Associations Between Access to Food Stores and Adolescent Body Mass Index

Lisa M. Powell, PhD, M. Christopher Auld, PhD, Frank J. Chaloupka, PhD, Patrick M. O'Malley, PhD, Lloyd D. Johnston, PhD

Background: Environmental factors such as the availability of local-area food stores may be important contributors to the increasing rate of obesity among U.S. adolescents.

Methods: Repeated cross-sections of individual-level data on adolescents drawn from the Monitoring the Future surveys linked by geocode identifiers to data on food store availability were used to examine associations between adolescent weight and the availability of four types of grocery food stores that include chain supermarkets, nonchain supermarkets, convenience stores, and other grocery stores, holding constant a variety of other individual- and neighborhood-level influences.

Results: Increased availability of chain supermarkets was statistically significantly associated with lower adolescent Body Mass Index (BMI) and overweight and that greater availability of convenience stores was statistically significantly associated with higher BMI and overweight. The association between supermarket availability and weight was larger for African-American students compared to white or Hispanic students and larger for students in households in which the mother worked full time.

Conclusions: Economic and urban planning land use policies which increase the availability of chain supermarkets may have beneficial effects on youths' weight outcomes.
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Introduction

Numerous studies have documented increasingly poor dietary behaviors among adolescents, including an excess intake of fat, sugar, snacks, soda, and fast food[1–3] and a low intake of fruit and vegetables.[4–7] Unhealthy food consumption patterns put youths at higher risk for overweight.[8–13] With an obesity epidemic among American society as a whole and a tripling of the prevalence of overweight among American adolescents aged 12–19 over the last few decades to a current level of 17.4%,[14] researchers are examining a broad range of environmental factors as potential contributors to these critical outcomes. Barriers to accessing healthful foods due to a lack of local-area supermarkets are one such factor that may affect weight outcomes.

Several studies have suggested indirectly that increased supermarket availability may affect weight by showing that availability is associated with increased fruit and vegetable consumption among adults[15] and with higher quality diets.[16] There is also evidence that the effect of access to food stores varies with the types of store. For example, larger food stores and chain supermarkets were more likely to stock healthful foods than smaller stores and nonchain supermarkets.[17–19] Larger stores and chain stores also offered foods at lower prices.[20,21] Cheadle et al.[22] found significant correlations between diet and the availability of healthful food in stores. While several studies have found significant associations among weight status, food prices,[23–25] and restaurant availability,[25] no existing studies have directly examined associations between food store availability and weight outcomes. Evidence is provided in this paper to relate availability of food stores of various types to weight outcomes controlling for food prices and restaurant outlet density.

Whether a lack of local-area food stores such as chain supermarkets are likely to be associated with adolescents' body mass index (BMI) and overweight status was examined. Specifically, the associations between BMI and overweight and the availability of four types of grocery food stores, including chain supermarkets, nonchain supermarkets, convenience stores, and other grocery stores, holding constant a variety of other individual- and neighborhood-level influences were ex-

From the Department of Economics (Powell, Chaloupka) and Institute for Health Research and Policy (Powell, Chaloupka), University of Illinois at Chicago, Chicago, Illinois; Department of Economics (Auld), University of Calgary, Calgary, Alberta, Canada; Survey Research Center (O'Malley, Johnston), Institute for Social Research, The University of Michigan, Ann Arbor, Michigan

Address correspondence and reprint requests to: Lisa M. Powell, PhD, Institute for Health, Research and Policy, University of Illinois at Chicago, 1747 West Roosevelt Road, M/C 275 Room 558, Chicago IL 60305. E-mail: powelll@uic.edu.

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amined. Repeated cross-sections of individual-level data on adolescents drawn from the Monitoring the Future (MTF) surveys linked at the ZIP-code level to data on food store availability were used. It was found that increased availability of chain supermarkets was statistically significantly associated with lower adolescent BMI and overweight and that greater availability of convenience stores was associated with statistically significantly higher BMI and overweight.

Methods

This study drew on individual-level national data for 8th- and 10th-grade students from the MTF study, combined with external data on four types of food store outlets and two types of restaurant outlets obtained from business lists developed by Dun and Bradstreet (D&B) and fast food and fruit and vegetable price data obtained from the American Chamber of Commerce Researchers Association (ACCRA). The external outlet density and food price measures were matched to the individual-level data at the school ZIP-code level for each year 1997 through 2003. Data on per capita income were drawn from the Census 2000.

