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ORIGINAL ARTICLE

# Child body mass index, obesity, and proximity to fast food restaurants

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*Objectives.* Using a sample of elementary and middle school students, we examined the associations between body mass index (BMI), obesity, and measures of the proximity of fast food and full service restaurants to students' residences. We controlled for socioeconomic status using a novel proxy measure based on housing values. *Methods.* We used BMI and obesity measures based on height and weight data collected as part of a school health assessment along with geocoded data on addresses of residences and food establishments. We constructed a proxy measure of socioeconomic status from public records of residential property assessments. These data were used to estimate logistic regression models of overweight and ordinary least squares models of BMI. *Results.* Students residing in homes with higher assessment values were significantly less likely to be obese, and had significantly lower BMIs. Upon controlling for socioeconomic status and other characteristics, the associations of BMI and obesity with proximity to food service establishments were reduced. Nonetheless, students who resided within one–tenth or one–quarter of a mile from a fast food restaurant had significantly higher values of BMI. The proximity of full service restaurants to residences did not have a significant positive association with either BMI or overweight. *Conclusion.* Public health efforts to limit access to fast food among nearby residents could have beneficial effects on child obesity. Public data on property value assessments may serve as useful approximations for socioeconomic status when address data are available.

**Key words:** *Child BMI, obesity, fast food restaurants, spatial analysis, environment*

## Introduction

Since the 1970s, the prevalence of obesity has more than doubled among American children aged 6 to 11, and more than tripled among American adolescents (1,2). Recent estimates suggest that now more than 16% of US children and adolescents are obese (2). Because of the many adverse health consequences associated with childhood obesity, there is an active research focus on its causes and correlates.

One factor that is fast gaining attention as a possible obesity determinant is proximity of student residences and schools to restaurants, especially fast food restaurants. While some studies in this literature measure restaurant access in terms of facilities per county or per state (3,4), a small number have constructed measures utilizing geographic information systems (GIS) to measure the actual proximity of restaurants to schools or residences (5–9). Two recent studies have reported significant positive associations between obesity and the proximity of schools to fast food restaurants. In a study of middle and high school students, the presence of fast food restaurants within one–half mile of the school was associated with a higher likelihood of being overweight or obese (8). In another study, rates of obesity among ninth grade students were significantly higher at schools located within one–tenth of a mile of a fast food restaurant (9). Such findings are intriguing; perhaps more so because there is little direct evidence that restaurant proximity affects dietary behaviors (10).

Another challenge faced by most such studies is the paucity of information on student background, especially socioeconomic status. Previous studies have shown that children in families with lower levels of income are more likely to be obese (11–13). If fast food restaurants tend to locate in lower income areas, then the reported associations between obesity and restaurant proximity may reflect the omission of socioeconomic status from models of obesity. One study of pre–school aged children that did control

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for family socioeconomic status found no significant association between obesity and restaurant proximity (5). However, because this study focused on low–income children, the income range in the sample was very limited. In the present study, we examine the association between obesity and restaurant proximity in a broad–based student population after adjusting for a novel measure of socioeconomic status, the property value of the student's residence.

## Methods

We used data on student heights and weights collected as part of an assessment of childhood obesity in a medium–sized public school district in Virginia. The school district is located within a Metropolitan Statistical Area, but the locale is designated as the "urban fringe of a large city" according to codes developed by the National Center for Education Statistics. According to the year 2000 Census statistics, the population density of the area represented by the school district was about 400 persons per square mile. This is more than twice the population density of the state as a whole, and five times the population density of the entire US (14). The percentage of residents between the ages of 5 and 19 is almost exactly that of Virginia.

