HHS Public Access

Author manuscript

Obesity (Silver Spring). Author manuscript; available in PMC 2016 May 18.

Published in final edited form as:

Obesity (Silver Spring). 2015 July ; 23(7): 1331–1344. doi:10.1002/oby.21118.

The relationship of the local food environment with obesity: A systematic review of methods, study quality and results

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Abstract

Objective—To examine the relationship between local food environments and obesity and assess the quality of studies reviewed.

Methods—Systematic keyword searches identified studies from US and Canada that assessed the relationship of obesity to local food environments. We applied a quality metric based on design, exposure and outcome measurement, and analysis.

Results—We identified 71 studies representing 65 cohorts. Overall, study quality was low; 60 studies were cross-sectional. Associations between food outlet availability and obesity were predominantly null. Among non-null associations, we saw a trend toward inverse associations between supermarket availability and obesity (22 negative, 4 positive, 67 null) and direct associations between fast food and obesity (29 positive, 6 negative, 71 null) in adults. We saw direct associations between fast food availability and obesity in lower income children (12 positive, 7 null). Indices including multiple food outlets were most consistently associated with obesity in adults (18 expected, 1 not expected, 17 null). Limiting to higher quality studies did not affect results.

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Conflicts of interest: Johns Hopkins School of Medicine has a consulting relationship with Healthways, which supported the POWER weight loss trial (led by Dr. Appel) and which has developed a commercial application, Innergy, based on the remote weight loss intervention delivered in POWER.

Contributions: LKC, CAMA and LJA conceived of the paper; LKC, CAMA, LJA, JCJS and MF contributed to the study design, LKC and AN conducted the literature search and data extraction, LKC analyzed the data and drafted the paper. All authors provided critical revisions and had final approval of the submitted and published versions.

Conclusions—Despite the large number of studies, we found limited evidence for associations between local food environments and obesity. The predominantly null associations should be interpreted cautiously due to the low quality of available studies.

Keywords

Obesity; food environment; systematic review

Introduction

The prevalence of obesity in the U.S. has more than doubled since the 1960s and currently affects 35% of adults and 17% of children. [1,2] The primary cause of the epidemic is thought to be an increase in daily kilocalorie intake, [3] which rose by ≥500 kilocalories in adults and ≥150 in children between 1977 and 2006. [4,5] Obesity prevalence, however, is not uniform, often differing across neighborhoods. [7] These disparities combined with evidence that neighborhood-level socio-economic status is associated with individual level obesity suggest a role for neighborhood factors in obesity. [8]

In light of this, researchers have begun searching for potential mechanisms linking neighborhood of residence with obesity, particularly those amenable to policy interventions. [9] The local food environment has been a primary focus of both researchers and policy-makers. Some studies have used food store surveys to directly measure the availability of nutritious foods such as fruits and vegetables (or in some cases, unhealthy foods such as snack or junk food) in a given area. More commonly, the availability of food outlets such as supermarkets, fast food or convenience stores is a proxy for the availability of certain types of food. [10] While studies have also looked at the food environment around schools, worksites, and other destinations, [11-13] the majority have examined the residential neighborhood.

Systematic reviews suggest that disparities in the availability of both healthy and unhealthy food exist in the US, with lower income communities and those with higher percentages of ethnic minorities having both greater access to outlets that sell unhealthy food and lower access to those selling healthy food. [14,15] Policies have attempted to redress these disparities by either increasing the availability of healthy options in small stores, [16] establishing traditional supermarkets in low-income neighborhoods [17] or, less commonly, restricting new fast food restaurants. [18]

To date, the evidence linking the local food environment to obesity is suggestive. [14] However, contradictory [19] and null [20] results coupled with a limited number of longitudinal or experimental studies that account for the bias due to individuals' selection of neighborhoods have made causal inference problematic. Other common quality issues in this literature include reliance on commercial lists of food outlets (low sensitivity and positive predictive values [21]), use of self-reported obesity, and ecological designs. While a number of reviews have been published to date, the only one to explicitly examine the potential of study quality to influence results used a generic quality score not necessarily applicable to neighborhood studies. [22] Additionally, recent reviews have considered studies to have significant findings if at least one finding was significant, likely underestimating the number

of null results. [23] Finally, most reviews have focused on the relationship of the availability of individual food outlet types (supermarkets, fast food, etc.) to obesity rather than measures that combine multiple food outlets or that directly measure food availability. [14,23,24]

For the purposes of this study, we consider the local food environment to mean the availability of food for purchase near the home, either as directly measured through in-store surveys or using proxy measures such as the distance to- or density of different types of food outlets. We chose the residential neighborhood as it is the most commonly studied and because of concerns that the food environment around work or school might have a different underlying association with obesity. Other aspects of the food environment that may impact obesity, such as food prices or marketing, are beyond the scope of this review. This paper aims to provide an empirical assessment of the association between objective measures of the local food environment and obesity in the US and Canada. We document the range of exposure measures used and assess study quality in order to explore whether these features influence associations between the local food environment and obesity. A priori, we decided not to conduct a meta-analysis due to the heterogeneity in outcome and exposure measurements across studies.

Methods

We searched for literature on the association between the local food environment and obesity published on-line or in print between January 1, 1990 and December 31, 2013 using Pubmed and Scopus (see Appendix 1 for search terms). Two independent reviewers screened the titles of 5,853 retrieved references and imported 738 into Abstrackr [25] for abstract review. The same two reviewers screened the full text of an additional 251 to determine final eligibility. Three additional articles were identified: two were found by hand-searching references in included articles and prior systematic reviews [8,14,22–24,26–28] and one through searching websites of relevant government agencies and a selected group of non-profits and foundations working in food policy and research in order to find grey literature such as government, and foundation, and non-profit reports (Appendix 1).

Exclusion criteria included a lack of individual level data for obesity, increasing the potential for ecological bias (n=24), less than 200 people (n=7), or an adiposity measure other than BMI, obesity, BMI change or weight change as an outcome (n=1). Exposures were the availability of supermarkets, grocery stores, convenience stores, fast food restaurants, full service restaurants, index variables including the above outlets, or the availability of food within the above outlets. We excluded studies that assessed exposures in the school neighborhood only (n=18), used measures of the food environment based on participants' perceptions (n=8), assigned exposures based on county of residence or other geographic units larger than a zip code (n=13), combined food availability with other physical environment characteristics (n=3), considered only specific or primary food outlets (n=4), had mismatched geographic units between food outlets and individuals (n=1), or had insufficient variation in exposure (n=1). One article was excluded for presenting a duplicate analysis (n=1). (Figure S1).

Extraction and Assessment

We used the Systematic Review Data Repository for data extraction. [29] The first ten articles were independently extracted and then jointly reviewed by two reviewers. Remaining articles were extracted by one reviewer and reviewed for accuracy by the other.

