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Associations between Food Environment around Schools and Professionally Measured Weight Status for Middle and High School Students

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Abstract

Background: Obesity rates among school-age children remain high. Access to energy-dense foods at home, in schools, in stores, and restaurants around homes and schools is of concern. Research on the relationship between food environment around schools and students' weight status is inconclusive. This study examines the association between weight status of middle and high school students and proximity to a comprehensive set of food outlets around schools.

Methods: Deidentified nurse-measured heights and weights data were obtained for 12,954 middle and high school students attending 33 public schools in four low-income communities in New Jersey. Geocoded locations of supermarkets, convenience stores, small grocery stores, and limited-service restaurants were obtained from commercial sources. Random-effect regression models with robust standard errors were developed to adjust for unequal variances across schools and clustering of students within schools.

Results: Proximity to small grocery stores that offered some healthy options (*e.g.*, five fruits, five vegetables, and low-fat/skim milk) and supermarkets was associated with healthier student weight status. Having a small grocery store within 0.25 mile of school and an additional such store within that radius was associated with a lower BMI *z*-score ($p < 0.05$). An additional supermarket within 0.25 mile of schools was associated with a lower probability of being overweight/obese ($p < 0.05$).

Conclusions: Improving access to healthy food outlets, such as small stores, that offer healthy food options and supermarkets around middle and high schools is a potential strategy for improving weight outcomes among students.

Introduction

During the past 30 years, childhood obesity rates have been on the rise in the United States.[1] According to the National Health and Nutrition Examination Survey in 2009–2010, 17% of US children and adolescents are obese.[2] Children and adolescents who are overweight or obese experience serious negative health, social, and psychological implications that persist into adulthood.[3–5]

Efforts to curb the epidemic of childhood obesity have highlighted the role schools can play in influencing students' exposure to healthy food during school days. Extensive research and associated interventions have focused on improving the school food environments.[6–19] In addition to the nutritional quality of food served in schools, the food environment around schools can also be influential in impacting the diets of children and adolescents. Schools are often surrounded by food outlets that sell energy-dense, low-cost foods, and students are more likely to purchase

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foods from these outlets if they are located within close proximity to their schools.[6,7,11,20] Borradaile and colleagues showed that students attending schools with high eligibility rates for free and reduced school lunch meals frequently shopped at small corner stores near schools and, on average, purchased approximately 360 calories for $1 during each visit to the store.

Researchers have examined the role of different types of food outlets in diet and weight outcomes among students, mostly focusing on convenience stores, limited-service restaurants, and supermarkets with mixed results.[7,8,19] A recent systematic review on the influence of the retail food environment around schools on obesity-related outcomes found that the evidence was inconsistent, and the studies often used different methodologies and different age groups, making comparisons difficult.[21] Most studies have relied on self-reported measures of heights and weights.[8,11–13,18] These measures have been shown to be biased and less reliable than professional measurements, but are often used because of easy availability of self-reported data. Further, small stores that offer some healthy offerings have not been investigated. These stores may be small ethnic stores, small grocery stores, or traditional convenience stores that carry a selection of healthy options. The role of these stores in changing the local food environment is important given that the initiatives aimed at upgrading convenience stores to carry healthy options are gaining momentum across the country.[22,23]

This study addresses a number of limitations in the literature by using professionally measured student height and weight data, adjusting for student, school, and neighborhood characteristics in the analysis, and examining a more comprehensive spectrum of different types of retail outlets around schools. We hypothesize that students attending schools that are located within 0.25 mile, an easy walking distance for middle and high school students, of convenience stores and limited-service restaurants will have less-healthy weight status, whereas those attending schools within 0.25 mile of supermarkets and small grocery stores with a selection of healthy options will have healthier weight status.

Methods

This cross-sectional analysis used data collected in 2008–2009 as part of the New Jersey Childhood Obesity (NJCOB) study. As part of the study, students' height and weight were obtained from public school districts in four urban, low-income New Jersey cities: Camden, New Brunswick, Newark, and Trenton. The current analysis is limited to students attending middle and high schools. Access to healthy foods in these communities was assessed using commercial data sources.

