Public Health Nutrition: 12(3), 397–405 doi:10.1017/S1368980008002267

Obesity and the community food environment: a systematic review

Joanna E Holsten*
University of Pennsylvania, School of Nursing & Graduate Program of Public Health Studies, 418 Curie Boulevard, Philadelphia, PA 19104, USA

Submitted 30 January 2007: Accepted 20 February 2008: First published online 14 May 2008

Abstract

Objective: To examine the relationship between obesity and the community and/or consumer food environment.
Design: A comprehensive literature search of multiple databases was conducted and seven studies were identified for review. Studies were selected if they measured BMI and environmental variables related to food outlets. Environmental variables included the geographic arrangement of food stores or restaurants in communities and consumer conditions such as food price and availability within each outlet. The study designs, methods, limitations and results related to obesity and the food environment were reviewed, and implications for future research were synthesized.
Results: The reviewed studies used cross-sectional designs to examine the community food environment defined as the number per capita, proximity or density of food outlets. Most studies indirectly identified food outlets through large databases. The studies varied substantially in sample populations, outcome variables, units of measurement and data analysis. Two studies did not find any significant association between obesity rates and community food environment variables. Five studies found significant results. Many of the studies were subject to limitations that may have mitigated the validity of the results.
Conclusion: Research examining obesity and the community or consumer food environment is at an early stage. The most pertinent gaps include primary data at the individual level, direct measures of the environment, studies examining the consumer environment and study designs involving a time sequence. Future research should directly measure multiple levels of the food environment and key confounders at the individual level.

Keywords
Food environment
Nutrition environment
Environment
Obesity
Overweight
Body mass index
Community
Consumer
Food outlets
Stores
Restaurants

Rates of obesity and associated co-morbidities have been escalating steadily over the past several decades[1,2]. Many researchers contend that environmental changes drive the obesity epidemic[3,4]. The environmental experience of Americans includes few opportunities for physical activity and an overabundance of high-energy foods. Widespread and profound societal changes during the last few decades have increased the availability of cheap, convenient, energy-dense food in larger portions[5,6]. These environmental changes have coincided with the grim trajectory of obesity in the USA[7].

Interventions targeting individual activity and dietary behaviours have had limited effectiveness[8]. While many health organizations call for environmental interventions[9,10], the evidence base linking obesity and the food environment is in an early stage. A review of studies examining this association needs to be conducted to better understand the state of this research.

The food environment involves the sources of energy and nutrients and the circumstances surrounding their procurement and consumption. Researchers have used the ecological framework to describe the multiple levels of the food environment[11,12]. The model of community nutrition environments developed by Glanz *et al.*[11] identifies four sub-environments: community, organization, consumer, and information nutrition environments. While each level impacts individual behaviour, the community and consumer environments have been recognized as high research priorities owing to their potentially far-reaching effects[11].

The present review analyses studies that have measured the relationship between obesity and the community and/or consumer food environments, as defined by Glanz *et al.*[11]. The community environment involves the 'number, type, location, and accessibility of food outlets' in a location[11]. The community food environment, also termed the neighbourhood food environment, is frequently measured using proximity or density measures of food outlets. Proximity is the distance between a food outlet and another location such as an individual's residence.

**Corresponding author:* Email jholsten@nursing.upenn.edu

Density is the number of food outlets in a defined area surrounding a location. Food outlets predominantly include stores and restaurants. Food stores can be classified by size and food selection in descending order as follows: supermarkets, grocery stores and convenience stores. Restaurants include full service and limited service establishments[13]. The consumer environment involves the conditions that consumers encounter inside the individual food outlets, including 'price, promotion, and placement' of different foods[11].

Materials and methods

The primary objective of the current review was to identify and evaluate studies that examined the relationship between BMI and environmental variables related to food outlets, including their geographic arrangement and consumer conditions. The inclusion criteria included measurement of the following main outcome variables:

1. BMI as a continuous or categorical variable computed using the formula and weight status ranges outlined by the Centers for Disease Control and Prevention (CDC)[14].
2. Physical measurement of environmental variables related to food outlets.

BMI was selected as the outcome for obesity because it is a widely accepted and validated unit of measurement correlated with body fat[14–16]. The standard weight status categories for adults included normal (BMI = 18·5–24·9 kg/m^2), overweight (BMI = 25·0–29·9 kg/m^2) and obese (BMI ≥ 30·0 kg/m^2)[17]. For children and adolescents aged 2 to 20 years, the weight status categories were based on the CDC BMI-for-age and sex percentile ranges, including 'at risk for overweight' (85th–95th percentile) and 'overweight' (>95th percentile)[18]. The review only included studies that utilized measures of the physical environment rather than individual perceptions of the food environment. While perceptions are important in influencing behaviour, environmental perceptions may not accurately reflect the actual conditions[19]. Due to the limited research on the community and consumer food environment, the review included studies that involved subjects of all age ranges and geographic locations. Studies were excluded from the review if they were not in the English language or did not involve human subjects.

