

Clustering of Fast-Food Restaurants Around Schools: A Novel Application of Spatial Statistics to the Study of Food Environments

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Over the past 3 decades, fast-food retail sales in the United States have soared 900%, from \$16.1 billion in 1975 to a projected \$153.1 billion in 2004.¹ The number of fast-food restaurants in the country now exceeds 280 000.² In this same period, Americans have become increasingly dependent on restaurants and fast-food chains for their meals,³ with almost half of US food spending going toward food eaten away from home.⁴ The fast-food industry markets heavily to children and adolescents, who make up an important part of the industry's consumer base.^{5,6} Among youths aged 12 to 18 years, the percentage of total energy intake consumed from fast-food and other restaurants has increased from 6.5% in 1977–1978 to 19.3% in 1994–1996.³ On a typical day, almost a third of children and adolescents eat fast food.⁷ Portion sizes and the corresponding caloric content of foods served at fast-food restaurants have also increased appreciably over the past several decades.⁸ On days when youths eat fast food, compared with days when they do not, they consume more total calories, more fat, more added sugars, more sugar-sweetened drinks, and fewer fruits and vegetables.^{7,9} Among adults, eating in fast-food restaurants is cross-sectionally associated with higher body mass index¹⁰ and longitudinally associated with weight gain^{11,12} and development of insulin resistance,¹² both important risk factors for diabetes.¹³

Consumers' ease of access to fast food is a priority for the industry, as business planners have long been aware of the potential to maximize sales by selecting restaurant sites that ensure close proximity to the consumer base.^{14–16} In restaurant site selection, business planners consider neighborhood demographics and the presence of other businesses, community organizations, and aspects of the neighborhood roadways that may draw in po-

Objectives. We examined the concentration of fast food restaurants in areas proximal to schools to characterize school neighborhood food environments.

Methods. We used geocoded databases of restaurant and school addresses to examine locational patterns of fast-food restaurants and kindergartens and primary and secondary schools in Chicago. We used the bivariate K function statistical method to quantify the degree of clustering (spatial dependence) of fast-food restaurants around school locations.

Results. The median distance from any school in Chicago to the nearest fast-food restaurant was 0.52 km, a distance that an adult can walk in little more than 5 minutes, and 78% of schools had at least 1 fast-food restaurant within 800 m. Fast-food restaurants were statistically significantly clustered in areas within a short walking distance from schools, with an estimated 3 to 4 times as many fast-food restaurants within 1.5 km from schools than would be expected if the restaurants were distributed throughout the city in a way unrelated to school locations.

Conclusions. Fast-food restaurants are concentrated within a short walking distance from schools, exposing children to poor-quality food environments in their school neighborhoods. (*Am J Public Health.* 2005;95:1575–1581. doi:10.2105/AJPH.2004.056341)

tential consumers.^{14–16} In recent years, public health researchers have begun to develop methods to characterize neighborhood patterns in location and density of different types of food establishments, such as fast-food restaurants or grocery stores.^{17–20} Given the fast-food industry's targeted marketing to children and adolescents and the importance of young people in the industry's consumer base, we used spatial statistical methods to examine whether fast-food restaurants may concentrate in areas proximal to kindergartens and primary and secondary schools where they would be highly accessible to students.

METHODS

Fast-Food Restaurant Database

In 2002, we compiled a comprehensive list of fast-food restaurants in Chicago along with their street addresses. To create the comprehensive list, we used as our primary source Technomic Inc, a food industry market research company that publishes a list of

