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The role of local food availability in explaining obesity risk among young school-aged children

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A R T I C L E I N F O

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A B S T R A C T

In recent years, research and public policy attention has increasingly focused on understanding whether modifiable aspects of the local food environment – the types and composition of food outlets families have proximate access to – are drivers of and potential solutions to the problem of childhood obesity in the United States. Given that much of the earlier published research has documented greater concentrations of fast-food outlets alongside limited access to large grocery stores in neighborhoods with higher shares of racial/ethnic minority groups and residents living in poverty, differences in retail food contexts may indeed exacerbate notable child obesity disparities along socioeconomic and racial/ethnic lines. This paper examines whether the lack of access to more healthy food retailers and/or the greater availability of "unhealthy" food purveyors in residential neighborhoods explains children's risk of excessive weight gain, and whether differential food availability explains obesity disparities. I do so by analyzing a national survey of U.S. children followed over elementary school (Early Childhood Longitudinal Study – Kindergarten Cohort) who are linked to detailed, longitudinal food availability measures from a comprehensive business establishment database (the National Establishment Time Series). I find that children who live in residentially poor and minority neighborhoods are indeed more likely to have greater access to fast-food outlets and convenience stores. However, these neighborhoods also have greater access to other food establishments that have not been linked to increased obesity risk, including large-scale grocery stores. When examined in a multi-level modeling framework, differential exposure to food outlets does not independently explain weight gain over time in this sample of elementary school-aged children. Variation in residential food outlet availability also does not explain socioeconomic and racial/ethnic differences. It may thus be important to reconsider whether food access is, in all settings, a salient factor in understanding obesity risk among young children.

Introduction

Much is still unknown about why childhood obesity prevalence has risen so markedly, but it is clear that shifting social and environmental contexts play a role. One hypothetical contextual driver of obesity risk is the availability of food retailers in residential neighborhoods, premised on the idea that what individuals have proximate access to is correlated with healthy and unhealthy forms of eating, which, in turn, are determinants of weight status. Furthermore, the children and families at greatest risk of obesity in the U.S. and in other industrialized countries – low-income and racial/ethnic minority groups – are seemingly exposed to relatively poor food environments, typified by a dearth of large grocery stores ("food deserts") and high concentrations of fast-food and convenience stores (see e.g., Beaulac, Kristjansson, & Cummins, 2009; Larson, Story, & Nelson, 2009, for overviews).

Policymakers are beginning to take action on the problem of limited and disparate healthy food availability – most notably in the U.S. through a federal initiative that will bring grocery stores and other healthy food retailers to underserved communities. Several major cities are also using zoning laws to regulate the establishment of new fast-food outlets, partly because of obesity risk concerns (Sturm & Cohen, 2009). Yet the empirical foundation of such food availability-based approaches, including the impact on excess weight gain, is still unclear.

This paper presents new research evidence on one aspect of food environments – availability of retail food establishments – and obesity risk among young children. Obesity prevalence among children in the elementary school years, between ages 6 and 11, has increased markedly over the past several decades in the U.S.

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(Ogden, Flegal, Carroll, & Johnson, 2002). Moreover, the early elementary ages represent a critical period for the development of excess adiposity (body fat) (Dietz, 1994), which is predictive of heaviness in adolescence and adulthood (Siervogel, Roche, Guo, Mukherje, & Chumlea, 1991). Drawing from comprehensive business establishment data, the National Time Series Establishment (NETS), my first research objective is to explore how measures of food outlet availability relate to key characteristics of children's home neighborhoods – particularly neighborhood racial/ethnic composition and poverty – based on a national sample. This descriptive analysis overcomes some of the limitations of earlier studies on food availability, which have often relied on aggregate business counts that are difficult to further refine (e.g., distinguish large-scale grocery outlets from small-scale, corner grocery stores or isolate fast-food chain vendors; disaggregate large boundary areas into smaller neighborhoods) or non-exhaustive address listings, and are often narrower in geographic scope. To understand whether food availability is a risk factor for *becoming* obese, it is critical to study children's weight transitions over time. Using a multi-level longitudinal modeling framework, my second objective is to analyze changes in children's body mass index (BMI) in relation to differential exposure to various retail food outlets, drawing from a national survey of elementary school children followed over a five year window (Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS-K)) who are linked to detailed food establishment information surrounding their homes. This analysis extends earlier work on child obesity risk by analyzing neighborhoods at a finer geographic level (Census tract) and weight changes in relation to changes (as opposed to only baseline exposure) in the residential retail food context.

Prior literature on local food availability and obesity risk

Obviously, "healthy" and "unhealthy" food purchases can be made almost anywhere, but the distinctions between the types and concentrations of food stores found in neighborhoods are important because they may proxy for quality, cost, and exposure (Larson et al., 2009). Large grocery stores sell and consistently stock a wide range of products, including nutritionally rich goods such as fresh produce, whole grains, low-fat protein and dairy items. Conveniences stores are considered less healthy food outlets because they predominantly stock non-perishable items that have shelf life, including snack or junk foods. Independent (non-chain) and smaller corner grocery stores, while offering fresh produce and healthy options, may not always consistently stock these good and tend to offer less variety (Jetter & Cassidy, 2006). Moreover, food prices tend to be higher in smaller grocery stores than in supermarkets (USDA, 2009). Goods in these smaller stores may also be of lower quality (e.g., wilting produce) (Andreyeva, Blumenthal, Schwartz, Long, & Brownell, 2008). While food stores remain the primary source for food purchases, American households spend more of their food budget (42%) on take-away or dining out than in previous time periods (Todd, Mancio, & Lin, 2010). Caloric content, fat, and portion sizes are all considerably greater in foods from take-out and sit-down places that in meals prepared at home (Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008), and the cost of a fast-food meal is inexpensive. Children who report eating fast-food consume, on average, 150 more calories a day than children who do not eat fast-food (Paeratakul, Ferdinand, Champagne, Ryan, & Bray, 2003).