We extracted overall study information including study design, study population, modeling strategy and adjustment variables. For exposures, we extracted the data source, food outlet or measure definition, geographic information systems (GIS) measurement type, and geographic unit. For the outcome measure, we extracted whether it was based on self-reported height or weight. We extracted results for each exposure-outcome relationship that met inclusion criteria (including all sub-groups). When possible, we used a cut-off for statistical significance of $p<0.05$. In evaluating results, we used study authors' final models. In the case that they did not present a single final model, we extracted the model that best fit the data. In longitudinal studies, we preferentially extracted longitudinal rather than cross-sectional results. If authors did not show results but reported that they were non-significant, we extracted that information. Associations reported in the same exact population in two different papers were only extracted once.

We used the Newcastle Ottawa Scale [30] as a guide to develop a quality score specific for food environment studies that tallied the number of potential biases. We identified eight quality concerns related to exposure and outcome measurements, study design, and statistical analysis. Exposure and outcome concerns included: (1): self-reported height and weight, (2) exposure assignment based on a neighborhood or administrative unit rather than individual location (or block), (3) food outlet data not validated in person. Design concerns included: (4) selection bias due to restriction to diseased/obese participants, (5) bias due to not accounting for neighborhood self-selection bias through either randomization, longitudinal design using fixed effects regression, or other causal inference methods. Analysis concerns included: (6) did not control for age, race, sex, SES, (7) controlled for variables on the causal pathway, (8) statistical analysis methods did not either account for clustering or use multi-level models if neighborhood-level data were used. We considered not accounting for neighborhood self-selection bias (#5) to be the biggest threat to causal inference.

We summarized food outlet definitions and exposure measurements, taking into account GIS measures, geographic units, and buffers around individual addresses. We then summarized the number of positive, negative and null associations of individual food outlets, food environment indices and food availability with adiposity measures. We first summed every extracted association individually and then grouped associations into studies (if multiple papers used data from the same population, year and exposure dataset they were also considered part of a single study) and divided these into four categories: at least one positive significant association, at least one negative significant association, both positive and negative associations, and null associations only. We also looked at results by type of exposure measurement (proximity measures v. density measures) as well as among low-income populations. We present data separately for studies conducted in children from those in adults. Finally, we conducted sensitivity analyses restricting to studies that met certain thresholds of study quality: (1) limited to studies with three or less flaws, [11,12,19,20,31–66] (2)

limited to studies with two or less flaws, [11,34,39,41,44,49,50,53,59,61,65] and (3) limited to studies that control for neighborhood self-selection (without flaw 5). [31,32,36,38,53,67]

Results

Study overview

Of the 71 included papers, 47 were limited to adults, 22 to children, one included both adults and children (separately), and one did not specify but was assumed to predominantly include adults. [68] Only 7 were conducted in Canada; the other 64 were in the U.S. Most were not limited to urban or rural areas, but were conducted in areas with varying population density. (Table 1; Table S1a)

Quality varied widely, with papers having on average between three and four flaws. Only one paper had less than two flaws [38] and 30 had more than three. Five papers in adults and six in children were longitudinal in design; only 6 accounted for neighborhood self-selection. (Table 2; Table S2) A total of 65 unique cohorts (papers using the same study population, year and exposure data) were identified. Papers from the same unique cohort have been combined in all analyses except the calculation of quality scores and henceforth will be referred to as studies.

The most common food outlets studied were fast food restaurants (45 studies), followed by convenience stores (n=34), and supermarkets (n=29). Eleven studies used index variables combining different types of food outlets into overall measures of the health of the food environment. Only five studies used in-store assessments. Study outcomes included BMI, BMI percentile or z-score, BMI change, weight change, obese status, overweight status (compared to normal), and overweight/obese status (Table 1). In examining study results, we did not separate studies by type of outcome and so henceforth refer to all outcomes as "obesity".

Local food environment (exposure) data source, measurement, and definitions

Food Outlet Definitions—The most common data source for food outlet locations was commercial lists (lists provided for a fee by private companies such as InfoUSA or Dunn and Bradstreet; n=28), followed by lists provided by government agencies (n=15), and combinations of these and other sources (n=10). Eight studies either collected or validated a majority of their data via in-person mapping (often called ground-truthing); another eight conducted phone or internet validation.

Most researchers based their definitions of different types of food outlets on those provided by the North American Industry Classification System (NAICS); however, specific definitions varied widely between studies leading to overlap of grocery store and supermarket criteria. According to NAICS, grocery stores and supermarkets are both "establishments primarily engaged in retailing a general line of food." [69] Studies (n=14) primarily distinguished supermarkets from grocery stores based on sales; however, only five used the ≥$2 million cut off designated by industry groups. [70] Studies also used square footage (n=2), number of registers (n=3), number of employees (n=7), or whether stores

were part of a chain (n=9) (Table 3). Another 14 studies did not separate grocery stores and supermarkets.

Fast food restaurant definitions also varied widely. Of the 52 studies that used fast food as an exposure (n=45) or part of an index (n=7), 19 limited their consideration to chain fast food, with four studies using only a subset of national chains. Other definitions (n=14) also included pizza places, hot dog stands, or places that provide snack food rather than full meals (Table 3).

Geographic measures—GIS measures of individual food outlet availability were divided between proximity (distance to nearest food outlet) and density measures. Density measures included simple counts, counts/population, counts/area, presence in area, or kernel density measures. Of the 56 studies that looked at individual food outlets, 21 used proximity measures and 48 density measures (13 used both). Simple counts were the most common density measures used (n=23), followed by binary measures of food outlet presence or absence (n=15). More advanced measures such as kernel density that provide greater weight to outlets closer to participants' homes were less likely to be used (n=2). (Table S3a)

Studies also differed in regards to the geographical unit used to assign exposures. Thirty-one studies used neighborhoods, usually defined by administrative units such as census tracts (n=13) or zip codes (n=9). Thirty-nine studies assigned exposure based on participants' addresses (some studies used both). Density measures using participants' addresses assessed exposure within a set radius or buffer (either measured along the road network or in a straight line). Buffers ranged in size from 0.1 to 6 miles, with one mile the most common (n=16) followed by 0.5 miles (n=11). Many studies tested associations with multiple buffers. (Table S3b-c)

Given all of the different measurement choices, there are dozens of ways to measure availability for even a single food outlet type. For instance, the 45 studies that use fast food as an exposure measured fast food availability in 31 different ways (Table 4).

Food environment indices and directly measured food availability measures—We examined two types of food environment indices, those that measure: (1) the availability of food outlets considered healthy or unhealthy based on the literature, or (2) the relative availability of healthy and unhealthy food outlets. Each index was used by between one and four studies; even when used in multiple studies exact definitions typically differed. For example, the Retail Food Environment Index, designed to capture the ratio of unhealthy to healthy outlets, was defined three ways in four studies. [20,33,46,71]

Directly measured food availability measures can be broadly divided into those that measured the shelf space of fruits and vegetables or snack/junk food within an area around participants as pioneered by Rose et al., [43] and those that used the Nutrition Environment Measures Survey (NEMS) developed by Glanz, et al. [72] The NEMS stores survey, more commonly used than the restaurant survey, was heavily adapted between studies and in one study based on imputed values only. [34]

Local food environment and obesity results: Adults

Food Stores and Restaurants—Overall, 35 studies examined 495 associations between individual food outlets and obesity in adults. While null results predominated, there were some notable findings. Supermarket availability was more likely to be negatively associated with obesity (22 associations in 10 studies) than positively (4 associations in 2 studies); 72% of the 93 associations were null.

