The Neighborhood Food Environment and Adult Weight Status: Estimates From Longitudinal Data

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Objectives. I used longitudinal data to consider the relationship between the neighborhood food environment and adult weight status.

Methods. I combined individual-level data on adults from the 1998 through 2004 survey years of the National Longitudinal Survey of Youth 1979 with zip code–level data on the neighborhood food environment. I estimated ordinary least squares models of obesity, body mass index (BMI), and change in BMI.

Results. For residents of urban areas, the neighborhood density of small grocery stores was positively and significantly related to obesity and BMI. For individuals who moved from a rural area to an urban area over a 2-year period, changes in neighborhood supermarket density, small grocery store density, and full-service restaurant density were significantly related to the change in BMI over that period.

Conclusions. Residents of urban neighborhoods with a higher concentration of small grocery stores may be more likely to patronize these stores and consume more calories because small grocery stores tend to offer more unhealthy food options than healthy food options. Moving to an urban area may expose movers to a wider variety of food options that may influence calorie consumption. (*Am J Public Health.* 2011;101:71–78. doi:10.2105/AJPH.2009.187567)

The dramatic rise in obesity in the United States since 1980 has led to increased interest in understanding the role that the physical environment plays in the development of obesity.[1–6] The physical environment is assumed to affect individual weight status by impacting both energy intake and energy expenditure. When the focus is on energy intake, it is often hypothesized that 2 important environmental influences on diet are the availability of food retail and food service establishments.[1–7]

Previous research has examined the relationship between the availability of food retail and food service establishments in an adult's neighborhood of residence (often referred to as the neighborhood food environment) and weight status.[8–13] Findings on the relationship between neighborhood food environment variables and weight status have differed considerably across studies. With the exception of the study by Currie et al.,[13] all previous research on the relationship between the neighborhood food environment and adult weight status used cross-sectional data. Currie et al.[13] found that proximity to fast-food restaurants was positively related to the likelihood of gaining more than 20 kg during pregnancy. However, the proximity of food retail establishments was not included in their models of pregnancy weight gain.

My study contributes to the previous research by using longitudinal data to consider the relationship between the neighborhood food retail and food service environment and current weight status as well as the relationship between these variables and the change in body mass index (BMI; defined as weight in kilograms divided by height in meters squared) over time. In addition to detailed measures of the neighborhood food environment, the models of weight status controlled for a large set of demographic, socioeconomic, and environmental characteristics and included individual fixed effects.

METHODS

I used individual-level data on adults from the National Longitudinal Survey of Youth 1979 (NLSY79) geocoded to the respondent's zip code area of residence. The NLSY79 began in 1979 with an initial sample of 6283 female youths and 6403 male youths aged 14 to 22 years in 8770 households. The NLSY79 sample was designed to be representative of the entire population of youths residing in the United States aged 14 to 21 years as of December 31, 1978.[14] Follow-up interviews were conducted annually until 1994 and biennially thereafter.

The sample used in my analyses included observations on respondents from the 1998 through 2004 years of the NLSY79, when respondents were between the ages of 33 and 48 years. I included an observation in the sample if there was information on the respondent's current weight, zip code area food environment, and long-term family income. I arranged the data as a panel so that there were multiple observations per respondent and the unit of analysis was a person-year. The analysis sample contained 14 191 observations on 4202 women and 13 634 observations on 4085 men. I refer to this sample as the main sample. I created a "change" sample from the main sample that included variables representing an individual's change in BMI and other characteristics between a given survey year and the subsequent survey year. The change sample consisted of 9468 observations on 3370 women and 9153 observations on 3624 men.

Body Mass Index and Obesity

I combined a respondent's self-reported weight in a survey year with self-reported height from 1985 (the most recent height information available in the NLSY79) to calculate the respondent's BMI in that survey year. I categorized a respondent as obese if the respondent's BMI was greater than or equal to 30 kg/m^2. Previous research has found measurement error in self-reported weight and height, with heavier individuals more likely to underreport their weight.[15] This measurement error suggests that the prevalence of obesity and

the average BMI may be understated in the NLSY79.