Variables and Data Sources

The outcome variables for the study were students' weight status as measured by their BMI *z*-scores and a dichotomous variable indicating whether they were overweight or obese. Students were classified as overweight or obese based on the age- and gender-specific percentile of their BMI calculated using nurse-measured height and weight and the CDC 2000 growth charts.[24] Students with BMI at or above the 85th percentile were considered overweight or obese. A student's BMI *z*-score represents the number of standard deviations (SDs) his or her BMI is from the mean for that age and gender based on the CDC growth charts. Nurse-measured height and weight and student demographic data, including age, grade, gender, and race/ethnicity, were obtained in deidentified format from public schools in four urban low-income New Jersey cities (Camden, New Brunswick, Newark, and Trenton) for the 2008–2009 school year as part of the NJCOB study. New Jersey's State Board of Education[25] requires all public schools to measure students' height and weight in grades K through 12. We obtained all available data from Camden, New Brunswick, and Trenton school districts, and given the large size of Newark school district, it was only feasible to get a sample of students from eight randomly selected middle and high schools. Also, student-level race data were only available from Camden, New Brunswick, and Trenton school districts.

The proximity to food outlets within 0.25 mile of school, the primary independent variable in the analysis, was measured in two ways: A dichotomous variable indicated presence or absence of a particular type of outlet within a 0.25-mile roadway network radius of the school, and count measured the number of a given type of food outlet within a 0.25-mile Euclidean radius of each school. A 0.25-mile radius around school was selected for these analyses because it is an easy walking distance to access food outlets located around schools. Geocoded data on locations of food retail outlets were obtained from two commercial sources (InfoUSA and Trade Dimensions) and classified using methodology developed by Ohri-Vachaspati and colleagues.[26] Briefly, food outlets were categorized as supermarkets (annual sales over $2 million, four or more checkouts, and offering many healthy and unhealthy food options), small grocery stores (annual sales between $1 and $2 million, offering five fresh fruits, five fresh vegetables, low-fat or skim milk, and fresh meats or specialty stores, such as fruit and vegetable markets and meat markets), convenience stores (annual sales below $1 million and not offering any healthy items), and limited-service restaurants (requiring that customers pay for their food before eating). In the original classification of food stores for the NJCOB study, small grocery stores also included meat markets. For the analysis presented in this article, meat markets were excluded because middle and high school students were not considered likely to shop in these stores for food and snack items. The distance between each school and a specific food outlet was estimated using the distance tools in ArcGIS.

The proportion of students receiving free or reduced meals and the proportion of students in a school from different race/ethnic groups were used to control for school-level

demographics. The US Department of Education collects annual student enrollment data from schools. The data were available from the National Center for Education Statistics' website[27] and included information on school name, ID, address, district, school type, grade level, and enrollment by demographic characteristics. This study used school-level data for the 2008–2009 school year.

Census tract data on total population, race, median household income, education attainment, and imputed census block group-level crime data were used to control for neighborhood characteristics. The US Census Bureau records information from every census tract in the counties of Camden (Camden city), Essex (Newark), Middlesex (New Brunswick), and Mercer (Trenton), and these data include census tract-level population, racial composition, median household income, educational attainment, and poverty status. Crime index (CrimeRisk) data were purchased from Applied Geographic Solutions (AGS). AGS developed census block group-level CrimeRisk index for personal and property crimes based on the FBI's Uniform Crime Report data from 1998 to 2006 and over 65 census socioeconomic characteristics. The AGS data were used to control for neighborhood crime.

Statistical Analysis

Descriptive statistics were examined for all independent, dependent, and control variables in the analyses. First, unadjusted bivariate association between various types of food outlets and students' weight measures were explored. Next, multivariate regression analyses were conducted to predict students' weight status using proximity to different types of outlets as explanatory variables and controlling for student-, school-, and neighborhood-level variables described above. Separate models were run for the presence and counts of outlets for each of the two outcome variables (BMI *z*-score and dichotomous overweight/obesity). Given that the students were clustered within schools, regression analyses were conducted using random-effects models using linear regressions with robust standard errors. Analyses were conducted in 2013 with Stata SE13 (StataCorp LP, College Station, TX), and significance was set at $p < 0.05$.

