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Association Between a Policy to Subsidize Supermarkets in Underserved Areas and Childhood Obesity Risk

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IMPORTANCE The establishment and renovation of supermarkets may promote healthy diet practices among youth by increasing retail infrastructure for fresh foods.

OBJECTIVE To estimate the association between the Food Retail Expansion to Support Health (FRESH) program and the weight status of children and adolescents.

DESIGN, SETTING, AND PARTICIPANTS Using a difference-in-differences (DiD) design and including 12 months before and after a FRESH supermarket opened, data were analyzed for residentially stable public school students in kindergarten through 12th grade with objectively measured height and weight data from the academic years 2009 through 2016. Of the 8 FRESH-subsidized supermarkets in residential neighborhoods in New York City, New York, 5 were new and 3 were renovation projects between December 2011 and June 2014. Data were analyzed from June 2021 to January 2022.

INTERVENTIONS The treatment group included students who resided within 0.50 miles of a FRESH-subsidized supermarket and had at least 1 body mass index (BMI) measurement within 12 months before and 3 to 12 months after the month a FRESH supermarket opened (n = 22 712 student-year observations). A 2-stage matching-weighting approach was used to construct a control group of students who resided more than 0.50 miles from a FRESH supermarket in a FRESH-eligible area (n = 86 744 student-year observations).

MAIN OUTCOMES AND MEASURES BMI *z* score was calculated using objectively measured height and weight data from FITNESSGRAM, an annual, school-based, standardized fitness assessment of every New York City public school student. Obesity was defined as 95th percentile or greater of the BMI *z* score using Centers for Disease Control and Prevention growth charts.

RESULTS The treatment group in the analytic sample had 11 356 students (22 712 student-year observations), and the control group had 43 372 students (86 744 student-year observations). The students were predominately Black (18.8%) and Hispanic and Latino (68.5%) and eligible for free or reduced-priced lunch (84.6%). There was a significant decrease in BMI *z* score among students who resided within 0.50 miles of a FRESH supermarket (vs control group students) in the 3- to 12-month follow-up period (DiD, −0.04; 95% CI, −0.06 to −0.02). This was true for those exposed to supermarkets that were either new (DiD, −0.07; 95% CI, −0.11 to −0.03) or renovated (DiD, −0.03; 95% CI, −0.06 to −0.01). A statistically significant decrease was also observed in the likelihood of obesity (DiD, −0.01; 95% CI, −0.02 to −0.002).

CONCLUSIONS AND RELEVANCE Government-subsidized supermarkets may contribute to a small decrease in obesity risk among children residing near those supermarkets, if part of a comprehensive policy approach.

Editorial

Supplemental content

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In 2015-2016, obesity prevalence in the United States was 18.5% among youth aged 2 to 19 years,[1] with a higher prevalence among youth living in neighborhoods with higher (vs lower) socioeconomic disadvantage.[2] The food environment, among several other factors, contributes to obesity risk among children and adolescents.[3] Although supermarkets stock a variety of inexpensive unhealthy foods, previous research suggests that expenditures on[4] and consumption of[5] fruits and vegetables are higher among individuals primarily shopping in supermarkets, potentially due to higher availability and lower price of fresh produce relative to other store types.[6,7] These findings suggest that policies designed to promote the establishment of new supermarkets may be promising, especially in lower-income neighborhoods, where access to supermarkets with affordable produce can be limited.[8,9]

The relationship between new supermarket openings and diet behaviors and weight status is unclear. Previous research has shown, for example, that the introduction of new supermarkets increases residents' proximity to supermarkets and increases the availability of healthy food options in intervention neighborhoods.[10-13] However, 2 reviews report that the majority of new supermarket interventions have no association with diet and food purchasing behaviors,[14,15] and some studies suggest that such interventions do not influence body mass index (BMI).[16,17] Yet other work shows that these efforts result in a decline in the purchase and consumption of less healthy items (eg, sugar-sweetened beverages)[18,19] and may mitigate food insecurity.[18]