Neighborhood Food Environment

I defined a respondent's neighborhood of residence as the respondent's zip code area of residence.[10,16a] I defined a respondent's neighborhood food environment in a given survey year by using data on food retail and food service establishments in the respondent's zip code area of residence from the corresponding year of the US Census Bureau's ZIP Code Business Patterns Data.[16b] I created separate variables for the neighborhood density per square mile of each of the following establishment types: supermarkets, small grocery stores, convenience and specialty food stores, limited-service restaurants, and full-service restaurants.

The US Census Bureau's ZIP Code Business Patterns Data are released annually and contain counts of the number of establishments in each zip code area in the United States and Puerto Rico by North American Industry Classification System (NAICS) codes and within NAICS codes by employment size.[16b] The ZIP Code Business Patterns Data do not contain information on establishment sales volume or whether establishments were part of a chain. I used NAICS codes to define grocery stores (code 445110), convenience stores (code 445120), specialty food stores (codes 445210, 445220, 445230, and 445291), limited-service restaurants (code 722211), and full-service restaurants (code 722110). Limited-service restaurants are establishments where patrons generally pay before eating (excluding snack and nonalcoholic beverage bars). This category is broader than, although roughly synonymous to, fast-food restaurants.

I categorized a grocery store as a supermarket if it had 50 or more employees and as a small grocery store if it had fewer than 50 employees.[16–18] Moore and Diez Roux[18] found that this employment-based definition of a supermarket was approximately equivalent to a commonly used sales-based definition of a supermarket that defines a supermarket as a grocery store with greater than $2 million in annual sales.[1,11,19,20] I combined convenience stores and specialty stores into 1 category because both types of establishments sell a limited set of food products. However, the results did not change if separate density variables were included for each type of establishment (results not shown).

I approximated the size of a zip code area by using 2000 Decennial US Census Data on the land area of the ZIP Code Tabulation Area (ZCTA) with the matching 5-digit number. A series of articles by Powell et al. on the relationship between neighborhood characteristics and food retail and food service availability used this approach for linking zip code areas to ZCTAs.[21–23] Although zip code area and ZCTA boundaries correspond where possible, they are not necessarily an exact match.[24]

Individual Fixed Effects

I included individual fixed effects in the models of weight status. Individual fixed effects control for unobserved individual characteristics that are associated with weight status and do not vary over time. Because models that include individual fixed effects use within-person variation in personal characteristics to explain within-person variation in outcomes, individual characteristics that do not vary over time, such as race, ethnicity, and gender, do not need to be included in these models.

Individual-Level Explanatory Variables

The individual characteristics I used as control variables were the respondent's long-term Food Stamp Program participation, long-term family income, age, age-squared, family size, pregnancy status, highest grade completed in school, marital status, number of weeks worked in the previous calendar year, vehicle ownership, frequency of light physical activity, frequency of heavy physical activity, region, and urbanicity of residence. I defined long-term Food Stamp Program participation as the percentage of time a respondent's family had participated in the Food Stamp Program over the previous 7 calendar years preceding the survey year. I calculated long-term family income as the mean over the previous 7 calendar years of a respondent's total family income in a given year divided by the US Census Bureau's poverty threshold appropriate for the family's size in that year.[25a] The models of weight status included separate long-term Food Stamp Program participation and long-term family income variables for women and men.[25b,26] The NLSY79 categorized a respondent's residence as urban if the respondent lived in an urbanized area or in a place with a population greater than 2500 and as rural otherwise.[14]

Additional Zip Code–Level Explanatory Variables

I defined the poverty rate and population density in a respondent's zip code area of residence in a given survey year by using 2000 Decennial US Census data on these variables from the corresponding ZCTA. A disadvantage of these US Census Bureau data is that for a given ZCTA, the values of the 2 variables will be constant over all of the NLSY79 survey years.

Two-Year Change Variables

I created change variables representing the change in each of the previously defined variables between a given survey year and the subsequent survey year (2-year changes). Additionally, I constructed indicator variables for each of the following possible residence changes over a 2-year period: remained in a rural area, moved to a rural area, moved to an urban area, and remained in an urban area. I created separate change variables for neighborhood food environment, neighborhood poverty rate, and neighborhood population density for each urban-rural residence change category.