The published research examining variation in local food environments in the U.S. is extensive, and has generally demonstrated that low-income and minority neighborhoods are significantly less likely to have access to supermarkets, have higher concentrations of convenience stores and corner grocery stores, and have greater concentrations of fast-food vendors as well (Alwitt & Donley, 1997; Block, Scribner, & DeSalvo, 2004; Galvez et al., 2007; Moore & Diez Roux, 2006; Morland, Wing, Diez Roux, & Poole, 2002; Powell, Chaloupka, & Bao, 2007; Powell, Slater, Mirtcheva, Bao, & Chaloupka, 2007; Zenk et al., 2005). For example, a study of New Orleans fast-food chains, using information derived from the city's Sanitation Department, telephone directories, and websites, found greater densities of fast-food outlets in predominantly black and lower-income neighborhoods (defined as Census tracts with varying buffers) (Block et al., 2004). A Chicago-based study analyzing ZIP Code Business Patterns (ZBP) data, collected by the U.S. Economic Census, found that supermarkets were less prevalent in poorer areas (Alwitt & Donley, 1997). Expanding the scope of analysis to the national level, Powell and colleagues (Powell, Chaloupka, et al., 2007; Powell, Slater, et al., 2007), analyzing Dun and Bradstreet's (D&B) comprehensive commercial database, have also found that low-income and predominantly minority postal ZIP codes have greater availability of fast-food restaurants and lower availability of supermarkets in urban contexts. Altogether, these patterns suggest a plausible hypothesis that retail food availability inequities are correlated with and may contribute to obesity inequalities (Moore & Diez-Roux, 2006).

However, data sources to identify and codify food establishments, an important comparative point, vary across studies (Larson et al., 2009). Walking or canvassing surveys of neighborhoods are perhaps the most accurate source of pinpointing and verifying location information (Galvez et al., 2007), but are challenging and costly to conduct on a larger scale. Government and public directories (e.g. state department lists, telephone or website listings) often do not have detailed information on the scale of operations, which limits the refinement of food industry categorization, and may not be updated regularly (Wang, Gonzalez, Ritchie, & Winkleby, 2006). Government business censuses (e.g., the U.S. County or ZIP Code Business Patterns data) have an additional limitation in that they cannot be disaggregated into smaller area boundaries. Commercial databases such as the NETS (analyzed in this study) overcome some of the above identified concerns because they contain more detailed information on operational scale and/or exact addresses of locations (Wang et al., 2006), but their listings may not be kept completely up-to-date. Still, the NETS is considered reliable and among the most comprehensive establishment sources available (Kolko & Neumark, 2007; Neumark, Zhang, & Wall, 2007).

In addition, some of the prior research on neighborhood food access has been limited to examining patterns of a singular food industry type (e.g., fast-food chains or grocery stores) (Alwitt & Donley, 1997; Block et al., 2004; Davis & Carpenter, 2009; Morton & Blanchard, 2007; Zenk et al., 2005). This approach does not allow for an examination of whether the story of differential availability depends on the type of food outlet examined. Most studies have also often focused on a single or a handful of locales, making it hard to generalize beyond those cities/areas (Larson et al., 2009; USDA, 2009). Prior national-level studies (Morton & Blanchard, 2007; Powell, Chaloupka, et al., 2007; Powell, Slater, et al., 2007) have used county and postal ZIP codes as the unit of comparison. Because these boundaries can encompass very large areas of land, they may not be reasonable proxies for proximate exposure to food outlets. More importantly, without information on residents' characteristics, it is impossible to examine whether food availability is independently associated with obesity risk.

Research on neighborhood food availability and individual BMI have offered mixed results (Boone-Heinonen et al., 2011) and often focus on adults. For instance, Mehta and Chang (2008) found a significant association between fast-food density (using ZBP data) and increased BMI in a national-level study, whereas Lopez (2007), measuring fast-food density with County Business Patterns data, does not. Zick et al. (2009) found that the presence of at least one grocery store, drawing from D&B data, is associated with lower BMI among adults in low-income Salt Lake City neighborhoods (block groups); Wang, Kim, Gonzalez, MacLeod, and Winkleby (2007), using government department (State Board of Equalization) and telephone directories, found no such association between supermarkets and lower BMI in a neighborhood tract-level study across several California cities.

Recent research on children, however, lends tentative support to the hypothesis that the retail food context bears an independent relationship to weight outcomes, at least among adolescents. For instance, one study analyzing repeated cross-sections of national survey data merged with D&B establishment information at the ZIP code level found that increased availability of supermarkets in school neighborhoods was associated with lower BMI among teenagers, whereas increased density of convenience stores was associated with higher BMI (Powell, Auld, Chaloupka, O'Malley, & Johnston, 2007). In a California-based study, high schools that had a fast-food restaurant within walking distance had significantly higher obesity prevalence among its student population compared to schools without a fast-food outlet nearby (Currie, DellaVigna, Moretti, & Pathania, 2010). These studies, however, may not be generalizable to younger children, as adolescents have more mobility and agency in food purchasing decisions, making walkable proximity potentially important. In contrast, younger children must often rely on their parents to access stores and purchase food on their behalf. Parents, in turn, may often rely on the retailers that are most convenient to where they live and where they work, in addition to other factors such as product diversity, price ranges, and brand loyalty (Briesch, Chintagunta, & Fox, 2009).

While I do not have information on food environments surrounding parental workplaces, I am able to assess residential food availability as proxies for what parents have consistent access to, with the caveat that residential measures cannot encompass all food stores parents may frequent. That said, a recent qualitative study of low-income households found that families without access to cars are often more dependent on their local retail and service options than higher-income families, suggesting that neighborhood food availability is relevant for more vulnerable populations (Clifton, 2004).

Much of what is known about the relationships between aspects of local food environments and obesity risk among younger children are based on examining correlational associations at a point-in-time, and at least one study found no association when examining proximity of family residences to fast-food restaurants (assessed through telephone and internet directories) and overweight status among low-income pre-school-aged children (Burdette & Whitaker, 2004). Results from longitudinal studies of younger children, which offer stronger evidence on associations, are also inconclusive. On the one hand, a national-level analysis of children followed over time (ages 6–17) documented a significant association between increased supermarket availability at the county-level (using D&B information) and lower BMI (Powell & Bao, 2009). On the other hand, Sturm and Datar (2005) demonstrated that while higher average fruit/vegetable prices in the metropolitan area was associated with greater increases in BMI among elementary school children followed from kindergarten to third grade, the density of food outlets (assessed using ZBP data) in the child's residential ZIP code was not.