In order to find the most comprehensive research, academic database searches, Internet searches and reference list reviews were performed. All searches were conducted in 2006. The following keywords and phrases were searched in multiple combinations: food environment, nutrition environment, environment, food availability, food outlets, restaurants, obesity, and overweight. The health science databases searched included MEDLINE, CINAHL, PubMed, Cochrane Central Register of Controlled Trials and CRISP. Database searches were limited to human subjects, English language and research when permitted by the search engine. The database searches resulted in over 4975 articles for initial screening. After reviewing titles and abstracts, only four of these articles met the sampling criteria and were eligible for review. General Internet search engines and health-related websites, such as the National Guideline Clearing House, WHO and the CDC websites, were also searched. The websites supplied additional commentary and recommendations for the food environment, but no new research articles were found.

Other methods of locating pertinent research included professional sources and searches of key article reference lists. Over the past 3 years, the author of the review has researched the food environment and discovered articles through professional conferences, presentations and recommendations. Recently published articles were brought to the author's attention in this manner. Reference lists of articles previously identified for the review and other key commentary and review articles were also searched. Three articles that had not surfaced in the database and Internet searches were found using these methods.

Many potential studies were identified that did not satisfy all of the review criteria. Some studies measured the community or consumer environment, but did not include BMI as an outcome variable[20–32]. Other studies were excluded because they only measured individual perceptions of the food environment and not the physical environment[33,34]. Studies that measured government influences[35] or other organizational settings, such as school, worksite or home food environments[36,37], surfaced in the search, but were excluded because they did not measure the community or consumer food environments as defined by Glanz *et al.*[11].

The literature search identified seven studies that measured both BMI and a variable in the community or consumer food environment[38–44]. The food environments were measured in several different ways, such as number of outlets per capita, proximity to or density of fast-food restaurants[38,40,41,43], food stores[39,42] or both restaurants and stores[44]. One study incorporated elements of the consumer food environment by analysing food price data[44]. All of these studies measured demographic variables, such as age, sex, race, ethnicity and varying socio-economic variables. The studies found mixed results and were subject to various limitations. A summary table provides a brief overview of all seven studies as they relate to the food environment.

Results

In 2004, Burdette and Whitaker[38] studied the association of overweight in pre-school children and the proximity of fast-food restaurants to their residences. The cross-sectional study collected information from 7020 children, aged 3 to 5 years, from low-income families in Ohio. Weight and height was measured at a WIC (Special Supplemental Nutrition Program for Women, Infants, and Children) visit to determine BMI percentiles. The food environment was determined by examining the distance of the nearest fast-food restaurant to each child's residence and presence of fast-food restaurants in their neighbourhood. The fast-food restaurant locations were obtained from US Yellow Page listings. Neighbourhoods were defined by political jurisdiction boundaries. Spatial relationships were calculated using Geographical Information Systems (GIS). There was no difference in mean distance to the nearest fast-food restaurant when comparing overweight with non-overweight children (0·70 (SD 0·40) *v.* 0·69 (SD 0·38) miles, $P = 0·91$, *t* test) and when comparing children at risk for overweight and not at risk (0·69 (SD 0·39) *v.* 0·70 (SD 0·38) miles, $P = 0·43$). Comparing children who were overweight and non-overweight, there was no significant difference in the percentage living in neighbourhoods without fast-food restaurants (44·0 % *v.* 44·5 %, $P = 0·84$)[38].

In a similar study with adults, Jeffery *et al.*[40] investigated the relationship between BMI and living or working near various types of restaurants, which served as a proxy measure for ease of access. The outcome variable of BMI was determined by self-reported height and weight during a random digit-dial telephone survey of 1033 Minnesota residents. The restaurant locations were obtained through a public domain database. Food outlet density was mapped and calculated as the number of fast-food restaurants within a 0·5, 1·0 or 2·0 mile radius of home and work addresses by GIS. There was a significant inverse relationship between BMI and number of fast-food outlets ($P = 0·008$, linear regression models), other restaurants ($P = 0·01$) and total restaurants ($P = 0·01$) within 2 miles of work for men only. The study did not find a significant relationship between BMI and restaurant density around the home address for either women or men.

Simmons *et al.*[43] examined the relationship between obesity and availability of takeaway outlets (take-out and fast-food outlets) and other restaurants. This cross-sectional study involved 1454 participants in Australia. The main outcome variables included BMI, calculated from measured height and weight, and number of local takeaway and sit-in restaurant outlets per 1000 residents. Unlike the other studies, some food outlets were identified via direct observation of the community, rather than relying solely on indirect databases. The food environment was assessed for three areal units: regional centre, large rural towns and small rural towns. The authors did not find an association between obesity and the density of takeaway outlets and restaurants. However, limited information was provided about the process of data collection and the results from the statistical analysis for the availability of food outlets.