In contrast, grocery store availability was more likely to be positively associated with obesity (14 associations in 5 studies v. 2 associations in 1 study); 83% of the 93 associations were null. Similarly, fast food restaurant availability was more likely to be positively associated with obesity (29 associations in 11 studies v. 6 associations in 3 studies); 67% of 106 associations were null. Evidence for associations with other individual food outlet types were weaker (Table 5).

We divided fast food and supermarket availability into four groups: proximity measures, density measures within administrative units, density measures within buffers of <1 mile, and density measures within buffers of ≥1 mile. Due to small numbers of each, different types of density measures were combined. Regardless of the measure used, null associations predominated. Beyond this, patterns differed between supermarket and fast food availability. There were no expected associations of obesity with proximity to supermarkets. In contrast, proximity to fast food restaurants was most likely to yield expected (positive) associations (40% of associations). Associations between density measures within buffers of ≥1 mile and obesity were among the most likely to be significant and in the expected direction for both outlet types (supermarkets: 35%; fast food: 33%). For supermarket availability, density of supermarkets within administrative units was also more likely to yield expected (negative) associations (37%). (Figure 1)

Limiting results by study quality did not change inferences overall. In studies with less than three flaws, all results for supermarket availability were null. However, in studies accounting for neighborhood self-selection, both studies including supermarkets found at least one negative association with obesity (Tables S4b-d). Only two studies looking at fast food availability were conducted in low-income, adult populations, one of which found positive associations. In supermarkets, we found no evidence for associations between supermarket availability and obesity in low-income populations (84% null, 8% positive, 8% negative) (Table S4e).

Food environment indices—While few studies looked at the relationship between food environment indices and obesity in adults (n=8), those associations were more likely to be significant and in the expected direction than associations with individual food outlet types. Relative measures of healthy and unhealthy outlets were both more common than raw counts of unhealthy or healthy food outlets as well as more likely to see significant and expected results (31 associations; 52% in the expected direction; 45% null). Two (40%) of the 5 associations using indices that combined healthy outlets or unhealthy outlets were in the expected direction; the rest were null. The two studies looking at food environment indices in children had only null findings. (Table 6)

Directly measured food availability—Results for directly measured food availability were more equivocal. In the four studies using the NEMS-S availability index, 72% of associations were null and positive (unexpected) associations outnumbered negative associations (4 associations in 2 studies v 1 association). Snack food shelf space was found to be significant in one of two studies (20% of associations) and the ratio of fruit and vegetable to snack food shelf space was significant in the one study it was examined in (but in only 50% of associations). No studies using these measures were conducted in children. (Table S4a)

Local Food environment and obesity results: Children

In children, there were 309 associations between individual food outlets and obesity in 21 studies. An even higher percentage of associations in children were null than in adults (85% overall). Notably, however, there was some indication of an association between convenience store availability and obesity: 50% of the 14 studies looking at this association found at least one positive association; no negative associations were found (82% of all associations were null). Results for fast food were more equivocal: while positive associations between fast food availability and obesity outnumbered negative ones (17% positive v. 3% negative), 80% of associations were null and an equal number of studies found negative associations as found positive associations (3 studies each). In low-income populations, however, fast food availability was more consistently associated with obesity: 12 of 19 associations (from 3 of 4 studies) were positive (Table S4e). [51,55,58,63] There was no indication of an association with supermarket or grocery store availability as associations were null ≥90% of the time (Table 5). Inferences did not change when limited to higher quality studies (Tables S4b-d).

Discussion

Overall, our main findings were that (1) associations between the local food environment and obesity were predominantly null, and (2) the overall quality of the studies reviewed was sub-optimal. The percent of null associations ranged from 45% for relative indices of unhealthy and healthy food outlets in studies conducted in adults; up to 96% for full service restaurant availability in studies conducted in children. Further, when we looked by study rather than by the direction of the association reported, this remained true (36 – 83% of studies looking at the availability of individual outlet types found only null results). These results are consistent with those from a recent review looking at associations between the food environment and diet. [15]

Despite this, noteworthy patterns emerged. In studies conducted in adults, we found some evidence that supermarket availability is negatively associated with obesity and fast food availability is positively associated. It is possible that this is the result of publication bias in favor of expected associations. However, we found a similar (though weaker) pattern that supports a positive association between grocery store availability and obesity, which is not necessarily expected.

In contrast to findings in studies of adults, there was no evidence of an association between either supermarket availability or fast food availability and obesity in children. While the

fast food result is consistent with prior reviews, [28] the lack of association with supermarket availability has not been previously documented. [14] Additionally, we saw some evidence of a positive relationship between convenience store availability and obesity in children. In contrast to our overall findings, we saw largely positive associations between fast food availability and obesity in children from households with lower incomes or those living in lower income neighborhoods.

In studies of adults, associations between obesity and food environment indices that provide overall measures of the healthfulness of the food environment were more consistent than those associations with individual food outlets. Results should be interpreted cautiously as few studies to date have tested these indices and, even here, 45% of associations were null. Indices theoretically provide a more complete picture of the food environment and may be a promising avenue for future research.

When we divided exposure measurements into density and proximity measures, we found no significant negative associations between proximity to supermarkets and obesity despite the fact that proximity is a frequently used measure and is a concept that underlies common definitions of food deserts. [10] Density measures have also been somewhat more likely to be associated with diet in a recent review. [15] Density measures using buffers of less than one mile were less likely to find expected associations than measures using larger buffers or within administrative units, suggesting that the immediate neighborhood may be less important than the larger surroundings, at least within the population densities included in this review.

Overall, study quality was an issue with 30 studies having more than three methodologic limitations. The number of longitudinal studies has increased in recent years; however, limitations including self-reported obesity and the use of non-validated food outlet lists remain common. It is important to note, however, that some of the studies receiving the lowest quality scores were not specifically designed to evaluate the association between neighborhood food environments and obesity. Further, only six studies accounted for the potential for bias due to neighborhood self-selection by participants and these studies also had critical limitations such as relying on self-reported BMI. Accounting for neighborhood self-selection is critical for causal inference because individuals are not randomly assigned to neighborhoods but choose to live in areas based on criteria that could be related to both our exposure and outcome of interest, and thus introduce bias. [73] Interestingly, limiting to studies with fewer limitations or to the six studies that controlled for neighborhood self-selection did not consistently change results. This is similar to findings from a review by Machenbach et al., though that study used quality criteria not specific to the association between obesity and the food environment. [22]

There are a number of potential explanations for our predominantly null findings. One possibility is that there is truly no relationship between the local food environment and obesity. This is consistent with our observation of similar findings even when our results were limited to higher quality studies. However, it should be noted that every study had at least 1 critical flaw, and most had several. Also in support of true null associations, while prior reviews recommended that researchers use directly measured food availability rather

than outlet-based measures, [14] we found equivocal and sometimes counter-intuitive results even in studies using these techniques. It is important to note, however, that even if there truly is no relationship with obesity, individuals in areas with lower quality food environments may have a poorer diet [15] and thus be more susceptible to diet-related diseases.