Building upon Sturm and Datar's (2005) work, which uses the same child-level data, this paper constructs more precise definitions of food retail categories at finer geographic levels (Census tracts versus ZIP codes) to examine whether residential food availability explains young children's weight shifts over the course of elementary school (from age 6 to 11). Furthermore, because the NETS track establishments over time, the models can examine whether changes in the retail food context are associated with changes in children's BMI. As longitudinal food establishment data is rarely available (Wang et al., 2006), this study, to my knowledge, is one of the first to examine how growth or decline in food purveyor types relates to shifts in children's weight-for-height stature.

Data and measures

Early childhood longitudinal study – kindergarten cohort (ECLS-K)

The ECLS-K is a national survey of children enrolled in kindergarten in 1998–1999, representative of all kindergarteners attending school that year. The survey uses a multistage probability sample design (counties, schools, then randomly selected children). The baseline (fall and spring of kindergarten) waves of the ECLS-K, conducted in 1998–1999, included about 20,000 children, with sizable over-samples of "at-risk" children, including poor and minority children. Children and families were followed in the fall and spring of first grade (1999–2000), spring of third grade (2002), and spring of fifth grade (2004).

In compliance with the National Center for Education Statistics (NCES) restricted data license user agreement for the ECLS-K, all sample size numbers reported in this study are rounded to the nearest 10 to protect against subject identification. Because the analyses relied on existing secondary data with strict security measures to protect confidentiality and identity of respondents in the ECLS-K, this study was considered exempt from human subjects' protocols required by the Public Policy Institute of California's Institutional Review Board.

I use the spring samples from kindergarten, first, third and fifth grades to construct the largest and most consistent panel. To remain in the longitudinal sample, students must have information collected in all four rounds of data ($N \sim 11{,}400$). As with all longitudinal surveys, there is notable sample attrition, which is an important qualifier to the results. The longitudinal kindergarten–fifth grade panel is thus not representative of all students nation-wide, and the findings should be viewed as based on a sample of elementary school-aged children. Compared to children who were in the kindergarten (baseline) wave but lost to follow-up, children who remained in the kindergarten–fifth grade panel were more likely to be white, older at kindergarten entry age, live in a rural residence, come from a dual-parent family, live in a household with fewer children, and have mothers with slightly higher educational levels, but they are not significantly different in their BMI at baseline.

Child, school, and neighborhood measures

The main variable of interest is the child's BMI and how it changes over time. Trained interviewers objectively assessed weight and height at each spring round, which reduces concerns regarding the reliability of parental reports. Height and weight measurements were taken twice by interviewers using a stadiometer (Schorr height boards) and scales; when the two reports for height were less than two inches apart or when the two reports for weight were less than five pounds apart, the average was calculated. For reports that were discrepant by more than two inches for height and five pounds for weight, the value that was closest to the average height and weight for the child's age and sex group was used (Tourangeau, Nord, Lê, Pollack, & Atkins-Burnett, 2006). BMI is expressed as weight in kilograms divided by height in meters squared (kg/m^2), which is commonly used to classify obesity among adults and is recommended by the U.S. Centers for Disease Control and Prevention (CDC) for children (CDC, 2000). I used BMI-for-sex-and-age (in months) specific growth charts published by the CDC in 2000 to calculate where each child fell in the percentile distribution. BMI percentiles are constructed for each child in each round (the higher the percentile, the heavier the child). Children who were missing information on weight or height or both at the kindergarten or fifth grade rounds were automatically excluded from the study ($N \sim 240$). Children with unreasonable or implausible values ($N \sim 380$) were also dropped. These included cases where: BMI values were <10 or >50 in the kindergarten or fifth grade wave; the absolute difference in BMI percentile between kindergarten and fifth grade was abnormally large (>80); and child's height in fifth grade was shorter than the kindergarten height report. These are likely data entry, coding, or reporting errors.

The ECLS-K attempted to collect parental information at each wave (generally from the child's mother). Using data from the parent interviews, I constructed measures of the child's racial/ethnic background, household income and federal poverty status, educational attainment of parents, parental health (self-reported), and family structure (e.g., single parent). These socio-demographic factors are important correlates of childhood obesity and may also be correlated with residential location and other neighborhood characteristics of interest. More proximate behavioral factors potentially related to weight status include parental reports of how many days per week the child engaged in 20 min or more of vigorous activity or exercise (where the child's heart rate is consistently elevated) outside the school context, and parental reports of hours the child spends watching television and videos. These two measures serve as indicators of how sedentary children's lives are outside the school environment. I also examined several school-based factors (public or private, urbanicity, and percent of students who are eligible for school meal programs – a proxy for school-level disadvantage) that may be indirectly related to obesity risk and tap into school-level dynamics.

Finally, I adjusted for characteristics of neighborhoods (based on 2000 Census tract-level information) that are correlated with both obesity risk and food retailer availability. These include neighborhood density (persons per land area size), living in a poor neighborhood (>20% of residents live below federal poverty threshold), and living in a neighborhood where the residents are predominantly non-white (>50%). Given regional variation in obesity rates in the U.S. (Wang, 2011), region of residence (Eastern, Central/Midwest, Southern, and Western area) is also controlled for.

NETS data

To examine the role of the local food environments, I draw from the NETS, a longitudinal dataset compiled by Dun and Bradstreet that contains information on all business establishments in the nation covering the period from 1992 to 2006.Each establishment is tracked over time with a unique identification (ID) number and contains detailed information on industry codes (both North American Industry Classification System (NAICS) and Standard Industrial Classification (SIC) codes), full address, business names, trade names, and employee size. The NAICS is the standard used by federal statistical agencies, developed by the U.S. Office of Management and Budget and adopted in 1997 to replace the SIC system in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the business economy. It was designed to allow for a high level of comparability in business statistics among the North American countries (U.S. Census Bureau, 2010).

An extract based on NAICS codes capturing the food retail context of neighborhoods was pulled for the years 1998–2004 (to correspond to the years of data collection in the ECLS-K). Nearly 5 million establishments were extracted and geocoded (assigned latitude and longitude). In cases where addresses were missing, previous and later years using establishment ID were examined to see if the establishment existed and had a valid address for other years. A total of 63,745 (1.3%) observations were excluded due to invalid or missing address. Of the resulting sample of observations to be geocoded, 95% were successfully mapped.

