Neighborhood Risk Factors for Obesity

Russ P. Lopez

Abstract

LOPEZ, RUSS P. Neighborhood risk factors for obesity. *Obesity.* 2007;15:2111–2119.

Objective: The goal of this study was to explore neighborhood environmental factors associated with obesity in a sample of adults living in a major U.S. metropolitan area.

Research Methods and Procedures: This was a multi-level study combining data from the U.S. Behavioral Risk Factor Surveillance System with data from the U.S. Census. A total of 15,358 subjects living in 327 zip code tabulation areas were surveyed between 1998 and 2002. The outcome was obesity (BMI >30), and independent variables assessed included individual level variables (age, education, income, smoking status, sex, black race, and Hispanic ethnicity), and zip code level variables (percentage black, percentage Hispanic, percentage with more than a high school education, retail density, establishment density, employment density, population density, the presence of a supermarket, intersection density, median household income, and density of fast food outlets).

Results: After controlling for individual level factors, median household income [relative risk (RR) = 0.992; 95% confidence interval (CI) = 0.990, 0.994], population density (RR = 0.98; 95% CI = 0.972, 0.990), employment density (RR = 1.004; 95% CI = 1.001, 1.009), establishment density (RR = 0.981 95% CI = 0.964, 0.999), and the presence of a supermarket (RR = 0.893; 95% CI = 0.815, 0.978) were associated with obesity risk. Fast food establishment density was poorly associated with obesity risk.

Discussion: Where one lives may affect obesity status. Given the influence of the presence of a supermarket on obesity risk, efforts to address food access might be a priority for reducing obesity.

Received for review September 11, 2006.
Accepted in final form January 17, 2007.
The costs of publication of this article were defrayed, in part, by the payment of page charges. This article must, therefore, be hereby marked "advertisement" in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.

Department of Environmental Health, Boston University School of Public Health, Boston, Massachusetts.
Address correspondence to Russ P. Lopez, Department of Environmental Health, Boston University School of Public Health, Talbot 2E, 715 Albany Street, Boston, MA 02118.
E-mail: rptlopez@bu.edu

Key words: epidemiology, environmental factors, socioeconomic deprivation

Introduction

The health effects of obesity include cardiovascular disease risk, increased risk of certain cancers, and overall increased mortality (1,2). While the proximate causes of obesity are well known (too many calories consumed and too few calories expended will lead to weight gain over time), the more distant factors associated with obesity are less understood (3,4). Major unresolved issues include risk factors for overeating and the reasons for continued underexpenditure of calories.

Obesity risk is not randomly distributed across the population. Certain groups are more likely to be obese than others. The reasons for this inequity are not known but may result from a combination of environmental, biological, and cultural factors. In general, older, poorer, and less educated individuals are more likely to be obese. Ethnic and racial minorities, particularly women of color, also have higher obesity risks (5).

One factor that may play a role in obesity risk is the built environment, which consists of human-made factors, including the characteristics, placement, and distribution of residences, neighborhoods, and metropolitan areas. Modern urban planning and public health had common beginnings in the 19th century urban reform movements that sought to mitigate the impacts of immigration, urbanization, and industrialization. One important result of this combined effort were building codes to reduce the risk of tuberculosis and zoning codes to create distances between residences and noxious land uses (6). The two fields diverged in the last half of the 20th century but have seen a reuniting because of an interest in studying the impact of the built environment on health (7,8).

Several studies have found an association between obesity risk and urban sprawl, a pattern of development characterized by decentralization, low density land uses, and automobile-focused transportation systems (9–12). One study found a relationship between neighborhood form, including street connectivity (the size of blocks, the number of intersections, and the ability to get from one part of a community to another in a direct manner or through multi-

ple pathways), and physical activity and obesity risk in Atlanta, GA (13). Similar results were found in a parallel study in Seattle/King County, WA (14). Another study that used data from the National Health Examination Study found that residents in neighborhoods built before 1973 were more likely to walk. The authors hypothesized that older neighborhoods were more likely to have highly connected street patterns, walkable destinations, and other amenities that may ultimately affect obesity risk (15). Other studies have found that mixed use communities, accessible parks, the presence of public transportation, walkable destinations, sidewalks, and other neighborhood factors can influence physical activity patterns and/or obesity risk (16–19).

