dates and school addresses, was obtained. Using school addresses, we successfully geocoded 96.7% of schools to latitude and longitude and to census tracts via geographic information system software. Census data from Summary File 3 of the 2000 Census were merged with school-level data from the California Department of Education by using census tract identifiers and subsequently with Fitnessgram data by using school identifiers.

Measures

We used combined overweight or obese status (hereafter “overweight”) versus not as a dichotomous outcome. Children were classified as overweight (27) if their age- and sex-specific body mass index (weight (kg)/height (m)²) was at or above the 85th percentile of the 2000 Centers for Disease Control and Prevention reference body mass index distribution (28). Given the evolving definitions of “overweight” (27) and the debated cutoffs to classify Asians as being overweight, we also used continuous body mass index and body mass index z scores (28) and dichotomous obese classification (body mass index ≥95th percentile (27)) in sensitivity analyses.

The primary predictors were the number of fast food restaurants or convenience stores within a half mile buffer around each school, a distance that can be walked by an adult in 10 minutes (29). Using geographic information system software, fast food restaurant and convenience store locations were merged with school locations to obtain the count of food outlets within the school buffer.

We included age, gender, race/ethnicity (Asian, blacks, Hispanics, and whites), as well as physical fitness, in the analyses. Using established criteria (30), we classified each child as unfit, fit, or fit above standard on the basis of the time the child took to run or walk 1 mile (1.6 km). Because Fitnessgram data do not include children’s socioeconomic status, we used the proportion of students eligible for free or reduced-price meals within a school as a proxy.

To account for the influences of school-level factors on childhood obesity, we used the proportion of adults with a college degree or higher within the school’s census tract as a measure of the school’s neighborhood socioeconomic resources (31, 32). School census tract average household income was not included in the final models because of high collinearity with the education variable. To adjust the models for racial/ethnic composition of the school, we computed a racial/ethnic heterogeneity measure (33) previously used to quantify residential segregation (34). The measure is computed on the basis of the proportions of the major racial/ethnic groups in the school; it ranges from 0, indicating homogeneity, to 1, indicating that all groups were equally represented.

For descriptive purposes, we categorized schools according to the racial/ethnic majority of the student body. For example, if a school’s student body was more than 50% Hispanic, the school was categorized as having an Hispanic majority, and similarly for other race/ethnicities.

Data exclusions

The 2007 Fitnessgram data consisted of 1,419,159 children. Children with race/ethnicity other than the 4 major groups were excluded (5.2%). To protect children’s confidentiality, the California Department of Education masked school identifiers for children who attended a school with 10 or less children of the same grade, sex, and race/ethnicity. Thus, these children (8.9%) were excluded because their school environment could not be identified. An additional 0.3% of children with available identifiers were excluded because they could not be matched to a school (e.g., they likely attended one of the 3.3% of schools that could not be geocoded). Children with incomplete data on demographics (3.2%), fitness (13.4%), or overweight status (3.7%) were also excluded, yielding an analytically sample of 926,018 children.

Statistical analysis

We calculated descriptive statistics for children and schools, overall and by either individual race/ethnicity or the racial/ethnic composition of the school. Using individual-level overweight status, we fitted log-binomial regression models (35) for clustered data, treating the school as the clustering
unit. Fast food restaurant or convenience store densities were modeled separately, each as a categorical variable (i.e., 0, 1, 2, or ≥ 3 stores). We tested the hypothesis that children in schools within at least 1 grouping of 0, 1, 2, or ≥ 3 stores differed in overweight prevalence from the others (denoted as $P_{≥ 1}$ differs). We included interaction terms to test if the food store count–overweight association differed by race/ethnicity, sex, or grade (denoted as, e.g., $P_{≥ 1}$ differs × ethnicity).