Food environment measures

I created five categories of food establishments intended to capture different elements of the food environment. These categories, described below, include: (1) large-scale grocery stores or supermarkets, (2) corner grocery stores, (3) convenience stores, (4) full-service restaurants, and (5) fast-food chain restaurants. The classifications are primarily based on 6-digit NAICS codes, although in some cases the 8-digit SIC codes are used to refine the definition, as well as business name, trade name, employee size, and annual sales information.

Grocery stores. I define three categories of grocery stores within all establishments classified as "supermarkets and other grocery stores" (NAICS 445110):

1) **Supermarkets/large-scale grocery stores** are establishments that have at least $2 million in annual sales, an industry definition standard (Wang et al., 2006). For large-scale grocery stores, I also appended "warehouse clubs and supercenters"(NAICS 452910) defined as establishments retailing a general line of groceries in combination with general lines of other merchandise that have at least $2 million in sales. I then used headquarters identification numbers available in the NETS to identify additional establishments that were likely large chain grocery stores but had different primary NAICS codes.
2) **Mid-size grocery stores** are grocery stores with less than $2 million in annual sales and more than three employees – these stores were examined in earlier analyses but for brevity are not analyzed.
3) **Corner stores** are establishments categorized as grocery stores in the NAICS, but are operated by three employees or less.

Convenience stores. Convenience stores (NAICS 445120) are establishments or food marts primarily engaged in retailing a limited line of goods.

Full-service restaurants. Full-service restaurants are establishments engaged in providing food services to patrons who order and are served while seated and pay after eating. Establishments coded as "full-service restaurants" (NAICS 722110) and "cafeterias, grill buffets and buffets" (NAICS 722212) are included in this category.

Fast-food restaurants. I examined multiple definitions of fast-food establishments, as there is not a recognized definition of what constitutes fast-food. The first is a broad measure that includes all "limited service restaurants" (NAICS 722211), except snack and non-alcoholic beverage bars; the second uses the business and trade name to identify the top 100 fast-food chains derived from the National Restaurants Associations list of total annual sales. The final analyses uses the second fast-food measure that includes all major fast-food chains, based on the rationale that they are popular and recognizable industries with well-established and fixed menu items, varying little if any across regions. This stability and consumer recognition is part of what is arguably important for frequent consumption.

I merged geocoded food establishment information with residential tract information of ECLS-K children at various survey waves to calculate food outlet density and composition within the child's neighborhood, and to assess changes in food outlet availability over time. I then constructed various measures of local food availability: the total number of store types or restaurants per capita (density per population); the number of outlet types per square mile in the tract (density per land area); and the percent of each establishment type out of all food outlets found within neighborhoods (percent shares). For each of these measures, I recorded and analyzed baseline measures of proximate access and densities, as well as changes (growth or decline) in these measures for each neighborhood over the study time period.

Analytic sample

From the potential kindergarten–fifth grade ECLS-K sample that excludes BMI outliers and missing values ($N \sim 10{,}220$), approximately 9740 had parental information over the survey waves. Of these 9740, about 82% had residential food environment and neighborhood information (i.e., Census tract identifiers) over time. Because residential food availability was the key independent variable of interest, I did not impute missing values for these variables, which reduced the potential analytic sample to ~8020. Using multiple imputation techniques ("*mi impute*" commands) in Stata 11.1 (StataCorp, 2009), missing values for those with incomplete information on the remaining set of explanatory variables outlined above (~3700 observations) were replaced with multiple sets ($N = 20$) of simulated values to complete the data (Little & Rubin, 2002). Estimates from the 20 imputed datasets were then pooled to generate a single set of parameter estimates for descriptive statistics and regression coefficients. The final analytic sample is composed of about 7730 students (not all incomplete observations were imputed). Those for whom missing data were imputed were slightly more likely to be of racial/ethnic minority background, reside in lower-income and single parent households, and they were more likely to live in denser, urban neighborhoods. They were not significantly different in terms of age, sex, reported behaviors (e.g., days exercised), region of residence, or BMI as baseline.

I also constructed and analyzed BMI changes over time for a subsample of children who did not switch schools or change home locations over the study time frame – about 5380 children. Most of the descriptive and regression results presented are based on the full analytic sample of 7730 students with imputed information, with dummy variables to indicate if and when the child moved. However, similar multi-level models were estimated for the subsample of non-mover children, as children who move might be select in some unobserved ways that dummy controls cannot fully account for. These and other sensitivity checks are shown in Table 5 and discussed later.

Summary statistics comparing the full, analytic sample with imputed information (~7730) and non-mover sub-sample with imputed information (~5350) are shown in Table 1. The profiles of both the full analytic and non-mover samples reveal similarities across almost all characteristics. For both samples, more than 60% are non-Hispanic white, around 40% have mothers with a high school education or less, and over 20% live in households that earn less than $25,000 a year. Most children attend public schools, and about 40% attend schools in an urban area. A small share (about 16%) reside in a neighborhood with high poverty rates at baseline (where more than 20% of residents live below the federal poverty threshold), and about one in four live in a neighborhood where the majority of residents are non-white.

Analytic strategy

By combining the ECLS-K child and school-level information with neighborhood-level characteristics, changes in BMI percentile from kindergarten to fifth grade are modeled as a function of a vector of child and family characteristics, school-level factors, residential food availability and neighborhood environment, and time. Because ECLS-K children change schools and residential locations over the study time frame and because children are not always nested within the same school *and* neighborhood, I estimate cross-classified random-effects models (CCREM), a special case of multi-level modeling for data that are not purely hierarchical or nested (see Rabe-Hasketh & Skrondal, 2005; Teitler & Weiss, 2000). This cross-classified framework allows for a systematic analysis of how characteristics conceptualized and measured at various levels of non-nested structures (i.e., children in the same school may live in different neighborhoods, and vice versa) affect child weight gain over time. All model estimation uses *xtmixed* commands in STATA 11.1, where observations are allowed to belong to a combination of levels – school and neighborhoods (using *R.id* commands) (Rabe-Hasketh & Skrondal, 2005). These models rely on an assumption that the random effects across different levels and the random effects across different groupings in the same level are uncorrelated. Because multi-level survey weights are unavailable for the ECLS-K, the regression results are unweighted.