An additional factor that might affect obesity risk is the presence of supermarkets. Research suggests that the accessibility of affordable, high quality food is associated with better diets and nutrition (20). These types of foods are more likely to be found in supermarkets than in convenience stores, and people who eat meals prepared at home, presumably made from foods purchased in supermarkets rather than purchased pre-made at a takeout restaurant or consumed at a restaurant, were more likely to have a reduced obesity risk (21). Unfortunately, there is evidence that supermarkets are less likely to be found in low income and non-white neighborhoods (22). The term "food desert" has been coined to describe these areas where it is difficult to purchase quality, nutritional food (23). Conversely, there are concerns that fast food consumption negatively impacts obesity (24,25). There is some evidence that vulnerable populations are disproportionately exposed to fast food establishments (26,27).

Health problems with complex etiologies potentially involving both individual and neighborhood factors are difficult to study. Multi-level modeling has been used to study effects above the individual level while simultaneously controlling for individual level risk factors (28–30). It allows for an apportionment of risk between levels and addresses concerns about ecologic fallacies, problems that arise when findings on higher levels are misapplied to individuals.

This study examines the role of neighborhood, the communities in which people live, in the distribution of obesity risk. Neighborhoods as used here are defined as Zip Code Tabulation Areas (ZCTAs),[1] U.S. Census-drawn polygon approximations of U.S. Postal Service zip codes. This study uses multi-level modeling to explore the association of obesity risk with individual and neighborhood level factors simultaneously. It combines data from the Behavioral Risk Factor Surveillance System (BRFSS) provided by the Massachusetts Department of Public Health (Mass DPH) with data from U.S. Census sources.

[1] Nonstandard abbreviations: ZCTA, Zip Code Tabulation Area; BRFSS, Behavioral Risk Factor Surveillance System; Mass DPH, Massachusetts Department of Public Health.

Research Methods and Procedures

This study uses data from the BRFSS, which is a national annual telephone survey overseen by the federal Centers for Disease Control and Prevention but conducted by individual states. States are allowed to add their own questions to the national survey; and beginning in 1998, Massachusetts asked respondents to report their zip code of residence. This detailed residential data necessitated special attention to the privacy of BRFSS participants. To ensure confidentiality, Mass DPH released a limited subset of variables, representing the most parsimonious data, for the analysis in this study.

Neighborhood data were from the 2000 U.S. Census (31) (percentage black, percentage Hispanic, percent post-high school education, population density, median income, intersection density) and the 2001 County Business Patterns (32) (establishment density, employment density, supermarket presence, fast food establishment density). The business patterns reports include data only by zip code, and 2000 Census data can also be downloaded by zip code. Together, these data sources provide a rich set of variables that represent a variety of potential risk factors for obesity. The business data are developed by the Census and are based on sources such as Social Security Administration, Internal Revenue Service, and Bureau of Labor Statistics and include the number of total establishments with employees, the total number of paid employees, and numbers of establishments of varying types. The establishment data include the number of fast food restaurants (industry code 722211, limited service restaurants) and supermarkets (industry code 445110, supermarkets and other grocery stores, excluding convenience stores, with 50 or more employees).

The Census also provides a set of cartographic files (TIGER, Topographically Integrated Geographic Encoding and Referencing system) that contain the layouts of all streets across the United States, as well as polygons representing census tracts and ZCTAs. Using Geographic Information Systems (GIS), street intersections can be converted to nodes, true intersections extracted (eliminating pseudo-nodes, those representing curving streets and dangles, ends of cul-de-sacs and courts) and the number of intersections counted. This count can then be divided by the area of each ZCTA to produce a measure of the density of intersections in each ZCTA.

Eastern Massachusetts ZCTAs vary in size from a few acres to over 80 square miles (the mean is 10.57 square miles). The BRFSS data do not include a subject's street address or census tract. In addition, business data are not available by tract. Thus, only ZCTAs provided the full range of potential neighborhood variables. Furthermore, Eastern Massachusetts tracts have a size distribution similar