the leading limited service chain brands (*2002 Technomic Top 100*),²¹ as ranked by total US sales, which includes the major fast-food chains.²¹ Consistent with food industry standards, Technomic defines limited service chain restaurants as eating places where customers order items and pay before eating and where food can be eaten on the premises or taken out.²¹ To ensure that our database was both comprehensive and appropriate for Chicago, we gathered information on fast-food restaurants in the city from several other sources. In addition to the Technomic list, we also referred to a privately run Web site, Fast Food Source (<http://www.fastfood-source.com>), to identify fast-food restaurants in Chicago. Two final sources, Centerstage (<http://centerstage.net>) and Citysearch (<http://chicago.citysearch.com>), which provide comprehensive online guides to Chicago's restaurants, were used to identify fast-food restaurants that might have been missed by the prior sources. Finally, we obtained full addresses for identified restau-

rants with the online Yahoo! Yellow Pages (<http://www.yahoo.com>) and Superpages (<http://www.superpages.com>). A private company that was shown in prior research to provide highly accurate geocoding for address databases geocoded the resulting database of 624 fast-food sites to assign longitude and latitude coordinates and census tract identification codes.²² All records were successfully geocoded, with 98% (n=610) matched to the street address, the best census code accuracy rating. Eleven sites were determined to be located outside Chicago city limits and were excluded, resulting in 613 fast-food restaurant sites within Chicago included in the analyses.

Restaurants in the database included 79 restaurant chain brands, which offered menu items such as hamburgers and french fries, fried chicken, pizza, submarine sandwiches, and doughnuts. The top 10 restaurant chains by number of sites were McDonald's (99 locations; 16% of total), Subway (90; 15%), Dunkin' Donuts (72; 12%), KFC (50; 8%), Burger King (41; 7%), Popeye's Chicken and Biscuits (38; 6%), Wendy's (22; 4%), Church's Chicken (19; 3%), Taco Bell (19; 3%), and White Castle (16; 2%). These 10 chains constituted 76% of our database.

School Database

In 2002, we used school listings from the National Center for Education Statistics (<http://nces.ed.gov>) and Chicago Public Schools to create a comprehensive list of Chicago public and private kindergarten and primary and secondary school names and addresses. A combined database with 1478 listings was geocoded, with 91% (n=1351) of the records matched to the street address. It was not possible to match 6% (n=85) of the schools, so they were excluded from the analyses. An additional 101 records were determined to be duplicates or located outside Chicago and were excluded. Analyses included 1292 schools within Chicago.

Statistical Analyses

Using several methods, we examined locational patterns of fast-food restaurants and schools in Chicago. First, we calculated the mean and median distance from schools to the nearest fast-food restaurant. Second, we

used the mapping and analytic capabilities of a geographic information system running ArcGIS 8.3 software²³ to create 400-m-radius and 800-m-radius buffers around each school and then calculated the number of fast-food restaurants located within buffers of each size. The 400-m buffer has been used as a primary unit of aggregation in research on walking and the environment, on the basis of an estimate that on average an adult can walk 400 m in 5 minutes.²⁴ We also created 800-m-radius buffers to characterize a larger section of the school neighborhood food environment.

Third, we used the bivariate K function method to quantify the degree of clustering (spatial dependence) of fast-food restaurants around school locations at distances ranging from 0 to 1.5 km from school addresses. Cuthbert and Anderson²⁵ provide a detailed description of the bivariate K function method and its application in analyses of commercial and residential land use. A strength of the K function method is that it provides a statistical test of clustering. The bivariate K function method estimates the spatial dependence between 2 different types of locations in a geographic region, identifying distances within which spatial dependence is evident and testing the statistical significance of the observed clustering relative to expected distribution of points if there were no spatial dependence.²⁵ We used the Splan program^{26,27} of the R statistical package²⁸ for the K function calculations.

