Food Environment, Built Environment, and Women's BMI: Evidence from Erie County, New York

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Abstract

The authors present the results of a neighborhood-scaled exploratory study that tests the association of the food environment and the built environment with women's body mass index (BMI) in Erie County, New York. The proximity of women's homes to a supermarket relative to a convenience store is associated with lower BMI. A diverse land use mix in a neighborhood is positively associated with women's BMI, especially when restaurants dominate nonresidential land use. The article offers suggestions for how food environments may be improved using planning strategies.

Keywords

food environment, built environment, women, BMI, food planning

This article examines the influence of the neighborhood food environment and the built environment on the body mass index (BMI) of women. More than one-third of U.S. adults were reported to be obese in 2006, with the prevalence of obesity slightly greater among women (35 percent) than men (33 percent) (Ogden et al. 2007). The prevalence of obesity is a significant public health concern because it places individuals at a risk for a variety of diseases (Ogden et al. 2007). In recent years, the role of environmental factors in contributing to obesity has received much recognition (Winson 2004). Current research suggests that a walkable built environment facilitates physical activity and reduces BMI (Frank et al. 2006; Ewing et al. 2003). Yet as the editor of a special issue of the *Journal of the American Planning Association* on planning and public health acknowledges, "the built environment [may not] be the dominant explanation for rising obesity rates" (Boarnet 2006, 6). The paradox in many low-income urban neighborhoods, where the built environment is walkable, yet obesity levels are greater than in the general population—especially among women—is a case in point (Day 2006). While the built environment may be walkable, the food environment may offer limited or no access to nutritious foods, an area commonly described as a "food desert" (Mari Gallagher Consulting and Research Group 2006). Because obesity is, in part, the *net* result of an imbalance between energy expenditure and energy consumption by individuals (Brug, Lenthe, and Kremers 2006), we hypothesize that the net effect of the built and food environment women live in (Boarnet 2006, 6) may be associated with their body weight.[1]

The focus on the role of food systems and food environments on community health is not new in planning. For nearly a decade, community and regional food planning scholars (e.g., Caton Campbell 2004; Kaufman 2004; Pothukuchi and Kaufman 2000, 1999) have argued that malfunctioning food systems negatively impact health, economy, and environments of communities. Yet this food planning literature offers limited quantitative evidence on the association of the food environment with people's BMI and even less regarding the collective association of the food environment and the built environment with BMI.[2]

This article fills this gap by asking how the attributes of a neighborhood—specifically, its food environment and its built environment—are simultaneously associated with women's BMI. We offer a conceptual framework to understand these associations and apply this framework to an exploratory empirical study of 172 female residents of Erie County,

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New York. The results of this exploratory study suggest that the neighborhood food environment has a strong association with women's BMI. In particular, the proximity of a woman's home to a supermarket relative to a convenience store is positively associated with a lower BMI. Contrary to previous reports (Frank et al. 2006), we find no significant association between the neighborhood walkability index (as defined by Frank et al. 2006) and BMI.[3] Instead, similar to Rutt and Coleman (2005), a particular component of the walkability index, namely, a more diverse land use mix in a neighborhood, is positively associated with BMI, especially when restaurants dominate nonresidential land use.

Food Environment, Built Environment, and Obesity

BMI, one indicator of women's health, is a function of many complex and interrelated factors. Some are a function of individual characteristics such as age, race/ethnicity, medical characteristics (e.g., genetic predisposition), behavioral factors (e.g., individuals' habits, preferences, and attitudes), economic status, and education levels (which may influence access to information about which foods are healthful). While these individual factors are important, there is a growing recognition that systemic/structural factors—including political, economic, social, and spatial/environmental factors—may create barriers or opportunities for individuals to be physically active and eat well (Winson 2004).[4] A subset of these structural factors stem from the design of neighborhood environments within which people live, work, and play—these are of special interest in this article because of planning's significant role in shaping these environments.

Planners' interest in the connection between the design of environments and individual health is anything but new. In the mid- to late 1800s, the noted landscape architect and planner Frederick Law Olmstead designed parkways and green spaces, believing that pastoral views and access to open space bring mental and physical health benefits to residents faced with the stresses of urban living. Much later in the twentieth century, scholars wrote about the influence of environmental design on health, ranging from the benefits of green landscapes, building design, and street patterns on physical and psychological well-being (Ulrich 1979; Kaplan 1973), quicker recovery from surgery (Ulrich 1984), and reduced physical violence (Sullivan and Kuo 1996).

More recently, a concern over obesity has resulted in a resurgence of planning research on the built environment's influence on health. This contemporary research largely examines the influence of physical development patterns—such as sprawl—and characteristics of the built form—such as land use patterns and street design—on physical activity and obesity (Boarnet 2006). Individuals living in counties with a lower degree of sprawl, for example, are reported to have a lower BMI (Ewing et al. 2003). At the finer geographic scale of a neighborhood, higher housing density, a more diverse land use, and a greater availability of parks are associated with greater physical activity (Frank et al. 2006; Roemmich, Epstein, Raja, and Yin 2006[5]) and lower levels of obesity (Frank et al. 2006).[6]

Most studies that test the influence of the built environment on health are observational because it is difficult to establish a control group and randomize subjects between a "test" and "control" group, and thus, they are unable to make any claims of causality. Nonetheless, a couple of studies suggest that a causal relationship is plausible. A study by Handy, Cao, and Mokhtarian (2006) finds that the built environment has an impact on health after correcting for any self-selection bias of study participants. A second study is an experimental study of youth by Epstein et al. (2006). In a randomized trial, the authors find that a clinical weight loss program intervention is more successful in reducing sedentary behavior among youth who live in neighborhoods with greater access to parks than among youth with lower access to parks.

Despite the growing evidence, further research is warranted on this topic because of some exceptions and contradictions in the literature. Some studies have found that attributes of the built environment, specifically availability of parks and recreational areas (Roemmich, Epstein, Raja, and Yin 2006; Roemmich, Epstein, Raja, Yin, et al. 2006), are significantly associated with physical activity but *not* the BMI of individuals. Unlike early studies (such as Frank, Andersen, and Schmid 2004) that suggest a negative relationship between walkable environments (as defined by a diverse land use mix, high residential density, and high street intersection density) and lower BMI, later studies (e.g., a study in El Paso, Texas, by Rutt and Coleman 2005) report a *positive* association between diverse land use mix and BMI.

Other studies report a limited association between a neighborhood's built environment and residents' physical activity levels and/or BMI. For example, research conducted in new urbanist neighborhoods has shown that although the built environment has a positive influence on utilitarian physical activity (e.g., walking to destinations), it has no impact on residents' leisure-time activity and overall level of physical activity (Rodriguez, Khattak, and Evenson 2006).