In January 2006, school district personnel sent parents and guardians of all third, sixth, and seventh grade students written notification of an effort to collect measures of height and weight. Parents who did not wish their children to be measured were asked to contact the school health coordinator to opt out of the study. During site visits to each school in February and March, trained personnel recorded height and weight (without shoes), date of birth, and sex for 2 105 of the 2 331 students in these three grades (or 90.3%). Students for whom heights and weights were not collected include those whose parents opted out, those who were absent, out of class, or participating at an off–campus event the day measurements were taken, and those whose families had moved out of the school district between January and March. In conducting this study, we obtained these data along with the name of the school attended and the street addresses to which parent notification had been sent. This project was found to comply with appropriate ethical standards by the College of William and Mary Protection of Human Subjects Committee. Height, weight, date of birth, and sex were used to calculate body mass index (BMI) and obesity. We calculated BMI as weight in kilograms divided by height in meters squared. We defined obesity as having a BMI at or above the $95^{th}$ percentile of the age– and sex–specific BMI distribution as defined in growth charts published by the Centers for Disease Control (CDC) (15).

Data on restaurants were obtained from the Division of Food and Environmental Services at the Virginia Department of Health, which provided names and addresses of all food service establishments licensed to operate in the state public health districts surrounding the schools in our sample between July 1, 2005 and January 1, 2006. From this list, we selected fast food and full service establishments located within a two–mile radius of students' residences in the school district. We supplemented this list with three additional food establishments (one fast food, and two full service) identified from local knowledge of the area; in these cases addresses were identified from the local White Pages listings for 2005 and 2006, and verified using internet search engines of business listings. Prior studies have found that the relationship between child obesity and restaurant proximity differs by type of restaurant (i.e., fast food versus full service); however, there is no commonly accepted definition of fast food. In our research, we classified fast food restaurants as the major fast food chain restaurants (e.g., McDonald's, Burger King, Taco Bell, etc.) and other limited service restaurants (e.g., Subway, Quiznos, carry–out pizza, and sandwich shops, etc.).

Using Centrus Geostan, all student and business addresses were geocoded, that is, assigned a latitude and longitude (16). Of the 2 105 student residences we excluded four students whose families lived outside of the school district and one missing an address. For inclusion in the sample used in the main analysis, we required a high level of geocoding accuracy. We required that addresses be geocodable to a street/house (n=1 838) or the center of a block group (n=216). We excluded 46 addresses that matched only to census tract, given the relatively large size of a tract. Of 257 restaurant addresses we included those that matched to the street/restaurant (n=235) or the center of a block group (n=14). We excluded 8 business addresses that geocoded to the census tract level. In total, the geocoding accuracy of all restaurants was 97% (n=249) and of all students was 98% (n=2 054).

Distances between each restaurant and each student address were calculated using Hawth's Analysis Tools extension to ArcGIS 9.3 (17,18). Hawth's tools uses point–to–point distance estimates. We used home addresses rather than school addresses because students in this area and age group are far more likely to access fast food near their homes than near their schools. Students are not permitted to leave school premises during the school day. Limited transportation options to and from school also restrict student access to restaurants near schools. Students in grades 3, 6, and 7 are not licensed to drive, and at the time of the study, there were no dedicated bike paths for students to use. Further, in communications with school district representatives we found that 84 percent of elementary school students and 80 percent of middle school students ride the bus to school (19).

Most prior research studies in this area employ a variety of proximity measures, including the presence of any restaurants or the number of restaurants defined within different-sized buffers (ranging from one-tenths of a mile to 5 kilometers) of the individual (6–9). Similarly, we measured restaurant proximity with several indicator variables for the presence of any establishment within one-tenth, one-quarter, one-half, and one mile from the home, and the number of establishments within these same ranges. Two prior studies have reported significant associations at relatively small distances, and given that restaurant access by students in our sample may be limited to areas within walking or bicycling distance, we include these short distance measures here. We defined separate sets of the above measures for fast food restaurants and full service restaurants.

Limited data on child characteristics were available in the school district records. We defined an indicator variable equal to 1 if the child was female and 0 if male, the age of the child at time of the height and weight measurement, and the grade attended by the child. Using the child's school name and grade level, we defined the percent black and percent Hispanic in the grade at the school, percent free lunch at the school, and the average scores on standardized reading tests for the child's grade within the school. These data were obtained from reports published by the Virginia Department of Education.