Statistical Analysis

I calculated descriptive statistics on a respondent's obesity status, BMI, and neighborhood food environment for the person-year observations in the main sample and for subsamples grouped by current urban or rural residence. I calculated descriptive statistics on a respondent's change in BMI and change in neighborhood food environment for the person-year observations in the change sample and for subsamples grouped by urban-rural residence change category. I tested differences in characteristics between the subsamples by using Pearson χ^2 test and a significance level of $P<.10$ for prevalences or 2-sample t-test with the assumption of unequal variance and a significance level of $P<.10$ for continuous variables.

I estimated ordinary least squares (OLS) models of obesity and BMI by using the main sample. The dependent variable in the models of obesity was an indicator variable equal to 1 if

a respondent was obese in a given survey year. Three models were estimated for each outcome. Model 1 included neighborhood food environment variables and individual fixed effects. Model 2 added individual characteristics and the neighborhood poverty rate and population density to the first model. Model 3 included separate neighborhood food environment variables for urban and rural areas as well as individual fixed effects, individual characteristics, and separate neighborhood poverty rate and population density variables for urban and rural areas.

Probit or logit models are often used for dichotomous outcomes such as obesity. However, it is not possible to estimate fixed-effects probit models, and fixed-effects logit models require strong assumptions to be made about the distribution of the coefficients on the individual fixed effects before it is possible to calculate how changes in the explanatory variables affect the predicted probability of obesity.[27] With fixed-effects OLS linear probability models, multiplying the coefficient on a variable by 100 provides an estimate of the change in the predicted probability of obesity expected from a 1-unit change in that explanatory variable. Currie et al.[13] also estimated fixed-effects OLS linear probability models.

I estimated an OLS model of the 2-year change in BMI by using the change sample. The models of BMI change included the variables from model 3 assessed at the start of the 2-year period, BMI assessed at the start of the 2-year period, variables that assessed the change in individual characteristics over the 2-year period, indicators for 3 of the 4 urban-rural residence change categories, and separate neighborhood food environment, neighborhood poverty rate, and neighborhood population density change variables for each urban-rural residence change category.

RESULTS

Of the person-year observations in the main sample, slightly more than 35% were obese, and the mean BMI was 28.9 kg/m^2 (Table 1). The zip code areas of residence of the person-year observations in the sample had a mean density per square mile of 0.16 supermarkets, 1.09 small grocery stores, 0.75 convenience or specialty stores, 2.12 limited-service restaurants, and 2.36 full-service restaurants. Obesity prevalence and mean BMI were not significantly different between the urban and rural subsamples. However, the densities and prevalences of food retail and food service establishments were significantly higher in the urban subsample than in the rural subsample.

Of the person-year observations in the change sample, the mean 2-year change in BMI was 0.27 kg/m^2, with a mean 2-year change in neighborhood density per square mile of −0.003 supermarkets, −0.016 small grocery stores, −0.037 convenience or specialty stores, −0.015 limited-service restaurants, and −0.133 full-service restaurants (Table 2). The mean change in BMI was not significantly different between urban-rural residence change categories. The mean changes in the neighborhood food environment density variables differed considerably and significantly between urban-rural residence change categories (Table 2).

The neighborhood density of small grocery stores was positively and significantly related to current obesity and BMI in model 1 (Tables 3 and 4). However, none of the other neighborhood food retail or food service density variables was significantly related to weight status. The addition of personal characteristics and the neighborhood poverty rate and population density variables did not sizably change the magnitude or significance of the coefficient on small grocery store density. Estimates from model 3, which included separate neighborhood food environment variables for urban and rural areas, revealed that the positive and significant relationship between neighborhood small grocery store density and weight status in models 1 and 2 was driven by urban areas. The coefficient of small grocery store density interacted with urban residence was positive and significant in models of both obesity and BMI, but the coefficient of small grocery store density interacted with rural residence was not statistically significant. For residents of urban areas, each additional small grocery store per square mile in a person's current neighborhood was associated with a 0.27 percentage point increase in the probability of current obesity and a 0.021 kg/m^2 increase in current BMI.