In another cross-sectional study, Morland *et al.*[42] studied the relationship between obesity, overweight and the presence of supermarkets, grocery stores and convenience stores in an individual's residential census tract. The study included 10 763 individuals from four sites in the USA that participated in the Atherosclerosis Risk in Communities study. Obesity status was determined by BMI and calculated from weight and height measurements collected in 1993. The food environment outcome was the number and type of food stores classified using the 1997 North American Industry Classification System (NAICS) codes and geo-coded to each census track. The food store addresses were collected in 1999 from local and state government agencies. The authors used binomial regression analysis to estimate prevalence ratios (PR) of overweight and obesity associated with the presence of food outlets and to control for types of food stores, demographic variables and physical activity. The presence of supermarkets was inversely related to the prevalence of overweight (PR = 0·94; 95 % CI 0·90, 0·98) and obesity (PR = 0·83; 95 % CI 0·75, 0·92). The presence of convenience stores was associated with a higher prevalence of overweight (PR = 1·06; 95 % CI 1·02, 1·10) and obesity (PR = 1·16; 95 % CI 1·05, 1·27) compared with areas without convenience stores. However, the presence of grocery stores was not significantly associated with overweight status (PR = 1·03; 95 % CI 1·00, 1·07) or obesity (PR = 1·06; 95 % CI 0·99, 1·16).

Inagami *et al.*[39] explored the relationship between individuals' BMI and proximity to and deprivation of their selected food store census tract. The study used a cross-sectional design and involved 2144 individuals in the Los Angeles Family and Neighborhood Study with a predominantly Latino population. Height and weight were self-reported and BMI was calculated as a continuous outcome. The community food environment was measured as the centroid-to-centroid distance from residential and selected grocery store census tracts (distance between the geometric centres). The difference between 'disadvantage scores' of the residential and the selected grocery store census tracts obtained from 2000 US Census information served as a proxy for grocery store quality. Through multilevel linear regression models, the authors found that BMI was greater for individuals who selected grocery stores in more disadvantaged neighbourhoods than their residential neighbourhood (data were not provided in the article). Exposure to neighbourhoods of worship, entertainment, medical care and work were not associated with BMI. In addition, the grocery store neighbourhood scores averaged for each census tract improved the model more than the individual scores. These results indicate that individual and group-level grocery store selection may be related to BMI. A distance of greater than or equal to 1·76 miles from home to grocery store was an independent predictor of a BMI increase of 0·775 units or '4·65 pounds for a 5′5″ person' ($P < 0·05$)[39].

Diverging from the other studies, Maddock[41] examined the relationship between obesity and the prevalence of fast-food restaurants with a cross-sectional analysis at the state level. Mean BMI for adults in fifty states excluding Alaska and including the District of Columbia were calculated from self-reported weight and height in the 2000 Behavioral Risk Factor and Surveillance System data. The food environment variables were square miles per fast-food restaurant and number of residents per fast-food restaurant by state. They were identified using data from the US Yellow Pages and the 2000 US Census. The author found a significant negative correlation between number of residents per fast-food restaurant and obesity prevalence ($r = -0{\cdot}53$, $P < 0{\cdot}001$): as the number of residents per fast-food restaurant decreased the percentage of obesity increased. The bivariate correlation between square miles per restaurant and obesity was not significant ($r = -0{\cdot}20$, $P < 0{\cdot}16$)[41]. Using multiple hierarchal regression analysis, the model that included population density, demographic variables, physical inactivity and fruit and vegetable intake explained 64 % of the state obesity rates ($P < 0.001$, SE 0·001). Adding the food environment variables to the model explained an additional 6 % of the variance, which was a significant improvement from the model without the environmental variables ($F_{\text{change}}(2,38) = 3{\cdot}96$, $P < 0{\cdot}01$). As the residents per fast-food restaurant and the square miles per fast-food restaurants decreased, state-level obesity prevalence increased.

Sturm and Datar[44] performed another national analysis of the community food environment, examining the relationship between food outlet density, food prices and change in BMI over four years among 13 282 elementary-school children in the Early Childhood Longitudinal Study. BMI change over one and three years was measured at the individual level. The US Census Bureau's 1999 Zip Code Business Patterns provided the per capita number and types of food outlets in each child's residential and school zip code areas. Similar to Morland *et al.*[42], Sturm and Datar used the 1997 NAICS to code the types of food outlets. In addition, the American Chamber of Commerce Research Association provided data on food prices for each Metropolitan Statistical Area. The results revealed that a higher per capita number of fast-food restaurants was associated with faster BMI gain, but was not statistically significant ($P < 0{\cdot}10$). Lower fruit and vegetable prices predicted a significantly lower gain in BMI over one ($P = 0{\cdot}016$, SE 0·022, multivariate analysis) and three years ($P < 0{\cdot}001$, SE 0·033). However, there were no significant differences for dairy prices ($P > 0{\cdot}10$) or fast food prices ($P > 0{\cdot}10$). Lower meat prices were related to an increase in BMI, but were not statistically significant over one ($P = 0{\cdot}095$, SE 0·022) or three years ($P = 0{\cdot}414$, SE 0·031). Children below the poverty line ($P = 0{\cdot}05$, SE 0·063), children at risk for overweight ($P = 0{\cdot}01$, SE 0·070) and Hispanics ($P = 0{\cdot}01$, SE 0·063) had a stronger effect of fruit and vegetable prices than the general population; however, subgroup analyses were not sufficiently powered to show statistical significance.