We used these models to estimate and plot crude and adjusted prevalence. We then assessed whether the associations between food store counts and (log) overweight prevalence deviated from linearity by using orthogonal polynomial contrasts, which enable testing of deviations from linearity without fitting models with parametric trends. When the association did not deviate from linearity, models with continuous food store counts were used to succinctly present numerical summaries. When the associations were nonlinear (e.g., ceiling effect) for at least 1 group, we estimated differences in overweight odds comparing specific levels of outlet densities (e.g., more than 1 against 0, denoted as $> 1$ vs. 0).

Models were estimated with and without adjustment for potential confounders and predictors of children being excluded (i.e., missing). Adjusting for predictors of missingness can minimize bias. Both individual- and school-level correlates were treated as confounders and predictors of missingness. Because children attending schools with smaller enrollments were more likely to have masked school identifiers, we adjusted for total school enrollment. Quadratic terms of school-level variables were included in the models to account for their nonlinear associations with children’s overweight.

All analyses were conducted in R, version 2.13.1, language and environment. Additional modeling and coding details are available in the Web Appendix.

**RESULTS**

Of the 926,018 students included in this study, 31.3% were white, 55.1% Hispanic, 5.7% black, and 8.0% Asian (Table 1). Overall, 22.0% of children were obese, and 41.0% were overweight. Asian children had the lowest overweight prevalence (25.7%), followed by white (29.8%), black (42.4%), and Hispanic (49.5%) children.

Study participants were nested within 6,362 schools (Table 2), of which 16%, 11%, and 17%, respectively, had 1, 2, or ≥ 3 fast food restaurants within a half-mile radius. There were 25% of schools with 1, 12% with 2, and 6.7% with ≥ 3 convenience stores nearby. The Spearman correlation between the food store counts was 0.38. The correlations between school-level factors and fast food restaurants (or convenience stores) were as follows—diversity index: $r = 0.00$ ($r = -0.11$); percentage of students in free and reduced-price meals program: $r = 0.15$ ($r = 0.31$); enrollment: $r = 0.07$ ($r = 0.04$); and percentage with bachelor’s degree in census tract: $r = -0.07$ ($r = -0.24$).

Compared with schools that had a majority white student population, schools with no racial/ethnic majority had a higher concentration of food outlets: 43.9% and 41.4%, respectively, had at least 1 fast food or convenience store compared with 31.8% and 28.8% of white majority schools.

The number of these outlets was even greater around schools with majority Hispanic, black, or Asian students: 50.8%, 57.8%, and 55.7%, respectively, had at least 1 fast food restaurant; 42.9%, 49.5%, and 51.1%, respectively, had at least 1 convenience store.

**Overall associations**

The crude and adjusted associations between fast food restaurant and convenience stores near schools and overweight are shown in Figure 1, A and B. The unadjusted difference in overweight prevalence comparing ≥ 3 against 0 fast food restaurants or convenience stores was 4% and 9%, respectively (Figure 1A). After adjustment for individual- and school-level covariates, fast food restaurant density appeared to have a ceiling effect (Figure 1A), with no additional increases in overweight prevalence associated with the availability of 2 versus 1 or ≥ 3 versus 2 outlets in the school’s neighborhood (deviation from linearity test, quadratic contrast $P = 0.021$). Although the confidence interval for the linear dose-response was consistent with a null association with the prevalence ratio $= 1.00$ (95% confidence interval (CI): 1.00, 1.01) ($P = 0.08$), children attending schools with 1 or more fast food restaurants had 2% higher overweight prevalence with the prevalence ratio $= 1.02$ (95% CI: 1.01, 1.03) than those in schools with no fast food outlets within the school’s half-mile radius (Figure 1B). In adjusted models, the number of convenience stores was linearly associated with higher overweight prevalence (Figure 1A). Each additional convenience store available within a half-mile radius of a school was associated with an estimated 1% higher overweight prevalence with the prevalence ratio $= 1.01$ (95% CI: 1.00, 1.01) (Figure 1B).

**Who is most affected?**

There was evidence of a differential effect of the food environment near schools by race/ethnicity but no strong indication of differential effects by grade or sex.