The school district data did not include any information on the socioeconomic status of the child's family, such as income, employment status, or poverty status. In order to obtain a proxy measure of socioeconomic status, we merged the parent or guardian's mailing address to public use data on property values obtained from the tax assessors' offices of the localities represented in the school district. For single family homes, we obtained tax assessments of the total property value as of July 1, 2006. From these data, we calculated quintiles in the distribution of property value, and constructed an indicators variable equal to 1 for single family homes in each quintile. For addresses that were not single family homes, we created an indicator variable equal to 1 for "rental," and coded all five of the property value distribution indicators to zero. Rental determinations were made in three ways. First, we searched address strings for terms, such as apartment, apt, unit, number, lot, and room. Second, we used fields in the parcel data containing short property descriptions. These descriptions usually identified apartment buildings and motels separately from single family homes. Third, for cases that were ambiguous because of missing data on property description (about 100), we determined whether the address was an apartment complex, motel, or mobile home based on a view of the property using the street view feature on Google Maps, or, if that was ambiguous, a site visit to the property. Of the 2 054 school district residents for which we constructed proximity measures, we were able to obtain property value information for 2 023. These constitute our main analysis sample.

Note that this procedure assigned property values to single family homes that may be rented and not owned. We had no way of making this distinction in the property value data. For any such single family homes that were rented, we assume that the value of the home is a useful proxy for the unit's rent, which is also an indicator of a family's financial means.

We performed statistical tests of the relationship between food establishment proximity and child obesity or BMI using multivariate regression models. The dependent variable in these models was either an indicator variable for obesity or a continuous measure of BMI, and the set of independent variables included at least one measure of proximity. The obesity models were estimated as logistic regressions and the BMI models were estimated using OLS. All models included controls for the student's sex, age, grade in school, and percent black, percent Hispanic and percent other race in each grade by school, the percent of students at each school eligible for free federal school lunches, and the average test score on reading standardized tests. To examine the impact of controlling for our proxy measure of socioeconomic status, housing value, we estimated all models excluding and then including the indicator variables for housing value described above. We report odds-ratios from the logistic regressions and unstandardized regression coefficients from the BMI models. The standard errors used to construct confidence intervals of the estimates were adjusted for the clustering of observations at the census tract interacted with student grade (this allowed the number of clusters to exceed the number of explanatory variables). All statistical analyses were completed using STATA software (20).

We then conducted several robustness checks of our main results. First, we tested the strength of our results to changes in the sample. Upon inspection of the 46 student records that did not meet our inclusion criteria based on geocoding accuracy, we found that 23 belonged to students who lived at a housing complex that was demolished after the data were collected but prior to our geocoding. We obtained the latitude and longitude coordinates for the center of the former housing complex and constructed proximity measures using this location to approximate the actual residence, added these 23 student observations to our sample, and re–estimated our models.

Second, we tested the sensitivity of our results to alternative definitions of income and the inclusion of school fixed effects. Because total property values may be very high for families living on large farm properties, we used alternative controls for socioeconomic status based on assessed values of improvements only. Because housing values for one year may be a noisy measure, we also used a set of indicator variables based on quintiles in the distribution of average total value across both 2006 and 2007. We also substituted the school– and grade–specific explanatory variables with a set of school–grade dummy variables in order to control for any unobserved school– and grade–specific attributes that may also be associated with our outcomes of interest (for example, physical education classes and resources, school nutrition plans, etc.).

As a final robustness check, we closely examined the 216 residences and 14 businesses that geocoded to the center of the block group. In our sample, block groups differ in spatial size, so the accuracy of the geocoding varies. A conservative approach might be to omit these observations altogether; however, this runs the risk of losing valuable information, especially in the smaller block groups where geocoding is more accurate. As an assurance that our results are not driven by the block group matches, we limited our sample to the students and businesses that had the highest degree of geocoding accuracy, re–calculated all proximity measures, and re–estimated the models.

## Results

For the main analysis sample, Table I reports descriptive statistics on the outcomes measures and on all explanatory variables except the measures of proximity. The average BMI was 20.4 kg/m$^2$ and 17.4% met the clinical definition of obese. The sample was nearly evenly divided by sex (49% female) and across the three grades in school, with slightly more than one–third of the sample from the sixth grade (35.5%). About 14% of the students resided in rental units; for the remainder of students, the mean total property value of the residence was $259 426. Upon classifying the single family homes based on quintiles of the income distribution using observations for which we had housing values (including some observations for which the geocoding was insufficient), about 17% of the sample fell into each of five property value ranges.

