Published in final edited form as:

J Adolesc Health. 2016 January ; 58(1): 111–118. doi:10.1016/j.jadohealth.2015.09.012.

Changes in the neighborhood food store environment and children's body mass index at peri-puberty in the United States

Hsin-Jen Chen, MS, PhD^{a,b} and Youfa Wang, PhD, MD, MS^{b,c}

^aInstitute of Public Health, National Yang-Ming University, Taipei, Taiwan

^bJohns Hopkins Global Center on Childhood Obesity, Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

^cDepartment of Epidemiology and Environmental Health, University at Buffalo, State University of New York, Buffalo, NY

Abstract

Background—Little is known about the relationship between changes in food store environment and children's obesity risk in the US. This study examines children's weight status associated with the changes in the quantity of food stores in their neighborhoods.

Methods—A nationally representative cohort of schoolchildren in the US was followed from 5th grade in 2004 to 8th grade in 2007 (n=7090). In 2004 and 2007, children's body mass index (BMI) was directly measured in schools. ZIP-Code Business Patterns data from the Census Bureau in 2004 and 2007 characterized the numbers of food stores in every ZIP-code area by type of store: supermarkets, limited-service restaurants, small-size grocery and convenience stores. Baseline and change in the numbers of stores were the major exposures of interest.

Results—Girls living in neighborhoods with 3 supermarkets had a lower BMI three years later (by -0.62 kg/m^2 ; 95% C.I.: $-1.05, -0.18$) than did those living in neighborhoods without any supermarkets. Girls living in neighborhoods with many limited-service restaurants had a greater BMI three years later (by 1.02 kg/m^2 ; 95% C.I.: $0.36, 1.68$) than did those living in neighborhoods with 1 limited-service restaurant. Exposure to a decreased quantity of small-size grocery stores in neighborhoods was associated with girls' lower BMI by eighth grade.

Corresponding authors, Youfa Wang, MD, MS, PhD, Professor, Department of Epidemiology and Environmental Health, School of Public Health and Health Professions, University at Buffalo, State University of New York (SUNY), Buffalo, NY 14214-8001, USA, Tel: 716-829-5383, youfawan@buffalo.edu, Hsin-Jen Chen, PhD MS, Assistant Professor, Institute of Public Health, National Yang-Ming University, No.155, Sec. 2, Linong St., Medical Building II, R213, Beitou District, Taipei City 112, Taiwan (R.O.C.), TEL: +886-2-28267974, FAX: +886-2-28221942, hsinjenchen@ym.edu.tw.

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Contributors' statements:

Hsin-Jen Chen: Dr. Chen conceived the study, carried out the analysis, and drafted initial manuscript.

Youfa Wang: Dr. Wang obtained the data, secured funding, directed the study, and critically reviewed the manuscript.

Both authors contributed substantially to data interpretation and manuscript writing, approved the final manuscript as submitted, and agree to be accountable for all aspects of the work.

Conflict of interest: The authors have no conflict of interest to disclose. The authors have no financial relationships relevant to this article to disclose.

Conclusions—The longitudinal association between neighborhood food environment and children's BMI differed by gender. For girls, supermarkets in neighborhoods seemed protective against obesity, while small-size grocery stores and limited-service restaurants in neighborhoods increased obesity risk. There was no significant longitudinal finding for boys.

Introduction

There is growing attention to the impact of food environments on health outcomes such as obesity [1–4]. In particular, the retail food environment in neighborhoods is being recognized as an important determinant of what people eat. Cross-sectional studies show that neighborhood access to supermarkets is associated with lower body weight and a healthier dietary pattern in youth [5–9]. In neighborhoods with more food outlets that provide wholesome food choices, children may have a better dietary quality and lower body weight. Children living in neighborhoods dominated by convenience stores and fast-food restaurants tend to have higher BMIs and consume less-healthy foods [6, 10–14].

Longitudinal studies on this issue often come from smaller-scale study settings and show some conflicting results. For instance, in one study the presence of convenience stores in neighborhoods was associated with 7-year-old girls' excessive BMI-for-age growth over three years, but produce vendors and farmer's markets were inversely associated with obesity risk [13]. However, a study based in Los Angeles County observed that children's greater weight-for-height was associated with having healthy food outlets in the neighborhood [15]. An unmeasured factor is that the food outlet environment in neighborhoods may change over time, and children's growth status could change with the dynamics of local food environment. To our knowledge, nevertheless, there is no larger-scale epidemiologic study examining this question longitudinally.

From childhood to adolescence, children experience drastic physical growth [16]. In addition, during this period children acquire more agency to explore the world outside of the home, and they have more opportunity to visit food stores in their neighborhoods [17]. The neighborhood environmental influences on children's growth and their BMI status thus could be critical during this life stage.

This study examined the association between the exposure to four types of food stores in home neighborhoods and children's changes in BMI and weight status using nationally representative data collected in the US. It provides evidence for the influence of the food store environment on children's obesity development. We used the nationally representative data from the 5th to 8th grade years of the Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS-K).

