

# Concerning Limitations of Food-Environment Research: A Narrative Review and Commentary Framed around Obesity and Diet-Related Diseases in Youth

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## ARTICLE INFORMATION

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**B**EFORE DESCRIBING COMMON AND CONCERNING limitations of food-environment research (and recommendations to address them), it may be useful to discuss the rationale for studying food environments in the first place. Food environments are relevant to diverse nutritional issues and health disparities. An especially compelling argument for studying food environments is the public health challenge of diet-related chronic diseases, particularly in youth.

Diet-related chronic diseases (eg, obesity, diabetes, and vascular diseases) are leading causes of disability and premature death in the United States.<sup>1,2</sup> Diseases that were once considered “adult-onset” now appear earlier in the life course, with preventable impairments affecting youth.<sup>3-5</sup> Over recent decades, young people have become more obese,<sup>6,7</sup> with obesity early in life linked to later-life obesity,<sup>8,9</sup> chronic-disease risk,<sup>10-12</sup> and premature death.<sup>13</sup>

Fortunately, if obese young people are able to transition to normal weights as adults, they might escape chronic disease risks as if they were never obese.<sup>14</sup> Unfortunately, such transitions rarely occur; with advancing age and passing generations, young people increasingly consume fewer healthy whole foods such as fruits, vegetables, and whole grains, and consume more unhealthy items, like refined sweets (eg, candy, sugary drinks), simple starches (eg, snacks chips), and various other refined and highly processed fare.<sup>15-17</sup>

There is little question that many factors influence what young people eat; individual, social, and cultural factors are undoubtedly important.<sup>18-21</sup> Also important are physical environments,<sup>22,23</sup> particularly the local environments in

which individuals can obtain foods and beverages: ie, “food environments.”<sup>18,24,25</sup> Modifying individual, social, or cultural factors may be quite difficult.<sup>26,27</sup> Modifying food environments—keeping individual, social, and cultural contexts in mind—could be a comparatively efficient strategy to improve nutrition and health by making healthier eating the default.<sup>26,27</sup>

## FOOD-ENVIRONMENT CONSIDERATIONS

Food environments include settings such as homes and schools, but much of young people’s unhealthy food consumption occurs away from these sites.<sup>17,25</sup> Thus, even well-intentioned interventions directed at home or school environments may be ineffective.<sup>28-30</sup> For instance, although a state ban on all sugar-sweetened beverages in middle schools reduced in-school access and purchasing of such beverages, it did not reduce overall consumption.<sup>31</sup> A reason, according to other research, may be that adolescents (even from low-income households) will typically spend approximately \$4 per day on items such as chips, candy, and soda from outside sources.<sup>32,33</sup>

Outside sources of food in environments around home and school may be especially relevant for adolescents. Unfortunately, such food environments, particularly in urban, low-income, and minority communities, tend to offer mostly less-healthy fast foods and convenience items with few healthy alternatives.<sup>34-37</sup> This food-distribution reality is a problem because some studies suggest that the greater the density of and proximity to fast-food outlets and convenience stores, the more likely adolescents are to consume fast foods and soda,<sup>38-40</sup> have less healthy diets,<sup>41</sup> be/become overweight or obese,<sup>39,40,42</sup> and have features of metabolic syndrome.<sup>43</sup> Conversely, greater distance to convenience stores<sup>44-46</sup> or fast food<sup>40</sup> and closer proximity to supermarkets<sup>42,47</sup> and restaurants serving vegetables<sup>48</sup> are associated with higher produce consumption,<sup>40,44,48</sup> fewer purchases of sugary beverages,<sup>45</sup> less fast-food intake,<sup>45</sup> overall healthier diets,<sup>46,47</sup> and healthier weights.<sup>42</sup>

## LIMITATIONS OF FOOD-ENVIRONMENT RESEARCH

Despite the associations noted above, some studies demonstrate no consistent relationship between access to fast-food restaurants or small stores on the one hand and dietary intake<sup>49,50</sup> or body weight on the other<sup>51-54</sup>; or between supermarket access and produce consumption on one hand

and diet quality on the other.<sup>21,39,55</sup> Some studies have even generated counterintuitive findings<sup>56-61</sup>: eg, that the odds of consuming vegetables is greater the farther an individual lives from a supermarket,<sup>56</sup> or that obesity rates are positively correlated with healthy food access and negatively associated with fast-food exposure.<sup>58-61</sup>