Table 1. Description of Student-Level Demographic Characteristics and Student Weight Measures

	% or mean (SD); all students $n = 12{,}954$
Demographic characteristics	
Age	
Mean age (years)	13.47 (3.46)
Gender	
Female	51.6
Race/ethnicity[a]	
Non-Hispanic black	52.2
Hispanic	44.5
Non-Hispanic white	1.9
Non-Hispanic other	1.4
City	
Camden	28.6
Newark	32.1
New Brunswick	9.7
Trenton	29.6
School-level characteristics	
Free or reduced meals participation	
Mean participation in schools	0.69 (0.11)
School size	
Mean school size	991.06 (620.56)
Student-level weight measures	
BMI z-score	0.81 (1.05)
Overweight or obese	43.6

[a]Race/ethnicity was not available for the Newark sample.
SD, standard deviation.

Results

The sample included 12,954 students from 33 middle and high schools; the average age of students was 13.5 years (Table 1). The majority of the students went to school in Camden, Newark, and Trenton—the three large school districts—with the smallest district, New Brunswick, contributing approximately 10% of the sample. A vast majority of the students (excluding Newark, for which race/ethnicity data were not available) were non-Hispanic blacks (52.2%) and 44.5% were Hispanics. The average BMI *z*-score was 0.81, and 43.5% of the students were overweight or obese.

A majority (78.8%) of schools had at least one convenience store located within 0.25 mile of their school, with each school, on average, having 2.58 convenience stores within this radius (Table 2). Approximately 73% of the schools had at least one limited-service restaurant located within a 0.25-mile radius, and there were, on average, 3.36 limited-service restaurants within 0.25 mile of each school. Fewer schools had small grocery stores (30.3%) and supermarkets (15.1%) within a 0.25-mile radius.

Table 3 displays the results of random-effects models examining the relationship between students' weight outcome (BMI *z*-score and overweight/obese status) and food environment around schools (presence or absence of food outlets and number of food outlets of within 0.25 mile). After adjusting for student-, school-, and community-level variables, results from the multivariate analysis show that schools' proximity to small grocery stores that offer a selection of healthy options was associated with healthier weight outcomes among students. Having a small grocery store within

Table 2. Description of Food Outlets around Schools and Unadjusted Associations between Proximity to Food Outlets and Students' Weight Status

	% or mean (SD); all schools $n=33$	Unadjusted association between proximity to food outlet and students' BMI z-score; all students[a] n=12,954		Unadjusted association between proximity to food outlet and students' overweight/obesity status; all students[a] $n=12,954$	
		Coefficient (95% CI)	p value	Coefficient (95% CI)	p value
Presence of food outlets within 0.25 mile of schools					
Convenience stores	78.79	−0.07 (−0.17, 0.02)	0.13	−0.01 (−0.05, 0.04)	0.73
Limited-service restaurants	72.73	0.03 (−0.07, 0.13)	0.56	0.02 (−0.02, 0.06)	0.27
Small grocery stores	30.30	−0.12 (−0.20, −0.04)**	0.002	−0.04 (−0.08, −0.01)*	0.02
Supermarkets	15.15	0.05 (−0.08, 0.18)	0.48	0.06 (0.01, 0.11)*	0.03
Count of food outlets within 0.25 mile of schools					
Convenience stores	2.58 (2.24)	−0.002 (−0.02, 0.01)	0.77	−0.001 (−0.01, 0.01)	0.91
Limited-service restaurants	3.36 (3.36)	−0.003 (−0.02, 0.01)	0.62	−0.001 (−0.01, 0.01)	0.8
Small grocery stores	0.24 (0.51)	−0.07 (−0.14, −0.004)*	0.04	−0.02 (−0.05, 0.02)	0.4
Supermarkets	0.18 (0.46)	0.04 (−0.06, 0.13)	0.45	0.04 (0.002, 0.08)*	0.04

[a]Unadjusted coefficients and confidence interval (CI) from random-effects regression model: *$p<0.05$; **$p<0.01$.