It is also possible that there is a true relationship between the local food environment that is not evident in the included studies because (1) the true effect size is too small given sample size and study quality issues, (2) it is not truly possible to detangle the independent effect of the food environment from other neighborhood factors, and/or (3) focusing solely on the food environment near the home does not completely capture exposure. Our sense is that given the many potential causes of obesity, the impact of any individual cause including the local food environment is likely to be small, making associations difficult to see in studies with small sample sizes or in the presence of exposure misclassification and errors that may bias results toward the null. Adding to this, our review captures availability of food (or food outlets) around the home , which is only one dimension of the food environment. Most studies to date have focused on the home neighborhood though some studies have also examined the food environment around children's schools (a recent review of the impact of the food environment around schools found similarly equivocal results [74]). The total impact of the food environment includes food (or food outlet) availability in the neighborhoods surrounding home, school, work (in the case of adults), travel paths and other commonly accessed venues.

In the context of these likely small effect sizes, even random error caused by non-differential misclassification is likely sufficient to bias results to the null. The commercial food outlet lists often relied on by researchers have been shown to have low sensitivity and specificity, particularly in terms of correctly classifying outlets. [21] Food outlets are used as a proxy for food availability and even occasionally for price, [10] but there is variation in healthy and unhealthy food availability between similar types of food outlets, not to mention price and marketing strategies. [75] The lack of gold-standard measures of local food availability combined with the need to adapt measures to the data available has led to the use of multiple different types of GIS measures and geographic units. While this does not necessarily imply misclassification, it is likely that not all measures are equally valid.

Additionally, it may not be possible to find an independent effect of the food environment. Saelens et al. found significant associations with obesity only when food and physical activity environment variables were combined, suggesting that neighborhood factors may act in concert to create obesogenic environments. [64] Similarly, studies have found that the availability of convenience stores increases the walkability of a neighborhood, [35] which has been associated with lower obesity. [24] Additionally, there is evidence that access to unhealthy foods is ubiquitous in the US, [76] making it impossible to see differences in associations with obesity at current exposure levels.

This study has a number of strengths and limitations. Strengths include the use of a systematic search, the inclusion of 71 individual-level studies covering a range of common food environment measures, and the creation of a quality score specific to studies of the

local food environment. Additionally, we summarized results by association and by study and examined whether they differed by study quality, exposure measurement, age, and socio-economic status. Limitations of this review include the use of combined studies or sub-groups in summarizing results although the groups may truly have different underlying associations between the local food environment and obesity. For instance, the inconsistency of definitions of rural, urban and suburban made it difficult to separate studies based on the type of geographic area. Further, although we conducted a sub-group analysis using studies with either low-income populations or in low-income areas, definitions differed between studies and over time. Finally, as noted above, we were unable to include all the potential domains of the local food environment in this single study, potentially underestimating the impact of the food environment as a whole on obesity.

A key finding of this study is that despite the explosion of research in this area in the past fifteen years [77], the evidence linking the food environment and obesity has not strengthened. Moving forward, there is a need for a new research paradigm. Additional longitudinal studies may be helpful as they have the ability to control for neighborhood self-selection. Because it is impossible to randomize people to local food environments, natural experiments may be one of the most powerful tools in this area of research. [31,78] However, both types of studies are subject to key issues such as exposure misclassification;. Moving forward, there is a need to reconsider how we both define and measure the food environment. Key ways forward include leveraging qualitative research to provide a stronger theoretical understanding of where and how people access food. [79] Further, with the proliferation of portable GPS technology, future studies could use participants' actual travel patterns to determine food availability rather than just relying on their home address. [80]

In conclusion, we found limited evidence for the association between the local food environment and obesity. Further, we found some evidence that food environment quality, rather than availability of specific outlet types, may be linked to obesity. Based on our results, it is unlikely that the existing literature will be deemed strong enough to derive concrete policy recommendations. In the absence of compelling direct evidence linking local food environments to obesity, policy makers will need to rely on other types of evidence as they address the environmental changes that contribute to the steep increase in obesity in the US. The rigorous evaluation of policies that do get implemented will also be critical to building the evidence base.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding: LKC was supported in part by NHLBI and is currently supported in part by NIDDK (Cardiovascular epidemiology training grant T32HL007024; Diabetes and Endocrinology Training Grant 2T32DK062707-11A1). Financial support for this project was provided by the Johns Hopkins Center for a Livable Future-Lerner Fellowship.

Appendix 1: Search

Pubmed Search terms

"Overnutrition"[Mesh] OR "Overweight"[Mesh] OR overnutrition[tw] OR "over nutrition"[tw] OR overweight[tw] OR "over weight"[tw] OR obes*[tw] OR "Body Mass Index"[Mesh] OR "Body Mass Index"[tw] OR BMI[tw] or "waist circumference"[tw] or weight change*[tw]

AND

"Food Industry"[Mesh:NoExp] OR "Food Supply"[Mesh] OR "Food Services"[Mesh] OR "Environment Design"[Mesh] OR grocer*[tw] OR supermarket*[tw] OR super market*[tw] OR food store*[tw] OR corner store*[tw] OR convenience store*[tw] OR food environment*[tw] OR "Residence Characteristics"[Mesh] OR food outlet*[tw] OR "fast food"[tw] OR restaurant*[tw] OR carryout*[tw] OR takeaway*[tw] OR "food supply"[tw] OR food desert*[tw] OR food swamp*[tw] OR "food availability"[tw] OR "food access"[tw] OR built environment*[tw] OR "food and physical activity environment"[tw] OR "food and physical activity environments"[tw]

Scopus search terms

TITLE-ABS-KEY(obes*) OR TITLE-ABS-KEY(overweight) OR TITLE-ABS-KEY("over weight") OR TITLE-ABS-KEY(BMI) or TITLE-ABS-KEY("body mass index") OR TITLE-ABS-KEY("waist circumference") OR TITLE-ABS-KEY("weight change") OR TITLE-ABS-KEY("weight gain") OR TITLE-ABS-KEY("weight loss")

AND

TITLE-ABS-KEY(grocer*) OR TITLE-ABS-KEY(supermarket*) OR TITLE-ABS-KEY("food store*") OR TITLE-ABS-KEY("corner store*") OR TITLE-ABS-KEY("convenience store*") OR TITLE-ABS-KEY(" food environment") OR TITLE-ABS-KEY("food outlet*") OR TITLE-ABSKEY("fast food") OR TITLE-ABS-KEY(restaurant*) OR TITLE-ABS-KEY(carryout) OR TITLE-ABS-KEY(takeaway) OR TITLE-ABS-KEY("food desert") OR TITLE-ABS-KEY("food swamp") OR TITLE-ABS-KEY("food access") OR TITLE-ABS-KEY("food availability") OR TITLE-ABSKEY("food and physical activity environment*")

Websites used in grey literature search

- US government: USDA, CDC, IOM
- Canadian government: Health Canada
- Other institutions: Rudd Center, Robert Wood Johnson Foundation, The Reinvestment Fund, The Food Trust, Center for Science in the Public Interest, Alliance for a Healthier Generation, Policy Link, Partnership for a Healthier America, Changelab Solutions, Prevention Institute, California Food Policy Advocates.