We analyzed data from the city as a whole and then conducted 3 additional stratified analyses. First, we examined spatial dependence within downtown Chicago (69 schools and 138 fast-food restaurants) and outside downtown (1223 schools and 475 fast-food restaurants). We defined downtown Chicago as a 3-km-radius circle centered at approximately the intersection of Dearborn and Monroe streets. We modified data from the Illinois Department of Natural Resources to define the city boundaries as a closed, contiguous polygon.²⁹ Second, we examined spatial dependence within 3 strata defined as high (314 schools), medium (479 schools), and low (498 schools) level of commercialization. Level of commercialization was based on 1995 Northern Illinois Planning Commission data, the most recent data available at the

time of our study.³⁰ Commercial land included shopping malls; business parks; offices; hotels; government administration and services; prisons; and medical, institutional, industrial, and transportation facilities. We calculated the percentage of commercial land in 1990 census tracts and divided the tracts into tertiles, categorizing them as high (>30.3%), moderate (14.6% to 30.2%), and low (<14.6%). We then identified the schools that fell in each of these tertiles. Third, we examined spatial dependence within 3 strata of median annual household income, based on 2000 US Census data, which we grouped into tertiles, defined as high- (441 schools; >\$43 700), moderate- (423; \$30 300 to \$43 700), and low-income (428; <\$30 300) regions.³¹ We assigned each school a median household income value by calculating an area-weighted average of block groups that intersect the school buffer.

It is important to note that our study databases were assembled as censuses, rather than samples, of schools and fast-food restaurants in Chicago; therefore, it was not necessary or appropriate to carry out statistical tests of strata differences in means and frequencies presented in Tables 1 and 2. In contrast, statistical tests were appropriate for the K function analyses, which examine differences between observed and expected clustering.

RESULTS

Figure 1 shows the location of fast-food restaurants and schools included in analyses and indicates schools that have at least 1 fast-food restaurant within 400 or 800 m. Table 1 presents the number of schools and fast-food restaurants and the distance from any school to the nearest fast-food restaurant in Chicago overall and within each stratum of neighborhood characteristics. In Chicago as a whole, the mean and median distance from any school to the nearest fast-food restaurant were 0.60 and 0.52 km, respectively (Table 1).

Table 2 shows the means, medians, and ranges for the number of fast-food restaurants in 400-m-radius and 800-m-radius buffers around schools. In Chicago as a whole, the number of fast-food restaurants within 400 m of a school ranged from 0 to 33, whereas the