The goal of the New York City (NYC), New York, Food Retail Expansion to Support Health (FRESH) program, which is administered by the NYC Economic Development Corporation in collaboration with the NYC Department of Health and Mental Hygiene, is to provide access to affordable, healthy food options to low-income neighborhoods by lowering the costs of owning, leasing, and renovating supermarket retail space via tax and zoning incentives.[20] To date, 22 projects have been approved for FRESH tax incentives (eg, building, land, and sales taxes) in all 5 boroughs, including 18 new or renovated supermarkets that have completed construction. The program requires that participating supermarkets provide at least (1) 5000 sq ft of retail space for grocery products, (2) 50% of retail space for food products, (3) 30% of retail space for perishable goods, and (4) 500 sq ft for fresh produce[21] and must be located in an eligible area. This eligibility is assessed according to several factors, including the square footage of existing supermarkets per resident and neighborhood poverty and unemployment rates. Thus, the program seeks to increase retail space for grocery products, including fresh produce, in low-income neighborhoods via retail infrastructure requirements, in addition to stimulating economic development (eg, generating new jobs).

Elbel et al[22,23] assessed the opening of a new FRESH-subsidized supermarket in the South Bronx in 2011 using dietary recalls and a quasi-experimental design and found no meaningful change in diet behaviors among children or adults living in the neighborhood where the new supermarket was located. However, in a follow-up study, Rogus et al[24] found that self-reported consumption of healthy items increased and servings of unhealthy foods decreased for adults who lived within 0.50 miles (vs >0.50 miles) of the new supermarket. To our knowledge, no assessments of the association between the FRESH program and weight status have been conducted among children and adolescents, and no assessments of multiple new and renovated supermarkets exist, regardless of health outcome. To address these gaps, we sought to examine the association between 8 FRESH-subsidized supermarkets and BMI *z* score and the likelihood of obesity among residentially stable public school students using objectively measured student-level weight data from the NYC Department of Education. We also performed secondary analyses, including assessing differences in new vs renovated FRESH-subsidized supermarkets and by grade level; we also assessed the association among students whose only supermarket was a FRESH-subsidized supermarket and students for whom a supermarket was located nearer to their home as a result of the FRESH program.

Key Points

Question What is the association of a program designed to subsidize supermarkets in underserved areas with public school students' weight status in New York City?

Findings In this cohort study using a difference-in-differences design, decreases in both body mass index *z* score and the likelihood of obesity were significant among students who resided within 0.50 miles of a subsidized supermarket compared with students who resided further away but still in eligible areas.

Meaning Subsidization of supermarkets may contribute to a small decrease in obesity risk among children residing near those supermarkets, if part of a comprehensive policy approach.

Methods

All study procedures were reviewed and exempted by the New York University Grossman School of Medicine institutional review because the research involves the collection of existing data and the data are deidentified. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Setting

The setting of our study was residential neighborhoods in FRESH-eligible areas of NYC. Between December 2011 and June 2014, 8 supermarkets subsidized by the FRESH program completed their projects (**Figure**), including 3 renovation projects in existing supermarkets and 5 new supermarket projects in lots where a supermarket was not previously located (**Table 1**). Three FRESH supermarkets were located in the Bronx, 2 in Queens, 1 in Brooklyn, 1 in Manhattan, and 1 in Staten Island (eTable 1 in the Supplement). All 8 FRESH supermarkets received financial incentives, and 1 FRESH supermarket in the Bronx also received zoning incentives (reducing the amount of required parking and permitting a larger grocery store size).[21]

Participants

Our sample included students in kindergarten through 12th grade (K-12) enrolled in NYC public schools from academic years