Appendix 2: Included studies

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What is already known about this subject?

- Evidence of whether the local food environment is associated with obesity is inconclusive
- Measurement of the local food environment varies widely between studies
- Overall, the quality of studies that evaluate the relationship between local food environments and obesity is low

What does this study add?

- We provide new evidence that the associations between measures of the local food environment and obesity are predominantly null
- Our analyses reveal limited evidence of an association between availability of supermarkets in local food environments and lower levels of obesity; and an association between fast food availability and higher obesity in adults
- We also find evidence of an association between fast food restaurant availability and higher obesity in low income children

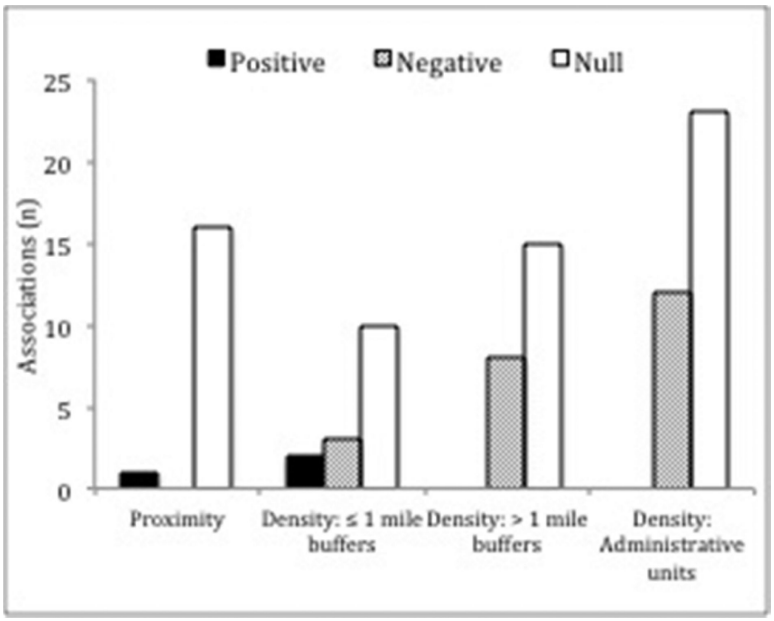
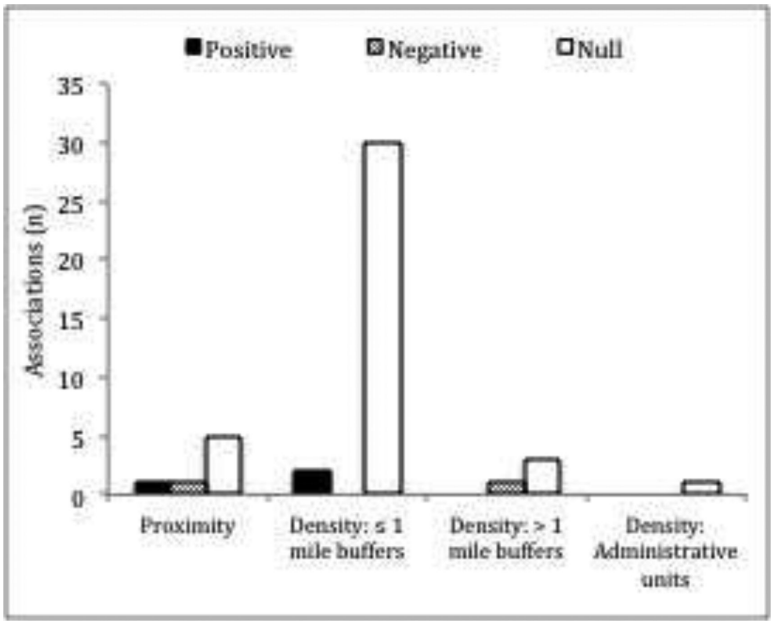


Figure 0001



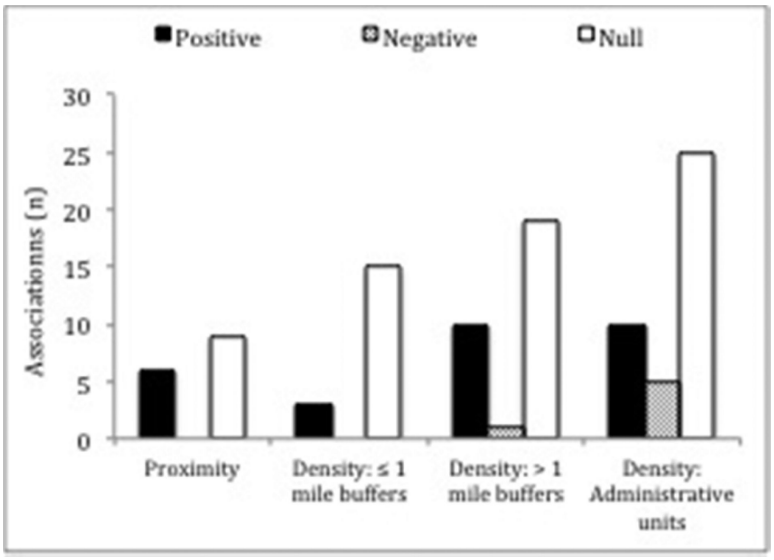


Figure 0002

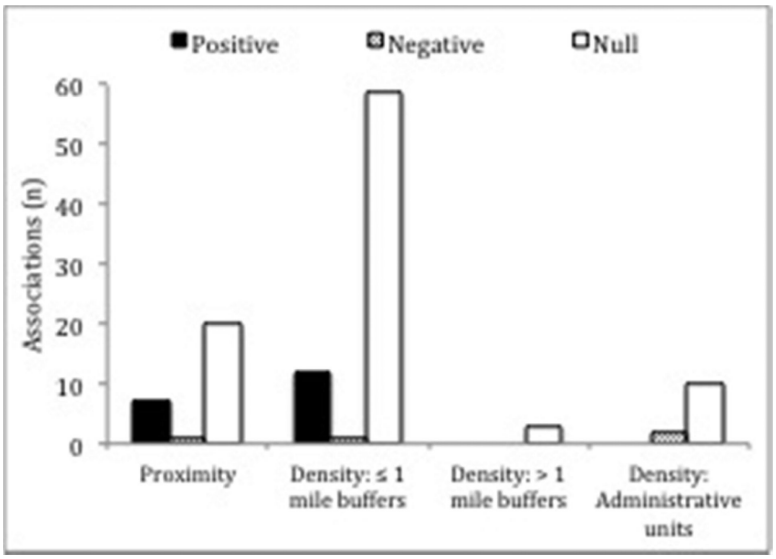


Figure 0004

Figure 1. Associations with obesity by type of exposure measurement: Supermarkets and fast food restaurant availability