Monitoring the Future Survey Data

Since 1975, the MTF study conducted at the University of Michigan's Institute for Social Research annually surveyed nationally representative samples of high school seniors in the coterminous United States. Since 1991, the MTF surveys also included over 30,000 8th- and 10th-grade students annually. These 8th- and 10th-grade students were located in approximately 280 schools that were selected annually for the MTF survey based on a three-stage sampling procedure (see Johnston et al.[26] for details on the sampling procedure). In order to cover the range of topic areas in the study, 8th- and 10th-grade students were administered four different questionnaire forms. This occurred in an ordered sequence, ensuring virtually identical subsamples for each form. Approximately one-third of the questions on each form were common to all forms, including the demographic variables used in this study. Questions on height and weight were form-specific. For the 7 years of data from 1997 through 2003 for 8th and 10th- students, the sample had a total of 73,079 observations for which information was available on height and weight and nonmissing information on the covariates. Sensitivity analyses were undertaken to assess the robustness of the results to the high number (13.1%) of missing observations on parent education. Analyses were rerun including dummy indicators for missing on these variables and found that the results for all of the key contextual variables were robust to their exclusion.

Outcome Measures

BMI was calculated based on the self-reported anthropometric information (height and weight) available in the MTF survey. BMI was calculated as equal to weight (kilogram)/height (meter)-squared. Adolescents were classified as overweight when BMI≥age-gender-specific 95th percentile based on the Centers for Disease Control and Prevention (CDC) growth chart.[27] Note that for children the CDC recommends using the term "overweight" rather than "obese". Table 1 shows that the average BMI for the full sample of students was 21.8 and that 10% of the students were overweight.

Table 1. Summary statistics: Outcomes, store access, and control variables

	Mean or percentage	SD for continuous variables
N	73,079	—
Body mass index	21.8059	4.2947
Overweight	10.28%	—
Number of grocery stores[a]	3.2835	3.0097
Number of convenience stores[a]	2.1535	2.2501
Number of chain supermarkets[a]	0.3037	0.5805
Number of non-chain supermarkets[a]	0.2609	0.5906
Number of fast food restaurants[a]	2.6009	2.2078
Number of non-fast food restaurants[a]	11.4236	9.2185
Price of fast food	2.7127	0.1740
Price of fruit and vegetables	0.7205	0.1046
Per capita income (in 10,000s)	2.2107	0.9665
Male	47.54%	—
Age	14.6542	1.1640
8th grade[b]	48.69%	—
10th grade	51.31%	—
White[b]	69.66%	—
Black	10.59%	—
Hispanic	9.67%	—
Other race	10.08%	—
Father less than high school	13.06%	—
Father complete high school[b]	29.43%	—
Father college or more	57.51%	—
Mother less than high school	11.11%	—
Mother complete high school[b]	28.00%	—
Mother college or more	60.89%	—
Live with both parents	80.02%	—
Live in rural area	24.10%	—
Students' weekly real income (in 100s)	0.2281	0.2666
Hours worked by student	3.8560	7.1366
Mother does not work[b]	17.60%	—
Mother works part-time	18.28%	—
Mother works full-time	64.12%	—
Year 1997[b]	14.73%	—
Year 1998	14.78%	—
Year 1999	13.98%	—
Year 2000	13.85%	—
Year 2001	13.93%	—
Year 2002	13.73%	—
Year 2003	15.00%	—

[a]Per 10,000 capita.
[b]Denotes omitted categories in regression models.
SD, standard deviation.

Individual-Level Control Measures

Controlled demographic measures available in the student surveys included: gender; grade; age; race/ethnicity; highest schooling completed by father; highest level of schooling completed by mother; rural/urban area neighborhood designation; total student income (earned and unearned, such as allowance) in real dollars (CPI base $82–$84); weekly hours of work by the student; and whether the mother works part-time or full-time. The summary statistics in Table 1 show that just under half of the sample was male and that approximately 70% of the students were white, 11% were African-American, 10% were Hispanic, and 10% were of other (or mixed) racial/ethnic backgrounds. The average age of the sample was 14.7 and just under half of the sample was in 8th grade. The majority of students' parents had at least some college education (58% of fathers and 61% of mothers). Most (80%) students lived with both of their parents and just under one quarter lived in a rural area. Students worked on average 3.9 hours per week. Students' average weekly real income was about $23. Approximately 64% of students' mothers worked full-time and 18% worked part-time. The sample was evenly distributed across years with about 14% in each of the 7 years from 1997–2003.