In a review of the literature from 2009, Larson and Story concluded that the majority of food-environment studies have “methodological limitations which limit their credibility to guide interventions and policy changes.”<sup>22</sup> Although this review was published 5 years ago, little has changed in the landscape of food-environment research to date to suggest much progress. Indeed, several common limitations remain substantial problems for the field.

The limitations described in the review that follows involve problems of assessing physical access to food sources in an environment. The review focuses specifically on measuring food-access issues relevant to young people transitioning to adulthood, but many of the issues are cross-cutting and generally relevant to other populations and groups. For any groups, assessments of additional aspects of food environments also merit critique (eg, assessments of items available in the home and in other settings like work and school, and assessments of the placement, prices, and promotion of items within surrounding retail spaces); these additional considerations are beyond the scope of this essentially geo-spatial–focused review. What follows here are descriptions of five common limitations in food-source physical-access assessment, along with recommendations to address each.

### Limitation 1: Inaccurate Datasets to Identify Food Sources

The use of pre-existing datasets, like commercial business lists, is exceedingly common in food-environment research.\* Such datasets were convenient, efficient, and appropriate for early exploratory studies, and helped produce findings that called attention to possible associations between food environments, individual diet, and downstream diet-related health outcomes. Unfortunately, such datasets inadequately reflect actual food environments on the ground.<sup>62,63</sup> For example, a study in one dense urban area showed that one of the most commonly used business lists had a sensitivity of only 39.3% overall (only 26.2% for general grocers) and a positive predictive value of only 45.5% overall (only 32% for specialty food stores) compared to direct observation.<sup>63</sup> Even if performance was twice as good in other settings (which other validation studies suggest is not the case<sup>62</sup>), findings from research linking food environments to diet and diet-related health outcomes relying solely on such business lists would be in question.

#### Recommendation 1

Universally validating commercial business lists with other sources of data or otherwise using two or more pre-existing data sources for retail information (eg, telephone or Internet directories, dining or shopping guides, various

\*Select list of 35 published studies available from the author upon request.

government records, or multiple commercial business lists)<sup>56,64-67</sup> may be a strategy for researchers to use moving forward. This strategy would be appropriate when geographic areas of interest are too large and/or too dense with food sources to reasonably allow for direct observation (eg, areas like an entire US state or a large urban county). When discrepancies exist between datasets, direct ground-truthing should be done to reconcile disagreements<sup>68,69</sup> or, if not possible, remote assessment using web-based or other street-viewing applications<sup>70</sup> (but only if pilot-testing in areas of interest demonstrates acceptable concordance with direct observation). If even remote reconciliation is unfeasible (or ill-advised), at a minimum sensitivity analyses are in order, modeling and reporting best and worst-case scenarios of discrepancies to see whether conclusions change (as done in validation studies reporting results by both exact/strict and nonexact/lenient matching<sup>63,71</sup>). For smaller geographic areas that are less dense with food sources (eg, areas like some urban zip codes or rural counties), the gold standard should probably be “boots on the ground” direct assessments.<sup>35,46,72-76</sup> Data from such primary collection may not only be more complete, accurate, and applicable than that from pre-existing retail sets, it might actually be more economical as well given the considerable human and monetary investment that could otherwise be required for data purchasing/acquisition, proper data cleaning, and dataset mergers and management.

### Limitation 2: Categorizations of Food Sources Based on Generalized Type

Most food-environment studies lump food sources of a certain type together<sup>77</sup> (eg, as if every small store were the same as every other small store in terms of varieties of foods offered when demonstrably this is not the case<sup>78-81</sup>). For example, supermarkets are usually considered as “healthy” food sources even though they often sell plenty of highly processed unhealthy fare.<sup>82,83</sup> Conversely, fast-food outlets are usually considered as “unhealthy” food sources even though they often offer whole foods like green salads, sliced fruit, and milk.