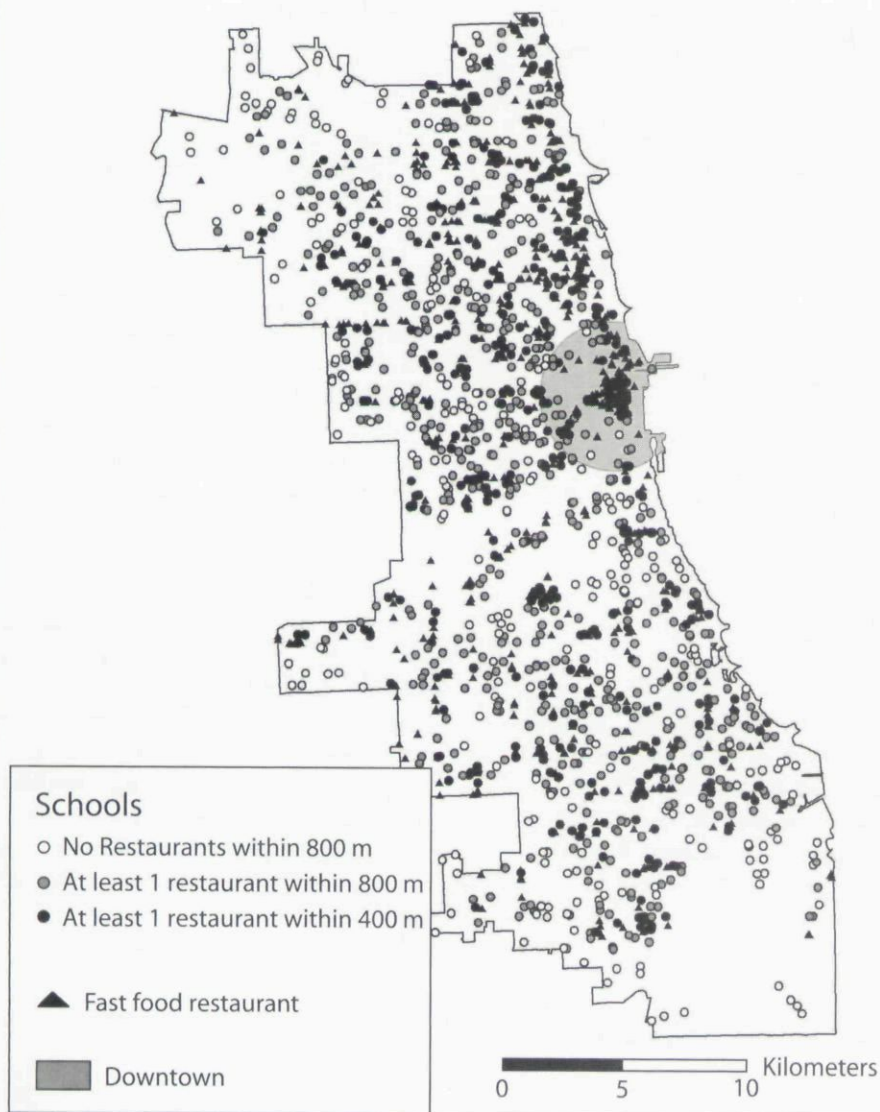


FIGURE 1—Locations of schools and fast-food restaurants in Chicago.

number within 800 m of a school ranged from 0 to 85. Thirty-five percent (452/1292) of schools in Chicago as a whole had at least 1 fast-food restaurant within 400 m, whereas nearly 80% (1010/1292) of schools had at least 1 fast-food restaurant within 800 m, approximately a 10-minute walk. Two schools had the same address as the nearest fast-food restaurant. In the downtown region, there were twice as many fast-food restaurants as there were schools, and 94% (65/69) of schools had at least 1 fast-food restaurant within 800 m. For schools within regions stratified by commercialization and median

annual household income, the percentage of schools with at least 1 fast-food restaurant within 400 m ranged from 27% to 40% and within 800 meters ranged from 76% to 80% (Table 2).

Figure 2a displays the results of bivariate K function analyses for Chicago as a whole. The value of the K function (shown on the y-axis) indicates the average number of fast-food restaurants within a specified distance from a school (shown on the x-axis), divided by the overall density of fast-food restaurants in Chicago. The solid line represents the observed value of the K function, and the dotted

line represents the expected value of the K function under the assumption of no spatial dependence between fast-food restaurants and schools. The dashed lines represent the upper and lower bounds of the 95% confidence interval around the expected-value dotted line. Confidence intervals are based on 100 simulations with the data under the assumption of no spatial dependence. The observed value of the K function in Figure 2a falls above the 95% confidence interval between distances of roughly 0.25 km and 1.5 km on the x-axis, indicating that a significantly greater number of fast-food restaurants are located within a short distance from schools than would be expected if there were no spatial dependence. Figure 2b displays a plot of the relative clustering of fast-food restaurants around schools within the corresponding distance on the x-axis ranging from zero to 1.5 km. We estimate that there are between 3 and 4 times as many fast-food restaurants within an area up to 1.5 km from schools than would be expected if the restaurants were distributed throughout the city in a way that was unrelated to the location of schools.

Results of stratified analyses revealed statistically significant clustering of fast-food restaurants within 1.5 km of schools located within areas of the city outside downtown (not shown). The relative clustering estimate indicated that fast-food restaurants were about 2.5 times more clustered around schools in areas outside downtown than would be expected under the null hypothesis. Although fast-food restaurants were much more numerous in the downtown area than outside downtown, they did not appear to cluster significantly around schools more than would be expected given the high density of fast-food restaurants in downtown Chicago.