Local-Area Socioeconomic Status

Local-area per capita income was controlled for at the ZIP-code level; shown in Table 1 to be, on average, $22,107. These data were obtained from the Census 2000.[28]

Local-Area Food Prices

Food price data were obtained from the ACCRA Cost of Living Index reports. These reports contained quarterly information on prices from more than 300 U.S. cities. The ACCRA collects 62 different prices for a range of products. These price data were matched to the MTF sample based on the closest city match available in the ACCRA data using school ZIP-code geocode data. Price data were drawn from quarters one and two as these reflected the time frame of the MTF surveys. From the items provided in the ACCRA data, two prices indices were created: a fruit and vegetable price index and fast food price index. All prices were deflated by the Bureau of Labor Statistics (BLS) Consumer Price Index (CPI) (1982–1984=1). The fruit and vegetable price index was based on the food prices available for this food category: potatoes, bananas, lettuce, sweet peas, tomatoes, peaches, and frozen corn. The fast-food price was based on the following three items included in the ACCRA data: a McDonald's Quarter Pounder with cheese, a thin crust regular cheese pizza at Pizza Hut and/or Pizza Inn, and fried chicken (thigh and drumstick) at Kentucky Fried Chicken and/or Church's Fried Chicken. Each price index was weighted based on expenditure shares provided by ACCRA derived from the BLS Consumer Expenditure Survey.

Outlet Density Measures

Data on food store and restaurant outlets were obtained from a business list developed by D&B.[1] This list was obtained through use of D&B MarketPlace software. MarketPlace contains information on more than 14 million businesses in the U.S. and D&B employs a staff of more than 1,300 individuals to compile and update quarterly these records through interviews, public documents, and directories. In addition to these sources, D&B has telecenters that conduct approximately 100 million phone calls annually to update and verify business list information.

D&B has a number of quality assurance protocols in place to ensure accuracy of the data. For instance, D&B utilized "match grade" technology to consolidate multiple business listings into one complete record to ensure that there are no duplicate entries of the same business and that data are not matched to the wrong business. D&B also assigns each business a unique numerical identifier to ensure validity of its data over time. This nine-digit number is never recycled and allows D&B to easily track changes and updates for all businesses contained in its database.

MarketPlace allows sorting by multiple criteria such as location (ZIP code, county, state) and Standard Industry Classification (SIC) codes. SIC codes allow for searching for, and selection of, specific types of businesses. The database allows for SIC code searches at varying levels of detail/specificity. Facilities may appear on the Marketplace list by both "primary" and "secondary" SIC codes. Primary SIC code listings were used to create the list of outlets used for this analysis.

Information on food store outlets available in the D&B data set was pulled by ZIP code for the years 1997 through 2003. The outlet density data were linked to the individual-level data by the students' school ZIP code. Information on the total number of grocery food stores was available at the 4-digit SIC code level. The 6- and 8-digit SIC classifications allowed us to examine the grocery food stores separately by type. These data were pulled and classified into four subcategories that included: (1) chain supermarkets, (2) nonchain supermarkets, (3) convenience stores, and (4) grocery stores. Supermarkets were substantially larger food stores compared to grocery stores and were more likely to have on-site food preparation such as a butcher, baker, and deli. For example, in the D&B sample of food stores, supermarkets averaged seven times the number of employees as grocery stores and 46 times the sales volume of grocery stores. Grocery stores averaged twice the number of employees as convenience stores. In terms of the presence of at least one food store by type, 45.4%, 34.3%, 92.9% and 88.5% of students in the sample had at least one available chain supermarket, nonchain supermarket, other grocery store, and convenience store present in their ZIP code area. Table 1 shows that the mean per 10,000 capita[28] number of chain supermarkets outlets was 0.30. The per 10,000 capita number of nonchain supermarkets was 0.26, the per 10,000 capita number of convenience stores was 2.2, and the per 10,000 capita number of grocery stores was 3.3.

Restaurant outlet data were available from D&B under the 4-digit classification of "Eating Places." Fast-food restaurants were defined by the full set of 8-digit SIC codes that fell under "Fast-food restaurants and stands," excluding coffee shops and including the two 8-digit SIC codes for chain and independent pizzerias. Nonfast-food restaurants, referred to as full-service restaurants, were defined as the number of total number of "Eating Places" minus fast food restaurants and excluding coffee shops; ice cream, soft drink, and soda fountain stands; caterers; and contract food services. Table 1 shows that on average in each ZIP code there were 2.6 fast-food and 11.4 full-service restaurants per 10,000 people.