**Race/ethnicity.** In adjusted models, we found a differential influence of fast food restaurant density near a school on overweight by student race/ethnicity ($P_{≥ 1}$ differs × ethnicity = 0.003) (Figure 2A). Although the gradients were attenuated after adjustment for individual and school characteristics, greater fast food restaurant density was associated with higher overweight prevalence, except among Asians. Confidence intervals for the fast food restaurant–overweight associations among white children included the null value, but among Hispanics and blacks each fast food restaurant near a school was associated with higher overweight prevalence (prevalence ratio $= 1.02$, 95% CI: 1.01, 1.03) and prevalence ratio $= 1.03$, 95% CI: 1.00, 1.06, respectively) (Figure 2B). Among Asian children, fast food restaurants and overweight were inversely associated (prevalence ratio $= 0.94$, 95% CI: 0.91, 0.97 for $≥ 1$ vs. 0 fast food restaurants).

Although an increasing trend in the association between convenience store density and overweight was found among white, black, and Hispanic but not Asian children, the associations were consistent with homogeneous effects across race/ethnicity in adjusted models (Web Figure 1A;
Table 1. Characteristics of California Children in the Study Sample Overall and by Race/Ethnicity According to 2007 Data\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Overall ((n = 926,018, 100%))</th>
<th>White ((n = 289,599, 31.3%))</th>
<th>Hispanic ((n = 510,089, 55.1%))</th>
<th>Black ((n = 52,553, 5.7%))</th>
<th>Asian ((n = 73,777, 8.0%))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Mean</td>
<td>% Mean</td>
<td>% Mean</td>
<td>% Mean</td>
<td>% Mean</td>
</tr>
<tr>
<td>Body mass index\textsuperscript{c}</td>
<td>20.8 19.9</td>
<td>21.8 21.3</td>
<td>21.3 19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index (z) score</td>
<td>0.78 0.49</td>
<td>1.02 0.84</td>
<td>0.36 0.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overweight or obese (body mass index (z) score, (\geq 85\text{th %}))</td>
<td>41.0 29.8</td>
<td>49.5 42.4</td>
<td>25.7 22.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obese (body mass index (z) score, (\geq 95\text{th %}))</td>
<td>22.0 13.3</td>
<td>28.5 22.2</td>
<td>10.5 8.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female sex</td>
<td>48.8 48.2</td>
<td>49.0 49.6</td>
<td>48.6 48.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>30.2 28.6</td>
<td>33.2 20.7</td>
<td>22.5 20.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seventh</td>
<td>36.0 35.8</td>
<td>35.3 41.9</td>
<td>37.8 37.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ninth</td>
<td>33.8 35.6</td>
<td>31.5 37.4</td>
<td>39.8 39.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age group, years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>15.9 14.5</td>
<td>17.5 11.2</td>
<td>13.5 11.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>13.4 13.6</td>
<td>14.4 8.7</td>
<td>8.9 8.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>19.8 18.8</td>
<td>19.7 22.8</td>
<td>22.6 22.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>15.9 16.8</td>
<td>15.4 18.2</td>
<td>14.8 14.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>18.8 18.9</td>
<td>17.8 21.5</td>
<td>23.7 23.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\geq 15)</td>
<td>16.0 17.5</td>
<td>15.0 17.4</td>
<td>16.5 16.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness status\textsuperscript{d}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fit</td>
<td>44.5 46.3</td>
<td>42.7 39.8</td>
<td>53.5 53.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unfit</td>
<td>36.8 28.2</td>
<td>42.3 46.8</td>
<td>25.3 25.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fit above standard</td>
<td>18.6 25.4</td>
<td>15.0 13.5</td>
<td>21.3 21.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a} Data are from the 2007 California physical fitness test (also known as “Fitnessgram”) and the California Department of Education.

\textsuperscript{b} For comparison across race/ethnicity, all \(P\)'s < 0.001 and were derived from chi-squared tests for categorical variables or Kruskal-Wallis nonparametric rank tests for continuous variables.