Scholars also note the possibility of a reverse relationship between the built environment and physical activity and/or BMI. People who are less obese and more physically active may *choose* to live in a walkable neighborhood where they can achieve greater physical activity. Plantinga and Bernell (2007) postulate that "incomes and lot prices are lower at locations farther from the central business district due to commuting costs, and this induces residents to substitute away from calorie expenditure and toward more land for housing." In market equilibrium, body weight and land use density are determined simultaneously and the "lines of causality between weight and urban form run in both directions"

(p. 860). They test this idea in a sample of individuals drawn from the National Longitudinal Study of Youth 1979, whose county of residence changed between 1998 and 2000, by modeling subjects' choice to move to a low- or high- sprawl county as a function of the built environment. They report that low-sprawl counties (sprawl index ≤ 120)[7] attract individuals with lower BMI and that a move to a low-sprawl county by primarily low-BMI individuals also results in a drop in their BMI.[8] Another study of a sample of adults also drawn from the National Longitudinal Survey of Youth finds that after controlling for unobservable heterogeneity—through fixed effects and first difference models—there is no association between level of sprawl in a county and BMI of residents (Eid et al. 2007).

What unobserved factors might explain these contradictory findings? And what other attribute of the neighborhood environment besides the built environment (which limits or facilitates physical activity) might contribute to rising obesity? A possible explanation is the lack of opportunities to obtain affordable and healthful foods within some neighborhoods (since one way of understanding obesity is as a net imbalance between energy intake and energy expenditure of individuals). A significant body of literature has documented inadequacies in food environments, especially in minority and low-income neighborhoods. Several studies, for example, report fewer supermarkets in minority neighborhoods (Raja, Ma, and Yadav 2008; Morland, Diez Roux, and Wing 2006).[9] It is plausible that the lack of high-nutrition, low-calorie food choices in some minority neighborhoods tilts the energy balance of the population. This may be one explanation for why at least one study (Frank, Andersen, and Schmid 2004) reports minority families to be more obese even when they walk significantly more.

A growing body of empirical work explores the role of food environments on obesity. A widely cited cross-sectional study in Mississippi, North Carolina, Maryland, and Minnesota by Morland, Diez Roux, and Wing (2006) found the prevalence of supermarkets in census tracts correlated with a lower prevalence of obesity among residents and the presence of convenience stores associated with a higher prevalence of obesity. However, the study measured obesity of subjects in 1993 to 1995, while the food environment in census tracts was measured in 1999, four years after the fact. As a result, the outcome variable, BMI, temporally precedes the key explanatory variable (the food environment). This is a significant limitation, especially in the applicability of their results to low-income neighborhoods where store turnover tends to be high.

More important, the Morland, Diez Roux, and Wing (2006) study, like other public health studies of the food environment, does not simultaneously consider how the built environment in neighborhoods might counterbalance the effect of the food environment on obesity. An exception is a recent study by Liu et al. (2007) that considers some aspects of the built environment as well as the food retail environment. The study, which focused on children ages three through eighteen, found that more vegetation (green space) in children's neighborhoods is associated with decreased risk for overweight, but only for those children residing in high-population-density areas. Increased distance between a child's residence and the nearest large, name-brand supermarket was found to be associated with increased risk of overweight, but only for subjects residing in low-population-density regions. Given that children's use of their environment is mediated by their parents, especially for very young children, it is important to understand how parents regulate children's use of their environment.

In conclusion, to fully understand the *net influence* of neighborhood environmental factors on obesity, it is important to understand how the environment contributes to both sides of the energy equation (Lake and Townshend 2006)—through the built environment (via physical activity opportunities) and the food environment (via healthy eating opportunities). This article does so by simultaneously examining the influence of the food and built environments on women's BMI.

Method

This article uses a cross-sectional research design and multivariate regression analysis to test the influence of the neighborhood built and food environments on women's BMI in Erie County, New York. Erie County is located in western New York. Between 1999 and 2004, the percentage of county's population reported to be obese increased from 20.3 to 22.8 percent (The UB Regional Institute). The prevalence of obesity (BMI > 30) in western New York varies by gender and age but is greatest for women among the ages of eighteen and forty-four, at 31.7 percent (Western New York Public Health Alliance Health Risk Assessment 2005)—a factor that partly shaped our choice to focus on women in this analysis. Our analysis relies partly on secondary data generated through screening and baseline assessments of previous clinical weight control studies of children and a parent. During these clinical studies, which occurred between 2000 and 2004, families living in Erie County, New York, were recruited using direct mailings, local newspaper advertisements, posters and brochures, and word of mouth. Women willing to be screened for participation in the studies visited the Division of Behavioral Medicine at the authors' university, the University at Buffalo, SUNY, where their height and weight were measured by trained research assistants. BMI was computed by dividing weight (in kilograms) of a subject by the square of height (in meters). Age and economic status were self-reported by the women during these visits.

The resulting sample includes 172[10] women living in Erie County, New York (see Figure 1). Women in the sample are on average forty-two years old and predominantly white.[11]

Table 1. Descriptive Statistics

Variables	Definition	Abbreviation	Mean	*SD* (±)
Dependent				
Body mass index	Weight/height squared (kg/m^2)	BMI	28.8	6.86
Explanatory				
Food environment				
Availability and access to food destinations within a five-minute *walk* from a subject's home	Number of food stores	FDWLK	0.24	0.69
	Number of restaurants	RTWLK	0.56	1.47
Availability and access to food destinations within a five-minute *drive* from a subject's home	Number of food stores	FDDRV	25.01	20.83
	Number of restaurants	RTDRV	64.41	50.74
Relative access to healthful foods	Ratio of distance to nearest convenience store to nearest supermarket (or grocery store) from a subject's home	FDAC	1.14	0.86
Built environment				
	Walkability index using combined z-scores of the following:	WLKNDX		
	Land use mix within an area accessible by a five-minute walk around a subject's residence, ranges from 0 to 1	LUM	0.47	0.12
	Intersection density (no. of intersection/sq. km) within an area accessible by a five-minute walk around a subject's residence	INT	37.72	21.71
	Block group residential housing density (units/sq. km)[a]	DEN	1,441	1,065
	Proportion of parks and recreational lands to total land available within an area accessible by a five-minute walk around a subject's residence	PRK	0.01	0.04
Social environment				
Poverty	Proportion of population below poverty level within a subject's block group	POV	0.06	0.07
Individual factors				
Age	Years	AGE	41.93	6.08
Ethnicity	White (1) or other (0)	ETH	90 percent white	
Socioeconomic status	Hollingshead index for the household	SES	46.22	10.42

[a]Except residential housing density, all the built environment variables were computed for an area around a subject's home that could be traversed by a five-minute walk along the street network. This definition is consistent with how we defined the food environment available within walking distance; this consistency is important since food destinations (e.g., restaurants) may compete with physical activity destinations (e.g., parks) for the share of the time a subject spends in her neighborhood.

As an indicator of women's socioeconomic status, we use the Hollingshead index, which combines years of education as well as occupational status into an ordinal score (Hollingshead 1975) that ranges from 11 to 77. Higher scores indicate a lower socioeconomic status.[12] This study's sample is approximately at the middle of this range, with an average index of 46.2. The descriptive statistics for all the variables are reported in Table 1.