[1]Information on D&B's methods was obtained from several sources that include: (1) www.zapdata.com; (2) "The DUNSright Quality Process: The Power behind Quality Information" (2005) Dun and Bradstreet; and, (3) Personal communication with Todd Mertz, Relationship Leader, U.S. DUNSright Customer Solutions, D&B, February 2, 2004.

Empirical Model

The goal of the empirical work was to estimate the associations between access to various types of food stores and adolescent weight, holding constant a variety of socioeconomic characteristics which may be correlated with both weight outcomes and neighborhood characteristics. Per capita availabilities of alternative types of food stores proxy the opportunity cost of the time spent acquiring healthful food. The extent to which alternative food stores are available within local communities is likely to affect eating patterns and weight outcomes. As discussed earlier, previous studies have found that larger versus smaller and chain versus nonchain food stores were more likely to stock healthful foods. Hence, increased availability of chain supermarkets was expected to be associated with lower weight outcomes, while greater availability of smaller stores such as convenience stores were likely to be associated with greater risk of overweight. Further, increased availability of chain supermarkets was expected to have a stronger protective association with weight outcomes compared to the availability of nonchain supermarkets or grocery stores. Differences in the availability of alternative choice sets for food shopping across different communities may result in systematic differences in eating patterns and weight status.

Reduced form models of individual BMI of the form

$$BMI_{ist} = \beta_0 + \beta_1 FT_{ist} + \beta_2 OC_{ist} + \beta_3 X_{it} + \beta_4 D_{it} + \varepsilon_{ist} \quad \mathbf{(1)}$$

were estimated by ordinary least squares (OLS), where FT_{ist} was a vector measuring food store outlet density available to individual i in geographic area s at time t, OC_{ist} measured other local-area contextual factors including per capita income, food prices, and restaurant availability in area s, D_{it} was a vector of year dummy variables, X_{it} was a vector of individual and household characteristics, β were conformable vectors of parameters to be estimated, and ϵ_{ist} was a disturbance term. The characteristics in the vector X_{it} included race/ethnicity, grade, highest schooling completed by father, highest level of schooling completed by mother, a rural/urban indicator, total student income, weekly hours of work by the student, and whether the mother worked part-time or full-time. In X_{it} complete sets of gender-specific age dummy variables also were included to remove gender-specific differences in BMI growth. These dummies implicitly included both a constant and a gender dummy. The coefficients on other covariates may then be interpreted as reflecting variation around arbitrary gender-specific growth curves.

The inclusion of the year dummy variables in the model was equivalent to nonparametrically detrending each variable in the analysis such that the estimates do not reflect common trends. Neighborhood per capita income was included in the model to account for local-area wealth effects distinct from food store availability that may affect health outcomes and variation in food store density related to local incomes. Several studies have shown that local-area supermarket availability varies with neighborhood-level socioeconomic status.[15,21,29,30] Not including a measure of neighborhood income confounds food store availability with other wealth effects. To control for other factors that may be related to weight outcomes through food access channels, full-service and fast-food restaurant outlet density measures were included in the model as well as fast-food and fruit and vegetable prices.[23–25]

Table 2. Effects of access to food stores on adolescent BMI and overweight (N=73,079)

	Overweight model 1	BMI model 1	BMI model 2	BMI model 3	BMI model 4
Number of chain supermarkets[a]	−0.0059** (0.0026)	−0.1093*** (0.0288)	−0.1116*** (0.0281)	−0.1100*** (0.0278)	−0.1169*** (0.0297)
Number of non-chain supermarkets[a]	0.0008 (0.0027)	0.0170 (0.0375)	0.0161 (0.0374)	0.0184 (0.0382)	0.0189 (0.0397)
Number of grocery stores[a]	0.0009* (0.0005)	0.0122 (0.0088)	0.0116 (0.0083)	0.0129 (0.0084)	0.0174 (0.0088)
Number of convenience stores[a]	0.0015** (0.0007)	0.0295** (0.0125)	0.0292** (0.0122)	0.0298** (0.0122)	0.0433*** (0.0129)
Restaurant and fast food restaurant, included in model[a]	Yes	Yes	No	No	No
Fast food and fruit and vegetable prices included in model	Yes	Yes	Yes	No	No
Neighborhood per capita income included in model	Yes	Yes	Yes	Yes	No