Figure. Food Retail Expansion to Support Health (FRESH) Supermarket Locations

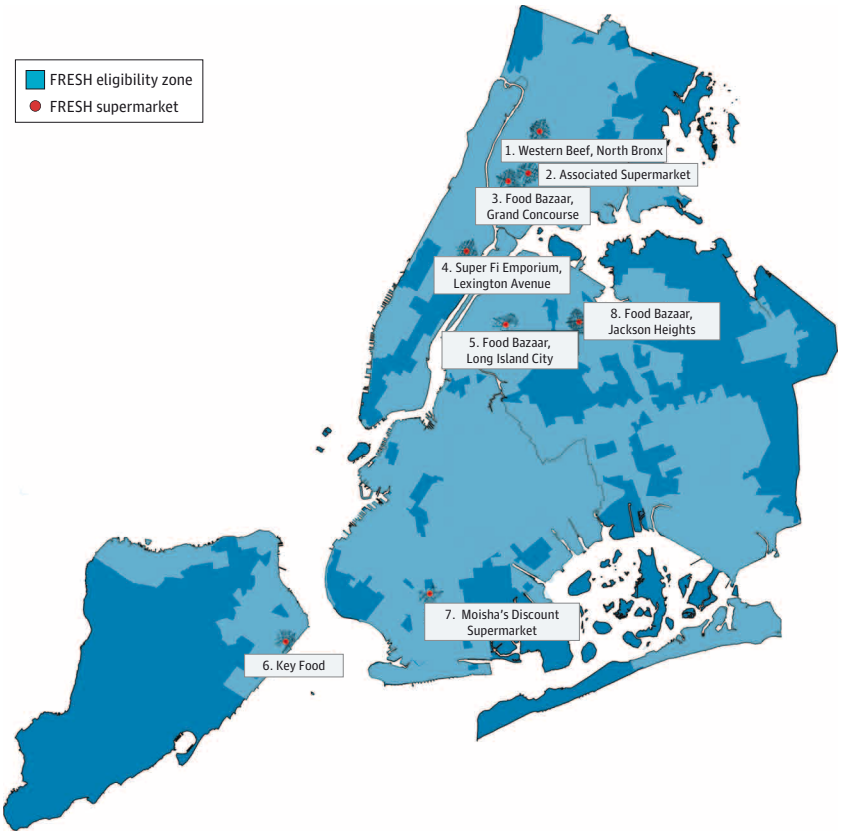

Table 1. FRESH Supermarket Characteristics

Supermarket name	Location	Project type	Incentive type	Opened[a]
Western Beef	2050 Webster Ave, Bronx	New	Financial	July 2011
Associated Supermarket	3470 Third Ave, Bronx	New	Financial and zoning	August 2011
Food Bazaar No. 1	238 E 161st St, Grand Concourse, Bronx	Renovation	Financial	May 2012
Super Fi Emporium	1635 Lexington Ave, Manhattan	New	Financial	June 2013
Food Bazaar No. 2	42-02 Northern Blvd, Long Island City, Queens	New	Financial	December 2013
Key Food Supermarket	300 Sand Ln, Staten Island	New	Financial	January 2014
Moisha's Discount Supermarket	305-325 Avenue M, Brooklyn	Renovation	Financial	March 2014
Food Bazaar No. 3	34-20 Junction Blvd, Jackson Heights, Queens	Renovation	Financial	May 2014

Abbreviation: FRESH, Food Retail Expansion to Support Health.

[a] Month and year of opening determined by communication with the New York City Economic Development Corporation, older Street View imagery using the desktop version of Google Maps, phone calls with retail owners, and/or internet searches (eg, news articles).

2009 through 2016, 83% of whom resided in FRESH-eligible areas (ie, neighborhoods with a low ratio of grocery retail space per capita and high poverty and unemployment rates). We defined our treatment group as students who resided within 0.50 miles of a FRESH-subsidized supermarket, which is an easy walking distance to retail destinations and aligns with previous work[24]; had at least 1 BMI measurement within 12 months before the month a FRESH supermarket opened; and had at least 1 BMI measurement 3 to 12 months after the month a FRESH supermarket opened.