Fast-food restaurants were found to cluster significantly around schools in both the high- and moderate-commercialization regions of the city (not shown). The relative clustering estimates indicated that in the high-commercialization areas, there were approximately 6 times more fast-food restaurants within 1.5 km of schools, and in the moderate-commercialization areas, there were approximately 3 times more fast-food restaurants within 1.5 km of schools than

TABLE 1—Number of Schools and Fast-Food Restaurants and Distance in Kilometers From Any School to Closest Fast-Food Restaurant, Overall and by Neighborhood Characteristic Strata: Chicago, 2002

	Schools, No.	Restaurants, No.	Distance, km			
			Mean	SD	Median	Range
Chicago overall	1292	613	0.60	±0.45	0.52	0-3.69
Downtown	69	138	0.32	±0.22	0.27	0-0.83
Outside downtown	1223	475	0.62	±0.46	0.53	0-3.69
High commercialization	314	305	0.61	±0.59	0.49	0-3.69
Medium commercialization	479	177	0.56	±0.40	0.47	0-3.25
Low commercialization	498	131	0.64	±0.39	0.61	0-3.20
High median household income (>\$43 700) ^a	441	282	0.61	±0.44	0.53	0-3.20
Moderate median household income (\$30 300-\$43 700)	423	296	0.64	±0.52	0.55	0-3.69
Low median household income (<\$30 300)	428	27	0.60	±0.44	0.51	0-3.61

^aExcludes 8 restaurants in census tracts with no information on median annual household income.

would be expected. We did not find evidence of clustering of fast-food restaurants around schools in low-commercialization areas.

Fast-food restaurants were found to cluster significantly around schools in regions of the city in the highest income tertile, where median annual household incomes were \$43 700 or greater (not shown). The relative

clustering estimate indicated that in these areas, there were approximately 5 to 7 times more fast-food restaurants within 1.5 km of schools than would be expected. We did not find evidence of clustering of fast-food restaurants around schools in areas where the median annual household income was less than \$43 700.

DISCUSSION

Fast-food consumption has increased dramatically over the past several decades and may be an important contributor to the rise in the prevalence of obesity in children and adolescents. In our study of fast food in Chicago, we found that although fast-food restaurants are located throughout the city, they are clustered in areas within a short walking distance from schools. We estimate that there are 3 to 4 times as many fast-food restaurants within 1.5 km from schools than would be expected if the restaurants were located around the city in a way unrelated to schools. The median distance from any school to the nearest fast-food restaurant was 0.5 km, indicating that in half the city's schools, students need to walk little more than 5 minutes to reach a fast-food restaurant. Nearly 80% of schools in Chicago had at least 1 fast-food restaurant within 800 m. In the downtown area, the median distance from any school to the nearest fast-food restaurant was just 270 m. We also found evidence of clustering of fast-food restaurants around schools in areas of the city outside downtown and within areas with high and medium levels of commercialization and areas where median annual household incomes were \$43 700 or greater.

TABLE 2—Number of Fast-Food Restaurants Within 400 and 800 m of Any School, Overall and by Neighborhood Characteristic Strata: Chicago, 2002