Overall limitations

The literature examining obesity and the community and/or consumer food environment shares many limitations. Six of the seven studies were cross-sectional, examining all variables at one point in time[38–43]. Cross-sectional designs have a limited ability to assess a temporal relationship[45]. The studies did not follow the individuals over time or account for the length of time the individuals lived in the communities. Exposures were measured in the most recent environment, which may not represent the majority of the lifetime exposure as noted by Burdette and Whitaker[38]. The results can suggest avenues of research that show promise for detecting an aetiological relationship, but cannot determine causation.

Six of the seven studies used secondary aggregate data or partnered with other ongoing research studies, which limited the collection of data about the variables under study[38,39,41–44]. The secondary data included large data sets, such as the US Census and national longitudinal studies, making small-scale analysis difficult. In addition, combining multiple databases that have different data collection periods erroneously assumes that dynamic variables like the food environment and BMI remain constant over a period of time greater than 1 year[42]. In addition, some of the data sets used in the studies had limited sample sizes in subpopulations of racial or ethnic minorities[41,42]. Only two studies examined children[38,44], indicating a need for more evidence on the effect of the food environment on minority populations and children. Some studies did not measure or control for key confounders or mediating variables such as dietary patterns[42,44], physical activity levels[38,39] and/or socio-demographic characteristics[43].

Several limitations were found in the measurement of the food environment. All seven of the studies focused primarily on the community food environment in measuring the geographic proximity, density or number of outlets per capita. The exceptions include Sturm and Datar's measurement of food prices[44] and Inagami *et al.*'s measurement of the deprivation score of the grocery store census tracts as a proxy for grocery store quality[39]. No studies directly measured the consumer environment at an individual food outlet level and its relationship with obesity, highlighting a large gap in the literature.

All but one of the studies defined communities with administrative units, including census tracts[39,42], political jurisdictions[38], shires[43], metropolitan areas[44], zip codes[44] or states[41]. Many of these areal units do not have a conceptually founded geographic context to the health outcome of overweight or obesity. In defining communities with these administrative boundaries, the actual shopping or dining locations of individuals living or working in those areas could be misidentified, as noted by Morland *et al.*[42]. In addition, since objects are spatially related and not independent, many analyses should have controlled for spatial autocorrelation[46].

With the exception of Sturm and Datar[44], the studies examined food stores or restaurants and placed emphasis on fast-food restaurants. While many organizations play a role in the food environment, it may be useful to examine all types of food outlets and their geographic arrangement in one analysis to synthesize the community food environment. In addition, the categorization of food outlets was inconsistent between studies. The 1997 NAICS codes were used to classify types of restaurants and stores in two studies[42,44]. Other studies did not specify their classification system, did not distinguish between different types of outlets or stipulated their own definitions of various outlets.

All of the studies utilized indirect methods to assess the environment, including telephone directories, census information or large databases. Simmons *et al.*[43] used some direct observation of restaurant locations, but also depended on indirect methods. Indirect measurement methods are convenient and inexpensive, allowing researchers to study large samples with minimal resources. However, they can provide imprecise and outdated information as noted by Booth *et al.*[47]. Along with the other limitations, this may have contributed to the lack of associations present in the limited research on the community food environment and obesity.

Conclusion

Research on obesity and the community food environment is in an early stage. Few studies have explored the link between obesity and the community food environment, and none has examined individual consumer environments. The seven pioneering studies utilized different methods and found mixed results. The samples, food environment variables, measurement methods and analysis varied substantially, making a comparison of the results difficult. Two studies did not find any significant association between obesity rates and the community food environment variable[38,43]; however, five others found significant results[39–41,42,44]. Significant findings were related to presence of different types of food stores, fruit and vegetable prices, disadvantage of the food store neighbourhood, distance travelled to the food store and distribution of fast-food restaurants on a state-wide basis. Only one study found a significant inverse relationship between BMI and restaurant density around work, which was only present for men[40]. All of the studies suffered from limitations, possibly limiting the generalizability and validity of the findings. While no overarching conclusions can be drawn at this juncture, these innovative studies form a firm foundation of research and establish a direction for future research.