A series of nested models are estimated to understand the adjusted relationship between changes in BMI percentile and changes in exposure to neighborhood food outlets. Model 1 examines the relationship between growth/decline in specific food outlets on BMI percentile shifts, with adjustments for whether the child moved and age only. Model 2 examines how food availability estimates are affected when correlated neighborhood characteristics (e.g., population density, neighborhood poverty, and racial/ethnic composition) and region are included. Model 3 incorporates adjustments for child and family factors (e.g., sex, race/ethnicity, maternal education, income), and characteristics of schools (i.e., public or private, school disadvantage). The final model, Model 4, includes adjustments for time-varying behavioral characteristics, including changes in reported television viewing and days/week child exercised over the study time frame.

For the food outlet measures, I examined each industry type separately and then jointly. I also explored whether the results were sensitive to food availability measurement (i.e., density per population versus land area, food outlet shares). The regression results center on the concentration measures per square mile, since this better captures the physical availability and visual cues of food stores in a neighborhood (Mair, Pierce, & Teret, 2005), but the results for other measurements revealed very similar results and are available upon request.

Results

As shown in Table 2, children, on average, experienced upward shifts in their BMI percentile rankings over the course of elementary school. By the spring of fifth grade, the average movement in BMI percentile was 4.76 points, but the increase was notably higher for poor (7.01), black (7.85), and Hispanic (5.88) minority children than their non-poor (4.34) and white (3.85) counterparts. For these minority and low-income sub-groups in particular, their weight gain is outpacing their height growth. These shifts in heavier weight-for-height status have been well-documented in other studies (Ogden et al., 2002; Sturm & Datar, 2005), and is clearly evident in this national sample of young school-aged children.

In the year that children begin formal schooling, children who reside in poor and non-white areas have greater access to fast-food

Table 1
Summary statistics for ECLS-K kindergarten to fifth grade panel (1999–2004), full analytic sample and non-mover sub-sample.

	Full analytic sample		Non-mover sample	
	Percent or mean	SD	Percent or mean	SD
Child and familial characteristics				
Child age in months at kindergarten	74.71	(4.32)	74.68	(4.33)
Sex				
Male	49.9%		49.6%	
Female	50.0%		50.4%	
Race/ethnicity				
Non-Hispanic white	62.5%		64.7%	
Black	9.7%		8.6%	
Hispanic	17.8%		16.5%	
Asian	6.0%		6.0%	
Other/multi-racial	4.0%		4.2%	
Maternal education				
Less than high school	11.3%		10.1%	
High school/GED	27.8%		27.3%	
Some college	32.1%		32.4%	
Bachelor's degree or higher	28.8%		30.2%	
Single parent	16.4%		14.6%	
Household income				
Less than $15,000	12.4%		10.9%	
$15,000–$25,000	11.5%		10.7%	
$25,000–$35,000	12.0%		11.6%	
$35,000–$50,000	18.6%		18.5%	
$50,000–$75,000	21.9%		22.6%	
$75,000–$100,000	14.0%		14.9%	
$100,000 or more	9.7%		10.8%	
Parental health				
Very good	70.2%		71.7%	
Good	22.0%		21.4%	
Fair/poor	7.8%		6.8%	
Level of activity				
Days child engaged in at least 20 min of exercise, kindergarten wave	3.87	(2.27)	3.84	(2.25)
Change in days exercised, kindergarten to fifth grade	−0.16	(2.56)	−0.13	(2.53)
Television viewing				
Number of hours of TV per day, kindergarten wave	0.93	(0.56)	0.92	(0.54)
Change in hours of TV per day, kindergarten to fifth grade	0.12	(0.60)	0.11	(0.59)
School characteristics				
Urbanicity				
City	38.1%		38.5%	
Suburb	41.9%		42.3%	
Rural	20.0%		19.1%	
School type				
Public school	77.7%		74.6%	
Private school	22.3%		25.4%	
Percent eligible for school meal program	33.2	(30.9)	31.3	(31.1)
Home neighborhood (census tract) characteristics				
Population density (persons per square mile)	4834	(9714)	5002	(10,418)
Poor neighborhood	16.4%		14.9%	
Majority non-white neighborhood	24.2%		23.6%	
Region of country				
East	19.3%		18.1%	
Midwest	28.7%		27.5%	
South	30.2%		30.0%	
West	21.7%		24.4%	
Child moved to different school				
Never changed schools	69.3%			
Changed between kindergarten and 1st grade	3.1%			
Changed between 1st and 3rd grade	7.7%			
Changed between 3rd and 5th grade	13.6%			
Switched schools more than once	6.3%			
Sample size	~7710		~5350	

Notes: All variables, unless otherwise indicated, are measured at the spring kindergarten wave. Sample size numbers are rounded to the nearest 10, in compliance with the National Center for Education Statistics restrictions regarding disclosure of restricted use ECLS-K data. However, the statistics presented in the tables are derived using all observations in the sample. SD = standard deviation.

establishments and convenience stores in terms of density per land area (Table 3), a finding generally consistent with studies reviewed earlier. However, less affluent and minority areas also have significantly greater access to food establishments that are not obviously linked to obesity risk, including large-scale grocery stores and full-service restaurants (Table 3). Specifically, children who live in high poverty neighborhoods have 0.77 supermarkets per square mile, compared to 0.41 in more affluent areas. Children who have access

Table 2
Shifts in BMI percentile over elementary school, ECLS-K kindergarten to fifth grade panel, 1999–2004.