Table 1. Individual level variables

Variable	Description	Hypothesized association with obesity
Age	Self-reported age in years (from BRFSS)	Increased age is associated with increased BMI and increased likelihood of obesity perhaps because of decreased physical activity or slower metabolism.
Education	Self-reported educational attainment (from BRFSS)	More highly educated individuals tend to report increased physical activity, greater health protection activities, and lower levels of risk behaviors. Access to health care and insurance may also be a factor reducing obesity risk.
Income	Self-reported total household income (from BRFSS)	Individuals in higher income households tend to report increased physical activity, greater health protection activities, and lower levels of risk behaviors. Access to health care and insurance may also be a factor reducing obesity risk.
Smoking	Self-reported ever smoked 100 cigarettes or equivalent (from BRFSS)	While smoking is associated with other health risk behaviors, smoking may also reduce total weight due to reduced calorie consumption or other factors.
Sex	Self-reported sex (from BRFSS)	Women are at greater risk for obesity than men.
Black	Self-reported as being of black race or of mixed race including black (from BRFSS)	Black race has been suggested as a risk factor for increased obesity perhaps because of culture, diet, genetic or other factor.
Hispanic	Self-reported Hispanic ethnicity (from BRFSS); people of Hispanic ethnicity may be of any race	Hispanic ethnicity has been suggested as a risk factor for increased obesity perhaps because of culture, diet, genetic or other factor.

BRFSS, Behavioral Risk Factor Surveillance System.

to that of ZCTAs; the very largest and the very smallest of both are often coextensive. Zip codes have been used in health research (33,34) and in the study of the access to food (35,36).

To avoid issues created by rural-urban differences, the analysis was limited to data from eastern Massachusetts, roughly from Cape Cod to Worcester between the New Hampshire and Rhode Island state borders. This area generally corresponds to the Massachusetts portion of the 2000 Boston Consolidated Metropolitan Statistical Area and the Barnstable Metropolitan Area.

Obesity was defined as a BMI greater than 30 kg/m^2 based on self-reported height and weight. BMI was not adjusted for reporting biases or for varying obesity standards for differing demographic groups.

Individual variables, previously found to be or hypothesized to be associated with obesity risk, were provided by the Mass DPH. These included age, education, income, race/ethnicity, smoking status, and sex. It was hypothesized that increasing age, non-white race/ethnicity, and being female would be associated with higher obesity risk; being a smoker or having a higher income or education would be associated with decreased obesity risk (Table 1).

Neighborhood (ZCTA) level variables included measures of the built environment: intersection density, employment density, retail establishment density, population density, fast food density, the presence of a supermarket, and total employment establishment density. With the exception of fast food density, it was hypothesized that as density increased, the risk of obesity would decline. Other ZCTA level variables that reflect the social/demographic environment included in the study were percentage black race, percentage Hispanic ethnicity, percentage of the population over 25 with a high school diploma or more education, and household median income (all from the 2000 Census). The race/ethnicity variables were thought to be associated with increased obesity risk; the other variables were hypothesized to be associated with declining obesity risk. The

supermarket variable was dichotomized as a yes/no variable because of the large number of ZCTAs with no supermarkets and the relatively small number of ZCTAs with more than one supermarket, and because we hypothesized that although there might be price and quality benefits resulting from the competition among multiple supermarkets, these benefits were small compared with those derived from the presence of any supermarket (Table 2).

BRFSS data must be analyzed taking into account the special sampling procedures it uses. Data must be weighted to avoid inaccurate point estimates, and sampling frames must be accounted for to avoid overly large confidence intervals. The variables for this methodology were included in the BRFSS dataset released by the Mass DPH. Multilevel modeling was used to allow for simultaneous consideration of neighborhood and individual level risk factors. This allows for the assignment of risk between the various levels of effects.

First, descriptive statistics of the sample were calculated. Then bivariate analysis of potential individual and neighborhood level risk factors were calculated, with obesity as the dependent variable. Next, a series of multiple logistic regression models were analyzed. Variables were eliminated from the final model if the preliminary model found no association between the variable and obesity risk. Relative risks were adjusted for the fact that obesity is fairly common for the subject population (37). Multivariate hierarchical linear modeling allows for the allocation of variance in the sample among levels. This was calculated for the final model.

ArcView Geographic Information System 3.2 (38) was used for the Geographic Information System analysis. Stata 9.0 (39) was used for descriptive statistics. HLM 6.0 (40) was used for multi-level modeling.

Results

The study sample consisted of 15,358 respondents who participated in the Massachusetts BRFSS from 1998 to 2002 and had a self reported zip code inside the study area. They resided in 327 zip codes. The obesity rate varied substantially across demographic subgroups, with white men having the lowest obesity rate and black women having the highest (Table 3). The obesity rate in this sample (19.8%) was higher than that in Massachusetts as a whole (16.8% in 2000).