SD, standard deviation.

0.25 mile of schools was associated with significantly lower (0.12 SD) student BMI z-scores ($p=0.03$), and an additional small grocery store located within 0.25 mile of schools was associated with significantly lower (0.1 SD) student BMI z-scores ($p=0.01$). The associations between presence and counts of small grocery stores and students' overweight/obese status, though not statistically significant, were in the hypothesized (negative) direction. Further, having an additional supermarket within 0.25 mile of schools was associated with a significantly lower probability of a student being overweight or obese ($p=0.01$) and marginally associated with students' BMI z-scores. Presence of a supermarket within 0.25 mile of school was also marginally inversely associated with student's BMI z-score ($p=0.09$) and their overweight/obese status ($p=0.08$). Marginally significant direct associations were observed between presence of a limited service restaurant and students' overweight/obese status ($p=0.08$) and between having an additional limited-service restaurant within 0.25 mile of school and students' BMI z-scores ($p=0.09$). No significant associations were observed between presence of a limited-service restaurant and students' BMI z-scores or having an additional limited-service restaurant and students' overweight/obesity status. Similarly, none of the associations for proximity to convenience stores and student weight status were statistically significant.

Discussion

We found that students attending schools that were located within 0.25 mile of small grocery stores that offered some healthy options, such as fruits, vegetables, and low-fat dairy, were likely to have lower BMI z-scores. These stores are likely to present healthier options to students for purchase before and after the school day. The small, but significant, difference in BMI z-scores provides evidence supporting the efforts across the country to change the food environment around schools by improving offerings at small stores.[6,7] Although the magnitude of the association observed between small grocery stores and students' weight status is small, community food environment is one of many factors affecting childhood obesity, and small, but significant, changes in each of these factors can potentially help mitigate childhood obesity.[28] Previous studies do not make a distinction between convenience stores and small grocery stores, which are neighborhood stores with a small selection of healthy food options.[8–10,17,29,30] As a result, these studies offer little insight into the potential of upgrading these neighborhood stores to improve their healthy food offerings. Unlike previous research,[8–10,17,29,30] we did not find a significant association between proximity to convenience stores and students' weight status. One possible reason for nonsignificance of these findings may be the lack of variation in our sample, where almost 80% of the schools had at least one convenience store within a 0.25-mile radius (Table 2). Further, our ability to establish causality is contrained by the cross-sectional design of the study; longitudinal research is needed to assess whether changing the offerings at convenience stores improves weight outcomes among middle and high school students. Findings from the present study highlight the importance

Table 3. Results from Random-Effects Model Examining the Relationship between Proximity to Food Outlets and Students' Weight Status[a]

	All students $n=12,954$	
	Coefficient (95% CI)	p value
Presence of food outlets within 0.25 mile of schools		
BMI z-score		
Convenience stores	−0.01 (−0.14, 0.12)	0.88
Limited-service restaurants	0.07 (−0.01, 0.15)	0.75
Small grocery stores	−0.12 (−0.24, −0.01)*	0.03
Supermarkets	−0.09 (−0.19, 0.12)	0.09
Overweight or obese		
Convenience stores	0.03 (−0.02, 0.07)	0.31
Limited-service restaurants	0.03 (−0.004, 0.06)	0.08
Small grocery stores	−0.02 (−0.06, 0.02)	0.32
Supermarkets	−0.03 (−0.07, 0.004)	0.08
Count of food outlets within 0.25 mile of schools		
BMI z-score		
Convenience stores	0.01 (−0.002, 0.03)	0.10
Limited-service restaurants	0.01 (−0.002, 0.02)	0.09
Small grocery stores	−0.10 (−0.17, −0.03)**	0.01
Supermarkets	−0.08 (−0.17, 0.01)	0.08
Overweight or obese		
Convenience stores	0.002 (−0.004, 0.01)	0.61
Limited-service restaurants	0.0001 (−0.004, 0.005)	0.96
Small grocery stores	−0.004 (−0.03, 0.02)	0.78
Supermarkets	−0.05 (−0.08, −0.01)**	0.01