Compared with all NYC youth,[25] students in the treatment group were more likely to identify as non-White and reside in areas with lower median household income, similar to students in the NYC public school system at large.[26] Data came from the NYC Department of Education and included administrative student-level data on race and ethnicity. The categories were Asian, Black, Hispanic and Latino, White, and other, which included responses that did not fit into the other categories. In our analyses, we grouped together values for the Asian and other categories because of small sample sizes in each category.

Two-Stage Matching-Weighting Approach

In this quasi-experimental study, we used a 2-stage matching-weighting hybrid approach to construct a control group to re-

flect counterfactual outcomes. We defined the group of students eligible for the control group in the matching-weighting process as those who resided more than 0.50 miles from a FRESH store in a FRESH-eligible area (n = 420 974 students; n = 2 152 301 student-year observations).[20] In the first stage, we conducted Mahalanobis distance matching with 1:5 matching and replacement using administrative student-level data, including gender, age, grade, race and ethnicity, poverty status (defined as whether the student ever qualified for free/reduced-price lunch, as a proxy for family income below 185% of the federal poverty level), special education status, weight, and height; and neighborhood food environment variables, including count of fast-food restaurants, wait-service restaurants, convenience stores, and supermarkets within 0.50 miles of students' residences and distance to closest food outlet (by type) from students' residences. Restaurant variables were derived from the NYC Department of Health and Mental Hygiene Restaurant Grading data, and food store variables were derived from the New York State Department of Agriculture and Markets Licensing and Inspection data.[27,28] We used python package NetworkX 2.4 to calculate food outlet count variables and the network distance between residential addresses and food outlet addresses, including FRESH supermarket addresses. In the second stage, we constructed control group weights using entropy balancing to improve covariate balance between students in the treatment and control groups.[29] We conducted the matching-weighting process for each FRESH-subsidized supermarket separately. We balanced all covariates to a 0.1 or less absolute standardized mean difference.

Outcomes and Measures

To measure BMI at each year, we used data from FITNESSGRAM, an annual, school-based, standardized fitness assessment of every NYC public school student in grades K-12.[30] Height and weight data were collected throughout the year by a physical education teacher or a school nurse, with good reliability and validity.[31] Mean (SD) duration from FRESH supermarket opening to data collection was 6.3 (2.1) and 6.8 (2.5) months for supermarkets in the treatment and control groups, respectively. From these data, BMI *z* score was calculated and standardized by age (in months) and sex. Based on the Centers for Disease Control and Prevention growth charts, we defined obesity as 95th or greater percentile of the BMI *z* score.

Statistical Analysis

We used a difference-in-differences (DiD) linear probability model using ordinary least-squares regression to estimate the average change in BMI *z* score and students' likelihood of obesity between the 12-month period before the month a FRESH supermarket opened and the 3- to 12-month follow-up period between the treatment and control groups. We excluded the first 3 months of data after a FRESH supermarket opened to allow for sufficient time for changes in food purchases and diet to effect changes in students' weight status.

Independent variables included exposure to a new or renovated FRESH supermarket; preintervention or follow-up period; an interaction term between exposure and period to capture DiD changes over time; and student-level, census tract-level, and food environment characteristics, to reduce bias due to residual imbalance. The model also included an unobserved time-invariant student-level fixed effect to control for possible endogeneity between student characteristics and FRESH supermarket exposure, so that estimates reflect changes within the same student over time, and robust standard errors to account for repeat control group observations.

We conducted several secondary analyses, including (1) estimating separate effect sizes for new and renovation projects, using an interaction term to assess statistical significance; (2) estimating effect sizes by grade level; (3) estimating separate effect sizes for individual stores; (4) estimating the effect size in a 13- to 24-month follow-up period; (5) restricting the treatment group to students who experienced a change in the count of supermarkets within 0.50 miles of their home as a result of a FRESH supermarket opening only (ie, no other supermarkets opened or closed between the preintervention and follow-up periods); and (6) restricting the treatment group to students who resided in proximity to a supermarket as a result of the FRESH program (ie, a FRESH supermarket opening caused those students to live closer to a supermarket). All analyses were conducted using Stata version 16.0 in the time period June 2021 to January 2022.