Table II reports descriptive statistics for various measures of proximity to food establishments. One

Table I. Means of selected student and school variables, n=2023 students.

| Outcomes | % or mean (standard deviation) |
|---|---|
| Overweight | 17.4 |
| Body mass index | 20.4 (4.8) |
| Individual level explanatory variables | |
| Female | 48.9 |
| Male | 51.1 |
| Age | 11.4 (1.7) |
| Grade 3 | 31.6 |
| Grade 6 | 35.5 |
| Grade 7 | 32.9 |
| Rental property | 13.9 |
| Single family home | 86.1 |
| Property value, in 2006 $ (n=1 742 single family homes) | 259 426 (144 618) |
| Property value in 1st quintile (<$138 800) | 17.1 |
| Property value in 2nd quintile ($138 800 – $211 200) | 17.1 |
| Property value in 3rd quintile ($211 200 – $275 100) | 17.4 |
| Property value in 4th quintile ($275 100 – $347 100) | 17.2 |
| Property value in 5th quintile (>$347 100) | 17.4 |
| School or school and grade level explanatory variables | |
| Percent Black | 21.4 (6.5) |
| Percent Hispanic | 4.7 (1.7) |
| Percent Other | 3.6 (1.4) |
| Percent free lunch | 18.6 (7.0) |
| Average Score on Standardized Test of Reading | 85.6 (3.2) |

percent of students lived within one–tenth of a mile from a fast food restaurant, 5% lived within one–quarter of a mile, and 22% lived within one–half mile. For all distances, a higher percentage of students resided near a full service restaurant than a fast food restaurant, and the mean number of nearby full service restaurants exceeded the mean number of nearby fast food restaurants.

We also examined demographic traits and proximity to restaurants among students for whom we lacked BMI measures. Recall that of the 2 331 total students in these grades, height and weight measurements were not obtained for 226 students. The grade distribution of these students is comparable with that in the analysis sample, with 31% in grade three, 36% in grade six and 33% in grade seven. We had data on sex and age for 204 of these students; the average age in this sample was about the same as the analysis sample (11.5 years), but there were slightly more males (55%) than females (45%) than in the analysis sample. We were able to geocode addresses (with the same accuracy as applied to the full sample) for 218 of the 226 records, and in terms of proximity to restaurants, the students excluded from our BMI

Table II. Means of GIS–based proximity measures, n=2 023 students.

| | Distance from residence | | | |
|---|---|---|---|---|
| | 0.1 mile | 0.25 mile | 0.50 mile | 1 mile |
| % of students with any fast food restaurant | 1 | 5 | 22 | 48 |
| % of students with any full service restaurant | 2 | 10 | 32 | 63 |
| Mean number of fast food restaurants (SD) | 0.01 (0.15) | 0.14 (0.70) | 0.77 (1.98) | 2.85 (4.43) |
| Mean number of full service restaurants (SD) | 0.03 (0.24) | 0.24 (0.98) | 1.18 (3.06) | 4.34 (8.04) |

SD: Standard deviation.



models are very similar to the analysis sample. For example, the percentage of students within one–tenth, one–quarter, one–half and one mile from a fast food restaurant were 1%, 6%, 27% and 48%, respectively, very close to the analysis sample statistics reported in the first row of Table II.

We first demonstrate the associations of BMI and obesity with our proxy measures of socioeconomic status. Table III reports the adjusted odds ratios and coefficients for the five indicator variables for property value quintile (with rental unit as the reference category). The results are as expected. Relative to those residing in rental properties, children in homes valued in the second to the fifth quintiles were significantly less likely to be obese, and the odds ratios decrease with each successive quintile. Compared with those living in rental properties, children who lived in homes valued at the third to the fifth quintiles had significantly lower BMIs, and the coefficients become larger in absolute value with each higher quintile. The coefficients and odds ratios for the housing value terms were also jointly significant in all models.