The 2-year changes in neighborhood supermarket density, small grocery store density, and full-service restaurant density were significantly related to the 2-year change in BMI for respondents who moved from a rural to an urban area during the 2-year period. The remaining neighborhood food environment variables were not significantly related to the 2-year change in BMI. Given the small number of significant coefficients on the neighborhood food environment variables, I did not include a table presenting the coefficient estimates. The adjusted R^2 of this model was 0.683. For respondents who moved from a rural to an urban area, an increase of 1 supermarket per square mile in neighborhood supermarket density over a 2-year period was associated with a 1.98 kg/m^2 decline in BMI over that period (P=.023), an increase of 1 small grocery store per square mile in neighborhood small grocery store density over a 2-year period was associated with a 0.147 kg/m^2 decrease in BMI over that period (P=.094), and an increase of 1 full-service restaurant per square mile in neighborhood full-service restaurant density over a 2-year period was associated with a 0.195 kg/m^2 increase in BMI over that period (P=.085).

DISCUSSION

The neighborhood density of small grocery stores was positively and significantly related to the current obesity and BMI of residents of urban areas. Farley et al.[28] hypothesized that a relative excess of unhealthy food compared with healthy food in a neighborhood may lead to less healthy and higher-calorie diets for residents of that neighborhood. The authors found that in small grocery stores, the average amount of shelf space devoted to fruits and vegetables was considerably smaller than the average amount of shelf space devoted to snack foods. If a higher neighborhood density of small grocery stores increases the likelihood of shopping at a small grocery store, residents of neighborhoods with a higher concentration of small grocery stores may have greater exposure to the low ratio of healthy to unhealthy food choices and consume more calories as a result.

Previous research has found that small grocery stores are more prevalent in poor, urban neighborhoods than in other types of neighborhoods.[1,20,29] This finding raises the concern that the coefficient on urban small grocery store density captured the unmeasured influence of neighborhood poverty on both the

TABLE 1—Weight Status and Neighborhood Food Environment of the Main Sample and Urban and Rural Subsamples: NLSY79, 1998–2004

	Main Sample (n = 27 825), % or Mean (SD)	Urban Subsample (n = 20 396), % or Mean (SD)	Rural Subsample (n = 7429), % or Mean (SD)
Weight status			
Obese	35.4	35.7	34.9
Body mass index, kg/m^2	28.9 (6.11)	29.0 (6.1)	28.9 (6.13)
Neighborhood food retail environment[a]			
Supermarket density per square mile	0.16 (0.34)	0.21 (0.45)**	0.024 (0.077)
Small grocery store density per square mile	1.09 (4.52)	1.45 (5.19)**	0.076 (1.18)
Convenience and specialty store density per square mile	0.75 (2.8)	0.99 (3.23)**	0.066 (0.379)
At least 1 supermarket	72.8	82.0**	47.7
At least 1 small grocery store	84.9	89.5**	72.1
At least 1 convenience or specialty store	83.3	91.0**	62.3
Neighborhood food service environment[a]			
Limited-service restaurant density per square mile	2.12 (6.32)	2.81 (7.23)**	0.23 (1.08)
Full-service restaurant density per square mile	2.36 (12.69)	3.13 (14.7)**	0.25 (1.22)
At least 1 limited-service restaurant	93.1	98.9**	77.2
At least 1 full-service restaurant	95.2	98.6**	86.0

Note. NLSY79 = National Longitudinal Survey of Youth 1979. Every year that an individual was included in the sample was a separate observation. Therefore, the percentages and means refer to person-year observations. A person-year observation was included in the urban sample each year in which the respondent resided in an urban area. A person-year observation was included in the rural sample for each year in which the respondent resided in a rural area.
[a]For zip code area of residence.
** $P < .05$, for significant difference from the rural subsample,.

neighborhood availability of small grocery stores and individual weight status. However, the models controlled for the neighborhood poverty rate and population density as well as for a detailed set of individual characteristics including long-term poverty status and individual fixed effects. Additionally, in models that included interactions of the urban and rural neighborhood food environment variables with an indicator for