Neighborhood level factors were calculated and show a great deal of diversity among ZCTAs reflecting the different neighborhood built and social environments between inner city Boston and its most distant suburbs. There were two ZCTAs (0.6%) without any retail establishments and 85 (26%) without any fast food restaurants. A total of 160 (48.9%) ZCTAs did not have a supermarket. The population density ranged from 11 to over 61,000 persons per square mile. The Census did not report median income for one ZCTA because of the small number of households in that area, and one ZCTA consisted of a single road without any intersections (the road intersected another road in the adjoining ZCTA) (Table 4).

All of the individual level variables performed as predicted in the bivariate analysis. The social and demographic ZCTA level variables all performed as predicted. For example, a 1% increase in the percentage of black residents resulted in a 0.539% increase in obesity risk; a 1% increase in the percentage of Hispanic residents was associated with a 0.717% increase in obesity risk. Neither the supermarket or fast food density variables were associated with obesity risk (Table 5).

In the initial multiple regression analysis, the median income variable was found to be associated with obesity risk (each $1000 increase in median household income resulted in a 0.6% decrease in obesity risk). A 1000 person per square mile increase in population density resulted in a 2.2% decrease in obesity risk, the presence of a supermarket resulted in a 10.3% decrease in obesity risk, 100 more establishments changed obesity risk by a 2.1% decrease, and a 100 person increase in total employment increased obesity risk by 0.5.

Five ZCTA level variables were in the final model. As median income, population density, and establishment density increased, the risk of obesity declined by 0.8%, 2%, and 1.9%, respectively. As employment density increased, obesity risk increased by 0.4%. Having one or more supermarkets in a ZCTA decreased the risk of obesity by 10.7%; ~11% of the variation in the final model was attributable to neighborhood level factors (Table 6).

Discussion

This study of Massachusetts adults based on a telephone survey and census-derived business and neighborhood data found that five neighborhood factors were associated with changes in obesity risk after individual level factors were controlled for: median household income, population density, employment density, establishment density, and the presence of a grocery store. Other neighborhood factors that have been hypothesized to be related to obesity did not affect risk in this model, including fast food density, intersection density, retail density, and various neighborhood level demographic variables.

The use of self-reported height and weight may be problematic. Research suggests that self-report may result in underestimates of obesity prevalence (41). The BRFSS has been used multiple times to study obesity, including obesity risk at the state and local level (42). Also, this study used obesity as a categorized dependent variable rather than BMI as a continuous variable. The cutoff between obese and non-obese may be arbitrary, and there may not be significant health differences between persons with a BMI just under and over 30.

Table 2. Neighborhood-level variables

Variable	Description	Hypothesized association with obesity
Percentage black	Number of persons reporting black race divided by total number of persons (from 2000 Census)	Potential lack of, or poorly maintained, infrastructure, including street lights, sidewalks, public transportation, or parks, would reduce physical activity. Public safety conditions or perceptions may decrease physical activity. Socioeconomic conditions or lack of private investment may reduce quality or availability of recreation facilities or places that sell nutritious food. Targeted advertising may include less healthy consumer products.
Percentage Hispanic	Number of persons reporting Hispanic ethnicity divided by total number of persons (from 2000 Census)	Potential lack of, or poorly maintained, infrastructure, including street lights, sidewalks, public transportation, or parks, would reduce physical activity. Public safety conditions or perceptions may decrease physical activity. Socioeconomic conditions or lack of private investment may reduce quality or availability of recreation facilities or places that sell nutritious food. Targeted advertising may include less healthy consumer products.
Percentage post-high school education	Number of persons 25 years or older reporting having graduated from high school or equivalent divided by the total number of persons 25 years or older (from the 2000 Census)	Neighborhoods with higher education may have better access to parks, better maintained infrastructure, and increased food options, all resulting in more physical activity and/or decreased caloric intake.
Retail density	Number of retail establishments divided by the area in square miles, in hundreds (from 2001 County Business Patterns)	Greater retail density may represent more destinations and better walkability or increase ease of health-promoting behaviors
Establishment density	Number of all establishments divided by the area in square miles, in hundreds (from 2001 County Business Patterns)	Increased establishment density may mean increased likelihood of walking, less travel time to work or to other destinations, and greater consumer choice of healthy food.
Population density	Total population divided by the area in square miles, in thousands (from 2000 Census)	Areas with higher population density may have more destinations closer to subjects' homes, reducing time in cars and promoting walking and bicycling as transportation alternatives.
Yes supermarket	The presence of a supermarket or grocery store with 50 or more employees (from 2001 County Business Patterns)	The presence of a supermarket may make lower cost or more nutritious food available. The lack of a supermarket may promote unhealthy eating habits.
Intersection density	Calculated from 2000 Census street shape files using Geographic Information Systems in thousands per square mile	A measure of "street connectivity." Areas with greater connectivity make walking safer and more efficient and promote pedestrian activity.