Implications for future research

Future research should include more in-depth descriptive studies of small areal units, selected with conceptual significance, in order to identify precise factors in the community and consumer food environment that are correlated with obesity. The relationship between obesity and consumer food environments, including food price, placement, availability, quality and promotion in individual food outlets, should be explored. In addition, researching multiple environments in one design would allow for a comparison of the effects of different environments, such as the home, community and consumer environments. By designing a study that addresses multiple environments, the results can be placed within the ecological model to gain a broader understanding of the overlapping contexts of the food environment. After more precise risk factors are identified across multiple environments, longitudinal designs will be needed to understand long-term exposures and the causal pathway between the food environment and obesity.

There is a crucial need for studies that measure the environment through direct methods, such as individual inventory of neighbourhoods or food outlets. Community Service Unlimited provides an example of direct measurement of neighbourhoods with their extensive, community-based, food environment assessment[48]. Glanz *et al.* developed the Nutrition Environment Measures Survey (NEMS) that reliably measures and scores store and restaurant environments[49]. Standardizing these tools and procedures will make it possible to compare similar food environments and research results across communities.

In addition to directly measuring the food environment, researchers should measure and adjust for all intervening individual-level factors, such as sociodemographics, dietary patterns, physical activity and physical inactivity. As discussed by Diez Roux[50], contextual and multilevel analyses allow the assessment of individual-level characteristics as modifiers of the environmental effect. This level of analysis is necessary to identify the independent effect of the community environment on individual health outcomes like obesity[50]. Furthermore, future research should include racial and ethnic minorities and children, since they are under-represented in the current literature and suffer from disparities in health and environmental exposures[51].

Future research exploring the relationship of obesity and the food environment should aim to address these recommendations and fill the gaps in the literature. It is important to build on the foundations provided by these studies and more extensively explore what makes up healthy food environments and how individuals interact with them. The food environment holds great promise for a lasting solution to the obesity epidemic, and more in-depth research is urgently needed.

Acknowledgements

The author is supported by the University of Pennsylvania, School of Nursing, as a doctoral student. The author declares no financial conflict of interest that would bias the information presented. Dr Charlene Compher was kind enough to read and comment on a draft of this manuscript.