Based on a review of the literature, we conceptualize the dependent variable BMI (weight divided by the square of height) as a function of neighborhood environment, individual characteristics, and technology variables (see Figure 2). Using our empirical data, we were able to test the variables shown in bold in Figure 2. Unlike a number of previous studies (Frank et al. 2006; Frank, Andersen, and Schmid 2004; Ewing et al. 2003) that rely on weight and height self-reported by subjects, we used objective measures of our dependent variable in that the weight and height of subjects were measured by researchers.

The key independent variables pertain to the neighborhood environment, namely, the food environment and the built environment. We present and test two measures of the neighborhood food environment: the relative proximity to a healthful food destination from a subject's home and the overall availability of food destinations within one's neighborhood. The former measures the comparative ease of access in reaching a food destination that offers healthful foods compared to a destination that offers less healthful foods, and this may influence individuals' choice to purchase and consume particular foods. To measure this relative proximity, we

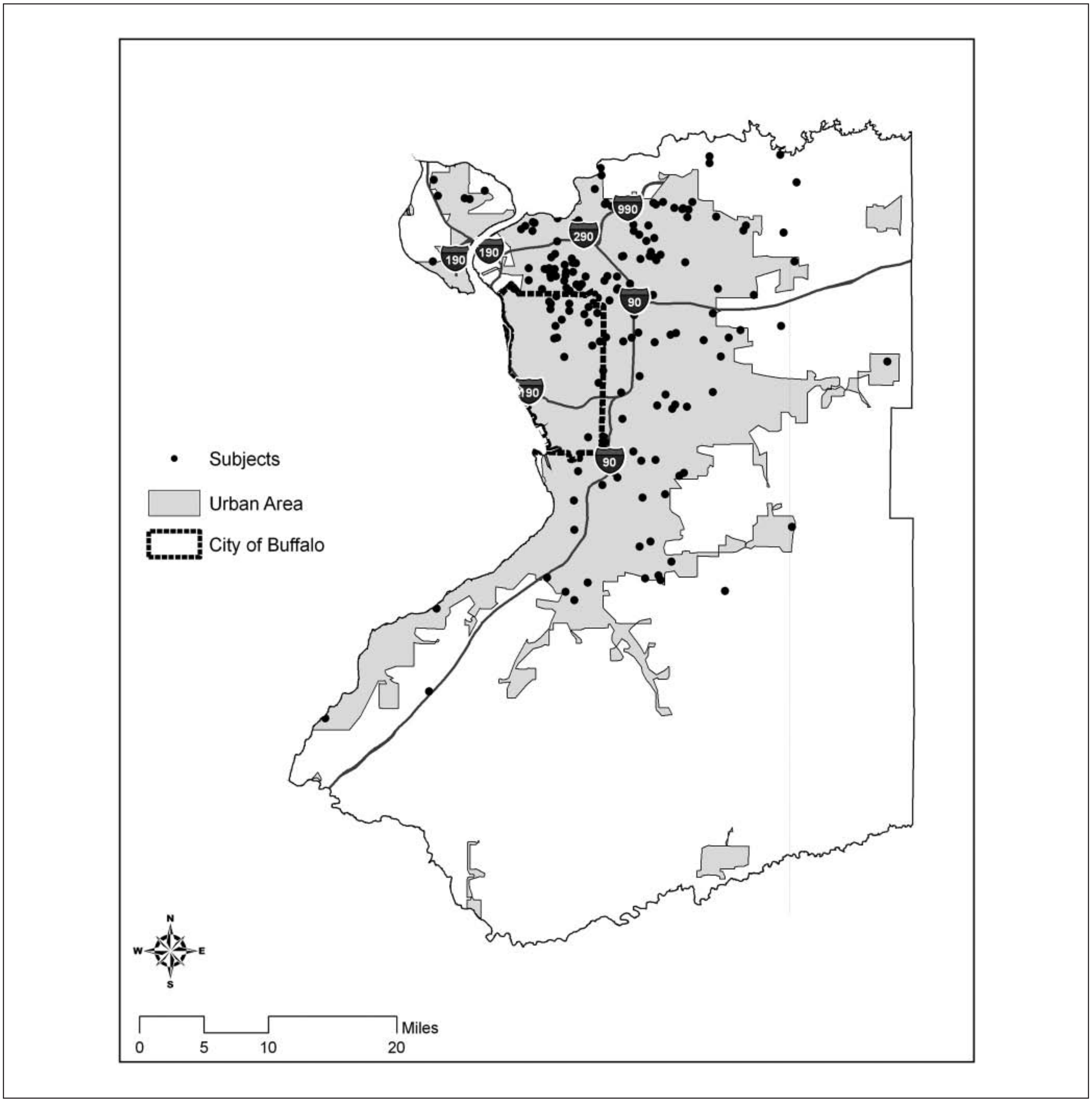

Figure 1. Study area, Erie County, New York

computed the ratio of the distance from each subject's home to the nearest healthful food destination to the distance from each subject's home to the nearest food unhealthful food destination. All distances were measured along the street network: in other words, these distances were not the straight-line distances between two points but rather the actual distance that an individual would have to walk along a street network to reach a destination.

A previous investigation in the study area (Erie County) found that convenience stores carry less healthful foods than supermarkets and grocery stores: 33 percent of convenience stores carried fresh produce in comparison to 100 percent of supermarkets; only 17 percent of convenience stores were found to carry whole grains in comparison to 80 percent of supermarkets (Raja, Ma, and Yadav 2008). Therefore, we used supermarkets and grocery stores as a proxy