Results

In academic years 2009 through 2016, a total of 2 042 718 students were enrolled in nonspecial education or noncharter schools. Of these students, 211 712 were ineligible for not having residential address data; 343 792 for not residing in a FRESH-eligible area; and 769 073 for not having a BMI measurement in the preintervention period, the follow-up period, or ever. A total of 285 757 were also ineligible for not being residentially stable (ie, those with a change in their residential address from 2009-2016), to ensure continuity in students' neighborhoods in the periods before and after a FRESH supermarket opened (or could have opened). The total number of students in the treatment group in the analytic sample was 11 356 (22 712 student-year observations). The total number of students in the control group in the analytic sample was 43 372 (86 744 student-year observations) because of replacement.

Our sample of public school students exposed to a FRESH supermarket from 2011 to 2014 was predominately Black (18.8%) and Hispanic and Latino (68.5%) and eligible for free or reduced-priced lunch (84.6%) (**Table 2**). In the preintervention period, the percentage of obesity was slightly higher among students in the treatment group (24.3%) compared with the control group (23.3%, $P = .008$). In the treatment and control groups, BMI *z* score and the percentage of obesity decreased between preintervention and follow-up periods.

We found a significant decrease in BMI *z* score between the preintervention and 3- to 12-month follow-up periods among students who resided within 0.50 miles of a FRESH supermarket compared with students in the control group (DiD, −0.04; 95% CI, −0.06 to −0.02), including those exposed to new supermarkets (DiD, −0.07; 95% CI, −0.11 to −0.03) and renovated super-

Table 2. Individual- and Neighborhood-Level Sociodemographic and Food Environment Characteristics for Treatment and Control Groups[a]

	All stores		All new FRESH supermarkets		All renovation FRESH supermarkets	
	Treatment (n = 11 356)	Control (n = 43 372)	Treatment (n = 5118)	Control (n = 20 559)	Treatment (n = 6238)	Control (n = 22 813)
Individual-level characteristics						
Female, %	50.6	50.6	50.7	50.7	50.5	50.5
Age, y, mean (SD)	10.7 (3.7)	10.7 (3.5)	11.0 (3.7)	11.0 (3.5)	10.5 (3.7)	10.5 (3.5)
Race and ethnicity, %[b]						
Asian and other	7.0	7.0	6.4	6.4	7.4	7.4
Black	18.8	18.8	26.0	26.0	12.9	12.9
Hispanic and Latino	68.5	68.5	61.5	61.5	74.2	74.2
White	5.1	5.1	5.3	5.3	5.0	5.0
Grade in school, %						
K-5	56.1 (0.5)	56.0 (0.5)	53.0 (0.5)	52.8 (0.5)	58.6 (0.5)	58.6 (0.5)
6-8	21.3 (0.4)	23.1 (0.4)[c]	22.1 (0.4)	24.4 (0.4)[c]	20.6 (0.4)	22.1 (0.4)[c]
9-12	22.6 (0.4)	20.9 (0.4)[c]	24.9 (0.4)	22.8 (0.4)[c]	20.8 (0.4)	19.4 (0.4)[c]
Eligibility for free or reduced-priced lunch, %	84.6	84.6	83.1	83.1	85.8	85.8
Students with a disability, %	12.5	12.5	14.8	14.8	10.6	10.6
BMI *z* score, mean (SD)	0.7 (1.2)	0.7 (1.1)	0.7 (1.2)	0.7 (1.1)	0.8 (1.1)	0.8 (1.1)
Obesity, %	24.3	23.3[d]	24.0	22.7[e]	24.6	23.8
Census tract–level characteristics						
Population count, mean (SD)	5462 (1840)	5448 (2255)	5296 (1646)	5176 (2141)[c]	5597 (1975)	5672 (2321)[d]
Household median income, $, mean (SD)	35 651 (13 195)	38 134 (15 974)[c]	31 416 (15 456)	36 026 (18 145)[c]	39 126 (9706)	39 863 (13 702)[c]
Population race and ethnicity, %						
Black	24.5	25.1[d]	31.7	31.2	18.6	20.0[c]
Hispanic	60.4	53.0[c]	53.1	51.2[c]	66.4	54.6[c]
White	35.0	31.4[c]	27.4	24.8[c]	41.2	36.8[c]
Age ≥18 y, %	74.6	75.1[c]	74.2	73.8[c]	74.9	76.2[c]
Male, %	48.2	48.6[c]	47.1	47.1	49.2	49.8[c]
College or more education, %	11.7	13.5[c]	13.5	13.3	10.2	13.6[c]
Living below FPL, %	15.6	15.4[c]	16.8	16.2[c]	14.6	14.7[c]
Count within 0.50 mi of restaurant or store type, No. (%)						
Fast food	58.2 (22.3)	58.2 (26.4)	56.8 (23.1)	56.8 (26.6)	59.3 (21.5)	59.3 (26.2)
Convenience	54.8 (19.3)	54.8 (21.5)	56.3 (22.4)	56.3 (25.0)	53.6 (16.3)	53.6 (18.0)
Wait service	24.7 (20.1)	24.7 (23.4)	16.9 (12.8)	16.9 (17.7)	31.1 (22.6)	31.1 (25.4)
Supermarket	4.8 (2.0)	4.8 (2.2)	4.7 (2.1)	4.7 (2.3)	4.9 (1.9)	4.9 (2.1)
Distance to closest, ft, mean (SD)[f]						
Fast-food restaurant	568 (306)	564 (283)[b]	519 (311)	518 (284)[b]	608 (296)	602 (277)
Wait-service restaurant	837 (463)	830 (439)[b]	867 (444)	859 (439)[b]	813 (476)	806 (436)[b]
Convenience store	448 (289)	445 (265)[b]	415 (297)	411 (263)[b]	476 (280)	474 (263)
Supermarket	1129 (477)	1116 (436)[b]	1142 (492)	1131 (445)[b]	1119 (465)	1105 (428)[b]