#### Recommendation 2

It is essential to not classify businesses based on name or generalized type (eg, Pleasantville Grocery=“healthy”) without knowing anything about the foods and beverages actually available. Distinctions of “healthy” and “unhealthy”—or preferably measures with greater gradation, like indexes or numerical scores accounting for inevitable product mixes—should be based on what businesses actually offer. Comprehensive audits are not necessarily required, particularly for studies at larger scales. Examining the availability (yes/no) of a few select categories (eg, sugary beverages, salty snacks, candy, fresh produce) may suffice for many purposes, with assessments of test-retest performance and inter-rater concordance to establish reliable tools and standardize methods. Studies at larger scales may benefit from remote-assessment methods, for instance using Internet menus, circulars, or other business advertisements (particularly for chain stores and restaurants that have consistent offerings across sites).<sup>84-86</sup> If actual assessments are not possible, studies should again include sensitivity analyses (eg,

modeling stores with unknown inventory as both having candy [just as an example] and then as not having candy and assessing whether reported results are robust to the uncertainty—an approach that is both novel and conservative). For studies at smaller scales (as with Recommendation 1 discussed earlier) “boots on the ground” direct assessments—in this case of select product categories—should probably be the gold standard.

### Limitation 3: Inclusion of Only a Limited Range of Food Sources

Most studies of food environments have focused almost exclusively on select stores (eg, supermarkets) and/or on various kinds of restaurants (mostly fast-food outlets).<sup>†</sup> Such focus neglects alternative, often nonintuitive, food sources such as gas stations, hardware stores, clothing outlets, book sellers, general merchandisers, salons, pharmacies, and other retailers offering food and/or drink.<sup>87</sup> It also neglects impermanent sources of food that may also be relevant, such as street vendors (ie, mobile food vendors<sup>75,76,88-90</sup> and farmers’ markets<sup>91-93</sup>). Certainly, the food environment is much broader than just select food stores and restaurants. Potential implications of including or excluding certain types of food sources are illustrated in the Figure.

### Recommendation 3

Researchers should consider the totality of food sources in their study areas of interest. Nonintuitive sources of highly processed, prepackaged, convenience items could potentially offset any healthy influence of sources of whole fresh foods in communities, and it is insufficient to focus on only major food retailers when calories may be nearly ubiquitous across diverse retailers. Recommendations for retail assessments—using pre-existing datasets, remote techniques, and sensitivity analyses vs direct observation—appear under Recommendations 1 and 2 (discussed earlier). All retail assessments should be as comprehensive as possible.

### Limitation 4: Consideration of Food Sources in Isolation

Just as it is ill-advised to consider individual nutrients out of the context of an overall food—and individual foods out of the context of an overall diet—so too it is ill-advised to consider individual food sources out of the context of an overall food environment. Unfortunately, most studies consider only the effect of food sources X (eg, supermarkets) and perhaps also the separate effect of food sources Y (eg, fast-food outlets), but not how food sources X and Y interact. A question such as: “Are fruit carts around schools associated with greater produce consumption regardless of whether fast-food outlets are present?” is just one of a type that remains unanswered. This type of question can only be addressed when a narrow focus on just fruit carts or just fast-food outlets is expanded to consider a broader, potentially interactive, “big picture.”

<sup>†</sup>Select list of 39 published studies available from the author upon request.

### Recommendation 4

Because food sources do not operate in a vacuum, simultaneous consideration of food sources is imperative. At least a few studies have made strides in this area, suggesting that it is a ratio or the proportional contribution of multiple food sources acting in concert that may matter more than any one type of food source acting alone.<sup>53,60,94-99</sup> Future studies should continue to explore the importance of proximity, distribution, and density of multiple food sources relative to one another, particularly keeping in mind Recommendations 1-3 (discussed earlier) for the greatest accuracy and completeness in making individual food-source assessments.