\textsuperscript{c} Body mass index: weight (kg)/height (m)\textsuperscript{2}.

\textsuperscript{d} Fitness status indicates whether a child was within, below, or above the Cooper Institute’s age- and gender-specific healthy fitness zone based on his/her performance in the 1-mile (1.6-km) run or walk.

\(P_{\geq 1} \) differs × ethnicity = 0.35. Irrespective of race/ethnicity, these associations did not deviate from linearity. Whereas the adjusted convenience store–overweight associations for white and Asian children were consistent with no difference in prevalence, each additional convenience store within a half-mile radius of a school was, respectively, associated with 1% and 2% higher overweight prevalence among Hispanic and black children, with prevalence ratios = 1.01 (95% CI: 1.00, 1.01) and 1.02 (95% CI: 1.00, 1.03) (Web Figure 1B).

For Asian children, adjustment for school- and individual-level correlates had a strong impact on the food environment–overweight associations. Adjustment for school-level correlates impacted the gradient, while individual-level correlates primarily impacted adjusted prevalence. (Refer to the sensitivity analyses in Web Figure 2.)

Grade. The estimated fast food restaurant–overweight association appeared to be homogeneous across grade in adjusted models (\(P_{\geq 1} \) differs × grade = 0.60) (Web Figure 3A). Nevertheless, a stronger association between fast food restaurant density and overweight was found among fifth grade children (prevalence ratio = 1.03, 95% CI: 1.01, 1.04) (Web Figure 3B) compared with seventh or ninth grade children. There was weak indication of heterogeneity of the convenience store density–overweight association by grade (\(P_{\geq 1} \) differs × grade = 0.12) (Figure 3A). For each additional convenience store, the prevalence ratio was 1.01 (95% CI: 1.00, 1.02) among fifth graders and 1.01 (95% CI: 1.00, 1.02) among seventh graders. Ninth grade children did not demonstrate higher prevalence with greater convenience store concentration (prevalence ratio = 1.00, 95% CI: 0.99, 1.01) (Figure 3B).

Sex. For both types of food stores, girls had stronger food store–overweight associations. Comparing \(\geq 1\) versus 0 fast food restaurants, the prevalence ratio = 1.01 (95% CI: 1.00, 1.02) among boys and 1.02 (95% CI: 1.01, 1.04) among girls. Further, for each additional convenience store,
Table 2. Characteristics of California Public Schools Included in This Study According to 2007 Data

<table>
<thead>
<tr>
<th></th>
<th>All (n = 6,362, 100%)</th>
<th>Racial/Ethnic Majority in the School&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>None (n = 1,493, 23%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White (n = 1,691, 27%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hispanic (n = 2,913, 46%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Black (n = 95, 1.4%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asian (n = 170, 2.6%)</td>
</tr>
<tr>
<td>No. of fast food restaurants</td>
<td>% Median</td>
<td>IQR&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>0</td>
<td>55.6</td>
<td>56.1</td>
</tr>
<tr>
<td>1</td>
<td>16.4</td>
<td>14.9</td>
</tr>
<tr>
<td>2</td>
<td>11.2</td>
<td>12.2</td>
</tr>
<tr>
<td>≥3</td>
<td>16.7</td>
<td>16.8</td>
</tr>
<tr>
<td>No. of convenience stores</td>
<td>% Median</td>
<td>IQR&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>0</td>
<td>54.8</td>
<td>59.6</td>
</tr>
<tr>
<td>1</td>
<td>25.7</td>
<td>25.4</td>
</tr>
<tr>
<td>2</td>
<td>12.8</td>
<td>10.7</td>
</tr>
<tr>
<td>≥3</td>
<td>6.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Diversity index</td>
<td>0.60</td>
<td>0.43–0.71</td>
</tr>
<tr>
<td>Percent of free or reduced price meals participation</td>
<td>55.4</td>
<td>26.3–79.4</td>
</tr>
<tr>
<td>Percent with bachelor's degree or more in the census tract surrounding the school</td>
<td>18.6</td>
<td>9.7–32.5</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, interquartile range.