TABLE 2—Changes in Body Mass Index (BMI) and Neighborhood Food Environment According to Residence Status Over a 2-Year Period: NLSY79, 1998–2004

2-Year Change Variable	Change Sample (n = 18 621), Mean (SD)	Stayed in a Rural Area (n = 4150), Mean (SD)	Moved to a Rural Area (n = 622), Mean (SD)	Moved to an Urban Area (n = 903), Mean (SD)	Stayed in an Urban Area (n = 12 946), Mean (SD)
Change in weight status: BMI	0.27 (2.55)	0.24 (2.45)	0.29 (2.32)	0.29 (2.36)	0.28 (2.61)
Change in neighborhood food retail environment[a]					
Supermarket density per square mile[b,c,e,f,g]	−0.003 (0.292)	0.006 (0.057)	−0.06 (0.15)	0.026 (0.006)	−0.003 (0.343)
Small grocery store density per square mile[e]	−0.016 (2.27)	−0.01 (1.44)	−0.189 (0.983)	0.054 (1.50)	−0.014 (0.983)
Convenience and specialty store density per square mile[b,c,d,e,f,g]	−0.037 (1.69)	0.005 (0.229)	−0.194 (0.72)	0.096 (0.531)	−0.052 (2.02)
Change in neighborhood food service environment[a]					
Limited-service restaurant density per square mile[b,c,e,f,g]	−0.015 (4.53)	0.015 (1.09)	−0.683 (1.92)	0.273 (1.59)	−0.013 (5.36)
Full-service restaurant density per square mile[d,f,g]	−0.133 (8.64)	−0.007 (1.09)	−0.636 (1.92)	0.324 (1.67)	−0.182 (10.33)

Note. BMI was defined as weight in kilograms divided by height in meters squared. Every year that an individual was included in the change sample was a separate observation. Therefore the means refer to person-year observations.
[a]For zip code area of residence.
[b]The 2-year changes differed significantly at the $P = .1$ level between the stayed in a rural area and moved to a rural area categories.
[c]The 2-year changes differed significantly at the $P = .1$ level between the stayed in a rural area and moved to an urban area categories.
[d]The 2-year changes differed significantly at the $P = .1$ level between the stayed in a rural area and stayed in an urban area categories.
[e]The 2-year changes differed significantly at the $P = .1$ level between the moved to a rural area and moved to an urban area categories.
[f]The 2-year changes differed significantly at the $P = .1$ level between the moved to a rural area and stayed in an urban area categories.
[g]The 2-year changes differed significantly at the $P = .1$ level between the moved to an urban area and stayed in an urban area categories.

TABLE 3—Coefficients on Neighborhood Food Environment Variables From Ordinary Least Squares Models of Obesity: NLSY79, 1998–2004

	Model 1, b Coefficient (SE)	Model 2, b Coefficient (SE)	Model 3, b Coefficient (SE)
Neighborhood food environment variables			
Supermarket density per square mile	−0.0089 (0.0085)	−0.0018 (0.0087)	
Small grocery store density per square mile	0.002* (0.0012)	0.0022* (0.0013)	
Convenience and specialty store density per square mile	0.001 (0.0021)	0.0024 (0.0021)	
Limited-service restaurant density per square mile	−0.0006 (0.001)	−0.0006 (0.001)	
Full-service restaurant density per square mile	−0.0004 (0.0005)	−0.0006 (0.0005)	
Urban neighborhood food environment variables			
Supermarket density × urban[a]			−0.0028 (0.0088)
Small grocery store density × urban			0.0027** (0.0014)
Convenience and specialty store density × urban			0.0024 (0.0021)
Limited-service restaurant density × urban			−0.0008 (0.001)
Full-service restaurant density × urban			−0.0005 (0.0006)
Rural Neighborhood food environment variables			
Supermarket density × rural[b]			−0.0073 (0.0694)
Small grocery store density × rural			0.0032 (0.004)
Convenience and specialty store density × rural			0.0104 (0.0225)
Limited-service restaurant density × rural			0.0064 (0.0079)
Full-service restaurant density × rural			−0.0055 (0.0059)
Model statistics			
Included controls for personal characteristics and zip code area poverty rate and population density[c]	No	Yes	Yes
Included individual fixed effects	Yes	Yes	Yes
Adjusted R-squared	0.7474	0.7499	0.7500