Table 2. Continued

Variable	Description	Hypothesized association with obesity
Median income	In thousands, reported by 2000 Census	Neighborhoods with higher median income may have better access to parks, better maintained infrastructure, and increased food options, all resulting in more physical activity and/or decreased caloric intake.
Fast food density	Number of limited-service restaurants divided by area in square miles (from 2001 County Business Patterns)	Increased number of fast food outlets may promote more meals outside home or may increase consumption of high fat meals, leading to higher calorie intake.

It is not clear why this study population had a greater prevalence of obesity than Massachusetts as a whole; perhaps it is the result of its having a smaller percentage of non-Hispanic whites than the statewide population. This study did not find an association between sex and obesity status. This may be due to special unknown circumstances in the study population, reporting issues, or other unknown factors.

It should be noted that because the study population was 81% non-Hispanic white and that the majority of ZCTAs were overwhelming white, the influence of black and Hispanic neighborhood demographics on obesity risk might not have been able to be determined by this study. Other studies have found that the racial characteristics of neighborhoods do influence obesity risk (43,44).

Increasing population density may be associated with greater walkability, more destinations for walking, increased likelihood that a person will use automobile alternatives, or amenities that increase the possibility that physical activity will take place. The high degree of collinearity between population density and intersection density might be responsible for the latter's poor performance in this study, although when the two were added to the full model separately, population density still outperformed the intersection variable. If studies on other areas find a similar pattern of high correlation, it might mean that the more easily calculable population density variable can be used as a proxy for the more difficult to calculate intersection density measure.

Table 3. Descriptive statistics

	Number	Percent obese (BMI >30 kg/m^2)
Black		
Women	750	35.47
Men	469	18.98
Hispanic		
Women	1118	25.40
Men	625	20.96
White		
Women	6465	21.79
Men	5931	18.11
Full sample		20.27

The association between the presence of a supermarket and obesity risk suggests that efforts to address food access and the presence of food deserts in some communities warrant the public policy attention they have received. The relative risk found here, 0.893, was similar to the 0.83 odds ratio found by a study on the effects of supermarkets on obesity risk in Mississippi, Maryland, North Carolina, and Minnesota (45). This association may not represent any actual causal pathway, but if it is indicative of the importance of low cost, quality, and selection (factors generally associated with both better nutrition and supermarkets), then the economic revitalization of poor neighborhoods and communities of color, which often includes the addition of a supermarket as a priority, is a public health issue.

Many observers of the U.S. obesity epidemic have suggested that fast food establishments are a contributing factor to the growing obesity problem in this country. The fast food variable in this study may not have been associated with obesity risk because fast food is ubiquitous and most ZCTAs had one or more establishments. Or it may be that people are willing to drive relatively large distances to a fast food establishment, and the presence of such a place nearby is not indicative of its being used by residents. The County Business Pattern definition of fast food establishment includes both franchised and independent establishments that serve a variety of foods with a spectrum of nutritional quality that may have affected the results here. Finally, it may be that most fast food patronage occurs at lunch, and because this is a residential study, it does not appropriately

Table 4. Zip code-level summary statistics

Variable	Mean	SD	Minimum	Maximum
Percentage black	0.033	0.085	0	0.81
Percentage Hispanic	0.047	0.089	0	0.76
Percentage high school diploma or greater	0.86	0.098	0.45	1
Density (1000s)	3.91	6.45	0.012	61.2
Supermarket	0.51	0.5	0	1
Median income ($1000s)	60.89	21.87	0	153.9
Intersection density (1000s)	2.27	4.18	0	44.04
Retail establishment density (100s)	0.227	0.76	0	8.63
Establishment density (100s)	1.99	8.07	0.009	90
Employment density (100s)	6.13	33.7	0.002	372.8
Fast food density	6.93	29.26	0	348.8

measure fast food establishment exposure. It should be noted that other studies have also failed to find a link between neighborhood fast food density and obesity status (46,47). This study does not suggest that there is no causal link between fast food consumption and obesity, only that residential proximity may not be the key factor in any such link.