Figure 1a: Supermarkets in adults: Results from 18 studies[a]

Figure 1b: Supermarkets in children: Results from 11 studies[a]

Figure 1c: Fast food in adults: Results from 25 studies[a]

Figure 1d: Fast food in children: Results from 19 studies[a]

[a]Studies using the same cohort, year, and exposure data set have been combined

Table 1

Overview of 71 studies examining the relationship between the food environment and obesity

Author, year (ID)[a]	Country	Key exposures	Exposure measurement	Geographical unit	Buffer (miles)	Outcomes
Adults, longitudinal						
Block, 2011 ([1])	US	S, GS, C, FF, FSR	Proximity, Distance to nearest 5	Address	None	BMI (M)
Gibson, 2011 ([2])	US	S, GS, C, FF, FSR	Count/land area	Zip/postal code	None	BMI change
Kapinos, 2014 ([3])	US	G&S, R	Count	Address	0.25 miles	Weight change, BMI change
Li, 2009 ([4])	US	FF	Count/land area	Census block group	None	Weight change (M)
Powell, 2011 ([5])	US	S, GS, C, FF, FSR	Count/population/area	Zip/postal code	None	BMI
Adults, cross sectional						
Babey, 2008 ([6])	US	Index	Ratio	Address	Varying	Obesity
Bodor, 2010 ([7])	US	S, GS, C, FF	Count	Census tract	1.25	Obesity
Inagami, 2009 * ([8])	US	FF, R	Count/road miles	Census tract	None	BMI
Brown, 2008 * ([9])	US	S, GS, C	Count/road miles	Census tract	None	BMI
Casagrande, 2011 ([10])	US	Availability (V)		Census tract	None	BMI (M)
Cerin, 2011 ([11])	US	G&S, C, FF, FSR, Availability (V)	Proximity, Count	Address	0.62	Overweight/obese
Chen, 2010 * ([12])	US	S	Count	Address, Census tract	1	BMI
Chen, 2013 * ([13])	US	FF	Count	Address	0.5	BMI
Drewnowski, 2012 ([14])	US	S	Proximity	Address	None	Obesity
Dubowitz, 2012 ([15])	US	G&S, FF	Count/population	Address	0.75, 1.5, 3	Obesity, BMI (M)
Dunn, 2012 ([16])	US	FF (V)	Proximity, Count	Address	1, 3	Obesity
Ford, 2010 * ([17])	US	S, GS, G&S, C	Count, Yes/no	Address	1, 3, 5	Obesity
Ford, 2011 * ([18])	US	S, GS, C	Count	Census tract	None	BMI
Gantner, 2013 ([19])	US	S, GS, G&S, C Availability (V)	Proximity, Count, Yes/no	Address	5	Overweight/obese, Overweight, Obesity (M)
Gary-Webb, 2010 ([20])	US	G&S, C, FSR	Count	Census tract	None	BMI (M)
Hattori, 2013 ([21])	US	S, GS, C, FF, FSR	Count	Address	1, 1.5, 3	Obesity, Overweight, BMI

Author, year (ID)[a]	Country	Key exposures	Exposure measurement	Geographical unit	Buffer (miles)	Outcomes
Hickson, 2011 (22)	US	FF	Count	Address	5	BMI (M)
Hutchinson, 2012 * (23)	US	S, GS, Availability (V)	Count	Address	0.25, 0.62, 1.25	Obesity, Overweight
Rose, 2009 * (24)	US	Availability (V)		Address	0.25, 0.62, 1.25	BMI
Jeffery, 2006 (25)	US	FF, FSR, R	Count	Address	2	BMI
Jilcott, 2013 (26)	US	S	Proximity	Address	None	BMI (M)
Jones-Smith, 2013 (27)	US	Index	Kernel Density	Address	1	Obesity (M)
Kestens, 2012 (28)	Canada	S, C, FF, FSR, Index	Kernel Density	Neighborhood	None	Overweight/obese
Kruger, 2013 (29)	US	FF	Count	Address	2	BMI
Li, 2008 * (30)	US	FF	Count/area	Census block group	None	Overweight/obese
Li, 2009 * (31)	US	FF	Count/area	Census block group	None	Obesity (M)
Lopez, 2007 (32)	US	S, FF	Yes/no, Count/area	Zip/postal code	None	Obesity
Minaker, 2013 (33)	Canada	G&S, C, AS, FF, R, Index, Availability (V)	Proximity, Count	Address	0.62	BMI
Mobley, 2006 (34)	US	S, C, FF, FSR	Count/population	Zip/postal code	None	BMI (M)
Moore, 2013 (35)	US	Index	Kernel Density	Address	1	BMI (M)
Morland, 2006 (36)	US	S, GS, C	Yes/no	Census tract	None	Obesity, Overweight (M)
Morland, 2009 (37)	US	S, GS, C, FF, FSR	Proximity, Count, Yes/no	Address, Census tract	None	Obesity
Pouliou, 2010 (38)	Canada	G&S, C, FF	Count/land area	Address	0.62	BMI
Prince, 2011 (39)	Canada	G&S, C, FF, FSR	Count/population	Neighborhood	None	Overweight/obese
Prince, 2012 (40)	Canada	G&S, C, FF, FSR	Count/population	Neighborhood	None	Overweight/obese
Reitzel, 2014 (41)	US	FF	Proximity, Count/road miles	Address	0.5, 1, 2, 5	BMI (M)
Roth, 2013 (42)	US	G&S	Count/population	Zip/postal code	None	Obesity, Overweight (M)
Rundle, 2009 (43)	US	Index	Count/area	Address	0.5	Obesity, Overweight, BMI (M)
Spence, 2009 (44)	Canada	Index	Ratio	Zip/postal code	0.5, 1	Obesity
Stark, 2013 (45)	US	Index	Count/area	Zip/postal code	None	BMI
Truong, 2010 (46)	US	Index	Ratio	Census tract	None	Obesity, BMI
Wang, 2007 (47)	US	S, GS, C, FF	Proximity, Count/area	Address, Neighborhood	0.5	BMI