Note. The sample size was n = 27 825.
[a]Urban was an indicator variable equal to 1 in a survey year if a respondent lived in an urban area in that survey year.
[b]Rural was an indicator variable equal to 1 in a survey year if a respondent lived in a rural area in that survey year.
[c]Personal characteristics controlled for were : respondent's long-term Food Stamp Program participation, long-term family income, age, age-squared, family size, pregnancy status, highest grade of school completed, marital status, number of weeks worked in the previous calendar year, vehicle ownership, frequency of light physical activity, frequency of heavy physical activity, region, and urbanicity of residence.
*P = .1; **P = .05.

whether the neighborhood had a poverty rate greater than 20%, the coefficients on these interactions were not significant (results not shown).

The neighborhood density of small grocery stores was not significantly related to current weight status for residents of rural areas. It may be that the likelihood of shopping at a small grocery store does not differ between residents of rural neighborhoods with a higher density of small grocery stores versus those with a lower density. Previous research has found that residents of rural areas are more likely than residents of urban areas to shop outside their neighborhood of residence.[1]

The neighborhood densities of other types of establishments were not significant predictors of current weight status for residents of urban or rural areas. Previous research has indicated that many families travel beyond their neighborhood supermarkets to shop at supermarkets outside their neighborhood.[1] This finding suggests that the neighborhood density of supermarkets may not have a large influence on the likelihood that a family shops at a supermarket, which may explain the lack of a significant relationship between neighborhood supermarket density and weight status.

Convenience stores typically have a very small amount of shelf space devoted to fruits and vegetables and a very low ratio of shelf space devoted to fruits and vegetables compared with snack foods.[28] However, most families do an extremely small fraction of their total food shopping in convenience stores and specialty stores,[1] and the neighborhood density of convenience and specialty stores may not influence the likelihood of shopping at such establishments. Following a similar line of reasoning, although previous research has found that restaurant meals tend to have more calories than do meals consumed at home,[30,31] the likelihood of eating at a restaurant may not differ substantially between residents of neighborhoods with a higher density of restaurants and those with a lower density.

With respect to BMI trajectory, encountering a change over time in neighborhood supermarket density or small grocery store density as the result of a move from a rural to an urban area was negatively and significantly related to the 2-year change in BMI. Previous research suggests that supermarkets in urban areas have lower prices, a larger

TABLE 4—Coefficients on Neighborhood Food Environment Variables From Ordinary Least Squares Models of Body Mass Index: NLSY79, 1998–2004

	Model 1, b Coefficient (SE)	Model 2, b Coefficient (SE)	Model 3, b Coefficient (SE)
Neighborhood food environment variables			
Supermarket density per square mile	−0.087 (0.071)	−0.040 (0.072)	
Small grocery store density per square mile	0.022** (0.01)	0.018* (0.01)	
Convenience and specialty store density per square mile	−0.020 (0.017)	−0.005 (0.017)	
Limited-service restaurant density per square mile	0.004 (0.009)	−0.004 (0.009)	
Full-service restaurant density per square mile	−0.003 (0.005)	−0.0002 (0.005)	
Urban neighborhood food environment variables			
Supermarket density × urban[a]			−0.029 (0.073)
Small grocery store density × urban			0.021* (0.011)
Convenience and specialty store density × urban			−0.002 (0.017)
Limited-service restaurant density × urban			−0.005 (0.009)
Full-service restaurant density × urban			−0.001 (0.005)
Rural neighborhood food environment variables			
Supermarket density × rural[b]			0.035 (0.573)
Small grocery store density × rural			−0.0002 (0.033)
Convenience and specialty store density × rural			0.009 (0.185)
Limited-service restaurant density × rural			−0.005 (0.065)
Full-service restaurant density × rural			0.041 (0.049)
Model statistics			
Included controls for personal characteristics and zip code area poverty rate and population density[c]	No	Yes	Yes
Included individual fixed effects	Yes	Yes	Yes
Adjusted R^2	0.8918	0.8956	0.8956