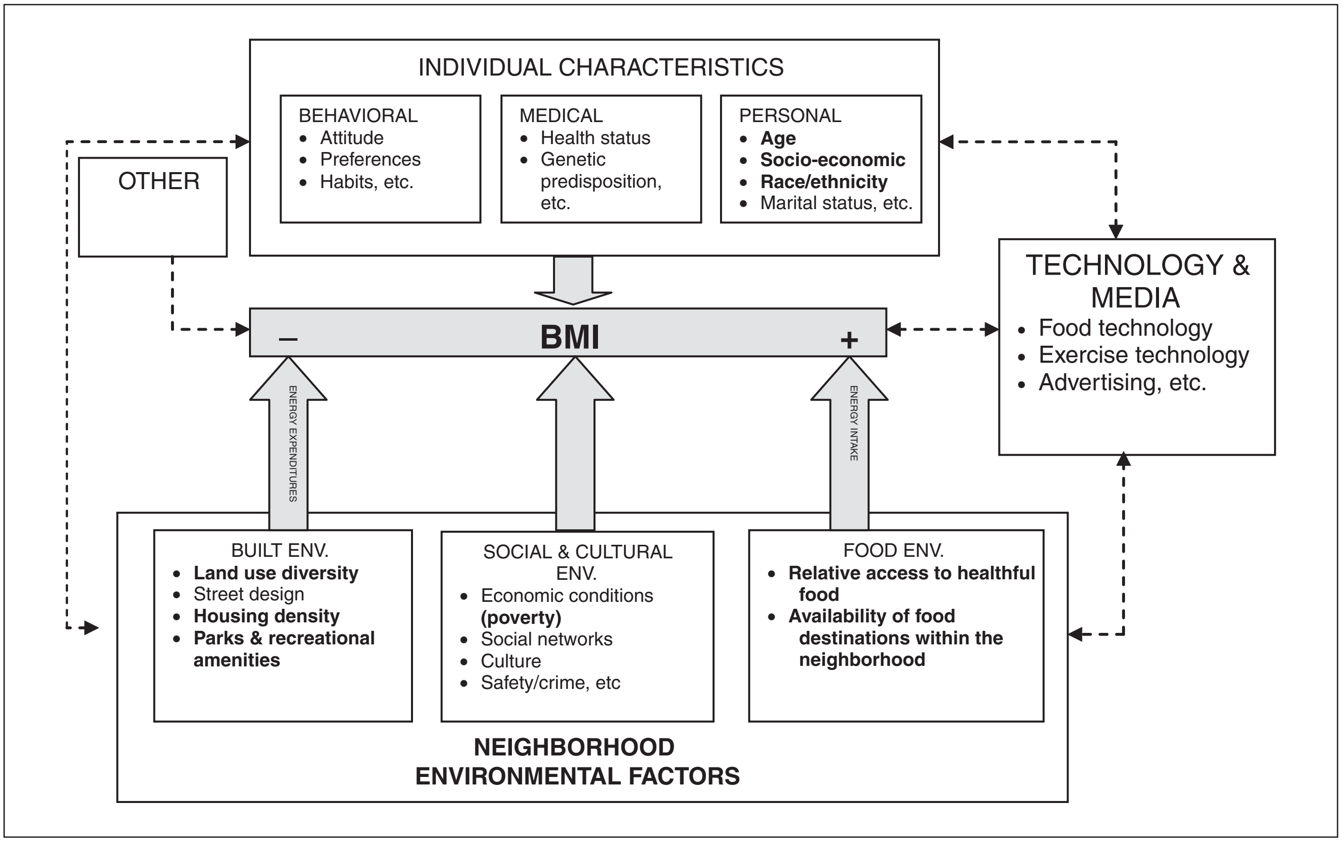

Figure 2. Factors associated with obesity
Note: Factors in bold are included in our analysis.

for healthful food destinations and convenience stores as a proxy for unhealthful food destinations. This is also consistent with previous studies (Morland, Diez Roux, and Wing 2006). Figure 3 illustrates study participants' relative proximity to healthful destinations. Larger circles denote that a subject's home is located in a healthier food environment, farther from a convenience store than a supermarket or grocery store. We hypothesized that the relative proximity to a supermarket or grocery store would be negatively associated with BMI.

Before measuring the second food environment variable, the availability of food destinations within a subject's neighborhood, we looked to precedent literature for definitions of a neighborhood. Typically studies define a neighborhood as a census tract (Morland, Diez Roux, and Wing 2006). However, the sizes of census tracts vary greatly across urban and suburban areas. Therefore, following Dunkley, Helling, and Sawicki (2004), we define a neighborhood as a standardized area encompassed by a five-minute travel-time radius along the street network around a subject's house. The five-minute area, although somewhat arbitrary, is not a cause for concern in this analysis because it normalizes the size (in terms of travel time) of all subjects' neighborhoods. The use of travel time (rather than distance) accounts for the opportunity cost of time associated with traveling to a particular food destination from a resident's home. We computed this area on the basis of a five-minute travel time on foot as well as on the basis of five-minute travel time by car.

In computing the number of food destinations in a neighborhood, we included grocery stores, supermarkets, convenience stores, fruits and vegetable markets, specialty stores, natural food stores, and restaurants. Food destinations were identified on the basis of standard industrial classification (SIC) codes and included the following categories: 5411, 5421, 5431, 5441, 5451, 5461, 5499, and 5812. In the final regression models, all food destinations were recombined into three categories: total number of food stores excluding convenience stores, total number of convenience stores, and number of restaurants. Using further disaggregated categories for food stores was not possible because this would yield zero observations for many subjects. Moreover, the use of disaggregated categories of restaurants—such as fast-food restaurants and sit-down restaurants—was not possible because of inaccurate classification of restaurants in the data, which may have yielded erroneous results.

Women in our sample had an average of 0.24 food stores and 0.56 restaurants within a five-minute walk, and 25 food stores and 64 restaurants within a five-minute drive, of their homes. Figure 4 illustrates high and low access to restaurants