Abbreviations: BMI, body mass index; FPL, federal poverty level; FRESH, Food Retail Expansion to Support Health; K, kindergarten.

[a] The sample includes 54 728 students (n = 109 456 student-year observations), including residentially stable students who were enrolled in nonspecial education or noncharter schools and resided in a FRESH-eligible area in academic years 2009-2016, with nonmissing residential address data, ≥1 BMI measurement within 12 months before the month a FRESH supermarket opened, and ≥1 BMI measurement 3-12 months after the month a FRESH supermarket opened.

[b] Administrative student-level data on race and ethnicity came from the NYC Department of Education. In our analyses, we grouped together values for the Asian and other categories because of small sample sizes in each category. Categories differed for US Census race and ethnicity data.

[c] $P < .001$ for differences in means and percentages in the treatment group vs control group.

[d] $P < .01$ for differences in means and percentages in the treatment group vs control group.

[e] $P < .05$ for differences in means and percentages in the treatment group vs control group.

[f] Excludes students who did not have that food outlet type within 0.50 miles of their residence.

markets (DiD, −0.03; 95% CI, −0.06 to −0.01) (**Table 3**). Estimates for new and renovated supermarkets were not significantly different ($P = .83$). We also observed an approximately 1-percentage-point decrease in the likelihood of obesity in the treatment (vs control) group between the preintervention and follow-up periods (DiD, −0.01; 95% CI, −0.02 to −0.002). The

Table 3. Difference-in-Differences Model Results at 3- to 12-Month Follow-up, Overall and by Project Type[a]