Methods

Study design and study sample

The ECLS-K is a cohort study of a nationally representative sample of kindergarteners in 1998–1999. The survey aimed to investigate US schoolchildren's experiences in school, and collected abundant information on home and school environments from kindergarten to the

5th grade (in year 2004) and 8th grade (in year 2007) [18]. In this study, we examined children's BMI and body weight status from the 5th to 8th grades. The study included only those children who had a measured BMI at 5th grade and at 8th grade, and who had information on their home ZIP code in 2004 and 2007 (N = 7090). The secondary data analysis study was approved by the Institutional Review Board of Johns Hopkins School of Public Health.

The children's resident ZIP code linked the individual data with data about the neighborhood environment. Data about food stores in neighborhoods came from the ZIP-Code Business Pattern (ZBP) database for 2004 and 2007. The ZBP system uses a nationwide business registry and releases the aggregate numbers of establishments with the same North American Industry Classification System (NAICS) code in each ZIP code [19]. The 2000 US Census provided neighborhood demographic and socioeconomic characteristics [20]. We used the 5-digit ZIP Code Tabulation Areas (ZCTA5) to define neighborhood units, as the Census Bureau designed the ZCTA5s to coincide with the 5-digit postal ZIP code areas. We linked the individual's data in ECLS-K to the neighborhood environmental characteristics by the ZCTA5 of the children's residence.

Outcome variables

Outcomes of interest included children's BMI (kg/m^2) and obesity status at the 5th and 8th grades. Obesity status was defined as a sex-specific BMI-for-age percentile $\geq 95^{\text{th}}$ on the 2000 CDC growth reference [21]. Children's body weight and height were measured twice during interviews using a digital scale (Seca model 840, Seca North America West, Chino, California) and the Shorr stadiometer (Shorr Productions LLC, Olney, Maryland). The two height measurements were averaged if they differed less than 2 inches; the two weight measurements were averaged if they differed less than 5 pounds. Otherwise, the measurement nearer to the median weight-for-age or height-for-age was retained. The changes in the anthropometric measurements from 2004 to 2007 were the outcome of interest.

Exposure variables

According to the ZBP data for the corresponding years of the study (i.e., 2004 and 2007), the built food environment in a given ZIP code was described by the quantities of supermarkets, small size grocery stores, limited-service restaurants and convenience stores in 2004 [3, 22]. For supermarkets (NAICS = 445110 and ≥ 50 employees) and small size grocery stores (NAICS = 445110 and < 10 employees), the categories were 0, 1, 2, ≥ 3 in the ZIP code area. For convenience stores (NAICS = 445120 or 447110 [convenience stores associated with gasoline stations]), the categories were 0–1, 2–5, 6–10, and ≥ 11 stores in the ZIP code area. For limited service restaurants (NAICS = 722211 [limited-service restaurants], 722212 [cafeterias], 722330 [mobile food services]), the categories were 0–1, 2–10, 11–25, ≥ 26 restaurants in the ZIP code area. "Limited-service restaurant" refers to a restaurant where customers order and pay before they are provided with food; we included cafeterias and mobile food services as limited-service restaurants. Convenience stores and limited service restaurants have a category of 0–1 store, since a very small proportion of children lived in a neighborhood lacking convenience stores or limited service restaurants.

Based on the ZBP data, children were categorized into exposures to different levels of food store environments in 2004. A change in status of the food store environment in the ZIP code areas was described as “increase,” “decrease,” and “no change” in the quantities of stores between 2004 and 2007. Furthermore, neighborhood food store dynamics were classified as (1) the type of store was absent in 2004 and in 2007 (“absent”); (2) the store was absent in 2004 but present in 2007 (“absent → present”); (3) the type of store was present in 2004, and the quantity increased in 2007 (“present, increased”); (4) the type of store was present in 2004, and the quantity decreased in 2007 (“present, decreased”); (5) the type of store was present in 2004, and the quantity remained the same (“present, remained”).

Covariates

Child-level covariates included age, sex, and race (Hispanic, black, white, and others). Information on socioeconomic status was based on parents’ reports. If the child had two parents, the parents’ education level was determined based on the parent who had the higher education level. If the child had one parent, the parent’s education level was determined by the only parent’s education level. The household’s poverty status was defined based on parent-reported income of less than 100% of the federal poverty line. Missing values for household socioeconomic covariates were imputed with an indicator of missingness.

Since the availability of stores that sell healthier food choices is lower in disadvantaged areas [22–25] and residents’ weight status is associated with neighborhood socioeconomics as well [26, 27], the contextual factors in neighborhood are potential confounding factors to be controlled. At neighborhood level, number of all establishments in the ZIP code area, including food and non-food stores, indicated the local economic activity level. Neighborhood social and demographic characteristics were obtained from the US Census in 2000, including poverty rate (continuous), urbanization level (three categories), proportions of Hispanic and non-Hispanic Black populations (< 5%, 5–14%, 15%+), proportion of foreign-born population (< 5%, 5–14%, 15%+), total population size (continuous), and land area size (continuous). Children may have lived in different ZIP code areas between 2004 and 2007, and we used such changes in residence ZIP code to indicate home moving.