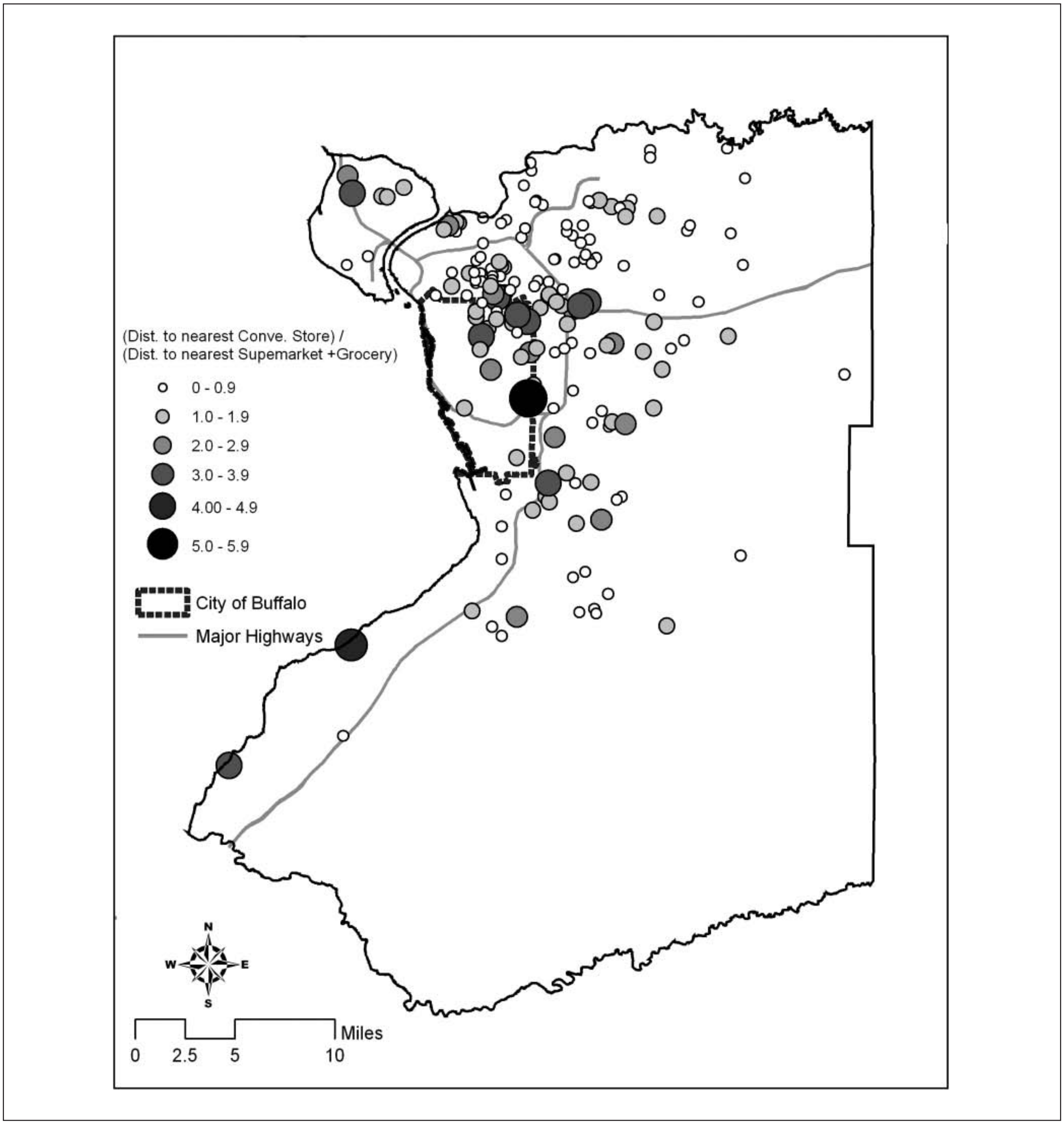

Figure 3. Relative access to healthful foods

within a five-minute walking distance in two subjects' neighborhoods.

We did not have an a priori hypothesis about the *direction* of the influence of the neighborhood food destinations on BMI. A greater number of food destinations in the vicinity of a residence may encourage people to walk (expenditure of energy) as implied by the built environment literature, yet these destinations could also be sites where people go to eat (intake energy).

The food environment data was obtained from the Erie County Food Environment Database described elsewhere in detail in Raja, Ma, and Yadav (2008). Briefly, GIS layers

Figure 4. High and low availability of restaurants

Table 2. Walkability Index

Measure	Definition	Data source
Net residential density	Residential units divided by residential land area (sq. km) in the census block group where a subject lives	U.S. Census 2000 and Erie County parcel data, 2000
Street connectivity	Number of intersections (with 3 or more intersecting streets) per square kilometer within an area accessible by a five-minute walk	Street centerline file, GDT technologies
Land use mix	Measured using Shannon's entropy index for an area accessible by a five-minute walk; ranges from 0 to 1	Erie County parcel-level data, 2002
Park and recreational areas	Proportion of neighborhood area in park or recreational use within an area accessible by a five-minute walk	Erie County parcel-level data, 2002

were developed by geocoding a database of food destinations obtained from Reference USA, a private vendor, in 2003. The database includes a field for the year a business was established and the first year a business was recorded in the database; we used both these fields to verify that the food establishments in subjects' neighborhoods existed *before* 2000 to 2004, the period when BMI was measured for study participants.

There was a large amount of precedent literature to guide the choice of explanatory variables pertaining to the built environment. Similar to Frank et al. (2006), we computed a walkability index for each subject's neighborhood (area encompassed within a five-minute walk) (see Table 2). This index includes four variables: residential density, land use diversity, street design, and the availability of park and recreational areas that may facilitate physical activity within a subject's neighborhood.

We included residential density as a variable since it has been previously been reported to be associated with greater physical activity (Frank et al. 2006). It was measured as the

Figure 5. High and low street intersection density

number of residential units (obtained from U.S. Census 2000) divided by the residential land area (obtained from parcel data).

Diversity of land use, or land use mix (LUM), was measured using an entropy index (Frank et al. 2006; Krizek 2003) as follows:

$$\mathrm{LUM} = \{-\Sigma_k p_i \times \ln(p_i)\} \div k,$$

where p_i is the proportion of each type of land use in a subject's neighborhood and k is the total number of land use types. In this analysis we include residential, commercial, parkland, and community service as land use types. The LUM ranges from 0 to 1, where 0 indicates that land is concentrated in one type of land use and 1 indicates that land is spread uniformly over all possible land uses. For women in our study, land use mix ranged from .23 to .83.

A grid-like street network, which tends to have a higher number of intersections per square kilometers compared to other street layouts such as networks with cul-de-sacs, has been previously reported to be associated with greater walkability (Roemmich, Epstein, Raja, and Yin 2006). Following Frank et al. (2006), we measured the number of intersections per square kilometer of the subject's neighborhood and included it in the walkability index. For women in the present study, the intersection density ranged from 0 intersections per square kilometer to 130 intersections per square kilometer. Figure 5 illustrates the highest and lowest street intersection density available to subjects in our study.

Unlike Frank et al. (2006), we chose to include park area in the walkability index based on previous findings (Epstein et al. 2006; Roemmich, Epstein, Raja, and Yin 2006) that access to parks in one's neighborhood is a strong predictor of physical activity. Specifically, we computed the proportion of public parkland and active recreational land area (e.g., land parcels where a subject may be able to obtain physical activity, for example, a swimming pool) within a subject's neighborhood. On average, women in the study lived in neighborhoods with .01 (or 1 percent) of land area dedicated to parks, although the proportion varied from .01 to .35.

Other than the inclusion of parks and recreational areas, the walkability index is identical to that of Frank et al. (2006). Similar to Frank et al., the z-scores of these four variables were combined to compute a walkability index for each subject's neighborhood. The definition and data source for each variable in the composite walkability index is shown in Table 2. Figure 6 illustrates neighborhoods of two subjects with the highest and lowest walkability scores, respectively.