There are a number of limitations to this study, and its results should be interpreted cautiously. Most importantly, associations found here are statistical outcomes only and do not necessarily imply degree of causality. This study is cross-sectional, and people with varying obesity risk may seek out neighborhoods that reinforce their pre-existing obesity status: obese people may choose neighborhoods where they can drive, while the non-obese may prefer communities where they can walk. The evidence on the temporal role of neighborhood choice and obesity risk is limited at this time. The Massachusetts version of the BRFSS is available in only English and Spanish and may not adequately include those who speak other languages. In addition, the effects of increasing cell phone usage and the ongoing problem that low-income households may not have access to telephones may have biased the results in unknown ways. The increasing difficulty in reaching households by phone may also be problematic.

Finally, the inaccuracies of self-reported height and weight may have affected the distribution of obesity risk in ways that influenced the outcomes found here. The degree of these effects, if any, cannot be determined.

This study of adults in eastern Massachusetts found that neighborhood level factors of median income, establishment density, population density, and the presence of a supermarket were associated with decreased obesity risk after controlling for individual level factors. The neighborhood level factor of employment density was associated with increased obesity risk. Two other neighborhood level

Table 5. Bivariate analysis

	Relative risk (95% confidence interval)
Individual-level variables	
Age	1.008 (1.005, 1.009)†
Education	0.891 (0.858, 0.925)†
Income	0.971 (0.957, 0.984)†
Smokers	0.828 (0.745, 0.919)†
Sex	1.087 (1.005, 1.172)†
Black	1.366 (1.153, 1.632)†
Hispanic	1.168 (1.009, 1.343)*
Zip code tabulation area-level variables	
Percentage black	1.539 (1.093, 2.059)*
Percentage Hispanic	1.717 (1.198, 2.319)†
Percentage post-high school education	0.258 (0.185, 0.358)†
Retail density (100s)	0.902 (0.779, 1.041)
Establishment density (100s)	0.997 (0.976, 1.002)
Employment density (100s)	0.998 (0.994, 1.002)
Population density (1000s)	0.991 (0.989, 0.998)*
Yes supermarket	0.931 (0.841, 1.028)
Intersection density (1000s)	0.982 (0.969, 0.995)†
Median income (1000s)	0.994 (0.991, 0.996)†
Fast food density	0.996 (0.991, 1.001)

* Significant at the 0.05 level.
† Significant at the 0.01 level.

Table 6. Multiple regression analysis

	Full model [OR (95% CI)]	Final model [OR (95% CI)]
Individual-level variables		
Age	1.006 (1.003, 1.009)†	1.007 (1.005, 1.009)†
Education	0.926 (0.889, 0.964)†	0.925 (0.888, 0.963)†
Income	0.990 (0.976, 1.006)	0.991 (0.976, 1.006)
Smokers	0.817 (0.733, 0.909)†	0.817 (0.733, 0.910)†
Sex	1.061 (0.980, 1.144)	1.061 (0.981, 1.146)
Black	1.445 (1.188, 1.708)†	1.455 (1.217, 1.716)†
Hispanic	1.153 (3987, 1.343)	1.160 (0.997, 1.341)
Zip code tabulation area-level variables		
Percentage black	1.166 (0.752, 1.701)	
Percentage Hispanic	0.853 (0.456, 1.470)	
Percentage post-high school education	0.685 (0.233, 1.322)	
Retail density (100s)	0.981 (0.815, 1.171)	
Population density (1000s)	0.978 (0.964, 0.994)†	0.980 (0.972, 0.990)†
Yes supermarket	0.897 (0.816, 0.984)*	0.893 (0.815, 0.978)*
Median income ($1000s)	0.994 (0.991, 0.998)†	0.992 (0.990, 0.994)†
Establishment density (100s)	0.979 (0.964, 0.995)*	0.981 (0.964, 0.999)*
Employment density (100s)	1.005 (0.998, 1.011)	1.004 (1.001, 1.009)*
Fast food density	1.001 (0.992, 1.011)	
Intersection density (1000s)	1.005 (0.976, 1.033)	

OR, odds ratio; CI, confidence interval.
* Significant at the 0.05 level.
† Significant at the 0.01 level.

factors often theorized to be associated with obesity risk, intersection density and fast food density, were not associated with changes in obesity risk in this study. If the associations found here reflect underlying risk factors, it could be that the built, social, and economic environments may have an important impact on the distribution of obesity prevalence.