Author, year (ID)[a]	Country	Key exposures	Exposure measurement	Geographical unit	Buffer (miles)	Outcomes
Zick, 2009 ([48])	US	G&S, C, FF, FSR	Yes/no	Census block group	None	Obesity, BMI
Children, longitudinal						
Lamichhane, 2012 ([49])	US	S, FF	Proximity, Count, Kernel Density	Address	1, 2, 6	BMI z-score (M)
Lee, 2012 ([50])	US	S, GS, C, FF, FSR	Count/area	Census tract	None	BMI percentile change (M)
Leung, 2011 ([51])	US	S, GS, C, FF, FSR	Yes/no, Count/population	Address	0.25, 1	BMI z-score change, Overweight/obese (M)
Sandy, 2009 ([52])	US	S, C, FF	Count	Address	0.1, 0.25, 0.5, 1	BMI z-score (M)
Shier, 2012 ([53])	US	S, GS, C, FF, Index	Yes/no, Count/population	Census tract	None	BMI percentile change (M)
Sturm, 2005 ([54])	US	G&S, C, FF, FSR, Index	Count/population	Zip/postal code	None	BMI change (M)
Children, cross sectional						
An, 2012 ([55])	US	S, GS, C, FF	Count	Address	0.1, 0.5, 1, 1.5	BMI percentile
Bader, 2013 ([56])	US	GS, FF	Count	Census tract	None	Obesity (M)
Burdette, 2004 ([57])	US	FF	Proximity	Address	None	Obesity (M)
Carroll-Scott, 2013 ([58])	US	G&S, FF	Proximity	Address	None	BMI (M)
Fiechtner, 2013 ([59])	US	S, GS, C, FF, FSR	Proximity	Address	None	BMI (M)
Galvez, 2009 ([60])	US	S, GS, C, FF, FSR (V)	Yes/no	Census block	None	BMI percentile categories (M)
Gilliland, 2012 ([61])	Canada	C, FF (V)	Count	Zip/postal code	0.25	BMI z-score
Jilcott, 2011 ([62])	US	C	Proximity	Address	None	BMI percentile (M)
Laska, 2010 ([63])	US	G&S, C, FF, R	Proximity, Yes/no	Address	0.5, 1, 1.85	BMI z-score (M)
Liu, 2006 ([64])	US	S, GS, C, AS, FF	Proximity	Address	None	BMI percentile categories (M)
Mellor, 2011 ([65])	US	FF, FSR	Count, Yes/no	Address	0.1, 0.25, 0.5, 1	Obesity, BMI (M)
Mushi-Brunt, 2007 ([66])	US	G&S	Proximity, Yes/no	Address, Census tract	None	Overweight/obese, Overweight (M)
Ohri-Vachaspati, 2013 ([67])	US	S, GS, C, FF	Proximity, Count, Yes/no	Address	0.25, 0.5, 1	Overweight/obese
Oreskovic, 2009 * ([68])	US	FF	Proximity, Count	Address	0.25	Obesity, Overweight (M)
Oreskovic, 2009 * ([69])	US	FF	Proximity, Count	Address	0.25	Obesity, Overweight (M)
Wall, 2012 ([70])	US	S, C, FF, R	Proximity, Yes/no, Count/ area	Address	0.75, 1	BMI z-score (M)
Both adults and children, cross sectional						

Author, year (ID)[a]	Country	Key exposures	Exposure measurement	Geographical unit	Buffer (miles)	Outcomes
Saelens, 2012 ([71])	US	Index	Count	Census block group	0.5	Obesity, Overweight (M)

S: Supermarket; GS: Grocery store; G&S: Grocery store and supermarket; C: Convenience store; AS: All stores; FF: Fast food; FSR: Full service restaurant; R: any restaurant; Index: Food environment index; Availability: directly measured food availability; V: Food outlets validated through in person mapping; M: measured height and weight

[*] Adjacent studies use both the same study population and year.

[a] References for studies in table can be found in the Appendix 2

Table 2

Summary of eight main quality concerns, n = 71 studies

	N	%
Exposure and outcome assessment		
Height and weight self-reported	34	47.9
Food outlets not validated in person	62	87.3
Exposure not based on participants' address[1]	33	46.5
Design		
Limited to obese participants or those with chronic conditions[2]	4	5.6
Does not account for neighborhood self-selection[3]	65	91.5
Analysis		
Controls for variables on the causal pathway[4]	6	8.5
Does not account for multilevel data[5]	15	12.7
Does not control for age, race, sex, SES	24	33.8
Summary		
Number of studies with 0 or 1 flaws	1	1.4
Number of studies with 2 or 3 flaws	40	56.3
Number of studies with >3 flaws	30	42.3

[1] Studies that define exposure to food outlets based on neighborhoods or administrative units such as census tracts or zip codes

[2] Participants are either obese or have diseases related to obesity, suggesting the potential for selection bias

[3] Study does not account for neighborhood self-selection bias through either randomization, a longitudinal design combined with fixed effects regression, or causal inference methods

[4] Includes controlling for or limiting analyses to those who use the food outlet in question (ie. supermarket shoppers) or controlling for diet.

[5] Study does not use hierarchical modeling strategies, account for the clustering via adjusted standard errors, or demonstrate that clustering is limited in cases where neighborhood variables are used.

Table 3

Definitions of food stores and restaurants used in the final sample of 65 independent cohorts

Outlet type (n/N)[a]	Missing (N)	Most common definition used (NAICS) + common variations	Number applying specific criteria					
			Sales	Square feet	Registers[b]	Employees[b]	Chain[b]	Size
Supermarkets (36/35)	2	Stores "primarily engaged in retailing a general line of food, such as canned and frozen foods; fresh fruits and vegetables; and fresh and prepared meats, fish, and poultry" [69] + produce vendors: 1 + supercenters: 1	>$1 million: 4 >$2 million: 5 >$5 million: 5 No criteria: 20	>15,000: 1 >30,000: 1 No criteria: 32	≥4: 2 >8: 1 No criteria: 31	>4: 1 ≥18: 1 >25: 1 ≥30: 1 >50: 3 No criteria: 27	Yes: 9 No: 1[c] No criteria: 24	Large: 4 No criteria: 30
Grocery stores (28/24)	0	Stores "primarily engaged in retailing a general line of food, such as canned and frozen foods; fresh fruits and vegetables; and fresh and prepared meats, fish, and poultry" [69] + specialty or other non-supermarkets selling food: 2	<$1 million: 6 $1-2 million: 1 $1-5 million: 4 <$2 million: 1 <$5 million: 1 No criteria: 15	<15,000: 1 No criteria: 27	2-3: 2 No criteria: 26	≤3: 1 <5: 3 ≥ 5: 1 <50: 2 "Few": 1 No criteria: 20	No: 5[c] No criteria: 23	Smaller/small: 3 No criteria: 25
Convenience stores (41/40)	4	Stores "primarily engaged in retailing a limited line of goods that generally includes milk, bread, soda, and snacks" [69] + gas stations: 6 + grocery or other food sources: 7	<$1 million: 2 No criteria: 35	<1,000: 1 No criteria: 36	1: 1 1-2: 1 No criteria: 35	≤2: 1 No criteria: 36	No criteria: 37	No criteria: 36
Fast food (53/52)	2	"Establishments primarily engaged in providing food services where patrons generally order or select items and pay before eating." [6] Limited to places were full meals are served + pizza: 5 + hotdog stands: 2 + Ice cream, donuts, coffee, and other snacks: 7	No criteria: 51	No criteria: 51	No criteria: 51	No criteria: 51	Yes: 19 No: 1[c] No criteria: 31	No criteria: 51
Full service restaurants (20)	1	"Establishments primarily engaged in providing food services to patrons who order and are served while seated (i.e., waiter/ waitress service) and pay after eating" [69]	No criteria: 19	>2,500: 1 No criteria: 18	No criteria: 19	No criteria: 19	No criteria: 19	No criteria: 19

NAICS: North American Industry Classification System

[a] N is the number of studies, where studies includes studies using the food outlet type as an exposure or as part of a food environment index (ie. Supermarkets + Grocery/Fast food + convenience). Studies using the same year, population and exposure data set have been combined; n is the number of definitions. Some studies have divided outlet types into multiple groups (ie. small v. large grocery stores). Supermarkets, convenience stores and fast food were split into 2 categories by 1 study each, grocery stores split into 2 categories by 4 studies.