We next report results from regression models in which BMI and obesity measures were regressed on separate measures of restaurant proximity controlling for age, sex, grade, and school–level characteristics. Table IV reports results in which proximity was measured using indicator variables for the presence of any restaurant within a given radius of the home; Table V reports results in which the number of restaurants within a given distance was included in the model. In both cases, we include separate measures for the fast food proximity and proximity to full service restaurants.

In Table IV, we find that when housing value is not included in the model, there are statistically significant positive associations between living within one–tenth, one–quarter, or one–half mile from any fast food restaurant and BMI. Further, students within one–tenth of a mile of any fast food restaurant were 3.9 times more likely to be obese. In Table V, we find that when we do not adjust for housing value, several associations between the number of nearby restaurants and BMI or obesity are also positive and significant. These associations diminish in size as the distance between restaurants and residence increases. For example, an additional fast food restaurant within one–tenth of mile from the residence was associated with a 2.32 unit increase in BMI, and an additional restaurant within one–quarter of a mile was associated with a 0.40 unit increase.

In both Tables IV and V, the addition of the proxy measures for socioeconomic status weakens but does not eliminate the effect of restaurant proximity, at

Table III. Associations between obesity and BMI, and property value, n=2 023 students.

| | Excluding controls for housing value | |
|---|---|---|
| | Obese AOR (95% CI) | BMI (95% CI) |
| Rental | 1.00 | — |
| Property value in 1st quintile (<$138 800) | 0.77 (0.51, 1.14) | 0.20 (–0.65, 1.04) |
| Property value in 2nd quintile ($138 800 – $211 200) | 0.57*** (0.41, 0.79) | –0.44 (–1.20, 0.33) |
| Property value in 3rd quintile ($211 200 – $275 100) | 0.33*** (0.20, 0.55) | –1.52*** (–2.28, –0.76) |
| Property value in 4th quintile ($275 100 – $347 100) | 0.44*** (0.32, 0.59) | –1.69*** (–2.20, –1.17) |
| Property value in 5th quintile (>$347 100) | 0.33*** (0.24, 0.46) | –1.95*** (–2.63, –1.28) |
| Test of joint significance of property value indicators (*p*–value) | $\chi^2$ statistic=72.78 (0.0000) | *F* statistic=16.07 (0.0000) |

*Notes*: Each cell reports either an adjusted odds ratio (AOR) from a logistic model of obesity or an OLS model of BMI. The 95% confidence interval of the estimate is shown in parentheses, and statistical significance is indicated by *for the 10% level, **for the 5% level, and ***for the 1% level. Each regression also includes controls for sex, age, grade in school, percent black, percent Hispanic, and percent other race in grade at school, percent of the school eligible for the federal free lunch program, and average score on a standardized test of reading for each grade and school. The standard errors used to construct confidence intervals adjusted for the clustering of observations by census tract by grade.

BMI: Body mass index.

Table IV. Association between obesity and BMI and presence of any fast food or full service restaurant near students' residences, with and without property value, n=2 023 students.

| | Obese AOR (95% CI) | | BMI (95% CI) | |
|---|---|---|---|---|
| | Excluding property value | Including property value | Excluding property value | Including property value |
| Model 1: Within 0.1 mile | | | | |
| Fast food | 3.92** (1.26, 12.20) | 3.83* (0.94, 15.63) | 4.20** (0.09, 8.31) | 4.16* (–0.03, 8.34) |
| Full service | 0.59 (0.19, 1.84) | 0.40* (0.14, 1.14) | –0.71 (–1.92, 0.50) | –1.50** (–2.7, –0.29) |
| Model 2: Within 0.25 mile | | | | |
| Fast food | 1.14 (0.72, 1.82) | 1.05 (0.67, 1.65) | 1.05* (–0.04, 2.14) | 0.77 (–0.24, 1.78) |
| Full service | 1.31 (0.80, 2.16) | 0.98 (0.60, 1.60) | 0.55 (–0.37, 1.47) | 0.10 (–0.74, 0.93) |
| Model 3: Within 0.5 mile | | | | |
| Fast food | 1.42* (0.93, 2.15) | 1.19 (0.80, 1.77) | 0.64* (–0.15, 1.44) | 0.35 (–0.42, 1.13) |
| Full service | 0.90 (0.62, 1.32) | 0.80 (0.56, 1.15) | 0.15 (–0.59, 0.90) | –0.13 (–0.75, 0.49) |
| Model 4: Within 1 mile | | | | |
| Fast food | 1.11 (0.75, 1.64) | 0.94 (0.64, 1.39) | 0.39 (–0.26, 1.04) | 0.03 (–0.62, 0.69) |
| Full service | 0.90 (0.65, 1.24) | 0.93 (0.67, 1.28) | –0.17 (–0.95, 0.60) | –0.06 (–0.74, 0.62) |