Acknowledgments

This study was supported by Grant R25 ES12084-03S1 from the National Institute of Environmental Health Sciences (NIEHS), NIH. Its contents are solely the responsibility of the author and do not necessarily represent the official views of NIEHS, NIH.

References

1. **Bianchini F, Kaaks R, Vainio H.** Weight control and physical activity in cancer prevention. *Obes Rev.* 2002;3:5–8.
2. **Blair S, Nichaman M.** The public health problem of increasing prevalence rates of obesity and what should be done about it. *Mayo Clin Proc.* 2002;77:109–13.
3. **Weinsier R, Hunter G, Heini A, Goran M, Sell S.** The etiology of obesity: relative contribution of metabolic factors, diet, and physical activity. *Am J Med.* 1998;105:145–50.
4. **Bray G, Champagne C.** Beyond energy balance: there is more to obesity than kilocalories. *J Am Diet Assoc.* 2005; 105(suppl):17–23.
5. **Schoenborn C, Adams P, Barnes P.** Body weight status of adults: United States, 1997–98. In: *Advance Data.* Hyattsville, MD: National Center for Health Statistics; 2002.
6. **Corburn J.** Confronting the challenges in reconnecting urban planning and public health. *Am J Public Health.* 2004;94: 541–6.
7. **Jandy S, Boarnet M, Ewing R, Killingsworth R.** How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002;23(Suppl 2):64–73.
8. **Northridge M, Sclar E, Biswas P.** Sorting out the connections between the built environment and health: a conceptual framework for navigating pathways and planning healthy cities. *J Urban Health.* 2003;80:556–68.
9. **Lopez R.** Urban sprawl and risk for being overweight or obese. *Am J Public Health.* 2004;94:1574–9.
10. **Ewing R, Schmid T, Killingsworth R, Zlot A, Raudenbush S.** Relationship between urban sprawl and physical activity, obesity, and morbidity. *Am J Health Promot.* 2003; 18:47–57.
11. **Sturm R, Cohen D.** Suburban sprawl and physical and mental health. *Public Health.* 2004;118:488–96.