<sup>a</sup> Data are from databases of InfoUSA on food outlet locations, the 2000 US Census, and the California Department of Education.
<sup>b</sup> Racial/ethnic majority in the school was defined as the group that constituted greater than 50% of the student body, according to enrollment data by race/ethnicity administered by the California Department of Education. When no racial/ethnic group exceeded 50% of the student population, the racial/ethnic majority was coded as "none."
<sup>c</sup> For comparison of the distribution of school-level factors by racial/ethnic majority of the schools, all P ≤ 0.001 and were obtained from chi-squared tests for categorical variables and Kruskal-Wallis nonparametric tests for continuous variables.
<sup>d</sup> First and third quartiles of distribution.
the prevalence ratio = 1.01 (95% CI: 1.00, 1.01) among boys and 1.01 (95% CI: 1.01, 1.02) among girls. However, overall the evidence of heterogeneity of the food store–overweight associations by sex was weak, particularly for convenience stores (fast food restaurant: $P_{\text{sex}} = 0.06$; convenience store: $P_{\text{sex}} = 0.25$).

The patterns of the association between the nearby food environment and overweight were largely similar regardless of the outcome measures used, including obesity, body mass index, and body mass index $z$ scores (refer to Web Figure 4 and Web Figure 5).

**DISCUSSION**

Using data involving nearly 1 million racially/ethnically diverse children attending public schools in California, we documented 4 findings in this study concerning the association between the food environment near schools and childhood overweight. First, after control for student and school characteristics, fast food restaurant density around schools was significantly related to overweight prevalence in the overall sample. Second, we found that the influence of fast food restaurant density on overweight was contingent upon student race/ethnicity, with greater density associated with higher overweight prevalence among Hispanics and blacks but lower prevalence among Asians. Third, we documented an association between greater convenience store density and childhood overweight in the overall sample. Fourth, we observed some evidence, although weak, that the food environment may have a stronger influence among younger (fifth grade) children and girls. This study contributes to the limited though growing body of literature concerning the food environment near schools and its potential influence on children’s body weight.

**Fast food restaurants**

Our study provides novel findings concerning the differential influence of fast food restaurant density near schools and overweight prevalence, with greater density associated with higher prevalence among Hispanic and black children but lower prevalence among Asian children. Although the influence of fast food restaurant density on overweight was small among Hispanics and blacks, this may translate into large detrimental effects for the population as a whole (39, 40). In their California study, Davis and Carpenter (1) also found a stronger effect for blacks than for the sample as a whole. Exposure to fast food restaurants near schools may influence susceptibility to overweight especially among
black and Hispanic children given this and prior research documenting that schools attended by Hispanic and black youth are disproportionately surrounded by fast food restaurants (20). Moreover, compared with white children, black and Latino youth are more likely to be exposed to fast food advertisements (17) or to recognize fast food logos (16) that may shape their food preferences. Fast food prices are inversely associated with adolescent body mass index, and the effect is greater for teens with lower socioeconomic status (4). The higher obesity risk among black and Hispanic children may be due to increased vulnerability resulting from a combination of greater access, greater exposure to marketing, and affordability of fast foods.

Further research investigating the observed inverse relation between fast food restaurant density and obesity among Asian children is warranted. One plausible explanation is that, although there is diversity in socioeconomic resources across Asian ethnic subgroups (41), in general, Asian children have greater socioeconomic resources than black and Hispanic children (42). Asian children may have increased access to the healthier, but more expensive, food options available in the same fast food restaurants. It is also plausible that other cultural factors such as dietary choices play a role (43), alone or in combination with socioeconomic resources.

Finally, our finding regarding the ceiling effect in the overall association between fast food restaurant density and obesity risk may partly explain the mixed results in this area. Similar to our analyses with linear terms, those of Powell and Bao (4) show null effects of fast food density on adolescent obesity. However, our analyses accounting for ceiling effects are also consistent with those of a study that found that students attending schools with at least 1 fast food restaurant had a 6% increase in the odds for overweight compared with students whose schools were not near fast food outlets (1). Estimated linear dose–response associations will tend to be diluted when associations demonstrate ceiling effects.