[a]All models adjust for students' gender, students' age, proportions of students receiving free or reduced meals at each school, proportions of blacks, Asians, Native Americans, and Hispanics at each school, city, census block group-level crime index, census tract-level population, census tract-level total households, census tract-level race, census tract-level median household income, and census tract-level education attainment.

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

CI, confidence interval.

of refining food-store classification to make a distinction between small stores that offer few healthy options (convenience stores) versus stores of similar size that offer a selection of healthy options.

We also found significant negative associations between proximity to supermarkets within a 0.25-mile radius of school and prevalence of overweight/obesity among students. Previous research investigating this association has also found negative associations, but they have not been statistically significant.[9]

Previous studies have found a positive association between a school's proximity to limited-service restaurants and students' weight outcome measures.[10] In this study, we found marginal association between proximity to limited-service restaurants and students'overweight or obese status. Our results did not support previous findings related to convenience stores.[10,31] None of the models in this analysis showed an association between convenience store exposure and students' weight outcomes. It is important to note that a vast majority of the schools had a convenience store within a 0.25-mile radius, providing limited variability in the sample. Unlike previous studies, this study adjusted for important neighborhood factors, such as neighborhood race/ethnicity, income, and crime, factors that have been associated with children's weight outcomes.

This study has several strengths. First, it uses data from a large number of students from low-income, diverse, urban communities that carry a disproportionate burden of obesity[32] and are exposed to unhealthy community food environments.[32] The focus on four cities with fairly similar socioeconomic and geographic characteristics minimizes the degree of heterogeneity that must be accommodated by the regression model, enhancing the model's internal validity.

Second, the study layered data representing students, schools, and neighborhoods, as well as objectively measured roadway network data, to capture proximities to food outlets that were carefully categorized using a refined methodology. Also, unlike most previous work, we incorporated neighborhood factors[8–10,18,19,29–31,33] in our model.

Third, the study used professionally measured student height and weight data, rather than self-reported survey data. Although there are missing observations because of the absence of students at the time of measurement, nurse-measured data are more likely to be accurate and may minimize biases that may arise from self-reports.[8,18,30,33]

One of the limitations of this study is that we were not able to control for food policies and environments in schools, food environment around students' homes, and availability of food in students' homes. Another limitation was that although a systematic approach was used for classifying food outlets into different types of stores based on their offerings,[26] the study team did not collect data on availability of items that are particularly likely to be purchased by school-age children. Also, accurate information on schools' open-school and busing policies are valuable to future studies of food environments neighboring schools. It is important to note that 54% of the sample in the NJCOB study walked or biked to school.

Further, because student-level data from Newark did not include race, we were not able to include students' race in the analysis. However, all the communities examined were predominantly Hispanic or non-Hispanic black and we did adjust for neighborhood- and school-level race/ethinicity in the models. In addition, random-effects models were analyzed with and without student-level race variables for the cities for which race was available, and it was found

that models without student-level race variables were similar to those with student-level race variables.

This is the first study to examine the role of small grocery stores that offer a limited selection of healthy options, in addition to conventional store categories (supermarkets, convenience stores, and limited-service restaurants) on middle and high school students' weight status. Our findings provide support for interventions that are aiming to improve the food environment around schools by encouraging convenience stores to stock healthier options. Future studies should examine the impact of these upgraded convenience stores using longitudinal research designs.

Conclusions

The findings of this study suggest that there is a small, but significant, association between proximity to healthy outlets, including small grocery stores, that offer healthy options and supermarkets near schools and students' healthier weight status. These results add to the existing literature on childhood obesity prevention research and suggest that presence of these stores may play a role in promoting healthy weight status among students.

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Author Disclosure Statement

No competing financial interests exist.

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