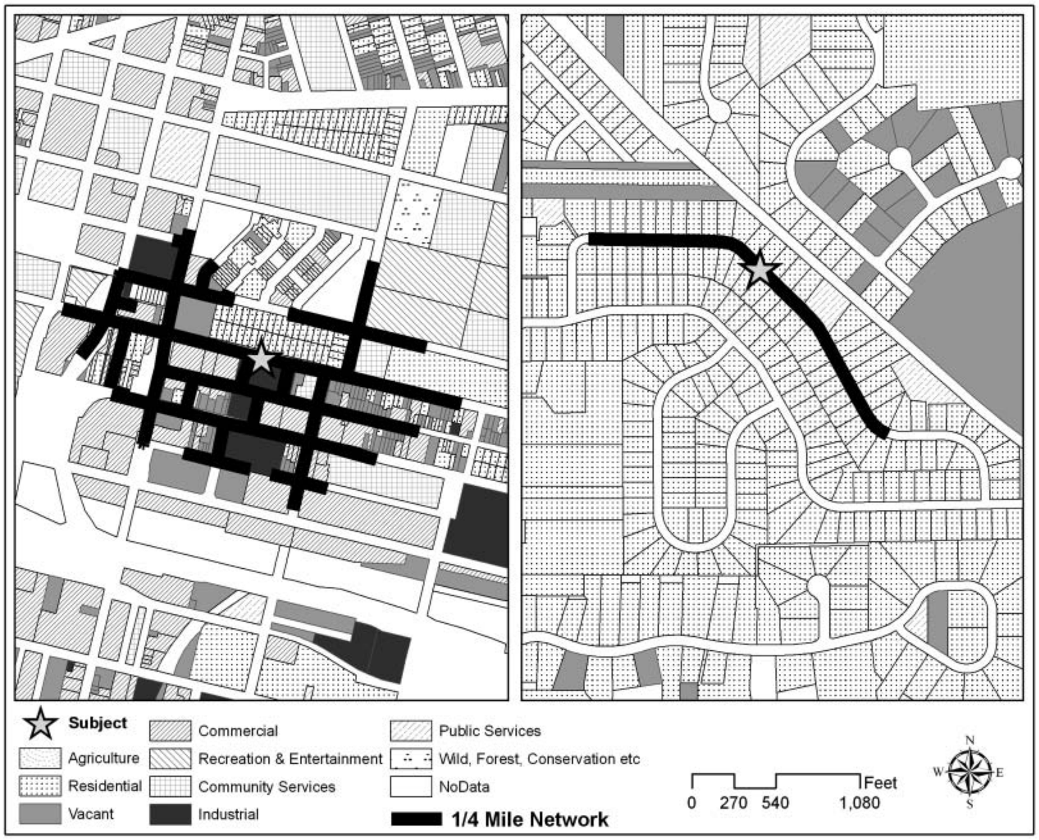

Figure 6. High and low walkability index

The built environment GIS layers were developed from a combination of sources, including the Erie County Government, New York State GIS Clearinghouse, and GDT technologies, a private data vendor. All built environment data was from years 2000 to 2002, which is the same or earlier than the years of BMI observation (2000-2004).[13]

We also controlled for other confounding variables. For example, the social environment—including racial segregation, crime, and poverty—in a neighborhood may influence women's willingness to be physically active, their choice of physical activity, and their BMI (Day 2006). Following Day's (2006) concerns, we include neighborhood poverty, measured as the proportion of population living below the poverty line within a subject's block group (from U.S. Census 2000), as a control variable in the regression model. Neighborhoods with high poverty may be redlined by supermarkets, limiting access to fresh produce for residents.

The association between individual outcomes, such as BMI, and environmental predictors (such as those we discuss above) have the potential to be viewed as environmentally deterministic unless one controls for individual-level characteristics that may influence individual's behaviors and choices, and subsequently their BMI. To account for this likelihood we controlled for individual characteristics including the age, ethnicity, and socioeconomic status of the women in the study.

We used multivariate regression to test the associations between the dependent and independent variables. The highlighted variables in Figure 2 shows the variables tested in the present study. We estimated three regression models. Models 1 and 2 test the association of the neighborhood food environment with BMI, while controlling for the built environment, the social environment, and individual-level factors. The two models differ in that the former includes food destinations available within a five-minute travel time on foot,[14] while the latter includes food destinations within a five-minute travel time by car. Model 3 tests the association of interactions between key food and built environment variables on BMI. In particular, it tests the association of the interaction between land use mix and the availability of restaurants (RTWLK × LUM) on BMI.

Model 1: Association of food and built environments within a five-minute walk with BMI (see Table 1 for definitions of variables):

$$BMI_i = \alpha + \beta_1(FDWLK_i) + \beta_2(RTWLK_i) + \beta_3(FDAC_i) + \beta_4(WLKNDX_i) + \beta_5(POV_i) + \beta_6(AGE_i) + \beta_7(SES_i) + \beta_8(ETH_i) + \varepsilon_i.$$

Model 2: Association of food and built environments within a five-minute drive with BMI:

$$BMI_i = \alpha + \beta_1(FDCAR_i) + \beta_2(RTCAR_i) + \beta_3(FDCAR_i) + \beta_4(WLKNDX_i) + \beta_5(POV_i) + \beta_6(AGE_i) + \beta_7(SES_i) + \beta_8(ETH_i) + \varepsilon_i.$$

Model 3: Association of *interaction* between food and built environments (within a five-minute walk) on BMI:

$$BMI_i = \alpha + \beta_1(FDWLK_i) + \beta_2(RTWLK_i \times LUM_i) + \beta_3(FDAC_i) + \beta_4(POV_i) + \beta_5(AGE_i) + \beta_6(SES_i) + \beta_7(ETHi \times RTWLK_i) + \varepsilon_i.$$

All models were checked for multicollinearity by reviewing variance inflation factors (VIFs) for the explanatory variables in individual models. VIFs for all independent variables were relatively low. The highest VIF was for the interaction variable RTWLK × LUM in model 3, at 3.79, suggesting that multicollinearity does not pose a threat to the model results. All statistical analyses were completed using SAS 9.1.

Results

Influence of the Food Environment and Built Environment on Obesity

The results suggest that the neighborhood food environment is associated with women's BMI (see Table 3). Model 1 demonstrates that, on average, the number of restaurants available within a five-minute walk of subjects' homes is positively associated (p = .037) with their BMI. On average, a unit increase in the number of restaurants available within a five-minute walk is associated with a 0.86 kg/m^2 increase in BMI, holding other factors constant (see Table 3, model 1). Whether the positive association between availability of restaurants and BMI is a result of the abundant supply of restaurants or of the rising trend to eat out is not possible to determine from these data. Nonetheless, this finding is important when one considers that restaurants are the most common type of food destination in Erie County neighborhoods (26.31 per 10,000 people) compared to all other food destinations (e.g., supermarkets are 0.43 per 10,000 people) (Raja, Ma, and Yadav 2008). Restaurants serve increasingly large portion sizes, which increases the possibilities of energy intake. Of course, not all types of restaurant are likely to have a similar influence on BMI (e.g., fast-food versus sit-down); however, discerning this differential influence was impossible because we had no way of accurately distinguishing between types of restaurants in our data set.

We also find that the farther a subject's home from an unhealthful food destination, relative to a healthful food destination, the lower the BMI (p = .025) (see Table 3, model 1). Specifically, as the ratio of distance from a subject's home to a convenience store to the distance from home to a supermarket or grocery store increases by 1, BMI drops by about 1 kg/m^2, holding other factors constant.

Contrary to previous reports (Frank et al. 2006), we find no association between the walkability index of a neighborhood—a composite of land use mix, street intersection, housing density, and park area[15]—and BMI (p = .90). One explanation for this contradictory result is that the various components of the walkability index may not exert an influence on BMI in the same direction. For instance, in our data set BMI has a low positive correlation with land use mix (r = .09) (a similar positive association is reported by Rutt and Coleman 2005), and low negative correlations with the proportion of parks (r = –.09) and street intersection density (r = –.02), respectively. This may result in a statistically insignificant relationship between BMI and the composite walkability index. An alternative explanation may be that neighborhood built environment interacts with certain elements of the food environment, a possibility we examine in the next section.