Statistical analysis

Differences in BMI and obesity status by neighborhood food store environment were the focus of this study. Mixed-effect models estimated the relationship between neighborhood environment, including baseline and the dynamics of the food stores in neighborhood, and change in children’s BMI. To model the association between food store environment and change in BMI and obesity status, we specified BMI/obesity at the 8th grade as dependent variables and the food store environment as independent variables, while adjusting for the baseline BMI/obesity status. Neighborhood-level random intercept accounted for the similarity of weight status among children living in the same area. Fixed-effect regression coefficients represented the differences in children’s weight status changes by neighborhood food store environment. The models also adjusted for children’s race/ethnicity, baseline age, home-moving during follow-up, household socioeconomic status, and the above-mentioned neighborhood socioeconomic and demographic characteristics. The model specification can be expressed as below, where γ is the term of interest and represents the difference in BMI

changes from time 1 to time 2. BMI_1 and BMI_2 denote weight statuses measured at time 1 and time 2, while Z denotes covariates.

$$BMI_2 = \beta_0 + \gamma(\text{environment}) + \beta_1 BMI_1 + \beta Z + \varepsilon$$

In order to examine the environmental influences on children who lived in the same ZIP code during the follow-up period, the final analysis was confined to children who had not moved ($n = 6330$). Boys' and girls' growth trajectory at the peri-pubertal period are different, as girls reach their height spurt earlier and have greater annual weight gain during young adolescence than boys do [28]. Hence, all the analyses were done for boys and girls separately. Survey sampling weights were re-scaled for mixed-effect model estimation [29]. Sampling weight and complex survey design were incorporated using SAS 9.2 (SAS Institute, Cary, NC).

Results

As the children grew older, the boys' BMI increased from the 5th (11 years old) to 8th grades (14 years old) by 2.3 units (95% CI: 2.1, 2.4), while girls' increased by 2.6 units (95% CI: 2.5, 2.9). However, the prevalence of obesity status declined a bit, from 23.0% to 22.8% for boys and from 18.6% to 16.7% for girls.

The participants came from 1734 ZIP codes; the median area size of the corresponding ZCTAs was 14.2 square miles (the 1st and 3rd quartiles were 6.1 and 46.7 square miles, respectively). Table 1 shows the distribution of exposure to food store environment in neighborhoods by gender. When boys and girls were pooled, 26.1% of the 5th-graders lived in neighborhoods without a supermarket, and 28.9% lived in neighborhoods without a small-size grocery store. Less than 10% of the children lived in neighborhoods with 1 convenience store or limited-service restaurant, and the majority of the children were exposed to areas of more convenience stores or limited-service restaurants. As for the changes in food store distribution in neighborhood between 2004 and 2007, about 59% of the children experienced an increment in number of limited-service restaurants in their neighborhoods, while 38–39% experienced an increment in quantity of convenience stores. About 60% of the children lived in neighborhoods where the quantity of supermarkets remained the same in the three years, whereas 24% and 16% of the children lived in neighborhoods where the quantity of supermarkets decreased and increased, respectively.

Table 2 shows the cross-sectional association between children's BMI at baseline and the food store environment in the neighborhood in 2004. For boys, this cross-sectional analysis indicated a positive association between quantity of convenience stores in neighborhood and their BMI level.

The longitudinal association of neighborhood food store quantities at baseline with children's BMI was revealed after the model adjusted for individual and neighborhood covariates (Table 3). A greater quantity of supermarkets in a neighborhood was associated with girls' lower increment in BMI. In particular, those living in places with 2 or more supermarkets had a lower BMI by 0.6 three years later, as compared with those living in

places without supermarkets. Meanwhile, a greater quantity of limited-service restaurants in a neighborhood was associated with girls' greater BMI three years later. For boys, BMI was not significantly associated with baseline food store in their home neighborhoods. As for obesity status (Table 4), more supermarkets in a neighborhood was associated with girls' lower odds of being obese three years later, whereas more limited-service restaurants in a neighborhood was associated with girls' greater odds of being obese three year later.

Exposure to a decrement in small-sized grocery stores was associated with girls' lower BMI three years later (Table 3). In terms of obesity status, a decreased number of supermarkets in neighborhoods was associated with greater odds of being obese for girls (Table 4).

We also examined the association between the food store environment and children's overweight status change (< 85th BMI-for-age percentile): the odds of developing overweight were significantly associated with the quantity of baseline limited-service restaurants for girls only. No significant association was found between boys' overweight status change and the food environment (data not shown).

Table 5 presents the association between the dynamics of the food store environment in neighborhoods and BMI among children living in the same ZIP code during the follow-up. Boys' BMI three years later did not differ by exposure to different food store environment dynamics. For girls, newly opened supermarkets in neighborhoods where there had been no supermarket at baseline (the "absent→present" group) were associated with greater BMI three years later. However, newly opened small-sized grocery stores in neighborhoods where there had been no small-sized grocery store ("absent→present" group) was associated with lower BMI in girls three years later. Furthermore, girls living in neighborhoods with "present, increased" grocery store dynamics had larger BMI three years later by 0.68 (SE = 0.25, $p = 0.0065$) than girls from the "absent→present" grocery store dynamic neighborhoods.