	Restaurants Within 400 m of a School, No.							Restaurants Within 800 m of a School, No.						
	Mean	SD	Range	Schools With at Least 1 Restaurant Within 400 m, No. (%)			Mean	SD	Range	Schools With at Least 1 Restaurant Within 800 m, No. (%)				
				5th Percentile	Median	95th Percentile				5th Percentile	Median	95th Percentile		
Chicago overall	0.9	±2.9	0-33	0	0	3	452 (34.9%)	3.1	±7.3	0-85	0	2	7	1010 (78.2%)
Downtown	6.6	±10.1	0-33	0	1	29	46 (66.7%)	19.9	±25.2	0-85	1	6	70	65 (94.2%)
Outside downtown	0.5	±1.0	0-7	0	0	3	406 (33.2%)	2.1	±2.1	0-19	0	2	6	945 (77.3%)
High commercialization	1.4	±4.7	0-33	0	0	4	124 (39.5%)	4.4	±11.5	0-85	0	2	11	248 (79.0%)
Medium commercialization	0.9	±2.5	0-26	0	0	3	191 (39.9%)	3.3	±7.1	0-66	0	2	7	382 (79.7%)
Low commercialization	0.4	±0.9	0-7	0	0	2	136 (27.3%)	1.9	±2.0	0-18	0	1	6	379 (76.1%)
High median household income (>\$43 700) ^a	1.5	±4.5	0-33	0	0	4	168 (38.1%)	4.7	±11.5	0-85	0	2	19	337 (76.4%)
Moderate median household income (\$30 300-\$43 700)	0.5	±1.4	0-17	0	0	2	124 (29.3%)	2.4	±4.3	0-58	0	2	6	330 (78.0%)
Low median household income (<\$30 300)	0.6	±1.0	0-7	0	0	3	160 (37.4%)	2.0	±1.9	0-18	0	2	6	343 (80.1%)

^aExcludes 8 restaurants in census tracts with no information on median annual household income.