*Notes*: Each cell reports either adjusted odds ratios (AORs) for measure of restaurant proximity from a separate logistic model of obesity or regression coefficients for measures of restaurant proximity from a separate OLS model of BMI. The 95% confidence interval of the estimate is shown in parentheses, and statistical significance is indicated by *for the 10% level, **for the 5% level, and ***for the 1% level. Each regression also includes controls for sex, age, grade in school, percent black, percent Hispanic, and percent other race in grade at school, percent of the school eligible for the federal free lunch program, and average score on a standardized test of reading for each grade and school. The standard errors used to construct confidence intervals adjusted for the clustering of observations by census tract by grade.
BMI: Body mass index.

least in the case of fast food. Specifically, in the BMI models in Table IV, residing within one–tenth of a mile from any fast food location continues to have a significant positive association, and in Table V, measures of the density of restaurants within one–tenth and one–quarter mile have significant positive associations with BMI as well. In the obesity models in Table IV, the presence of any restaurants within one–tenth of a mile continues to have a positive and significant association with obesity. Upon controlling for housing value, we find no evidence of statistically significant positive associations between full service restaurant proximity and either outcome. In fact, we find that the presence of a full service restaurant within one–tenth of a mile from the home has a significant negative association with BMI and obesity.

Table V. Association between obesity and BMI, and number of fast food and full service restaurants near students' residences, with and without controls for property value, n=2 023 students.

| | Obese AOR (95% CI) | | BMI (95% CI) | |
|---|---|---|---|---|
| | Excluding property value | Including property value | Excluding property value | Including property value |
| Model 1: Within 0.1 mile | | | | |
| Fast food | 3.10**(1.21, 7.95) | 3.07 (0.75, 12.59) | 2.32*** (0.81, 3.84) | 2.27*** (0.63, 3.91) |
| Full service | 0.72 (0.42, 1.22) | 0.61 (0.32, 1.15) | –0.28 (–1.25, 0.70) | –0.60 (–1.71, 0.51) |
| Model 2: Within 0.25 mile | | | | |
| Fast food | 1.09 (0.96, 1.23) | 1.04 (0.92, 1.19) | 0.40*** (0.15, 0.66) | 0.30** (0.05, 0.55) |
| Full service | 1.04 (0.89, 1.21) | 1.00 (0.86, 1.16) | 0.08 (–0.25, 0.41) | 0.02 (–0.25, 0.29) |
| Model 3: Within 0.5 mile | | | | |
| Fast food | 0.99 (0.90, 1.07) | 0.97 (0.89, 1.06) | 0.014 (–0.14, 0.17) | 0.004 (–0.15, 0.16) |
| Full service | 1.04* (0.99, 1.10) | 1.02 (0.98, 1.07) | 0.106** (0.01, 0.20) | 0.05 (–0.02, 0.13) |
| Model 4: Within 1 mile | | | | |
| Fast food | 0.98 (0.94, 1.02) | 0.98 (0.94, 1.03) | 0.006 (–0.07, 0.08) | 0.002 (–0.08, 0.08) |
| Full service | 1.03** (1.00, 1.06) | 1.02 (0.99 1.04) | 0.05** (0.01, 0.09) | 0.03 (–0.01, 0.06) |

*Notes*: Each cell reports either adjusted odds ratios (AORs) for measure of restaurant proximity from a separate logistic model of obesity or regression coefficients for measures of restaurant proximity from a separate OLS model of BMI. The 95% confidence interval of the estimate is shown in parentheses, and statistical significance is indicated by *for the 10% level, **for the 5% level, and ***for the 1% level. Each regression also includes controls for sex, age, grade in school, percent black, percent Hispanic, and percent other race in grade at school, percent of the school eligible for the federal free lunch program, and average score on a standardized test of reading for each grade and school. The standard errors used to construct confidence intervals adjusted for the clustering of observations by census tract by grade.
BMI: Body mass index.