Discussion

In this study, we defined two dimensions of exposure to food store environments in neighborhoods: (1) The baseline quantity of food stores, which may have an influence on children's weight status three years later; and (2) a changed number of food stores in neighborhoods, which may influence children's future weight status. Based on a nation-wide sample of schoolchildren in the US, the 5th grade girls living in neighborhoods with more limited-service restaurants had larger subsequent BMIs than those who lived in neighborhoods with fewer limited-service restaurants. A greater quantity of supermarkets in neighborhoods at baseline was associated with lower BMI three years later for girls.

Food store availability in neighborhoods shapes children's dietary habits. For example, children living farther away from takeaway restaurants and convenience stores would have healthier dietary habits [8, 9, 12]. Comparing children's longitudinal weight status between different neighborhood food store dynamics may serve as a natural experiment to answer whether the food store environment could affect children's BMI. As the results show, girls living in neighborhoods where there had been supermarkets and later the number of

supermarkets increased had a lower change in BMI (not statistically significant). Contrarily, girls living in a neighborhood where the number of supermarkets increased from zero had a greater BMI increment. The number of supermarkets increased in both cases, but the baseline presence of supermarkets was different. Since children's dietary habits tend to continue from childhood into adolescence [30, 31], the above-mentioned finding implies that the newly opened supermarkets actually fulfill residents' original dietary needs. For example, in neighborhoods without supermarkets, residents may have been using other food stores that sold energy-dense, processed foods. When the supermarket came in, the residents continued their existing dietary habits and used the supermarket to procure energy-dense processed foods. Thus, the influence of the neighborhood food environment on weight status may be not only an external linear effect, but is likely to interact with individuals' existing habits and lifestyles.

On the other hand, girls living in neighborhoods where the number of grocery stores increased in the three years had a greater change in BMI than girls living in neighborhoods where there was no small-sized grocery store and later on new grocery stores were opened. The greatest BMI change in girls living in the "present, increased" grocery store dynamic neighborhood may reflect that the cumulative exposure to small-size grocery stores could play a role in girls' BMI.

The gender differences in the association between the food store environment in neighborhoods and children's BMI changes is noteworthy. As previous studies showed, boys' and girls' BMI may be influenced by different environmental factors [10, 32]. For instance, a cross-sectional survey shows a positive cross-sectional association between BMI and the number of fast food stores in a neighborhood among boys but not girls [10]. Cross-sectionally, boys' fast food consumption is associated with fast-food restaurant density around their homes [33], and this gender difference in the influence of neighborhood food store quantity on children's food consumption may explain the cross-sectional association between boys' BMI and unhealthy food stores in neighborhoods.

Longitudinally, for girls, the exposure to more limited-service restaurants at baseline was associated with a greater BMI in the future, and the exposure to more supermarkets was associated with a lower BMI three years later. These directions of the observed associations for girls are in accord with the findings from other cross-sectional studies [6, 9, 10, 32, 34, 35]. In addition, the associations of the changes in exposure to different quantities of supermarkets and small grocery stores with girls' future weight status may serve as a stronger evidence of the relationship between neighborhood food stores and girls' BMI changes and obesity risk.

Gender difference in sensitivity to the influences of neighborhood food stores on children's BMI may be explained by the gender differences in 1) age of puberty and 2) physical activity. First, the participants' age grew from 11 to 14 during the follow-up period. A larger proportion of girls than of boys would have passed the age of the peak height velocity, because girls' peak height velocity is generally earlier than boys' [28, 36]. After the age of the height growth spurt, excess weight accumulation due to an obesogenic environment would be more sensitively reflect in the change in BMI, because growth in height had

slowed down. Second, adolescent girls have a lower physical activity level than boys do [37]. As physical activity contributes to about a quarter of daily energy expenditure, persons having lower physical activity energy expenditure would be more likely to have excess energy intake. One supportive study done in California found that girls' BMI increment was associated with the neighborhood food environment but not with neighborhood recreational space and walkability [38]. On the contrary, boys' greater physical activity level may even out the excess energy intake in the long run, thus negating the influence of neighborhood food store dynamics on their subsequent BMI. Although further research is necessary to elucidate the gender differences in the built environment's influences, the results from the present study indicate that intervention in food store environments for obesity prevention should focus especially on gender differences.

The main strength of this study is its longitudinal design. This provides better evidence on temporality between neighborhood food stores and children's BMI. Second, the large nationally representative sample of schoolchildren gives a generalizable picture of the country. In addition, this national-level analysis could accurately reflect the heterogeneity of the food store landscape across the country. Third, children's body weight and height used were direct measured, so the accuracy of information regarding weight status/BMI was better than other surveys that rely on reported weight and height.