Note: Standard errors are shown in parentheses and are adjusted using a Huber-white covariance matrix estimate which is robust to both clustering at the zip code level and heteroskedasticity of unknown form. All of the models include but do not report on the following control variables: gender and age interaction terms, grade, race, fathers' education, mothers' education, living with both parents, living in rural areas, students' weekly real income, hours worked by students, mother works part-time, mother works full-time, and year effects.
[a]Per 10,000 capita.
*, **, and *** denote statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

A Huber–White covariance matrix estimate which is robust to clustering at the ZIP-code level and heteroskedasticity of unknown form was used.[31] Finally, the full model was also estimated with overweight as the outcome using maximum likelihood probit regression, for which the marginal effects were reported.

Results

Table 3 reports the results from the BMI and overweight regressions. Also, the table provides results for three additional BMI model specifications: (1) no restaurant outlet density control variables; (2) no restaurant outlet density or food price control variables; and (3) no restaurant, food price, or local-area SES control variables.

Focusing first on the results from the full model specification for both BMI and overweight with all variables (Model 1), it was found that availability of chain supermarkets had a statistically significant negative relationship with adolescent BMI and overweight status. Each additional chain supermarket outlet per 10,000 capita was estimated to reduce BMI by 0.11 units and to reduce the prevalence of overweight by 0.6 percentage points. BMI and overweight were statistically significantly higher in areas where there were more convenience stores; an additional convenience store per 10,000 capita was associated with a 0.03 unit increase in BMI and a 0.15 percentage point increase in overweight. The availability of nonchain supermarkets and general grocery stores was not statistically significantly associated with adolescent BMI, although increased availability of grocery stores had a very small positive and statistically weak association with overweight.

Comparing the results across models for BMI in Table 2, it can be seen that the parameter estimate for chain supermarkets was robust (falling slightly from −0.1169 in Model 4 to −0.1093 in Model 1) to the exclusion of local-area per capita income, restaurant availability and fast-food and fruit and vegetable prices. Previous research has shown lower availability of supermarkets in low-income neighborhoods.[15,21,29,30] The parameter estimate for convenience stores fell substantially in the BMI models once local-area income was controlled. These results implied that part of the positive correlation between adolescent BMI and convenience and grocery stores was attributable to greater density of these outlets in low-income neighborhoods. Similarly, the neighborhood income effect fell once food store contextual effects were included (not shown in the table) which, in a parallel argument, suggested that some of the correlation between income and adolescent body weight was attributable to differential access to food stores in low-income neighborhoods.

In Table 3 the sample is broken down by race/ethnicity and mother's work status to explore differ-

Table 3. Effects of access to food stores on adolescent BMI by sub-population

	Full sample	White	Black	Hispanic	Mother works full-time	Mother works part-time	Mother does not work
Number of chain supermarkets, per 10,000 capita	−0.1093*** (0.0288)	−0.0959*** (0.0349)	−0.3187*** (0.0987)	−0.0898* (0.0478)	−0.1261*** (0.0348)	−0.1066 (0.0851)	−0.0268 (0.0728)
Number of non-chain super-markets, per 10,000 capita	0.0170 (0.0375)	0.0494 (0.0324)	−0.0721 (0.1608)	−0.0578 (0.1613)	0.0265 (0.0433)	0.0821 (0.0576)	−0.0684 (0.0813)
Number of grocery stores, per 10,000 capita	0.0122 (0.0088)	0.0105 (0.0083)	0.0026 (0.0238)	0.0401 (0.0354)	0.0061 (0.0132)	0.0258 (0.0222)	0.0213 (0.0243)
Number of convenience stores, per 10,000 capita	0.0295** (0.0125)	0.0162 (0.0121)	0.0476 (0.0341)	0.0988** (0.0515)	0.0293* (0.0152)	−0.0026 (0.0256)	0.0635** (0.0258)
N	73,079	50,459	7,821	7,064	46,745	13,590	12,744

Note: Standard errors are shown in parentheses and are adjusted using a Huber-white covariance matrix estimate which is robust to both clustering at the zip code level and heteroskedasticity of unknown form. All of the models include but do not report on the following control variables: gender* age interaction terms, grade, race, fathers' education, mothers' education, living with both parents, living in rural areas, students' weekly real income, hours worked by students, mother works part-time, mother works full-time, year effects, per capita restaurant and fast food restaurant outlet density, fast food and fruit and vegetable prices, and neighborhood per capita income.
*, **, and *** denote statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

ences in the associations between weight and food store access across these subpopulations. Increased availability of chain supermarkets had a substantially stronger association with BMI among African-American students compared to their white and Hispanic counterparts. For example, one additional local-area chain supermarket per 10,000 capita was associated with lower BMI among African-American students by 0.32 units whereas the associated BMI of white and Hispanic students was lower by 0.10 and 0.09 units, respectively.