Because individuals may obtain food by purchasing it farther from a five-minute walk from home, we tested the influence of the food environment on BMI using an alternative model 2, where we replaced the explanatory variables measuring the availability of food destinations within a *five-minute walk* with those measuring availability within a *five-minute drive*.[16] The remaining explanatory variables are similar to model 1. Neither the availability of food stores (p = .55) nor the number of restaurants (p = .49) within a five-minute drive were associated with BMI, although, similar to model 1, the relative access to healthful food destinations has a significant association (p = .09). It is important to note that compared to model 1, which explained BMI to a similar extent as previous studies (Frank et al. 2006), model 2 has a rather low explanatory power as evidenced by the lower R-squared.

Influence of the Interaction between Food Environment and the Built Environment on Obesity

As conceptualized earlier, it is possible that the interaction of a neighborhood food environment and the built environment may influence BMI of residents. For example, the benefit of a diverse land use mix in encouraging physical activity may be offset by the presence of eating establishments that offer residents greater opportunity to eat highly palatable, energy-dense foods. In other words, while a land use mix that includes a restaurant-rich environment may encourage people to walk, the net result may be a net positive energy balance and greater BMI. We test this possibility in model 3. The results from model 3 (R^2 = .15; adjusted R^2 = .11) confirm that the

Table 3. BMI Regression Results

Explanatory variables	Model 1: Five-minute walk				Model 2: Five-minute drive				Model 3: Interaction			
	Coefficient[a]	t-value	p-value	Standardized coefficient	Coefficient[a]	t-value	p-value	Standardized coefficient	Coefficient[a]	t-value	p-value	Standardized coefficient
Intercept	43.83	6.17	.00		47.05	6.47	.00		37.01	9.20	.00	
Individual factors												
SES	**−0.14**	−2.62	.01	−0.21	**−0.15**	−2.89	.00	−0.23	**−0.13**	−2.60	.01	−0.19
AGE	−0.04	−0.46	.64	−0.04	−0.02	−0.24	.81	−0.02	−0.03	−0.39	.70	−0.03
ETH	−1.20	−1.12	.26	−0.10	**−1.88**	−1.74	.08	−0.15				
Built environment												
WLKNDX	0.00	−0.12	.90	−0.01	0.00	−0.13	.89	−0.02				
Food environment												
FDAC	**−1.42**	−2.26	.02	−0.18	**−1.07**	−1.67	.09	−0.13	**−1.40**	−2.23	.03	−0.17
FDWLK	0.37	0.41	.68	0.00					0.63	0.73	.47	0.06
RTWLK	**0.86**	2.10	.04	0.18								
FDDRV					−0.05	−0.59	.55	−0.16				
RTDRV					0.02	0.68	.49	0.16				
Social environment[b]												
POV	0.44	0.05	.96	0.00	1.34	0.13	.89		0.37	0.05	.96	0.00
Interaction variables												
RTWLK × LUM									**4.01**	3.80	.00	0.53
ETH × RTWLK									**−2.05**	−2.81	.01	−0.39
R^2.11				.08				.15				
Adjusted R^2	.07				.03				.11			
F-value	2.53		.01		1.72		.09		4.14		.00	

See Table 1 for definitions of variables.

[a]Coefficients highlighted in bold are statistically significant.

[b]We would have liked to control for crime, but historical crime data at the desired geographic scale of a neighborhood was available only for the city of Buffalo, while our subjects are from twenty different municipalities within the county. Nonetheless, we ran a separate regression for subjects from Buffalo only and found that while crime is a significant predictor of BMI, controlling for crime does not alter the key influence of the food environment variables.

interaction between LUM and the availability of restaurants within a five-minute walk has a positive association ($p \leq .000$) with BMI of women (see Table 3, model 3). In other words, being in an environment with a diverse land use mix increases the chances of eating in that environment. Interestingly, the interaction model also shows that women of color may be more sensitive to the quality of a neighborhood food environment. Specifically, on average, an increase in one restaurant within a five-minute walk of a resident's home is associated with a BMI increase of 0.53 kg/m^2 (= 2.49 – 1.96) among white women, while a similar increase in restaurants is associated with an increase in BMI of 2.49 kg/m^2 among women of color, holding all else constant.

Food Environment or Built Environment: What Has a Greater Influence on BMI?

Finally, to gauge the relative influence of the food environment and the built environment on BMI, we compared the magnitude of the standardized partial slope coefficients.[17] In model 1, the food environment variables have a larger standardized coefficient (b^*) than that of the built environmental variables. The influence of the built environment variables (specifically, that of the number of restaurants within a five-minute walk from subjects' homes [$b^* = .18$] and of the relative proximity of subjects' homes to healthful food destinations [$b^* = –.18$]) surpasses that of the key built environment variable (i.e., the walkability index [$b^* = –.01$]) on BMI. Interestingly, the influence of each of the two food environment variables is *only* slightly smaller than that of an individual's socioeconomic status ($b^* = –.21$). This suggests that the food environment in which we live may have an equally important role to play—say, as a barrier to healthy eating—along with our individual economic characteristics (which may influence what foods we are able to buy and what modes of transportation we are able to avail when confronted with a poor food environment). In models 2 and 3 as well, the standardized coefficients indicate a relative dominance of the food environment over the built environment variables. In summary, the neighborhood food environment plays a greater role than the built environment in explaining the BMI of women in Erie County. These findings are supported by previous research that has found the built environment to be a weaker predictor of physical activity (energy expenditure) for women than for men.

Conclusion

This article expands the framework for understanding environmental correlates of BMI by simultaneously considering the influence of the built environment and the food environment. Using GIS-based measures of the food and built environments and individual-level measures of BMI, this article applies this framework to an exploratory study of women in Erie County, New York. We find that the neighborhood food environment and built environment are strongly associated with the individual BMI of women living in Erie County and that the association between the food environment and BMI surpasses that between the built environment and BMI. While we agree with previous research that the built environment likely plays a significant role in facilitating *physical activity*, we contend that its influence on net energy balance and obesity also depends on the type of food environment available within the neighborhood. In particular, three findings are significant. First, a greater number of restaurants within a five-minute walk of a subject's house is associated with a greater BMI, holding other factors constant. Second, on average, women who live within relative proximity to supermarkets and grocery stores (as opposed to convenience stores) tend to have lower BMIs. Third, and perhaps most important, is that the interaction of the food environment and the built environment in a neighborhood carries significant consequences for obesity. For example, a diverse land use mix, while beneficial for promoting physical activity, has a *net* positive influence on BMI when dominated by restaurants. Future research on the built environment and health must take into account the role of the food environment on women's health.

Our study has several limitations. Most importantly, we do not know where our subjects shopped for food. We were also not able to classify restaurants based on their quality. Fast-food restaurants and sit-down restaurants are treated as a single category even though there is evidence suggesting that the quality of food varies widely across different types of restaurants. This study raises several questions for future research: How do individual behaviors, such as food shopping patterns, food preferences, attitudes toward food, and exercise, mediate the link between the built environment, food environment, and obesity among women? And what explains these behaviors? These questions can help unpack the complex relationship between human behavior and the quality of the food and built environments.