	Total	By poverty		By race/ethnicity				
		Poor	Non-poor	White	Black	Hispanic	Asian	Other
Mean BMI percentile in kindergarten (SD)	61.11 (28.02)	64.31 (27.67)	60.53 (28.03)	59.87 (27.73)	64.53 (27.92)	65.84 (27.24)	56.68 (29.66)	59.88 (28.78)
Mean BMI percentile in fifth grade (SD)	65.87 (29.21)	71.32 (27.98)	64.87 (29.31)	63.73 (29.12)	72.27 (27.41)	71.72 (28.08)	61.35 (30.36)	65.41 (31.11)
Mean change in BMI percentile (SD)	4.76 (21.08)	7.01 (19.98)	4.34 (21.24)	3.85 (21.36)	7.85 (19.34)	5.88 (19.85)	4.89 (22.43)	5.53 (21.55)
Sample size	~7710	~1160	~6550	~4780	~750	~1390	~480	~310

Notes: Child is poor if reported household income at baseline wave (kindergarten) is <100% of the federal poverty line ($17,050 for a family of four in 2000). "Other" racial/ethnic category includes Native Americans, Pacific Islanders, and multi-racial individuals. SD = standard deviation.

to one type of food industry thus typically have access to others. While this finding seems inconsistent with much of the extant literature on neighborhood food availability patterns, it is in line with a multi-study report published by the U.S. Department of Agriculture (2009), which found that low-income households tend to have greater proximate access (in terms of distance to nearest supermarket) than higher-income households in the U.S. (see also Rose et al., 2009), and a review of food desert evidence in the United Kingdom (Cummins & Macintyre, 2002). When alternative measures of fast-food and supermarket density (per 1000 persons) are examined in sensitivity specifications (also shown in Table 3), there generally appears to be no significant differences by neighborhood race or poverty, although corner stores have significantly higher per capita prevalence in poor and minority neighborhoods, and convenience stores per capita are larger in poor areas. In terms of food outlet composition, the percentage of large-scale grocery stores out of all food establishments is identical across neighborhood poverty status and racial/ethnic composition, whereas corner stores have a larger presence in poor and non-white neighborhoods. And somewhat surprisingly, more affluent and majority white neighborhoods have greater shares of fast-food chains within their retail food context.

Taken together, it seems that proximity to a wider variety of food retailers describes the food environments of children in poor and minority neighborhoods in this sample. The question remains as to whether greater food availability surrounding families partly and independently explains differential likelihoods for obesity risk. To address this question, I now turn to regression results from a series of nested, cross-classified random-effects models (Table 4), where changes in BMI percentile ranking on changes in food availability (density per square mile) are shown.

The results suggest that food outlet exposure holds no independent relationship to child weight gain, even in the simplest model (Model 1). In this model, out of the five food establishment categories examined, increased convenience store exposure over time seems to have the largest positive association with upward shifts in BMI percentile, but the estimate is not significant at the 5% level. Adjusting for neighborhood-level covariates of the food environment (Model 2) does not change the magnitude or significance of the food availability coefficients. Furthermore, adjusting for school-level and child socio-demographic characteristics (including race/ethnicity, maternal education, and income) (Model 3) and behavioral characteristics (Model 4) does very little to change any of the food availability estimates.

All model results imply that children who experience greater exposure to fast-food or convenience food establishments in their home neighborhoods are no more likely to gain excess weight than their counterparts who experience less exposure. In fact, the association with proximity to fast-food outlets goes in the opposite direction to that which was expected, but this is not statistically significant. Also, children with better access to supermarkets/large-scale grocery stores over time experienced slightly higher shifts in

Table 3
Residential food environment by neighborhood poverty and race, ECLS-K and NETS, kindergarten year, 1998–1999.

	Neighborhood characteristics						
	All	Poor	Non-poor	*p*-Value	White	Non-white	*p*-Value
Density, per square mile							
Fast-food chain	0.97	1.55	0.84	0.000	0.77	1.44	0.000
All other restaurants	7.34	10.54	6.58	0.017	6.01	10.13	0.004
Supermarkets/large-scale grocers	0.48	0.77	0.41	0.001	0.32	0.83	0.000
Corner stores	0.72	2.02	0.40	0.000	0.34	1.56	0.000
Convenience stores	1.91	3.00	1.65	0.000	1.41	3.02	0.000
Density, per 1000 population							
Fast-food chain	0.24	0.26	0.24	0.253	0.25	0.21	0.018
All other restaurants	1.03	1.14	1.00	0.059	1.05	0.99	0.278
Supermarkets/large-scale grocers	0.09	0.08	0.09	0.583	0.09	0.08	0.112
Corner stores	0.17	0.37	0.13	0.000	0.12	0.30	0.000
Convenience stores	0.4	0.47	0.38	0.003	0.40	0.39	0.642
Shares[a]							
Fast-food chain	8.5%	7.4%	8.7%	0.024	8.9%	7.5%	0.005
All other restaurants	38.8%	33.8%	40.0%	0.000	40.6%	34.8%	0.000
Supermarkets/large-scale grocers	3.8%	3.3%	3.9%	0.156	3.8%	3.7%	0.666
Corner stores	9.0%	16.4%	7.3%	0.000	6.3%	15.2%	0.000
Convenience stores	18.6%	18.7%	18.5%	0.881	19.4%	16.8%	0.001
***N* (number of tracts)**	~2690	~520	~2170		~1860	~830	

Notes: Descriptive statistics based on residential food environments in the baseline (kindergarten) year of the full analytic sample of the ECLS-K kindergarten to fifth grade panel ($N \sim 7710$).
[a] Among neighborhoods with at least one establishment.

Table 4
Multi-level models predicting change in BMI percentile on change in food outlet density (per sq. mile), ECLS-K and NETS, 1999–2004.