References

1. Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR & Flegal KM (2004) Prevalence of overweight and obesity among US children, adolescents, and adults, 1999–2002. *JAMA* **291**, 2847–2850.
2. US Department of Health and Human Services (2005) Overweight and Obesity. http://www.cdc.gov/nccdphp/dnpa/obesity/ (accessed March 2006).
3. Flegal KM, Carroll MD, Kuczmarski RJ & Johnson CL (1998) Overweight and obesity in the United States: prevalence and trends, 1960–1994. *Int J Obes Relat Metab Disord* **22**, 39–47.
4. Hill JO, Wyatt HR, Reed GW & Peters JC (2003) Obesity and the environment: where do we go from here? *Science* **299**, 853–855.
5. Schmitz KH & Jeffery RW (2002) Prevention of obesity. In: *Handbook of Obesity Treatment*, pp. 556–594 [TA Wadden and AJ Stunkard, editors]. New York: The Guilford Press.
6. Johnson-Taylor WL & Everhart JE (2006) Modifiable environmental and behavioral determinants of overweight among children and adolescents: report of a workshop. *Obes (Silver Spring)* **14**, 929–966.
7. Binkley JK, Eales J & Jekanowski M (2000) The relation between dietary change and rising US obesity. *Int J Obes Relat Metab Disord* **24**, 1032–1039.
8. Summerbell CD, Waters E, Edmunds LD, Kelly S, Brown T & Campbell KJ (2005) Interventions for preventing obesity in children. *Cochrane Database Syst Rev* issue 3, CD001871.
9. Kumanyika SK (2001) Minisymposium on obesity: overview and some strategic considerations. *Annu Rev Public Health* **22**, 293–308.
10. World Health Organization (2003) *Diet, Nutrition and the Prevention of Chronic Diseases. Joint WHO/FAO Expert Consultation. WHO Technical Report Series* no. 916. Geneva: WHO.
11. Glanz K, Sallis JF, Saelens BE & Frank LD (2005) Healthy nutrition environments: concepts and measures. *Am J Health Promot* **19**, 330–333.
12. Booth SL, Sallis JF, Ritenbaugh C *et al.* (2001) Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. *Nutr Rev* **59**, S21–S39.
13. US Census Bureau (2002) 2002 NAICS Codes and Titles. http://www.census.gov/epcd/naics02/naicod02.htm (accessed January 2007).
14. US Department of Health and Human Services (2004) BMI – Body Mass Index. http://www.cdc.gov/nccdphp/dnpa/bmi/index.htm (accessed March 2006).
15. Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI & Dietz WH (2002) Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. *Am J Clin Nutr* **75**, 978–985.
16. Garrow JS & Webster J (1985) Quetelet's index (W/H^2) as a measure of fatness. *Int J Obes* **9**, 147–153.
17. US Department of Health and Human Services (2006) BMI – Body Mass Index: About BMI for Adults. http://www.cdc.gov/nccdphp/dnpa/bmi/adult_BMI/about_adult_BMI.htm (accessed January 2007).
18. US Department of Health and Human Services (2007) BMI – Body Mass Index: About BMI for Children and Teens. http://www.cdc.gov/nccdphp/dnpa/bmi/childrens_BMI/about_childrens_BMI.htm (accessed January 2007).
19. Kirtland KA, Porter DE, Addy CL, Neet MJ, Williams JE, Sharpe PA, Neff LJ, Kimsey CD Jr & Ainsworth BE (2003) Environmental measures of physical activity supports: perception versus reality. *Am J Prev Med* **24**, 323–331.
20. Reidpath DD, Burns C, Garrard J, Mahoney M & Townsend M (2002) An ecological study of the relationship between social and environmental determinants of obesity. *Health Place* **8**, 141–145.
21. Block JP, Scribner RA & DeSalvo KB (2004) Fast food, race/ethnicity, and income: a geographic analysis. *Am J Prev Med* **27**, 211–217.
22. Cummins SC, McKay L & MacIntyre S (2005) McDonald's restaurants and neighborhood deprivation in Scotland and England. *Am J Prev Med* **29**, 308–310.
23. Morland K, Wing S, Diez Roux A & Poole C (2002) Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med* **22**, 23–29.
24. Moore LV & Diez Roux AV (2006) Associations of neighborhood characteristics with the location and type of food stores. *Am J Public Health* **96**, 325–331.
25. Zenk SN, Schulz AJ, Israel BA, James SA, Bao S & Wilson ML (2005) Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit. *Am J Public Health* **95**, 660–667.
26. Lewis LB, Sloane DC, Nascimento LM, Diamant AL, Guinyard JJ, Yancey AK & Flynn G; REACH Coalition of the African Americans Building a Legacy of Health Project (2005) African Americans' access to healthy food options in south Los Angeles restaurants. *Am J Public Health* **95**, 668–673.
27. Winkler E, Turrell G & Patterson C (2005) Does living in a disadvantaged area entail limited opportunities to purchase fresh fruit and vegetables in terms of price, availability, and variety? Findings from the Brisbane Food Study. *Health Place* **12**, 741–748.
28. Macintyre S, McKay L, Cummins S & Burns C (2005) Out-of-home food outlets and area deprivation: case study in Glasgow, UK. *Int J Behav Nutr Phys Act* **2**, 16.
29. Edmonds J, Baranowski T, Baranowski J, Cullen KW & Myres D (2001) Ecological and socioeconomic correlates of fruit, juice, and vegetable consumption among African-American boys. *Prev Med* **32**, 476–481.
30. Morland K, Wing S & Diez Roux A (2002) The contextual effect of the local food environment on residents' diets: the Atherosclerosis Risk in Communities study. *Am J Public Health* **92**, 1761–1767.
31. Pearson T, Russell J, Campbell MJ & Barker ME (2005) Do 'food deserts' influence fruit and vegetable consumption? – a cross-sectional study. *Appetite* **45**, 195–197.
32. Laraia BA, Siega-Riz AM, Kaufman JS & Jones SJ (2004) Proximity of supermarkets is positively associated with diet quality index for pregnancy. *Prev Med* **39**, 869–875.
33. Boehmer TK, Lovegreen SL, Haire-Joshu D & Brownson RC (2006) What constitutes an obesogenic environment in rural communities? *Am J Health Promot* **20**, 411–421.
34. Ayala GX, Mueller K, Lopez-Madurga E, Campbell NR & Elder JP. Restaurant and food shopping selections among Latino women in southern California. *J Am Diet Assoc* **105**, 38–45.