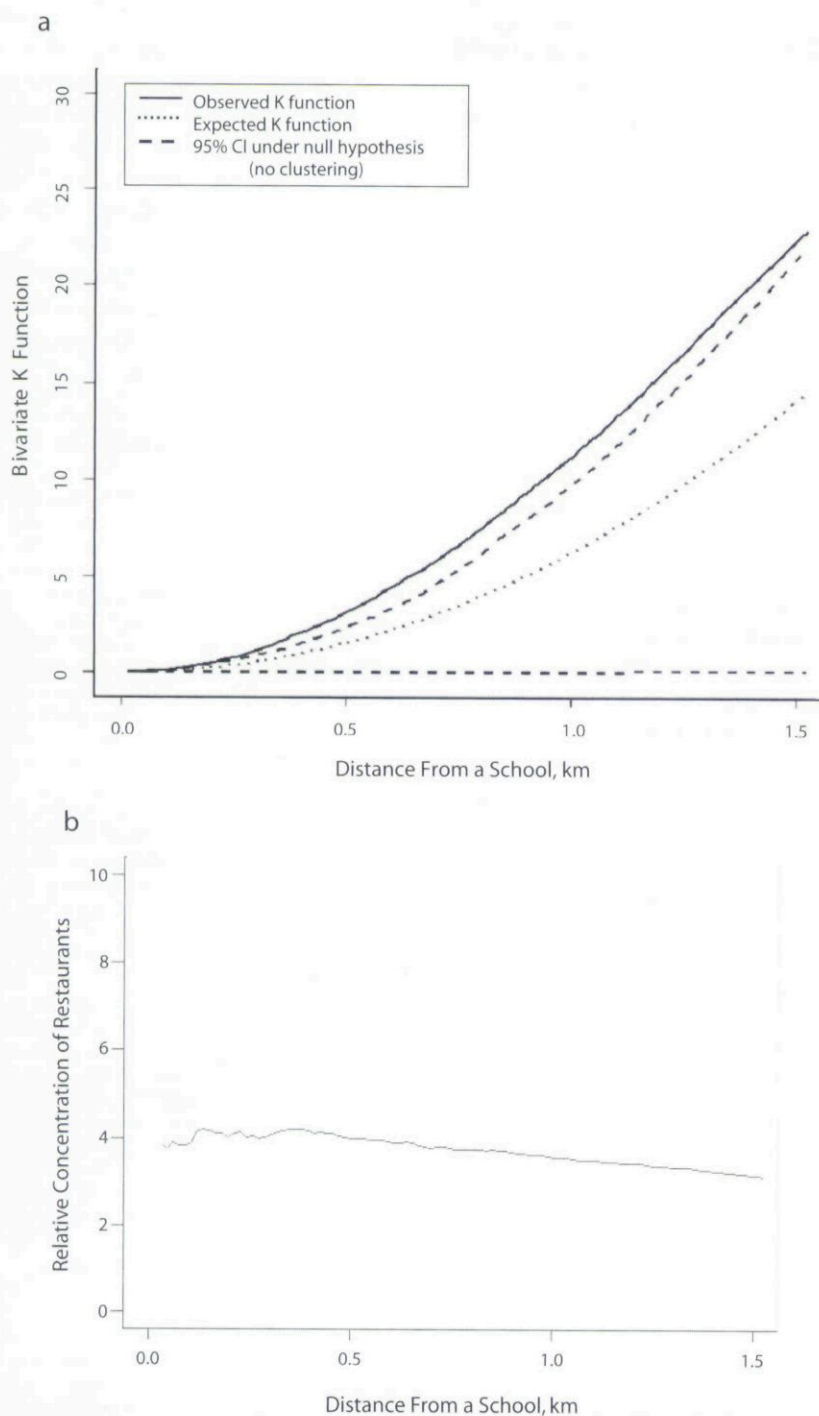


FIGURE 2—Clustering of fast-food restaurants in Chicago: (a) bivariate K function plot with 95% confidence intervals showing clustering of fast-food restaurants around schools and (b) relative concentration of fast-food restaurants around schools.

Students in all grades may have access to fast-food restaurants before and after school, and older students are also likely to have access at lunchtime, because of widespread

open-campus policies in Chicago high schools. Approximately 6% of students attending Chicago public schools are provided transportation in school buses, whereas most walk, take

public transportation, or ride in cars to and from school (G. Mancuso, director, School Demographics and Planning, Board of Education of the City of Chicago, e-mail correspondence, January 6, 2005). These modes of transportation may give schoolchildren opportunity to access fast-food restaurants in their school neighborhoods.

Our methods were designed to characterize the degree of fast-food clustering around schools. The specific mechanisms underlying the patterns of clustering we observed are not clear. The degree to which restaurant industry site selection practices, city zoning regulations on commercial land use, or other factors may contribute to the patterns will need to be explored in future studies. Nevertheless, the concentration of fast-food restaurants around schools within a short walking distance for students is an important public health concern in that it represents a deleterious influence in the food environment that may undermine public health efforts to improve nutritional behaviors in young people.

We found clustering of fast-food restaurants in both moderate and high-commercialization areas, indicating that proximity to fast-food venues affects the majority of schools in our study, not just those in the most commercialized areas. In fact, we found more evidence of clustering outside downtown than inside, perhaps because the downtown area is so suffused with fast-food restaurants that these venues are present in most neighborhoods. Of note is our finding of a small number of fast-food restaurants (Table 1) in the lowest-income-tertile areas (median household income <\$30 300). It is plausible that fast-food restaurant owners are reluctant to locate in impoverished areas. It was in the highest-income-tertile areas (median household income >\$43 700) where we found evidence of fast-food clustering, suggesting that children attending schools in these areas of the city rather than in low-income areas may be most exposed to the problem of concentrated fast-food venues in school neighborhood food environments.

The neighborhood food environment is a relatively new concept in public health research, and methods for defining, characterizing, and quantifying the food environment are still under development. Studies have

used varied methods to characterize fast food in neighborhood environments. For instance, in a study with geocoded data from the Cincinnati area, Burdette and Whitaker¹⁷ estimated that the average distance from a child's home to the nearest fast-food restaurant was 0.7 miles. In a study using geocoded 1990 US Census data from 4 states, Morland et al.³² characterized food environments in terms of the mean number of fast-food restaurants per census tract, finding an estimated 2 fast-food restaurants per tract. We are not aware of studies similar to ours that used spatial statistical methods to quantify the degree of clustering of fast-food restaurants around schools. We believe our method represents a novel and potentially informative and powerful technique for quantifying and statistically testing spatial patterns in the food environment and land use in relation to important public health concerns.