The present study also has limitations. First, the neighborhood characteristics were based on aggregate data (ZIP code level) but not on individualized measurements (e.g., distance to stores.) Children living in the center and at the border of the ZIP code areas were treated as one group. Therefore, the variation in the exposure to neighborhood environment based on ZIP code-level data was lower than the exposure measured as individuals' distances between home and stores. Second, in this study, the local socioeconomic condition was derived from Census 2000. The Census data provided ZCTA5, which was designed to coincide with ZIP code boundaries in 2000. Since the ZIP code could be re-designated according to the postal service volume in 2004 and 2007, a mismatch could have happened [39]. Nevertheless, ZCTA5 data were useful for providing neighborhood socioeconomic covariates herein. As for children's residence and food store environments, we used the ZIP code of the same year. In this way, children's weight status and their exposure to the neighborhood food store environment should match well. Third, local economic changes could lead to changes in the food store environment and people's health. We adjusted for the total number of business establishments as indicators of local economic conditions in 2004 and 2007. Nevertheless, there could be residual confounding that cannot be captured well by these indicators. Fourth, the children's pubertal stage was not measured in this study. As the growth in height could differ before and after the age at peak velocity, it is difficult for this study to examine whether the gender differences in the present study resulted from the gender difference in the pubertal stage.

Conclusion

This nationally representative study suggests a longitudinal association of neighborhood food environments with children's weight status. Further research is needed to understand how boys' and girls' weight status during the transition from childhood to adolescence was

affected differently by their neighborhood food environmental conditions. This study suggests the potential influence of the food store landscape on childhood obesity in the US. Thus, the neighborhood food environment should be target for childhood obesity prevention. At least, community health officials should assess and consider the local food store environment when planning obesity prevention programs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

The authors thank Drs. Hong Xue and Maria Au's comments in helping improve the study. The study was supported in part by research grant from the U.S. National Institute of Child Health and Human Development (R01HD064685-01A1). Part of Drs. Hsin-Jen Chen and Youfa Wang's effort was supported by a research grant from the U.S. National Institute of Child Health and Human Development (U54HD070725-03). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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Implications and contributions

This study shows a longitudinal association between neighborhood food stores and girls' weight status change in the US. The number of supermarkets was associated with girls' lower BMI three years later. The neighborhood food environment should be thus targeted as an important venue for childhood obesity prevention.

Children's exposure (% being exposed to) to food store environment in the neighborhood of home in the U.S. at baseline (in 2004) and during the 2004–2007 (the changes): The U.S. Early Childhood Longitudinal Study-Kindergarten Cohort (ECLS-K), 2004–2007

Table 1

	Boys (N=3550 ^a)				Girls (N=3540 ^a)			
	n ^a	% ^b	95% CI	n ^a	% ^b	95% CI	n ^a	95% CI
Quantity of food stores in neighborhood, 2004 (%)								
# Supermarkets								
0	960	24.7	(20.2, 29.2)	970	27.6	(22.7, 32.4)		
1	950	26.4	(22.5, 30.4)	940	25.2	(21.3, 29.2)		
2	690	18.6	(15.5, 21.8)	660	18.2	(15.2, 21.2)		
>=3	940	30.2	(25.9, 34.5)	960	29.0	(24.6, 33.4)		
# Small-size grocery stores								
0	1180	28.4	(24.6, 32.2)	1160	29.5	(25.8, 33.2)		
1	850	23.0	(19.7, 26.2)	870	23.9	(20.6, 27.3)		
2	400	14.2	(11.2, 17.3)	410	13.8	(10.5, 17.2)		
>=3	1110	34.4	(30.9, 37.9)	1090	32.7	(29.1, 36.3)		
# Convenience stores								
0–1	400	8.8	(6.8, 10.8)	380	9.6	(7.6, 11.6)		
2–5	930	23.3	(19.7, 26.8)	980	26.3	(22.5, 30.0)		
6–10	980	27.1	(23.3, 31.0)	940	25.6	(21.9, 29.3)		
>=11	1230	40.8	(35.7, 46.0)	1250	38.5	(34.2, 42.9)		
# Limited-service restaurants								
0–1	460	10.6	(8.2, 13.1)	450	11.2	(8.3, 14.1)		
2–10	710	18.3	(15.1, 21.5)	700	20.2	(16.9, 23.5)		
11–25	1120	31.4	(27.3, 35.5)	1060	30.6	(26.2, 34.9)		
>=26	1260	39.6	(34.9, 44.4)	1320	38.0	(34.0, 42.1)		
Changes in quantity of the stores in neighborhoods, 2004–2007 (%)								
Supermarkets								
Decrease	760	26.2	(22.5, 29.9)	750	22.8	(19.0, 26.6)		
No change	2220	58.5	(54.2, 62.8)	2250	61.4	(56.4, 66.3)		
Increase	560	15.3	(12.3, 18.3)	540	15.8	(12.6, 19.0)		
Small-size grocery stores								
Decrease	1070	32.8	(29.1, 36.5)	1060	32.0	(28.8, 35.1)		
No change	1490	38.5	(34.5, 42.6)	1510	40.2	(36.0, 44.4)		
Increase	990	28.7	(24.5, 32.8)	970	27.8	(24.0, 31.6)		
Convenience stores								
Decrease	1300	38.1	(33.0, 43.2)	1360	39.5	(34.9, 44.1)		

	Boys (N=3550 ^a)			Girls (N=3540 ^a)		
	n ^a	% ^b	95% CI	n ^a	% ^b	95% CI
No change	920	24.3	(20.1, 28.5)	870	21.6	(18.4, 24.7)
Increase	1330	37.6	(32.5, 42.7)	1300	38.9	(34.5, 43.3)
Decrease	910	28.2	(24.6, 31.7)	960	25.9	(22.7, 29.0)
No change	560	12.9	(9.7, 16.2)	570	14.9	(11.6, 18.2)
Increase	2080	58.9	(54.9, 62.9)	2010	59.2	(55.7, 62.6)

^a Sample sizes were rounded to the nearest 10 in accordance to the ECLS-K's requirement of reporting restricted-use data.