	Mean (SD)					
	Treatment group		Control group		Difference-in-differences estimate (95% CI)	
	Baseline	Follow-up	Baseline	Follow-up	Unadjusted	Adjusted
BMI *z* score						
All FRESH supermarkets	0.75 (1.15)	0.70 (1.15)	0.75 (1.10)	0.74 (1.10)	−0.03 (−0.05 to −0.02)[b]	−0.04 (−0.06 to −0.02)[b]
New FRESH supermarkets	0.72 (1.16)	0.68 (1.18)	0.72 (1.11)	0.71 (1.12)	−0.03 (−0.06 to −0.002)[c]	−0.07 (−0.11 to −0.03)[b]
Renovation FRESH supermarkets	0.77 (1.14)	0.72 (1.13)	0.77 (1.09)	0.76 (1.09)	−0.04 (−0.06 to −0.02)[b]	−0.03 (−0.06 to −0.01)[e]
Obesity, %						
All FRESH supermarkets	24.3 (42.9)	23.3 (42.3)	23.3 (42.3)	23.3 (42.3)	−0.01 (−0.02 to −0.001)[c]	−0.01 (−0.02 to −0.002)[c]
New FRESH supermarkets	24.0 (42.7)	23.6 (42.5)	22.7 (41.9)	22.5 (41.8)	−0.001 (−0.01 to 0.01)	−0.02 (−0.03 to −0.003)[c]
Renovation FRESH supermarkets	24.6 (43.1)	23.0 (42.1)	23.8 (42.6)	23.9 (42.6)	−0.02 (−0.03 to −0.004)[d]	−0.01 (−0.02 to 0.001)

Abbreviations: BMI, body mass index; FRESH, Food Retail Expansion to Support Health.

[a] Effect sizes were estimated using a difference-in-differences model with an unobserved time-invariant student-level fixed effect and adjusting for the time-varying individual-level characteristics, census tract–level characteristics, and food environment variables described in Table 2. The sample includes 54 728 students (n = 109 456 student-year observations), including residentially stable students who were enrolled in nonspecial education or noncharter schools and resided in a FRESH-eligible area in academic years 2009-2016, with nonmissing residential address data, at least 1 BMI measurement within 12 months before the month a FRESH supermarket opened, and at least 1 BMI measurement 3-12 months after the month a FRESH supermarket opened.

[b] $P < .001$.

[c] $P < .05$.

[d] $P < .01$.

decreases in BMI *z* score (DiD, −0.04; 95% CI, −0.06 to −0.02) and obesity status (DiD, −0.02; 95% CI, −0.03 to −0.005) were also larger in the treatment (vs control) group between the preintervention period and 13- to 24-month follow-up period (eTable 2 in the Supplement).

We observed a significant decrease in BMI *z* score between the preintervention and follow-up periods among students exposed to the Western Beef supermarket in the Bronx vs the control group (DiD, −0.16; 95% CI, −0.23 to −0.08) (eTable 3 in the Supplement). We also found a significant decrease in BMI *z* score in the follow-up period among students in the treatment (vs control) group in grades K-5 (DiD, −0.05; 95% CI, −0.08 to −0.03) and an approximately 2-percentage point decrease in the likelihood of obesity among students in the treatment (vs control) group in grades 6-8 (DiD, −0.02; 95% CI, −0.04 to −0.01) but no differences in weight outcomes between the preintervention and follow-up periods among students in the treatment and control groups in grades 9-12 (eTable 4 in the Supplement).

About 37% of students in the treatment group were exposed to a non-FRESH supermarket that opened or closed within 0.50 miles of their home in the follow-up period (eTable 5 in the Supplement). Among students who did not experience a change in the count of non-FRESH supermarkets in the follow-up period, we observed a significant decrease in BMI *z* score compared with the control group, including among those exposed to only a new FRESH supermarket (DiD, −0.11; 95% CI, −0.16 to −0.05) (eTable 6 in the Supplement). However, we did not find that the FRESH program had a significant association with BMI *z* score or obesity between the preintervention and 3- to 12-month follow-up periods among students who resided closer to a supermarket as a result of a new FRESH supermarket opening within 0.50 miles of their home (eTable 7 in the Supplement).