By mothers' work status, the food store access variables had a stronger impact on students whose mothers worked full-time; for example, the effect of a chain supermarket was slightly higher in the subsample of students whose mothers worked full-time compared to those with mothers who worked part-time and roughly four times as great compared to students whose mothers did not work. These results suggest that the effect of access to healthful food outlets was stronger in families with a working mother. The opportunity cost of time spent acquiring food is high in such families, so lack of access to supermarkets is more likely to result in substitution of less healthful fast foods or other convenience foods in these families.

The results presented above were not without their limitations. First, the outlet density data were linked to the individual-level data by the student's school's ZIP code. There might have been measurement error in the density data to the extent that students lived in different areas than their schools, which might have been a particular problem for the high school subsample. This error was mitigated by the fact that access near the school was also an important factor and because neighborhood characteristics might have been spatially correlated. A second limitation to bear in mind was that the estimated coefficients on food stores might only be interpreted as causal if, holding everything else in the model constant, variation in food store density came from the supply side (for example, variation in local zoning laws) or if supply was perfectly inelastic. However, if, all else equal, some of the variation in food store density was because of variation in demand across ZIP codes, the estimated associations cannot be interpreted as recovering the causal effect of changes in density on adolescent weight, given that supply was not perfectly inelastic.

Discussion

The results showed statistically significant associations between food store availability and adolescent BMI. Controlling for individual- and family-level characteristics and holding neighborhood per capita income, restaurant availability and food prices constant, an additional chain supermarket per 10,000 capita was associated with 0.11 units lower BMI and a 0.6 percentage point reduction in the prevalence of overweight, whereas an additional convenience store per 10,000 capita was associated with 0.03 units higher BMI and a 0.2 percentage point increase in overweight. The availability of nonchain supermarkets and other grocery stores was not found to be statistically significantly associated with adolescent weight outcomes. Although it was found that differential access to alternative types of food stores revealed significant associations with BMI, these contextual factors explained relatively little of the observed increase in mean BMI over the 1997 through 2003 sampling period. As shown in the summary statistics in Table 1, the sample mean number of chain supermarkets was only 0.3 per 10,000 capita. Model 1 suggests that increasing the availability of chain supermarkets from 0.3 per 10,000 to 1 per 10,000 people (a 230% increase) would decrease mean adolescent BMI by only 0.35%.

However, running the same model with overweight status as the dependent variable, it was found that similarly increasing supermarket availability would reduce overweight prevalence by 4.0%, substantially more than the impact on BMI. These results suggest that adolescents in and around the upper tail of the BMI distribution were more strongly affected by supermarket availability. Put differently, the large sample allows us to precisely estimate the associations between mean BMI and food store availability; the associations are small but were not zero. There was some evidence that overweight adolescents may respond more than the average adolescent, suggesting further research ought to investigate the distribution of BMI rather than its conditional mean.

Different groups of adolescents also responded differently to changes in food store availability. The results showed that the association between chain supermarket availability and BMI was three times higher among African-American students compared to their white and Hispanic counterparts, and for students with mothers who worked full-time the association was slightly greater compared to students with mothers who worked part-time and substantially greater compared to those with mothers who did not work. A similar pattern of differences in effect sizes was found across the subpopulations in models of overweight. At the same time, as noted earlier, existing research has shown that neighborhoods with higher proportions of minority populations are likely to have fewer supermarkets. Taken together, these results suggest that food store availability may be most important for African-American adolescents and those with mothers who work full-time, particularly if the youth is at risk of overweight.

The associations found in this study between food store availability and BMI and overweight were consistent with earlier findings that link healthful food consumption patterns with food store availability.[15,16] The study findings suggest that economic and urban planning land-use policies that encourage commercial development to improve the local food store environment in underserved areas may have beneficial effects on youth weight outcomes.

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