^b Population estimates of proportion of children exposed to the neighborhood's food store environment.

Cross-sectional association a between neighborhood food store environment and children's baseline body mass index (BMI) in the U.S.: ECLS-K 2004

Table 2

	Boys				Girls						
	Model 1 ^a		Model 2 ^b		Model 1 ^a		Model 2 ^b				
	b	s.e.	b	s.e.	b	s.e.	b	s.e.			
Quantity of food stores in neighborhood, 2004 (%)											
# Supermarkets											
0 (ref)							0.00				
1	-0.31	(0.31)	-0.19	(0.30)	-0.26	(0.29)	-0.09	(0.28)			
2	-0.64	(0.35)	-0.32	(0.35)	-0.23	(0.33)	0.01	(0.33)			
>=3	-0.57	(0.36)	-0.11	(0.36)	-0.26	(0.34)	0.09	(0.34)			
# Small-size grocery stores											
0 (ref)											
1	0.52	(0.26)	*	0.46	(0.26)	0.15	(0.25)	0.21	(0.25)		
2	0.08	(0.34)		0.20	(0.34)	-0.14	(0.33)	0.08	(0.33)		
>=3	0.40	(0.28)		0.07	(0.31)	0.06	(0.27)	0.13	(0.30)		
# Convenience stores											
0-1 (ref)											
2-5	0.84	(0.39)	*	0.76	(0.39)	0.37	(0.35)	0.27	(0.35)		
6-10	1.47	(0.44)	***	1.34	(0.45)	**	0.60	(0.40)	0.40	(0.40)	
>=11	1.78	(0.47)	***	1.56	(0.50)	**	0.93	(0.42)	*	0.65	(0.45)
# Limited-service restaurants											
0-1 (ref)											
2-10	-1.23	(0.41)	**	-0.70	(0.42)	-0.41	(0.36)	0.01	(0.38)		
11-25	-1.59	(0.47)	***	-0.82	(0.50)	-0.94	(0.42)	*	-0.21	(0.46)	
>=26	-1.89	(0.52)	***	-0.93	(0.59)	-1.33	(0.47)	**	-0.27	(0.55)	

^aBased on mixed-effect linear models adjusting for children's race/ethnicity and age.

^bBased on mixed-effect linear models adjusting for children's race/ethnicity, age, moving to another ZIP Code, household socioeconomic status (household poverty status, parents' highest education level), and the neighborhood socioeconomic (neighborhood poverty rate, urbanicity, total business size), neighborhood demographic characteristics (proportion of Hispanic, Black, and foreign-born population, total population size).

Abbreviations: b, regression coefficient estimate; s.e., standard error of the estimate; ref. reference group.

* p < 0.05,

**

p < 0.01,

p < 0.001.

Association between the neighborhood food store environment and children's body mass index (BMI) at 8th grade in the U.S.: ECLS-K 2004-07

Table 3

	Boys						Girls					
	Model 1 ^a		Model 2 ^b		Model 1 ^a		Model 2 ^b					
	b	s.e.	b	s.e.	b	s.e.	b	s.e.				
Quantity of food stores in neighborhood, 2004 (%)												
# Supermarkets												
0 (ref)												
1	0.10	(0.17)	0.13	(0.18)	-0.20	(0.16)	-0.18	(0.17)				
2	0.08	(0.19)	0.15	(0.21)	-0.67	(0.20)	***	-0.64 (0.21)				
>=3	0.05	(0.21)	0.17	(0.23)	-0.66	(0.21)	**	-0.62 (0.22)				
# Small-size grocery stores												
0 (ref)												
1	-0.19	(0.15)	-0.22	(0.16)	0.15	(0.15)		0.10 (0.16)				
2	-0.05	(0.19)	0.16	(0.20)	0.19	(0.20)		0.23 (0.20)				
>=3	-0.08	(0.17)	0.04	(0.20)	0.40	(0.17)		0.53 (0.20)				
# Convenience stores												
0-1 (ref)												
2-5	-0.10	(0.21)	-0.12	(0.23)	0.04	(0.20)		0.04 (0.21)				
6-10	-0.08	(0.24)	-0.11	(0.27)	-0.02	(0.23)		-0.09 (0.25)				
>=11	0.02	(0.26)	-0.13	(0.30)	-0.10	(0.25)		-0.28 (0.28)				
# Limited-service restaurants												
0-1 (ref)												
2-10	-0.16	(0.22)	-0.02	(0.25)	0.07	(0.21)		0.32 (0.23)				
11-25	-0.18	(0.26)	-0.05	(0.30)	0.27	(0.25)	*	0.69 (0.29)				
>=26	-0.28	(0.29)	-0.13	(0.36)	0.42	(0.29)	**	1.02 (0.34)				
Dynamics of quantity of the stores in neighborhoods, 2004-2007 (%)												
Supermarkets												
Decrease	0.04	(0.15)	0.12	(0.15)	0.25	(0.15)		0.25 (0.14)				
No change (ref) Increase	0.09	(0.15)	0.05	(0.15)	0.02	(0.15)		-0.06 (0.16)				
Small-size grocery stores							*					
Decrease	0.18	(0.14)	0.14	(0.14)	-0.32	(0.14)		-0.37 (0.14)				
No change (ref) Increase	0.05	(0.13)	0.04	(0.13)	-0.11	(0.13)		-0.11 (0.13)				
Convenience stores												
Decrease	0.05	(0.14)	0.08	(0.15)	0.20	(0.15)		0.24 (0.14)				
No change (ref) Increase	0.22	(0.14)	0.22	(0.14)	0.04	(0.14)		0.05 (0.14)				
Limited-service restaurants												
Decrease	-0.07	(0.18)	0.08	(0.19)	-0.19	(0.18)		-0.19 (0.18)				
No change (ref) Increase	-0.15	(0.16)	-0.15	(0.17)	-0.09	(0.16)		-0.09 (0.16)				