Findings from various robustness checks lend additional support for our results. After adding the 23 student observations from the former housing complex, results were nearly identical in terms of the direction, size, and statistical significance of the associations. The use of alternative measures of housing value yielded very similar results, as did the inclusion of school fixed effects. Results from our final robustness check actually increased the statistical significance of the association between BMI and restaurant proximity. Limiting the sample to only those residences and businesses with the highest level of geocoding accuracy (i.e., omitting the block group matches), we find that fast food restaurant proximity at distances of one–tenth, one–quarter, *and* one–half mile are significantly associated with higher BMI values. Table VI shows these results, controlling in all cases for property value. To summarize, the results of various robustness checks confirm that proximity to fast food restaurants has a positive and statistically significant association with BMI and obesity.

## Discussion

This study examined the association between BMI, obesity, and proximity to fast food restaurants among elementary and middle school students. A novel feature of our work is the use of local government assessments of property values to control for socioeconomic status in models of BMI and obesity. In doing so, we address a particular limitation in the existing literature, where few studies control for individual–level socioeconomic status despite the established link between obesity and low socioeconomic status. Some prior studies include proxy measures, such as other economic development near school or car and computer ownership in the household (6,8). One study controlled for socioeconomic status using household income data and found no association between BMI and proximity (5). As that study examined a sample of pre–school aged children drawn from a low–income population, its results may not be generalizable to broader populations.

We found that students who resided in homes in successively higher ranges of the property value distribution were significantly less likely to be obese, thus offering support for the use of our proxy. We also found that upon controlling for housing value, the size of the association between BMI and overweight, and proximity to fast food restaurants diminished, as expected given the hypothesized association between low socioeconomic status and proximity. This suggests that relationships between fast food restaurants and obesity, or BMI in studies that do not control for socioeconomic status may overstate proximity effects.

Our results show that the significant association between proximity and BMI persisted for children living within short distances of a fast food restaurant. While findings from studies of adult populations are mixed (21–24), past studies of children and adolescents illustrate a pattern that is supported by our

Table VI. Obesity and BMI and proximity of both fast food and full service restaurants to students' residence controlling for housing value, n = 1 810 students.

| | Obese AOR (95% CI) | | BMI (95% CI) | |
|---|---|---|---|---|
| | Any restaurant | Number of restaurants | Any restaurant | Number of restaurants |
| Model 1: Within 0.1 mile | | | | |
| Fast food | 3.89* (0.97, 15.56) | 3.22 (0.76, 12.68) | 4.16* (–0.01, 8.33) | 2.28*** (0.62, 3.95) |
| Full service | 0.39* (0.14, 1.11) | 0.60 (0.32, 1.16) | –1.58** (–2.8, –0.38) | –0.68 (–1.77, 0.41) |
| Model 2: Within 0.25 mile | | | | |
| Fast food | 1.11 (0.70, 1.74) | 1.04 (0.91, 1.20) | 0.86* (–0.05, 1.76) | 0.32** (0.08, 0.56) |
| Full service | 0.89 (0.55, 1.43) | 1.00 (0.84, 1.17) | –0.28 (–0.96, 0.39) | –0.03 (–0.32, 0.25) |
| Model 3: Within 0.5 mile | | | | |
| Fast food | 1.67** (1.08, 2.59) | 1.00 (0.92, 1.10) | 0.69* (–0.06, 1.45) | 0.03 (–0.15, 0.22) |
| Full service | 0.52 (0.34, 0.77) | 1.00 (0.95, 1.06) | –0.74 (–1.24, –0.24) | 0.02 (–0.07, 0.11) |
| Model 4: Within 1 mile | | | | |
| Fast food | 1.06 (0.68, 1.66) | 0.99 (0.95, 1.04) | 0.13 (–0.42, 0.69) | 0.01 (–0.07, 0.09) |
| Full service | 0.79 (0.52, 1.21) | 1.01 (0.98 1.04) | –0.28 (–0.93, 0.37) | 0.02 (–0.02, 0.06) |