**Convenience stores**

This is one of a handful of studies that examined the impact of convenience store density near schools on student weight outcomes (3, 5, 44). Novel aspects of our study include its systematic analyses regarding the shapes of the associations between convenience store density on obesity across race/ethnic groups and grade levels. The patterns of associations between convenience stores and overweight prevalence were consistent with linear effects among fifth and seventh grade
students. Linear dose–response associations between the density of convenience stores and obesity have been reported (3, 7, 17, 45).

Our findings are consistent with literature on both school and residential exposures to convenience stores (45). Powell et al. (3) documented that each additional convenience store per 10,000 capita at the school zip code level was associated with a 0.15% increase in overweight, although their effect is not directly comparable to ours because of their per 10,000 capita adjustment and their use of school-level zip code as a measure of food outlet exposure. School zip codes likely overlap with children’s residential environment, which has also been shown to affect childhood overweight. For instance, living on street blocks with 1 or more convenience stores (46) would suggest that the level of aggregation may have a role for capturing effects. It has also been found that a greater concentration of convenience stores at the county level was associated with 30% higher obesity odds among children aged 5–18 years (7).

We documented weak evidence regarding heterogeneity of the food environment’s influence on overweight by sex, with point estimates for the associations being higher for girls than boys, as in a prior study (47). However, it is plausible that adjustments for differential effects of other school neighborhood predictors by sex (48) (i.e., models that included sex interactions with all other factors) may have resulted in nearly homogeneous associations between food stores and weight by sex. Further research in this area is warranted.

**Limitations**

This study is cross-sectional and relied on secondary data, lacking information on potentially important individual- and family-level factors, including socioeconomic status. Although fidelity with test administration protocols may vary, Fitnessgram data included direct measures of height and weight and allowed us to control for physical fitness. Food environment measures were from a commercial source, the accuracy of which is uncertain (20), although these data sources are one of the few available to conduct large-scale studies regarding the availability of food outlets near schools. Because identifying other limited-service restaurants with precision is difficult and the effect of franchised establishments was found previously to be stronger compared with other restaurants (1), we used only franchised fast food restaurants. To our knowledge, the list of convenience stores is comprehensive. Finally, estimating various types of associations (e.g., store-type stores, linear vs. threshold effects, subgroups) may increase false positive findings. However, examination of specific food stores and the shapes of the associations is needed to better understand their potentially distinct influences.
Conclusion

Our study findings suggest a differential influence of fast food restaurant density on overweight, with detrimental effects for Hispanic children and black children. Convenience store density exerted a detrimental influence on children’s weight, particularly among fifth and seventh graders. Future programs and policies to reduce race/ethnic disparities and to prevent childhood obesity at the population level stand to benefit from a nuanced understanding of the food environment near schools.

ACKNOWLEDGMENTS

Author affiliations: Department of Biostatistics, School of Public Health, University of Michigan, Ann Arbor, Michigan (Brisa N. Sánchez, Jonggyu Baek, Lindy Zhang); Department of Health Education, College of Health and Human Services, San Francisco State University, San Francisco, California (Emma V. Sanchez-Vaznaugh, Ali Uscilka); and Center on Social Disparities in Health, Department of Family and Community Medicine, University of California San Francisco, San Francisco, California (Emma V. Sanchez-Vaznaugh).

This research was funded in part by grants from The Robert Wood Johnson Foundation’s Healthy Eating Research Initiative, the Salud! America Research Network to Prevent Childhood Obesity among Latino Children, and the Kaiser Permanente Burch Minority Leadership Awards Program. B. N. S. also acknowledges salary support from grant 1-P20-SE18171-01 from the National Institutes of Health.

The authors thank the Center for Advancing Health for providing other support.

Conflict of interest: none declared.

REFERENCES