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^dBased on mixed-effect linear models adjusting for children's race/ethnicity and age.

^gBased on mixed-effect linear models adjusting for children's race/ethnicity, age, moving to another ZIP Code, household socioeconomic status (household poverty status, parents' highest education level), and the neighborhood socioeconomic (neighborhood poverty rate, urbanicity, total business size), neighborhood demographic characteristics (proportion of Hispanic, Black, and foreign-born population, total population size).

Abbreviations: b, regression coefficient estimate; s.e., standard error of the estimate; ref, reference group.

* $p < 0.05$,
** $p < 0.01$,
*** $p < 0.001$.

Table 4

The association between the neighborhood food store environment and children's obesity status at 8th grade in the U.S.: ECLS-K 2004–2007

	Boys				Girls			
	Model 1 ^a		Model 2 ^b		Model 1 ^a		Model 2 ^b	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Quantity of food stores in neighborhood, 2004 (%)								
# Supermarkets								
0 (ref)								
1	0.89	(0.55, 1.43)	0.92	(0.56, 1.53)	0.80	(0.50, 1.31)	0.90	(0.54, 1.49)
2	0.89	(0.51, 1.56)	0.95	(0.52, 1.73)	0.39	(0.21, 0.70)	0.44	(0.23, 0.83)
>=3	1.07	(0.59, 1.96)	1.22	(0.64, 2.33)	0.43	(0.23, 0.83)	0.54	(0.27, 1.06)
# Small-size grocery stores								
0 (ref)								
1	0.81	(0.53, 1.25)	0.76	(0.48, 1.20)	1.25	(0.79, 1.99)	1.44	(0.88, 2.35)
2	1.12	(0.64, 1.95)	1.32	(0.74, 2.37)	1.02	(0.54, 1.94)	1.18	(0.60, 2.30)
>=3	1.09	(0.66, 1.78)	1.21	(0.68, 2.14)	1.39	(0.81, 2.37)	1.64	(0.88, 3.06)
# Convenience stores								
0–1 (ref)								
2–5	1.40	(0.75, 2.60)	1.34	(0.69, 2.61)	0.97	(0.53, 1.77)	0.86	(0.45, 1.61)
6–10	1.93	(0.94, 3.98)	1.78	(0.82, 3.87)	0.80	(0.40, 1.62)	0.68	(0.32, 1.43)
>=11	1.83	(0.85, 3.95)	1.36	(0.57, 3.20)	0.94	(0.45, 1.99)	0.76	(0.33, 1.77)
# Limited-service restaurants								
0–1 (ref)								
2–10	0.72	(0.38, 1.37)	0.72	(0.36, 1.44)	1.44	(0.75, 2.75)	1.98	(0.96, 4.08)
11–25	0.57	(0.27, 1.19)	0.61	(0.26, 1.42)	1.81	(0.85, 3.83)	2.90	(1.21, 6.94)
>=26	0.49	(0.21, 1.11)	0.56	(0.21, 1.51)	2.33	(0.99, 5.48)	4.45	(1.54, 12.83)
Dynamics of quantity of the stores in neighborhoods, 2004–2007 (%)								
Supermarkets								
Decrease	0.97	(0.64, 1.49)	0.96	(0.62, 1.48)	1.60	(1.02, 2.50)	1.68	(1.07, 2.64)
No change (ref) Increase	1.03	(0.67, 1.58)	1.03	(0.66, 1.62)	1.39	(0.87, 2.21)	1.33	(0.81, 2.18)
Small-size grocery stores								
Decrease	1.25	(0.83, 1.89)	1.21	(0.79, 1.85)	0.80	(0.52, 1.24)	0.70	(0.44, 1.09)
No change (ref) Increase	1.22	(0.84, 1.77)	1.24	(0.84, 1.84)	0.73	(0.49, 1.09)	0.64	(0.42, 0.97)
Convenience stores								
Decrease	0.90	(0.60, 1.35)	0.95	(0.62, 1.44)	0.87	(0.56, 1.35)	0.98	(0.62, 1.55)
No change (ref) Increase	1.21	(0.82, 1.79)	1.28	(0.85, 1.91)	1.00	(0.65, 1.53)	1.02	(0.66, 1.59)
Limited-service restaurants								
Decrease	1.23	(0.72, 2.09)	1.42	(0.82, 2.47)	0.77	(0.46, 1.29)	0.75	(0.44, 1.29)
No change (ref) Increase	0.92	(0.57, 1.48)	0.98	(0.60, 1.61)	0.73	(0.46, 1.18)	0.68	(0.41, 1.11)

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^dBased on mixed-effect linear models adjusting for children's race/ethnicity and age.