12. **Vandegrift D, Yoked T.** Obesity rates, income, and suburban sprawl: an analysis of US states. *Health Place.* 2004;10: 221–9.
13. **Frank L, Andersen M, Schmid T.** Obesity relationships with community design, physical activity, and time spent in cars. *Am J Prev Med.* 2004;27:87–96.
14. **Frank L, Sallis J, Conway T, Chapman J, Saelens B, Bachman W.** Many pathways from land use to health. *J Am Planning Assoc.* 2006;72:75–87.
15. **Berrigan D, Troiano R.** The association between urban form and physical activity in U.S. adults. *Am J Prev Med.* 2002; 23(Suppl 2):74–9.
16. **Sallis J, Rochaska J, Taylor W.** A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc.* 2000;32:963–75.
17. **Ross C.** Walking, exercising, and smoking: does neighborhood matter? *Soc Sci Med.* 2000;51:265–74.
18. **Saelens B, Sallis J, Black J, Chen D.** Neighborhood-based differences in physical activity: an environmental scale evaluation. *Am J Public Health.* 2003;93:1552–8.
19. **King W, Brach J, Belle S, Killingsworth R, Fenton M, Kriska A.** The relationship between convenience of destinations and walking levels in older women. *Am J Health Promot.* 2003;18:74–82.
20. **Morland K, Wing S, Diez-Roux A.** The contextual effect of the local food environment on residents'diets: the atherosclerosis risk in communities study. *Am J Public Health.* 2002; 92:1761–7.
21. **McCrory M, Suen V, Roberts S.** Biobehavioral influences on energy intake and adult weight gain. *J Nutr.* 2002; 132(suppl):3830–4.
22. **Morland K, Wing S, Diez-Roux A, Poole C.** Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med.* 2001;22:23–9.
23. **Wrigley N, Warm D, Margetts B, Whelan A.** Assessing the impact of improved retail access on diet in a 'food desert': a preliminary report. *Urban Stud.* 2002;39:2061–82.
24. **Pereira M, Kartashov A, Ebbeling C, et al.** Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet.* 2005;365:35–42.
25. **Agras S, Mascola A.** Risk factors for childhood overweight. *Curr Opin Pediatr.* 2005;17:648–52.
26. **Austin S, Melly S, Sanchez B, Patel A, Buka S, Gortmaker S.** Clustering of fast-food restaurants around schools: a novel application of spatial statistics to the study of food environments. *Am J Public Health.* 2005;95:1575–81.
27. **Block J, Scribner R, DeSalvo K.** Fast food, race/ethnicity, and income: a geographic analysis. *Am J Prev Med.* 2004;27: 211–7.
28. **Korff MV, Koepsell T, Curry S, Diehr P.** Multi-level analysis in epidemiological research on health behaviors and outcomes. *Am J Epidemiol.* 1992;135:1077–82.
29. **Diez-Roux A.** Bringing context back into epidemiology: variables and fallacies in multilevel analysis. *Am J Public Health.* 1998;88:216–22.
30. **Hox J.** *Multilevel Analysis: Techniques and Applications.* Mahwah, NJ: Lawrence Erlbaum Associates; 2002.
31. **U.S. Bureau of the Census.** *Summary Tape File 3.* http://www.census.gov/main/www/cen2000.html (Accessed October 3, 2005).
32. **U.S. Bureau of the Census.** *County Business Patterns.* Washington, DC: U.S. Bureau of the Census; 2001.
33. **Eibner C, Sturm R.** US-based indices of area-level deprivation: results from HealthCare for Communities. *Soc Sci Med.* 2006;62:348–59.
34. **Thomas A, Eberly L, Davey-Smith D, Neaton J.** Zip-code-based versus tract-based income measures as long-term risk-adjusted mortality predictors. *Am J Epidemiol.* 2006;164:586–90.
35. **Kaufman P.** Rural poor have less access to supermarkets, large grocery stores. *Rural Dev Perspect.* 1999;13:19–26.
36. **Chung C, Myers S.** Do the poor pay more for food? An analysis of grocery store availability and food price disparities. *J Consumer Affairs.* 1999;33:276–96.
37. **Zhang J, Yu K.** What's the relative risk? A method of correcting the OR in cohort studies of common outcomes. *JAMA.* 1998;280:1690–1.
38. **Environmental System Research Institute.** *ArcView GIS 3.2.* Redlands, CA: Environmental System Research Institute; 1992–1999.
39. **StataCorp LP.** *Stata v9*. College Station, TX: StataCorp LP.; 2005.
40. **Raudenbush S, Bryk A, Congdon R.** *Hierarchical Linear and Nonlinear Modelling.* 6th ed. Lincolnwood, IL: Scientific Software International; 2004.
41. **Yun S, Zhu B, Black W, Brownson R.** A comparison of national estimates of obesity prevalence from the Behavioral Risk Factor Surveillance System and the National Health and Nutrition Examination Survey. *Int J Obes (Lond).* 2006;30: 164–70.
42. **Jiles R, Hughes E, Murphy W, et al.** Surveillance for certain health behaviours among states and selected local areas: Behavioral Risk Factor Surveillance System, United States, 2003. *MMWR Surveill Sum.* 2005;54:1–116.
43. **Glass T, Rasmussen M, Schwartz B.** Neighborhoods and obesity in older adults: the Baltimore Memory Study. *Am J Prev Med.* 2006;31:455–63.
44. **Zhang X, Christoffel K, Mason M, Liu L.** Identification of contrastive and comparable school neighborhoods for childhood obesity and physical activity research. *Int J Health Geogr.* 2006;5:14.
45. **Morland K, Diez-Roux A, Wing S.** Supermarkets, other food stores, and obesity: the Atherosclerosis Risk in Communities Study *Am J Prev Med.* 2006;30:333–9.
46. **Jeffrey R, Baxter J, McGuire M, Linde J.** Are fast food restaurants an environmental risk factor for obesity? *Int J Behav Nutr Phys Activity*. 2006;3:2.
47. **Sturm R, Datar A.** Body mass index in elementary school children, metropolitan area food prices and food outlet density. *Public Health.* 2005;119:1059–68.