### Limitation 5: Problems with Defining “Exposure” to Food Sources

Methodological choices matter when defining “exposure” or “access” to food sources.<sup>100</sup> One strategy commonly used to define “exposure” in food-environment studies is to use administrative areas such as block groups, census tracts, or zip codes (Figure, panel A).<sup>‡</sup> Such administrative areas may be quite problematic for food-environment conclusions though, because there could be highly uneven exposures within administrative boundaries. For example, fast-food outlets in a zip code might matter little to individuals living in an area of the zip code far from where most of the fast-food outlets are concentrated. Also, the boundaries of administrative units might have little relation to the areas where individuals actually engage with food (eg, one’s concept of “neighborhood” may be quite different than the zip code where one lives).

A second strategy some studies use to define food-source exposure is to specify proximity or physical distance. Most often, the method in this case is to draw a circular area with a radius of linear or Euclidean distance “as the crow flies” from a central point of interest (Figure, panel B).<sup>§</sup> However, linear distances may be poor measures of actual exposure or accessibility.<sup>101-104</sup> For instance, straight lines ignore possible travel routes and barriers to transit like train tracks, rivers, and divided highways.

A third strategy used in studies to define food-source exposure is to delineate unimpeded paths of an existing street network to characterize proximity (Figure, panel C). A problem here is often an exclusive focus on travel routes around individuals’ homes, not around other points of potential relevance (eg, around work or school).<sup>||</sup> Another problem with proximity by street network (or by Euclidean distance) is the question of what length of travel might be most relevant (eg,  $\frac{1}{4}$  mile,  $\frac{1}{2}$  mile, 1 mile); associations obtained may be quite different depending on distances chosen.<sup>103,105-107</sup>

Of the three strategies discussed, only exposure defined by administrative area (Figure, panel A) inherently involves

<sup>‡</sup>Select list of 16 published studies available from the author upon request.

<sup>§</sup>Select list of 13 published studies available from the author upon request.

<sup>||</sup>Select list of 10 published studies available from the author upon request.

**A Administrative Area**

- Exposure defined by geopolitical, census, or other administrative boundary
- Inherent administrative borders or “edges”
- Ignores barriers to travel like rivers, railroads
- Ignores some food sources<sup>a</sup>



2 “healthy” typical food sources  
 2 “unhealthy” typical food sources  
 (2 uncounted street vendors)  
 (4 uncounted non-intuitive food sources)  
**2 “healthy” vs. 2 “unhealthy”**

**B Euclidean distance/Circle area**

- Exposure defined by linear distance “as the crow flies” from a central point
- Respects administrative “edge” of study area<sup>a</sup>
- Ignores barriers to travel like rivers, railroads
- Ignores some food sources<sup>a</sup>



3 “healthy” typical food sources  
 0 “unhealthy” typical food sources  
 (1 uncounted street vendor)  
 (3 uncounted non-intuitive food sources)  
**3 “healthy” vs. 0 “unhealthy”**

**C Street-network area**

- Exposure defined in terms of travel along existing paths like road networks
- Ignores administrative borders or “edges”<sup>a</sup>
- Respects barriers to travel like rivers, railroads
- Counts all food sources<sup>a</sup>



0 “healthy” typical food sources  
 3 “unhealthy” typical food sources  
 1 “unhealthy” street vendor  
 4 “unhealthy” non-intuitive food sources  
**0 “healthy” vs. 8 “unhealthy”**

Geo-spatial features:			Food sources:		
Home, school, or job	River	“Edge” or admin. border	“healthy” typical	Counted/uncounted “unhealthy” street vendor	Counted/uncounted “unhealthy” non-intuitive
City street	Railroad	Other admin. border	“unhealthy” typical		

**Figure.** Same food environment, three different strategies to measure “exposure,” three very different implications. <sup>a</sup>Not an inherent property of the strategy (A, B, or C) used to define exposure, but another consideration that highlights the different findings that might result from different assessments of “exposure.”