Discussion

Results from this quasi-experimental study suggest that the establishment and renovation of government-subsidized supermarkets vis à vis zoning and financial incentives may contribute to a small decrease in childhood obesity risk. Students exposed to FRESH-subsidized supermarkets within 0.50 miles of their home had a larger decrease in BMI *z* score and the likelihood of obesity than their counterparts who resided further away (but still in FRESH-eligible areas). However, our effect size was small: the decrease in BMI *z* score was about a 4% to 10% change from baseline and about a 1-percentage point decrease in the likelihood of obesity. This translates to a BMI *z* score change from 0.72 in the preintervention period to 0.68 in the follow-up period among students exposed to a new FRESH supermarket. Recent evidence from an expert panel suggests that a BMI *z* score reduction of 0.15 to 0.20 units is clinically meaningful and associated with a healthier cardiometabolic profile,[32] which is 3 to 5 times larger than our estimates. Therefore, the subsidy of supermarkets may be most effective in promoting healthy food purchasing behaviors as part of a comprehensive policy approach (eg, nutrition incentives, marketing restrictions, warning labels).[33-37]

Similar work in Pittsburgh and Philadelphia showed that a new supermarket did not change BMI or obesity status in intervention neighborhoods.[16,17] Findings related to the asso-

ciations between a new supermarket and purchase and consumption of healthy and less healthy foods are similarly mixed.[10,12,16,17,38-42] However, our study was unique in that we looked at the combined association of an intervention targeting 8 subsidized supermarkets in 8 different neighborhoods over a 7-year period, which may have provided more power to detect small effect sizes.

Our assessment showed that both new supermarkets and renovation projects were associated with a small decrease in BMI *z* score and obesity risk. The magnitude of effect was larger (yet still small) when we focused on students who were not exposed to openings and closings of non-FRESH supermarkets, but we observed no aggregate association with weight outcomes among students who resided closer to a new supermarket in the follow-up period. Taken together, these results suggest that greater access to supermarkets around students' homes may matter for obesity risk, all things being equal, but not necessarily living closer to a new supermarket. Furthermore, we observed a significant association with obesity status among students in grades K-8 but not grades 9-12, potentially because older children have autonomy to purchase food outside of their residential neighborhoods.

Variation in the magnitude and significance of effect estimates in our store-specific analyses may reflect insufficient statistical power, but it may also speak to true differences in the success of the program across neighborhoods. These differences may arise from differences in the price of food items or other unknown factors. For example, previous work has shown that the price of fresh produce is higher in new supermarket sites compared with existing stores in other areas.[12,19,40] Although the FRESH program aims to improve access to "affordable and healthy food options" via retail infrastructure requirements,[20] it does not directly reduce the cost of healthy items. These changes in infrastructure in turn may result in the presence of healthy, albeit unaffordable, food options,[43] which may undermine the program's success. Therefore, future supermarket interventions might be more successful if paired with financial incentive programs, such as subsidies for produce.

Limitations

Our study had a few limitations, including a lack of dietary and food purchasing data. The latter may have provided insights to retailers who are interested in the direct and indirect relationships between supermarket interventions and store revenue. Similarly, we lacked data regarding the presence and price of fresh food items within intervention stores (the ostensible targets of the FRESH program) so we do not know if such products actually became more available and less expensive to customers relative to preintervention. Another limitation was a lack of qualitative data that speak to the perceptions of parents and students shopping at FRESH-subsidized supermarkets or any data about students' nonresidential food environments. Our study was conducted in NYC, so results may not be generalizable to less urbanized areas. Though our quasi-experimental design allows for a more causal interpretation, we also cannot rule out all sources of residual confounding, such as local changes in food shopping and diet practices.

Conclusions

Using a quasi-experimental study design, we assessed the association of a government-subsidized supermarket intervention with obesity risk among youth residing in 8 underserved neighborhoods. Our results suggest that greater access to supermarkets around students' homes may contribute to a small decrease in BMI *z* score and a lower likelihood of obesity. Although these changes were not large enough to be clinically meaningful, small policy-oriented changes have the potential to reach a large number of students. And given how no single policy will work on its own, supermarket subsidies may be most effective in tandem with other policies, such as nutrition incentives, marketing restrictions, and warning labels.

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