	Model 1			Model 2			Model 3			Model 4		
	Coef.	SE	*p*-Value	Coef.	SE	*p*-Value	Coef.	SE	*p*-Value	Coef.	SE	*p*-Value
Change in food outlet density (per sq. mile)												
Fast-food outlets	−0.53	1.36	0.70	−0.54	1.36	0.69	−0.63	1.36	0.64	−0.66	1.35	0.63
All other restaurants	−0.18	0.56	0.76	−0.19	0.56	0.74	−0.17	0.56	0.76	−0.19	0.56	0.73
Convenience stores	1.10	1.04	0.29	0.92	1.04	0.38	0.89	1.04	0.39	0.93	1.04	0.37
Corner stores	−0.06	1.18	0.96	−0.40	1.18	0.74	−0.54	1.17	0.65	−0.48	1.17	0.68
Supermarkets/large-scale grocers	0.58	0.37	0.12	0.59	0.37	0.11	0.55	0.37	0.14	0.54	0.37	0.58
Neighborhood and regional controls												
Population density (in 1000s)				0.00	0.00	0.37	0.00	0.00	0.41	0.00	0.00	0.46
Poor neighborhood (non-poor)				3.57	0.88	0.00	1.97	0.92	0.03	1.80	0.92	0.05
Minority neighborhood (majority white)				2.58	0.85	0.00	−0.13	0.93	0.89	−0.28	0.93	0.76
Region of country (east)												
Midwest				−1.70	0.93	0.07	−2.07	0.91	0.02	−2.16	0.91	0.02
South				−0.63	0.92	0.49	−2.10	0.92	0.02	−2.30	0.93	0.01
West				−3.00	1.00	0.00	−4.12	1.01	0.00	−3.89	1.01	0.00
School characteristics												
Urbanicity of school (urban area)												
Suburban							1.02	0.71	0.15	1.09	0.71	0.13
Rural							1.76	0.88	0.05	1.60	0.89	0.07
Private school (public)							1.11	0.85	0.19	1.17	0.85	0.17
% Students eligible for free/reduced price lunch							0.01	0.01	0.30	0.01	0.01	0.47
Child and family socio-demographic characteristics												
Female (male)							−2.95	0.53	0.00	−2.61	0.54	0.00
Race/ethnicity (non-Hispanic white)												
Black							3.20	1.08	0.00	2.19	1.09	0.04
Hispanic							5.64	0.92	0.00	5.58	0.92	0.00
Asian							−3.44	1.21	0.01	−3.47	1.21	0.00
Other							1.85	1.43	0.20	1.59	1.42	0.27
Mother's education (less than high school)												
High school/GED							−0.20	0.97	0.83	−0.39	0.97	0.69
Some college							−1.03	1.00	0.30	−0.98	1.00	0.33
Bachelor's degree or higher							−2.08	1.11	0.06	−1.54	1.11	0.17
Household income (<$15,000)												
$15,000–$25,000							1.32	0.83	0.11	1.38	0.83	0.10
$25,000–$35,000							1.67	0.87	0.05	1.72	0.87	0.05
$35,000–$50,000							0.36	0.87	0.68	0.40	0.87	0.65
$50,000–$75,000							−0.04	0.92	0.97	0.02	0.92	0.98
$75,000–$100,000							−0.51	1.01	0.62	−0.44	1.01	0.66
$100,000 or more							−1.92	1.10	0.08	−1.70	1.10	0.12
Single parent (married)							0.45	0.63	0.48	0.19	0.63	0.77
Parental health (excel lent/very good)												
Good							1.43	0.47	0.00	1.33	0.47	0.01
Fair/poor							2.44	0.75	0.00	2.32	0.75	0.00
Child behaviors												
Change in number of days child exercised at least 20 min										−0.30	0.11	0.01
Change in number of hrs. of television watched per day										1.26	0.45	0.01
Other controls												
Child's age in months	−0.15	0.06	0.02	−0.13	0.06	0.04	−0.17	0.06	0.01	−0.16	0.06	0.01
Child moved to different school (never moved)												
Moved between K and 1st grade	2.44	1.44	0.09	2.37	1.43	0.10	1.64	1.41	0.25	1.66	1.41	0.24
Moved between 1st and 3rd grade	1.72	0.97	0.08	1.51	0.96	0.11	1.03	0.94	0.28	1.02	0.94	0.28
Moved between 3rd and 5th grade	2.05	0.78	0.01	1.66	0.77	0.03	1.32	0.76	0.08	1.34	0.76	0.08
Moved more than once	2.44	1.06	0.02	2.15	1.05	0.04	1.12	1.04	0.28	0.98	1.04	0.35
Year 2004 (1999)	4.88	0.28	0.00	4.91	0.28	0.00	4.96	0.30	0.00	4.47	0.33	0.00
Constant	71.42	4.76	0.00	70.65	4.82	0.00	74.33	5.07	0.00	69.28	5.15	0.00
Intraclass correlation, schools	0.038			0.030			0.024			0.025		
Intraclass correlation, neighborhoods (tracts)	0.026			0.021			0.017			0.018		

Notes: SE = standard error. Model estimates derived from cross-classified random-effects multi-level models, based on full analytic sample of ECLS-K fifth grade panel linked to residential food environment information over the same time period. Food availability measured at the U.S. Census tract-level ($N \sim 7710$).

BMI percentiles than their counterparts, but again, the estimate is not significantly different from zero.

Moreover, as revealed in Models 3 and 4, black and Hispanic children still have sizably greater weight-for-height gains compared to their white counterparts—differences that remain robust to adjustments for variation in residential food environments and other characteristics. Maternal education at the highest level also appears to be significantly protective of weight gain over time in adjusted models, as does income at the highest levels (although the estimates for high income do not reach significance at the 5% level).

These conclusions regarding the limited role of food availability on BMI hold up to alternative specifications and sample restrictions. For instance, I examined the relationship between food outlet

Table 5
Sensitivity of results to sub-sample restrictions, ECLS-K and NETS, 1999–2004.

	Non-mover sub-sample			Low-income (at baseline) sub-sample			Black and Hispanic minority sub-sample			Exclude children in rural areas sub-sample		
	Coef	SE	*p*-Value	Coef	SE	*p*-Value	Coef	SE	*p*-Value	Coef	SE	*p*-Value
Change in food outlet density (per sq. mi le)												
Fast-food outlets	−0.41	0.31	0.19	−0.87	0.48	0.14	−0.12	0.32	0.70	−0.49	0.32	0.12
Al l other restaurants	−0.01	0.04	0.88	−0.03	0.11	0.77	−0.01	0.04	0.84	−0.04	0.05	0.46
Convenience stores	0.09	0.12	0.46	−0.32	0.29	0.27	0.02	0.12	0.84	−0.01	0.14	0.93
Corner stores	−0.46	0.25	0.07	−0.64	0.51	0.21	−0.50	0.24	0.04	−0.52	0.26	0.05
Supermarkets/large-scale grocers	0.65	0.41	0.11	0.40	0.48	0.41	0.60	0.50	0.23	0.63	0.41	0.12
Sample size	~5350			~1160			~2140			~6170		

Notes: SE = standard error. Model estimates derived from cross-classified random-effects multi-level models (with the exception of the non-mover sub-sample, for which random-effects multi-level models are run), based on various sub-samples of ECLS-K fifth grade panel. Model accounts for child/family socio-demographic factors, behaviors, school-level characteristics, and other neighborhood controls.

shares and food outlet densities per capita on BMI changes (results not shown), and found no significant associations. The results remained unchanged when I restricted the sample to children who remained in stable home and school environments over the course of elementary school (Table 5). It is plausible that the associations between fast-food outlet or supermarket density might be more salient among vulnerable sub-samples – that is, children who live in poverty or are of racial/ethnic minority backgrounds. Yet the role of residential food availability was weak in explaining BMI gains among poor and minority sub-populations as well, with one exception of corner grocery stores among black and Hispanic children and children in non-rural areas (Table 5). Among these sub-samples, those with greater access to corner stores experience significantly lower BMI shifts ($p < 0.05$).