[b] Combined with sales criteria for one or more studies.

[c] Required to be independent.

Table 4

Diversity of measurement strategies for fast food availability: Number of studies[a] using combinations of GIS measures, geographic units and buffer sizes (n=45 studies)

	Geographic units									
	Administrative areas				**Address & buffer (miles)**					**Other**
GIS Measures	**Census block**	**Census block group**	**Census tract**	**Zip or postal code**	**No buffer**	**≤ 0.25**	**>0.25 & ≤0.5**	**>0.5 & ≤1**	**>1**	**Neighborhood**
Proximity measures										
Distance to nearest					16					
Distance to nearest 5[b]					1					
Density measures										
Presence in area	1	1				4	3	4	1	
Count			4	1		7	5	8	8	
Count/land area		2	1	3				2		1
Count/population			1	2				2	2	2
Count/road miles			1				1	1	2	
Kernel Density								1		1
Count/population/ land area				1						

GIS: Geographic information systems.

[a]Studies using the same year, population and exposure data set have been combined. Many studies use multiple measures of fast food availability.

[b]Proximity measure of mean distance to the nearest five fast food restaurants

Table 5

Associations between food outlet availability and obesity[a]

	All associations[b] (N adults = 495, N children=309)						By study[c] (N adults=35; N children=21)							
	Positive		Negative		Null		At least 1 positive		At least 1 negative		Null only		Both positive and negative	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Adults														
Stores														
Supermarket	4	*4*	22	*24*	67	*72*	1	*11*	9	*42*	7	*42*	1	*5*
Grocery	14	*15*	2	*2*	77	*83*	5	*38*	1	*8*	5	*46*	1	*8*
Grocery and Supermarket[d]	4	*8*	11	*22*	35	*70*	2	*18*	5	*45*	4	*36*	0	*0*
Convenience[d]	10	*10*	5	*5*	81	*84*	5	*30*	1	*10*	12	*60*	1	*0*
All stores	1	*50*	0	*0*	1	*50*	1	*100*	0	*0*	0	*0*	0	*0*
Restaurants														
Fast food[d]	29	*27*	6	*6*	71	*67*	12	*48*	3	*12*	10	*40*	0	*0*
Full service[d]	0	*0*	8	*18*	36	*82*	0	*0*	4	*33*	8	*67*	0	*0*
All restaurants	1	*9*	2	*18*	8	*73*	1	*25*	1	*25*	2	*50*	0	*0*
Children														
Stores														
Supermarket	3	*6*	2	*4*	45	*90*	3	*27*	2	*18*	6	*55*	0	*0*
Grocery	0	*0*	3	*8*	37	*93*	0	*0*	2	*22*	7	*78*	0	*0*
Grocery and Supermarket	0	*0*	1	*13*	7	*88*	0	*0*	1	*25*	3	*75*	0	*0*
Convenience	10	*18*	0	*0*	46	*82*	7	*50*	0	*0*	7	*50*	0	*0*
All stores	0	*0*	0	*0*	2	*100*	0	*0*	0	*0*	1	*100*	0	*0*
Restaurants														
Fast food	19	*17*	4	*3*	92	*80*	2	*10*	2	*10*	14	*75*	1	*5*
Full service	0	*0*	1	*4*	27	*96*	0	*0*	1	*17*	5	*83*	0	*0*
All restaurants	2	*20*	0	*0*	8	*80*	1	*50*	0	*0*	1	*50*	0	*0*

[a] Outcomes include BMI, obesity, overweight, BMI percentile (children only), BMI z-score (children only), BMI change, and weight change.

[b] Many included studies either use multiple exposure measures, multiple outcome measures, and/or examine associations in multiple sub-groups, all of which are included here.

[c] Since associations within an individual study are not necessarily independent, we have also looked at results by study overall. For clarity, we have classified them into 4 categories: finding at least one positive (associated with higher obesity/BMI) result, finding at least one negative result, finding only null results, and finding both positive and negative results. Studies that use the same population, year, and exposure data set have been combined.

[d] Results from Zick et al. (id=48) were not aggregated here as the comparison group was having no food outlets at all in tract and not comparable to other studies (Supermarkets: 4-, 2 null; Convenience: 4-, 2 null; Fast food: 6 null; Full service: 4-, 2 null).

Table 6

Associations between food environment indices and obesity (11 studies; 8 in adults, 3 in children)

Index[b]	Definition	Studies (N)	All associations			By study[a]			
			Positive	Negative	Null	Positive	Negative	Null only	Both
Indices that combine outlets considered either good or bad for health									
Unhealthy food outlets[d]	Fast food + pizza + bakeries + meat markets + convenience stores + candy and nut stores + bodegas	1	0	0	1	0	0	1	0
Healthy outlets [d]	Supermarkets + produce markets + natural and health food stores[c]	2	0	2	2	0	1	1	0
Indices that capture the relative amount of healthy and unhealthy outlets									
Retail Food Environment Index (P)[e]	Fast Food + Convenience/ Supermarkets + Produce vendors[c]	4	3	0	4	2	0	2	0
Physical Food Environment Index (P)[e]	Fast Food + Convenience + Small food stores/(Numerator + Supermarkets + Produce vendors)[b]	2	2	0	1	1	0	1	0
Convenience ratio (P)[f]	Convenience stores/All food stores	1	0	0	1	0	0	1	0
Fast food ratio (P)[e]	Fast food/ All restaurants	2	3	0	2	1	0	1	0
Proportion Unhealthy outlets (P)[d]	Fast food + pizza + bakeries + meat markets + convenience stores + candy and nut stores + bodegas /(Numerator + supermarkets + fruit and vegetable markets + natural food stores + non-fast food restaurants + grocery stores + fish markets + specialty food stores)	1	2	0	1	1	0	0	0
Net Density Food Environment Score (N)[d]	2 *Supermarkets + Produce Vendors - (Fast Food + Convenience)	1	1	6	9	0	0	0	1
Grocery to convenience ratio (N)[f]	Grocery stores/Convenience stores	1	0	0	1	0	0	1	0
Full service to fast food restaurant ratio (N)[f]	Full service restaurant/fast food restaurant	1	0	0	1	0	0	1	0

*P: Positive relationship with obesity/BMI expected. N: Negative relationship with obesity/BMI expected

[a]Studies using the same cohort, year, and exposure data set have been combined

[b]One study by Saelens at all that uses and index not included here as index is community specific and has community-specific cut offs for both fast food and supermarkets.

[c]Defined differently across studies

[d]Studies in adults only.

[e]One study is in children (one null association).

[f] Studies in children only