^gBased on mixed-effect linear models adjusting for children's race/ethnicity, age, moving to another ZIP Code, household socioeconomic status (household poverty status, parents' highest education level), and the neighborhood socioeconomic (neighborhood poverty rate, urbanicity, total business size), neighborhood demographic characteristics (proportion of Hispanic, Black, and foreign-born population, total population size).

Abbreviations: b, regression coefficient estimate; s.e., standard error of the estimate; ref, reference group.

Bolded: 95% CI does not cover 1.

BMI between 5th and 8th grade by dynamics of neighborhood food store environment among children who did not move to other ZIP Code during follow-up (N=6330)

	Dynamics	Boys						Girls							
		n	Mean at 5th grade	Mean at 8th grade	a	b ^a	s.e.	p	n	Mean at 5th grade	Mean at 8th grade	a	b ^a	s.e.	p
Supermarket	Absent	770	20.8	22.9	2.1	-0.29	(0.17)	0.10	780	20.6	23.2	2.7	0.02	(0.18)	0.89
	Absent→present	90	20.1	22.7	2.5	0.33	(0.34)	0.33	90	20.8	23.9	3.0	0.78	(0.35)	0.03
	Present, increased	350	21.1	23.3	2.2	-0.20	(0.19)	0.29	320	20.2	22.5	2.3	-0.18	(0.21)	0.38
	Present, decreased	610	20.5	22.8	2.3	0.01	(0.15)	0.94	600	21.0	23.5	2.5	0.02	(0.16)	0.91
	Present, remained (ref)	1360	20.6	22.9	2.3				1360	20.1	22.8	2.6			
Grocery store	Absent	770	20.3	22.5	2.1	0.15	(0.18)	0.39	800	20.4	23.2	2.7	-0.03	(0.19)	0.88
	Absent→present	300	19.9	22.1	2.1	0.15	(0.22)	0.50	260	19.8	21.9	2.0	-0.51	(0.24)	0.04
	Present, increased	580	20.5	23.0	2.5	0.14	(0.18)	0.44	600	20.9	23.9	3.0	0.17	(0.19)	0.37
	Present, decreased	890	21.1	23.4	2.3	0.17	(0.16)	0.28	870	20.3	22.8	2.5	-0.13	(0.17)	0.44
	Present, remained (ref)	630	20.8	23.0	2.2				630	20.4	22.9	2.5			
Convenience store	Absent	90	20.0	22.7	2.7	0.005	(0.33)	0.99	90	19.7	21.6	1.9	-0.03	(0.36)	0.93
	Absent→present	40	19.6	22.2	2.6	0.07	(0.48)	0.89	30	18.6	21.2	2.7	0.09	(0.53)	0.87
	Present, increased (ref)	1130	20.4	22.8	2.3				1090	20.5	23.2	2.7			
	Present, decreased	1120	20.9	23.2	2.3	-0.17	(0.13)	0.20	1170	20.3	23.0	2.7	0.18	(0.14)	0.19
	Present, remained	800	20.8	22.8	2.1	-0.25	(0.14)	0.08	770	20.6	23.1	2.5	0.002	(0.16)	0.99
Limited-service restaurant	Absent	230	20.8	23.2	2.4	0.13	(0.27)	0.64	200	21.2	23.9	2.7	-0.24	(0.29)	0.42
	Absent→present	30	20.2	22.4	2.2	0.15	(0.50)	0.77	40	20.1	22.3	2.2	-0.16	(0.48)	0.74
	Present, increased (ref)	1860	20.8	23.0	2.2				1780	20.3	22.8	2.5			
	Present, decreased	730	20.1	22.4	2.3	0.15	(0.14)	0.28	770	20.5	23.2	2.7	-0.01	(0.14)	0.94
	Present, remained	320	21.2	23.7	2.4	0.22	(0.19)	0.25	360	20.6	23.6	3.0	0.20	(0.19)	0.31

: Crude change in BMI between 5th and 8th grade

^a Sample sizes were rounded to the nearest 10 in accordance to the ECLS-K's requirement of reporting restricted-use data.

^b Based on mixed-effect linear models adjusting for children's race/ethnicity, age, moving to another ZIP Code, household socioeconomic status (household poverty status, parents' highest education level), and the neighborhood socioeconomic (neighborhood poverty rate, urbanicity, total business size), neighborhood demographic characteristics (proportion of Hispanic, Black, and foreign-born population, total population size).