Returning to Table 4, it thus appears that the more relevant factors for understanding unhealthy weight gain are the socio-demographic characteristics of children and families and proximate behaviors within the home context. These findings are to be expected but they underscore the importance of familial and home environments in explaining obesity risk among young children. For example, poor self-reported parental health is significantly associated with higher risk of weight gain, suggesting a relationship between parental health and child health. Television viewing is a highly significant predictor of BMI gains over time. For every additional hour per day of television viewing, there is a predicted 1.5 percentile gain in BMI ranking by the end of fifth grade. Physical activity level is also important: increases in the number of days per week the child engaged in exercise significantly reduced their BMI gains.

Discussion and conclusion

Similar to other studies, this research finds that children in predominantly minority and poor neighborhoods have higher concentrations (per land area) of fast-food outlets and convenience stores than children who reside in majority white and non-poor neighborhoods. However, when the picture is broadened to include concentrations (per land area) of other food establishments near children's homes, it appears that poor and minority neighborhoods not only have greater access to fast-food restaurants and convenience stores, they also have access to large-scale grocery stores and full-service restaurants. When other measures of local food availability are examined, including concentrations adjusted for population size and food outlet composition, there are no significant differences across neighborhoods in their access to large-scale grocery stores, and somewhat surprisingly, I find larger shares of fast-food chains (out of all food establishments) in majority white and non-poor areas.

These findings suggest that availability of supermarkets is not obviously limited in low-income or residentially minority areas. In fact, for some measurements, poor and minority neighborhoods had greater availability (per land area) of supermarkets. These latter results diverge from much of the earlier literature on relative lack of supermarket access in disadvantaged communities, which is likely due to several reasons, including the use of different datasets (except for Powell, Chaloupka, et al., 2007; Powell, Slater, et al., 2007), the creation of more detailed food industry categorizations, and the examination of several different measurements of retail food access and composition. In addition, this study is national in its lens, which may mask city or area-specific patterns in food access by community markers of disadvantage or segregation.

This is not to say that food deserts are non-existent. The findings documented here do suggest that, on average, the more salient food availability issue facing most economically disadvantaged and minority communities in this national sample is not lack of access but rather ease of access. This shift in the food access framework, though uncommonly discussed, has recently been highlighted in several notable review and research studies (Cummins & Macintyre, 2002; Rose et al., 2009; USDA, 2009). It further indicates that examining food availability by solely looking at a particular industry type (e.g., fast-food availability) can result in a misleading picture of the whole of local food environments.

An important limitation of this study is that the NETS data lack information on aspects of food quality or product diversity of establishments, which may indeed differ across neighborhood settings in meaningful ways. Prior research has found that while food prices and variety do not seem to markedly vary across similar types of food stores, the produce quality may be worse in lower-income neighborhoods (Andreyeva et al., 2008; Horowitz, Colson, Hebert, & Lancaster, 2004). In addition, food availability measures cannot capture the role of food advertising and marketing, especially to children, which has come under increasing scrutiny. A significant line for further research will be to better understand how accessibility, quality, and marketing interact to influence food purchasing and consumption behaviors. Indeed, one of the missing mechanisms in this and many other food availability studies is information on dietary practices and actual consumption. Understanding how these elements work in tandem could help inform the direction of public health policy in improving dietary practices among vulnerable populations.

It is also important to note that proximity could be variably interpreted in terms of accessibility for different residents in the same neighborhood. People who own a car have greater access to food stores than their counterparts who do not (USDA, 2009), and there are differences in car ownership rates by socioeconomic status and race, although car ownership has increased among disadvantaged groups (Berube, Deakin, & Raphael, 2006). Still, unless a large-scale grocery store is easily walkable for households without a car, greater availability may not always imply ease of access to such resources, especially if public transportation is limited. The limited research on automobiles, access, and proximity has revealed a nuanced story. One study, for instance, found that low-income consumers are more likely to drive (using their own car or borrowing one) to a "supercenter" (a low-cost, very large retail goods store), which is often further away from their local supermarket. They also tend to spend a greater share of their food budget at these low-cost outlets compared to other families (Broda, Leibtag, & Weinstein, 2009).

Earlier studies have also documented that low-income households make qualitatively different types of food purchase decisions than do middle and higher-income households, decisions that are intricately and sensibly tied to maximizing calories and consumption on limited budgets. For instance, low-income households choose generic goods, tend to buy non-perishable items in bulk, and will settle for the less expensive product (e.g., will purchase higher fat content beef than lean beef selections or will buy chicken legs over chicken breasts) (Liebtag & Kaufman, 2003). It may thus be the case that macro food pricing and the psychology of food purchase patterns are more pertinent to understanding obesity risk and disparities than availability, and these hypotheses merit further research.

The analysis presented in this paper also reveals that differential exposure to food environments bears little relationship to the key outcome of interest, childhood obesity development. Furthermore, they do not help explain differences in the propensity to become obese among "at-risk" children. Since the longitudinal ECLS-K sample is not nationally representative, whether these results hold under different populations is an open, empirical question. Sample attrition in the ECLS-K is non-random, a primary limitation of this study. Moreover, while the establishment data used to capture food availability is one of the best secondary sources available to researchers, it may also contain inaccuracies because of lags in updates or entry (Boone, Gordon-Larsen, Stewart, & Popkin, 2008; Powell, Chaloupka, et al., 2007). As noted earlier, this study only examined food stores surrounding children's homes, which does not capture other places or areas where parents may access food (e.g., near work or commuting from work-to-home). Collecting and combining information on where and when parents shop would be a useful area of future investigation.

If lack of access to food stores is not the most pressing food problem facing most American families today and if residential exposure to food stores bears no relationship to children's BMI shifts, as suggested by the set of findings presented here, it is worth asking whether targeting limited food availability represents a promising childhood obesity prevention strategy.

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