(by definition) administrative boundaries or “edges.” Proximity measures like Euclidean distance and street-network areas (Figure, panels B and C) need not be bounded by “edges,” but almost invariably are. Food-environment studies generally only consider data in sample areas of interest (eg, in county A), not data in areas directly adjacent (eg, in bordering county B). This is a problem because any assessment of a food environment in an area (regardless of Limitations 1-4 discussed earlier) may be incorrect if “edge effects” (ie, the effects of exposure across study-area boundaries) are not considered. For instance, if there are no supermarkets in a study area but there are plenty of supermarkets just over the border (or “edge”) in an accessible adjacent area, then the assessment of accessibility or exposure for study individuals, considering only the study area, may be completely wrong. In fact, one study demonstrated that 37% of distance estimates for accessibility to food retailers were wrong when edge effects were not considered.<sup>108</sup>

Finally, the exposure issues described earlier all relate to strategies for defining fixed and bounded geospatial areas, but the experience of most individuals is probably not fixed or bounded. It may be more important to understand how people navigate within local geographies to obtain their food. Certainly, residential area may be important (and other areas like those around school or work), but

proximity is not the only concern. Indeed, studies have shown that other concerns may trump physical proximity because individuals rarely shop at their nearest markets.<sup>109-113</sup> For example, travel times may relate to food procurement,<sup>114</sup> and access to private vehicles or public transportation may be modifiers of the role local food environments play.<sup>21,115-118</sup>

**Recommendation 5**

Research should consider potential travel routes<sup>119,120</sup> or actual “activity spaces” as attempted in only a few studies to date.<sup>60,121-124</sup> The former is theoretically possible even on larger scales (eg, states, countries), using geographic information systems (GIS) software packages. As with other issues of uncertainty, sensitivity analyses could be done (eg, modeling different possible travel paths between food sources and home, school, and/or work locations). For smaller studies, measuring actual “activity spaces” (ie, how individuals actually travel in their daily routines) is possible using global positioning systems (GPS) or, somewhat less ideally, using participant reports of travel routes and activities.

**DISCUSSION**

The limitations discussed in this article represent not only challenges for future food-environment research, but also



concerning sources of error in the existing food-environment literature. If the error is random, its effect is to create noise, masking true associations when they actually exist. This possibility challenges the “null” findings of many studies that examined associations between food environments and diet or health outcomes.<sup>¶</sup> More worrisome, though, is that error could be systematic, and some evidence suggests that at least some of it is.<sup>66,71,125</sup> The issue in this case is the potential for biased findings, creating associations that do not actually exist or exaggerating the magnitude of those that do. Either way, the Figure makes it clear that any food environment might produce very different, even opposite, findings depending on the methods used for assessment.

Of additional concern is that the issues discussed in this article represent only a sample of limitations in food-environment studies. Other common limitations include relying mostly on cross-sectional rather than longitudinal designs (with a nontrivial potential for false-positive error<sup>126</sup>) and problems with measurement on the “outcome side” of presumed associations: eg, assessing dietary intake, such as fruit-and-vegetable consumption, through single-item survey questions or assessing diet-related health outcomes like body mass index using self-reported heights and weights.<sup>#</sup> The take-away message from all of these limitations is one of caution. Available research still does not allow us to confidently identify the ways in which food environments influence diet<sup>22</sup> or diet-related health outcomes.<sup>127</sup> In fact, our limited knowledge base challenges the development of interventions and policies that would be of net benefit.<sup>128</sup>

Future research needs to build on prior studies, improve on past designs, and overcome the limitations of foundational work in the field. Although previous studies picked low-hanging fruit and called attention to important areas for investigation, there is still much hanging fruit to collect (and probably some collected fruit that is past its prime and ready to compost). Future picking will require greater effort, resources, and investment than has become the norm. The studies needed to advance the field will require higher-quality, more complete, and more nuanced data on food sources, considering interactions between food-source exposures and how people may navigate through their lived spaces in more sophisticated ways. Gains in these areas could help inform initiatives and address unanswered questions about public health nutrition—questions such as: Do supermarkets matter for community nutrition when there is a high density of fast-food exposure? Would adding a farmers’ market help? If so, where? What if hot dog carts move in?

The path ahead is not an easy one. But generations of young people growing up obese and unhealthy may be depending on us to do better.

<sup>¶</sup>Select list of 19 published studies available from the author upon request.

<sup>#</sup>Select list of 20 published studies available from the author upon request.

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