Note. The sample size was n = 27 825.
[a]Urban was an indicator variable equal to 1 in a survey year if a respondent lived in an urban area in that survey year.
[b]Rural was an indicator variable equal to 1 in a survey year if a respondent lived in a rural area in that survey year.
[c]Personal characteristics controlled for were as follows: respondent's long-term Food Stamp Program participation, long-term family income, age, age squared, family size, pregnancy status, highest grade completed in school, marital status, number of weeks worked in the previous calendar year, vehicle ownership, frequency of light physical activity, frequency of heavy physical activity, region, and urbanicity of residence.
*P = .1; **P = .05.

selection of brands, and a greater availability of fresh produce than do supermarkets in rural areas.[1,20,29] Therefore, a person who encounters an increase in supermarket density over time because of a move from a rural to an urban area may find it easier than before to make healthy food choices and to consume a lower quantity of calories. By contrast, a person who does not move or who moves from an urban to a rural area is likely to experience a decline in supermarket density over time. The lack of significance of the change in neighborhood supermarket density variables for these groups suggests that people found ways to replicate their prior consumption patterns despite declines in supermarket density. These explanations may also apply to the results for small grocery stores; however, it has not been established whether small grocery stores in urban areas offer price and selection advantages over small grocery stores in rural areas.[1,20,29]

The 2-year change in full-service restaurant density resulting from a move from a rural to an urban area was positively and significantly related to the 2-year change in BMI. Full-service restaurants may be likely to offer a wider variety of cuisines in urban areas than in rural areas. This change in variety is less likely to be the case for limited-service restaurants, because a fairly standard set of cuisines are offered in such establishments in both urban and rural areas. Therefore, a person who experiences an increase in full-service restaurant density as a result of a move to an urban area may choose to go to full-service restaurants more frequently because of the chance to sample new types of food, resulting in an increase in calorie consumption and weight gain. In contrast, encountering an increase in limited-service restaurant density as a result of a move to an urban area may not increase the likelihood that a person patronizes these establishments because the food is already familiar.

Limitations

The models estimated here included detailed measures of the neighborhood food environment; a large set of demographic, socioeconomic, and environmental characteristics; and individual fixed effects. However, it is possible that the estimates of the relationship between the neighborhood food environment and weight status were biased as a result of

reverse causality from weight status to the neighborhood food environment or omitted variable bias. A possible source of bias is that the models did not include measures of a person's history of neighborhood food environments. Before 1997, the ZIP Code Business Patterns data used Standard Industrial Classification codes to categorize establishments. Because the Standard Industrial Classification codes combine limited-service and full-service restaurants and also combine convenience stores and grocery stores, it was not possible to construct appropriately detailed neighborhood food environment history variables. A further concern is that the models did not include measures of the food environments encountered outside the neighborhood of residence.

An additional issue is whether the zip code area establishment density variables adequately captured an individual's neighborhood food environment. One problem is that these variables missed establishments that were near a resident of a zip code area but were located beyond the boundary of the zip code area. Another problem is that ZCTA land area may not be a good proxy for the land area of the numerically corresponding zip code area.

Conclusions

The finding that the neighborhood density of small grocery stores was positively and significantly related to the current obesity and BMI of residents of urban areas raises the question of whether policies that offer incentives for food retail establishments to increase the relative availability of healthy food or policies that foster the creation of neighborhood stores specializing in healthy food would be expected to improve food choices and health outcomes for neighborhood residents. Early results from small-scale interventions that increased store-level availability and promotion of healthier food items found increased sales and small increases in the consumption of these healthier items.[1] However, other research found that the neighborhood availability of fruits and vegetables, defined as the total amount of shelf space for fruits and vegetables within a specified distance of a person's residence, was not significantly related to BMI.[32] The same study found that the shelf space of energy-dense snack foods had a small positive association with BMI.[32] Further research is needed to understand how changing the in-store and neighborhood availability of food options influences food choices before these policies should be recommended. ■

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Human Participant Protection

This project analyzed secondary data on individuals and establishments. Institutional review board approval for this project was not required by Baruch College because it was not possible to determine the identity of individual respondents or to identify specific establishments by use of these data.

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