Future research in this area will also require innovation in research design in order to offer greater evidence of causality by exploring the use of longitudinal designs that incorporate panel or lagged analyses. One example is a longitudinal study of individuals who have moved residence in the past few years to see how a change in location (and hence change in exposure to a particular food) and/or built environment affects their physical activity and eating behavior as well as health outcomes.

In recent years, planners have paid significant attention to facilitating physical activity through the design of the built environment. The American Planning Association (APA) has published several articles and reports on the topic (Boarnet 2006). Yet as this article suggests, along with the neighborhood built environment, the food environment in Erie County, New York, is also—and more strongly—associated with women's BMI. Community and regional food planners have begun to recognize the importance of transforming food environments to facilitate healthy living. The APA, for example, recently adopted a policy guide on food that includes several directives geared toward health promotion. Policy number 3A, for example, declares that planners "support food systems that offer healthful and culturally appropriate healthful foods, especially for low income households in urban and rural areas" (APA 2007).

Several planning strategies and tools are available to improve community food (and built) environments to support healthy eating behavior. We identify three—comprehensive plans, regulatory mechanisms, and financial incentives—that can be used individually or in concert to improve community food environments. Planners can expand the scope of comprehensive plans by including food within more traditional elements such as land use and transportation, or as a stand-alone element. References to improving food systems and environments within comprehensive plans, although unusual, have begun to appear within the natural and agricultural element of comprehensive plans (e.g., Madison, Wisconsin, in 2006 and Dane County, Wisconsin, and Marin County, California, in 2007). More recent plans (e.g., Harrison County, Mississippi, in 2008), have included stand-alone sections on health/food. Specifically, comprehensive plans can direct policies to ensure a minimum number of supermarkets (or other source of healthful foods) within neighborhoods, especially those where there are low rates of automobile ownership.

A second strategy is to use regulatory mechanisms such as zoning to facilitate land uses dedicated to healthy food sources such as supermarkets, green grocers, community gardens, and farmers' markets and to limit less healthy food destinations. An innovative precedent is a recent special regulation adopted in New York City that offers higher floor area ratios to fresh food stores in underserved neighborhoods. The definition of fresh food stores includes stores "where at least 6,000 square feet of floor area, or cellar space used for retailing, is used for the sale of a general line of food and nonfood grocery products such as dairy, canned and frozen foods, fresh fruits and vegetables, fresh and prepared meats, fish, and poultry, intended for home preparation, consumption and utilization," and "at least 500 square feet of such retail space shall be used for the sale of fresh produce" (NYC 2009).

The final strategy is to use financial incentives to support the entry of healthy food destinations into local markets. In particular, states and local governments can target economic development subsidies and incentives toward local grocery stores that fulfill the dual goals of offering fresh fruits and vegetables *as well as* employment opportunities through new and expanded local food businesses. For example, the state of Pennsylvania's Fresh Food Financing Initiative (FFI) draws on a multi-million-dollar public private fund to award grants for equipment, acquisition, construction, renovation, leasehold improvements, and energy-efficiency measures for grocery store development in underserved neighborhoods. These planning, regulatory, and fiscal tools can be used individually or collectively to improve food environments.

Ultimately, to design healthy communities, planners must integrate the goals of "healthy eating" and "active living" by addressing the shortcomings of *both* the food *and* built environments. Instead of just building a sidewalk to facilitate walking, it is important to ask, Does the sidewalk lead to a healthful food destination?

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Notes

1. The description of obesity as a net result of energy expenditure and intake is a partial one. It ignores, for example, the many discourses that shape individual and community understanding of body (Gard and Wright 2001). However, our purpose in this article is not to "explain" obesity but to simply shed light on aggregate trends—in this case of the association between spatial patterns in the built environment and levels of BMI in the population.
2. We recognize that the food environment (such as the presence of a fast-food stores in a commercial plaza) could be considered a subfeature of the built environment. However, for the purpose of this article, we define the food environment as a vector of factors that *directly* impact where people are able to purchase, grow, or otherwise obtain food of a particular quality and price for consumption. For example, if two different neighborhoods were home to a commercial plaza each, the built environment of each would be described as similar in terms of land use (holding everything else constant). However, if one commercial plaza were to contain a supermarket and another were to contain a fast-food restaurant, then the food environment in the neighborhood would be significantly different even though the *physical* built environment would be similar.
3. Frank et al. (2006) included both women and men in their study. Previous studies, which typically include both women and men in their sample, report stronger relationships between built environment and obesity for men than for women.

4. For discussion of structural barriers in the food system, see Marion Nestle (2002) on the role of the food industry in pushing less healthful foods through extensive expenditures on food advertising, Winson (2004) on the colonization of supermarkets by food manufacturers through the introduction of "pseudo food" products, and Caton Campbell (2004) and Pothukuchi and Kaufman (1999) on the problems within the conventional food system.
5. Roemmich, Epstein, Raja, and Yin's (2006) study focuses on youth.
6. Such walkable features are also desirable for other planning goals such as promoting community, reducing crime, and reducing traffic.
7. As defined by Ewing et al. (2003).
8. In a different study, Handy, Cao, and Mokhtarian (2006) report that even after accounting for self-selection bias, the neighborhood built environment influences residents' physical activity.
9. To be sure, food environments are not inadequate across all minority neighborhoods. Short, Guthman, and Raskin (2007) and Raja, Ma, and Yadav (2008) report the presence of an adequate number of *small* grocery stores in minority neighborhoods. Furthermore, Short, Guthman, and Raskin find that the small stores contribute to community food security by serving affordable, healthful, and culturally appropriate produce in an immigrant neighborhood.
10. A power analysis shows that for a statistical power of 0.80, a sample size of 172 is sufficient to detect a medium-sized effect ($f^2 = 0.15$) in a model with nine independent variables.
11. Since in the original clinical study women were recruited along with their child, all the women included in this particular analysis had at least one child at the time of data collection.
12. The Hollingshead index has been tested for reliability and is used extensively in the health literature (see, for example, Epstein et al. 2007).
13. Although having built environment data from a simultaneous or preceding period from the date of BMI observation is important from the point of view of causality, this is not a significant concern in Erie County since it is a slow-growth county where little land use change has occurred in the past decade.
14. This is equivalent to a distance of about one-quarter mile.
15. Frank et al. (2006) do not include proportion of park area in the walkability index. Even when we exclude proportion of park area from the walkability index, we find no association between the walkability index and BMI in the regression model.
16. We did not put the five-minute walk and five-minute drive variables in the same model because of high collinearity between them.
17. Standardized slope coefficient of an independent variable was computed by multiplying its partial slope coefficient by the ratio of the standard deviation of the independent variable to that of the dependent variable. Because standardized slope coefficients are unit-free, they are a useful measure for comparing the relative influence of different explanatory variables on a dependent variable.

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