We were not able to identify any accepted criteria in the public health literature to define fast-food restaurants. As described previously, to create our fast-food database, we relied on information from the food industry marketing research firm Technomic Inc and other sources providing lists of restaurants in Chicago. For their analyses, Morland et al.³² defined fast-food restaurants as those listed in the limited-service restaurant category of the 1997 North American Industry Classification System.³³ Their category includes fast-food franchises and other restaurants that serve food over the counter and encompasses an array of restaurants very similar to that identified by our Technomic source. One difference is that the Technomic category *limited-service restaurant* includes doughnut shops among fast-food restaurants, whereas the North American Industry Classification System does not.³³ In a Cincinnati-based study, Burdette et al.¹⁷ defined fast-food restaurants as those that had franchises in multiple states, had more than 1 restaurant in Cincinnati, served meals without waiters, and provided seating for customers. They identified 8 chain restaurant brands in Cincinnati, 7 of which were also included in our database for Chicago. To the extent that definitions of fast-food restaurants differ across studies, comparisons of findings are limited. Our study was

restricted to schools and fast-food restaurants in Chicago. Further research will need to explore to what degree other cities and rural and suburban areas differ from what we observed in Chicago.

Our study has several limitations. The most recent land use data available to us to classify level of commercialization were compiled in 1995 by the Northern Illinois Planning Commission, but more recent data might have allowed more accurate classification. There is precedent in the health research literature for using 400-m-radius buffers for analyses of physical environments in part because it is a distance easily walked by most adults in 5 minutes,²⁴ but young children may be expected to take longer to walk this distance. We were not able to assess the relation between density of fast-food restaurants in school neighborhoods and student nutritional patterns. Burdette and Whitaker¹⁷ did not find an association between proximity of fast-food restaurants to a child's home and the child's weight status, although they did not assess nutritional behaviors. Future research will need to examine the relation between the presence of fast-food restaurants in school and home neighborhoods and fast-food consumption, diet quality, and caloric intake.

A groundbreaking report on childhood obesity issued by the Institute of Medicine in 2004 calls on the food industry to voluntarily restrict advertising unhealthy foods to children.³⁴ In addition, the Institute of Medicine report recommends that schools improve the nutritional quality of foods served and restrict sales of sodas and nonnutritious snack foods.³⁴ Other school policy changes that may warrant consideration include restricting unhealthy foods that can be brought into the school by students and curtailing open-campus rules that allow students access to nearby fast-food restaurants at lunchtime. Our findings suggest that additional municipal or state policy initiatives may be needed to address the concentration of fast-food venues in neighborhoods surrounding schools.

Ashe et al.¹⁸ argued that there is legal precedent for local governments to impose stricter controls on fast-food restaurant sites, similar to site selection restrictions placed on alcohol and firearm vendors, such as distance limits from schools and playgrounds and

caps on the number of venues permitted in a neighborhood. New regulation initiatives such as these may be a way to remove noxious elements in the food environments that schoolchildren are exposed to every day. They may also help to spur the fast-food industry to improve the nutritional quality of its products to avoid zoning restrictions. Greater public attention to the proximity of fast-food restaurants to schools may add urgency to efforts to improve food environments for schoolchildren. ■

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Contributors

S. B. Austin was responsible for study conception, data analysis and interpretation, and article preparation. S. J. Melly provided geographic information systems expertise and carried out data analysis. B. N. Sanchez provided statistical expertise. S. J. Melly, B. N. Sanchez, A. Patel, S. Buka, and S. L. Gortmaker contributed to study conception, data interpretation, and critical revision of the article.

Human Participant Protection

No protocol approval was needed for this study.

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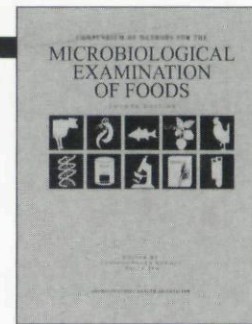
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