*Notes*: Each cell reports either adjusted odds ratios (AORs) for measure of restaurant proximity from a separate logistic model of obesity or regression coefficients for measures of restaurant proximity from a separate OLS model of BMI. The 95% confidence interval of the estimate is shown in parentheses, and statistical significance is indicated by *for the 10% level, **for the 5% level, and ***for the 1% level. Each regression also includes controls for quintiles in the housing value distribution, sex, age, grade in school, percent black, percent Hispanic, and percent other race in grade at school, percent of the school eligible for the federal free lunch program, and average score on a standardized test of reading for each grade and school. The standard errors used to construct confidence intervals adjusted for the clustering of observations by census tract by grade.
BMI: Body mass index.

results. In two prior studies that define proximity as within 2 or 5 kilometers from the student's home or school, results show no positive association between being near a fast food outlet and either obesity or BMI (6,7). In two other studies where proximity is defined as within one–tenth to one–half of a mile from the student's school, results show that middle and high school students who attend schools near fast food locations are significantly more likely to be obese (8,9). Thus, like previous studies that define proximity in terms of school locations, we found similar evidence that proximity to the home also matters for short distances of one–quarter mile or less. Also like these two prior studies, we found no evidence that proximity to full service restaurants had a significant positive association with child BMI or obesity (8,9).

Despite having access to a novel proxy for socioeconomic status, our study has a number of limitations. We selected point–to–point analysis partly because transportation options available to this age group may include walking through lots or between parcels, and thus may not be restricted to roadways. Nonetheless, there may be cases where significant physical boundaries prohibit direct access; for this reason subsequent analyses could build on our findings by conducting a network analysis (5), or by calculating travel time. Because we have access to only one year of data, we use a cross–sectional design. In future research, the use of panel data consisting of multiple observations of the same children over time or instrumental variables analysis would further help distinguish causality from correlation. In one study of California high schools, the authors used panel data techniques in a model of school obesity rates and reported that changes in the proximity of restaurants to schools over time was associated with changes in the school obesity rate over time (9). Another study examined respondents to the US Behavior Risk Factor Surveillance System, and used variation in the interstate highway system to identity the causal effect of restaurant proximity on obesity among rural adults. In contrast, these authors reported that proximity had no significant effect on obesity (24).

Other limitations of our study are based on the features of our sample. For example, we lack information on other student characteristics, such as race and ethnicity, and parents' education. We are also unable to account for the possible influence of other unobserved traits that are correlated with BMI and/or obesity and also correlated with fast food proximity. These might include proximity to parks and recreation opportunities, for example. To the degree that these factors are correlated with housing value, our inclusion of the property value indicators addresses this concern somewhat. The relatively small size of the sample also limits our findings. Table IV and V report some associations that, while statistically insignificant, are substantively meaningful. Further, one distance measure that retains its significant association upon control for housing value, proximity at one–tenth of a mile, applies only to 1 percent of the sample, and another applies to 5 percent of the sample. A larger sample would help to increase the precision of the estimated associations between obesity and restaurant proximity, and to examine the link between close proximity and obesity in a larger group of students.

Future research is needed to investigate the causal pathways by which fast food proximity affects obesity. Only a few existing studies directly examine the link between food consumption and restaurant proximity (10,21,25). Only one provides statistically significant evidence that fast food variety is associated with fast food purchasing; yet no significant associations were found between distance or density and purchasing (10). As prior studies examine adults, more work is needed to investigate these relationships among children and adolescents.

Childhood obesity has become a national health priority, and policy makers within federal, state, and local governments are seeking ways to promote healthier lifestyles. In some communities these efforts have included calls for zoning laws that restrict access to fast food in certain neighborhoods (26–28). In spite of the strength of some calls for action, the research evidence is sparse. This study adds to the small number of existing studies by showing that children who reside in very close proximity to fast food restaurants have higher values of BMI even upon controlling for a proxy measure of socioeconomic status. Taken together with findings from previous studies, our research suggests that public health efforts targeted at controlling access to fast food by nearby residents could have beneficial effects on BMI.

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