35. Rabin BA, Boehmer TK & Brownson RC (2007) Cross-national comparison of environmental and policy correlates of obesity in Europe. *Eur J Public Health* **17**, 53–61.
36. French SA & Stables G (2003) Environmental interventions to promote vegetable and fruit consumption among youth in school settings. *Prev Med* **37**, 593–610.
37. Campbell KJ, Crawford DA & Ball K (2006) Family food environment and dietary behaviors likely to promote fatness in 5–6 year-old children. *Int J Obes (Lond)* **30**, 1272–1280.
38. Burdette HL & Whitaker RC (2004) Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. *Prev Med* **38**, 57–63.
39. Inagami S, Cohen DA, Finch BK & Asch SM (2006) You are where you shop: grocery store locations, weight, and neighborhoods. *Am J Prev Med* **31**, 10–17.
40. Jeffery RW, Baxter JE, McGuire MT & Linde JA (2006) Are fast food restaurants an environmental risk factor for obesity? *Int J Behav Nutr Phys Act* **3**, 2.
41. Maddock J (2004) The relationship between obesity and the prevalence of fast food restaurants: state-level analysis. *Am J Health Promot* **19**, 137–143.
42. Morland K, Diez Roux AV & Wing S (2006) Supermarkets, other food stores, and obesity: the Atherosclerosis Risk in Communities study. *Am J Prev Med* **30**, 333–339.
43. Simmons D, McKenzie A, Eaton S, Cox N, Khan MA, Shaw J & Zimmet P (2005) Choice and availability of takeaway and restaurant food is not related to the prevalence of adult obesity in rural communities in Australia. *Int J Obes (Lond)* **29**, 703–710.
44. Sturm R & Datar A (2005) Body mass index in elementary school children, metropolitan area food prices and food outlet density. *Public Health* **119**, 1059–1068.
45. Gordis L (2004) *Epidemiology*. Philadelphia, PA: Elsevier Saunders.
46. Wong D (1996) Aggregation effects in geo-referenced data. In *Practical Handbook of Spatial Statistics*, pp. 83–106 [S Lacch Arlinghaus, D Griffith, W Arlinghaus, W Drake and J Nystuen, editors]. Boca Raton, FL: CRC Press.
47. Booth KM, Pinkston MM & Poston WS (2005) Obesity and the built environment. *J Am Diet Assoc* **105**, Suppl. 1, S110–S117.
48. Community Services Unlimited, Inc. (2004) Active Community To Improve Our Nutrition. ACTION Food Assessment Report 2004. http://www.csuinc.org/report/Report.pdf (accessed April 2008).
49. Glanz K, Clawson M, Young M & Carvalho M (2006) *Nutrition Environment Measures Training Manual*. Atlanta, GA: Emory University.
50. Diez Roux AV (2001) Investigating neighborhood and area effects on health. *Am J Public Health* **91**, 1783–1789.
51. Kumanyika S & Grier S (2006) Targeting interventions for ethnic minority and low-income populations. *Future Child* **16**, 187–207.

Summary Table. Review of studies that explored the relationship between BMI and variables in the community or consumer food environment.

Author (Year)	Overall Purpose	Sample: Number & Location	Obesity Outcome Variable	Food Environment Variable: Unit of Measurement & Data Source(s)	Other Variables (Source)	Findings for association of obesity and the food environment	Limitations
Burdette & Whitaker (2004)[38]	Examined the relationship between overweight status in kids and the proximity of residences to fast food restaurants.	7,020 low-income preschool children, 3 to 5 years of age Cincinnati, Ohio	BMI percentile for age and sex (Measured height and weight)	*Unit of Measurement:* • Distance from residence to nearest fast food restaurant • Number of fast food restaurants in a neighborhood (political jurisdiction) *Data Source:* • Location of fast food restaurants- U.S. Yellow Pages (phonebook and internet)	• Demographics* • Playground proximity • Number of serious crimes and 911 call rate (Cincinnati police department)	• No association between child overweight or at risk for overweight status and proximity to fast food restaurants. • No difference in percentage of overweight and non-overweight children living in neighborhoods without fast food restaurants.	• Cross-sectional design • Restaurant density data not fully explored. • Political jurisdiction may not be the most accurate classification of food outlet exposure. • Neighborhoods lacked variation • Use of secondary aggregate data • Did not control for individual dietary or physical activity practices.
Maddock (2004)[41]	Examined the relationship between fast food restaurants and obesity prevalence rates on the state level.	Adults in 50 states (exact number in sample not identified)	BMI (Self-report height and weight)	*Unit of Measurement:* • Square miles per fast food restaurant • Residents per fast food restaurant *Data Sources:* • Location of fast food restaurants- 2002 U.S. Yellow Pages • Total residents and area of land per state – 2000 U.S. Census	• Individual demographics* • Physical inactivity • Fruit & vegetable intake • Population density • Males per 100 female • Age of adults in states	• Both the number of residents per fast food restaurant and the square miles per fast food restaurants were significantly correlated with obesity prevalence.	• Ecologic/Cross-sectional design • Self-report height and weight • Use of secondary aggregate data • Sample size used was the minimum needed for analysis • Categorized exposure at a state level (urban and rural environments were indistinguishable) • Only included two fast food chains
Simmons, et al. (2005)[43]	Examined the relationship between selection and availability of takeaway and restaurant food and obesity among adults.	1,454 adults Victoria, Australia	BMI (Measured height and weight) Waist circum-ference (Measured)	*Unit of Measurement:* • Number of eating places per 1000 residents *Data Sources:* • Location of takeaway and restaurant food outlets – direct observation and phone directory • Total residents per town – 2001 Australian census	• Demographics* • Weekly Activity • TV or video viewing • Fruit, vegetable, dairy, & takeaway consumption	• No relationship between availability of eating places and prevalence of obesity was found.	• Cross-sectional design • Limited detail provided about data collection and statistical analysis of food environment variables • Lacked statistical adjustment for income • Categorized exposure at a "shire" level which was broad and undefined
Sturm & Datar (2005)[44]	Examined the association between food prices and food outlet density and changes in the BMI among elementary school children.	6,918 children National Sample, U.S. (59 MSA, 37 states)	BMI change over 1 and 3 yrs (Measured height and weight)	*Unit of Measurement:* • Per capita number and types of food outlets in each child's residential and school zip codes • Price of food groups by MSA *Data Sources:* • Number of food outlets by zip code-1999 U.S. Census Zip Code Business Patterns files • Average food prices by MSA-	• Demographics* • Birth weight • Physical Activity • Television viewing • Parent activities with children	• Food outlet density had no significant effect on BMI gain. • Lower fruit and vegetable prices predicted a significantly lower gain in BMI. • Dairy prices or fast food prices did not have a significant affect on BMI gain. • Lower meat prices predicted a higher gain in BMI, but the	• Incongruent categorization of exposures (BMI was measured as change over time, but food environment variable was measured at one point.) • Use of secondary aggregate data • Types of stores not differentiated (Small grocery store indistinguishable from supermarkets) • Limited sample size in subpopulations • Did not measure or control for dietary

				1999 4th quarter ACCRA data		results were insignificant.	intake.
Jeffery, et al. (2006)[40]	Examined the relationship between BMI and living or working near fast food restaurants.	1,033 adults Minnesota	BMI (Self-report height and weight)	*Unit of Measurement:* • Total number of restaurants and the number of fast food restaurants within circles with radii of 0.5, 1.0, and 2.0 miles with home and work addresses as center of the circles *Data Source:* • Location of fast food restaurants- public domain database	• Demographics* • Physical Activity • Television viewing • Eating habits (emphasis on frequency of eating away from home)	• The fast food, non fast food, and total restaurants within different mile radii of home and work addresses were not positively associated with overall BMI. • A significant inverse relationship between BMI and number of restaurants near work addresses was found for men only.	• Cross-sectional design • Self-report height and weight • GIS mapping by food outlets by Standard Industrial Codes from database may be inaccurate.
Inagami, Cohen, Finch, & Asch (2006)[39]	Examined the relationship between individual BMI, distance to and deprivation of the census tract in which individuals shop for groceries.	2,144 households Los Angles, California	BMI (Self-report height and weight)	*Unit of Measurement:* • Centroid-to-centroid distances between residential and grocery store census tracts • Difference between residential and grocery store census tracts Neighborhood "Disadvantage Score" (DSG-DSR) *Data Sources:* • Residential and grocery store census tracts – Participant survey and 1990 U.S. Census • Neighborhood "Disadvantage Score" – 2000 U.S. Census	• Demographics* – aggregated for each residential neighborhood • Location of work, entertainment, medical care, & worship	• Individuals' BMI was greater when they selected grocery stores in more-disadvantaged neighborhoods. • Average grocery store neighborhood scores for each census tract explained BMI more than individual scores. • A distance of greater than or equal to 1.76 miles from home to grocery store was an independent predictor of a BMI increase.	• Cross-sectional design • Self-report height and weight • Did not distinguish between types of food stores • Use of secondary aggregate data • Did not control for individual dietary intake or physical activity • Grocery store neighborhood "Disadvantage Score" was proxy measurement for grocery store quality • Centroid-to-centroid distances between census tracts are crude estimates.
Morland, Diez Roux, & Wing (2006)[42]	Examined the relationship between the availability of supermarket, grocery stores and convenience stores and cardiovascular disease risk factors.	10,763 adults Mississippi, North Carolina, Maryland, Minnesota	BMI (Measured height and weight)	*Unit of Measurement:* • Presence or absence of convenience stores, grocery stores, and/or supermarkets in residential census tract *Data Source:* • Location of food stores- local departments of environmental health and state departments of agriculture in 1999	• Demographics* • Diabetes • Hypertension • Hyper-cholesterolemia • Physical Activity	• The presence of convenience stores vs. no convenience stores was associated with a higher prevalence of overweight and obesity in the census tract. • The presence of supermarkets in census tracts was inversely related to the prevalence of overweight compared to census tracts without supermarkets.	• Cross-sectional design • Use of secondary aggregate data • Lack of individual shopping data may have lead to misclassification of shopping census tract • Lack of food environment data between 1993 and 1999. • Only controlled for physical activity and no other neighborhood or dietary variables • Excluded data from some minorities due to inadequate sample size

*Demographics include various population characteristics such as age, sex, race, ethnicity, education level, employment status, income level, marital status, or other social attribute. Varied by study.
BMI – Body Mass Index
GIS – Geographic Informational Systems
DSG-DSR – difference between "Disadvantage Scores" of residential and selected grocery store census tract
MSA – Metropolitan Statistical Area
ACCRA – American Chamber of Commerce Research Association