Int J Public Health (2012) 57:599–608
DOI 10.1007/s00038-011-0276-2

ORIGINAL ARTICLE

Perceptions of the food environment are associated with fast-food (not fruit-and-vegetable) consumption: findings from multi-level models

Sean C. Lucan · Nandita Mitra

Received: 2 February 2011 / Revised: 30 June 2011 / Accepted: 4 July 2011 / Published online: 20 July 2011

Abstract
Objectives Diets low in fruits and vegetables and/or high in fast foods are associated with obesity and chronic diseases. Such diets may relate to different aspects of neighborhood food environments. We sought to evaluate if people's perceptions of their neighborhood food environment are associated with reported fruit-and-vegetable and fast-food consumption.
Methods Cross-sectional analysis of a community health survey from Philadelphia, PA and four surrounding suburban counties ($n = 10{,}450$ individuals). We used mixed-effects multi-level Poisson models, nesting individuals within *neighborhoods*—i.e. census tracts ($n = 991$).
Results Negative perceptions of the food environment (perceived difficulty finding fruits and vegetables, having to travel outside of one's neighborhood to get to a supermarket, and perceived poor grocery quality) were each directly associated with fast-food consumption (incident rate ratios [IRRs] 1.31, 1.06, 1.20; $p < 0.001$, 0.04, < 0.001 respectively), but not significantly associated with fruit-and-vegetable consumption.
Conclusions Perceived difficulty finding or accessing produce and high-quality groceries may support the eating of more fast food. Neighborhoods where food-environment perceptions are worst might benefit from interventions to improve availability, accessibility, and quality of healthy foods, towards shifting consumption away from fast foods.

Keywords Fruits and vegetables · Fast food · Food environment · Multi-level models · Neighborhoods

S. C. Lucan (✉)
Department of Family and Social Medicine,
Albert Einstein College of Medicine/Montefiore Medical Center,
Bronx, NY, USA
e-mail: slucan@yahoo.com

N. Mitra
Department of Biostatistics, University of Pennsylvania,
Philadelphia, PA, USA

Introduction

Diet-related diseases are among the leading causes of death and disability in the developed world.(Michaud et al. 2001; Mokdad et al. 2004) Cardiovascular disease and cancer lead the list in the U.S.,(Mokdad et al. 2004) and are contributed by other diet-related conditions such as high blood pressure, diabetes, high cholesterol, and obesity (American Heart Association; National Cancer Institute 2009). Such conditions are all associated with dietary patterns high in fast foods (ready-to eat convenience items generally rich in unhealthy fats, sodium, and/or added sugars) and/or low in fruits and vegetables (Bazzano et al. 2003; Berkey et al. 2004; He et al. 2006; Key et al. 1999; Pereira et al. 2005; Rolls et al. 2004; Vainio and Weiderpass 2006).

While people's dietary patterns may depend in part on a host of individual factors,(Booth et al. 2001; Wetter et al. 2001) experts increasingly emphasize the importance of local environments in shaping individuals' dietary behaviors (Booth et al. 2001; Frieden 2010). Aspects of local environments that may be particularly important include the availability, accessibility, and quality of various foods. Food availability, food-store and restaurant accessibility, and overall grocery quality are characteristics of local food environments that may influence whether residents have predominantly healthy or unhealthy dietary patterns (Cheadle et al. 1991; Dibsdall et al. 2003; Franco et al. 2009;

Giskes et al. 2009; Laraia et al. 2004; Moore et al. 2009; Morland et al. 2002; Pearce et al. 2008; Pearce et al. 2009; Pearson et al. 2005; Zenk et al. 2009). In fact, local food environments that are less than ideal in any of these aspects may discourage fruit-and-vegetable consumption and/or encourage the consumption of fast foods.

Unfortunately, past studies of local food environments present inconsistent results with regard to fruit-and-vegetable and fast-food consumption. For instance, with regard to fruit-and-vegetable consumption, it is unclear if greater access to supermarkets is associated with greater fruit-and-vegetable consumption, (Morland et al. 2002) lesser fruit-and-vegetable consumption, (Timperio et al. 2008) or not associated with fruit-and-vegetable consumption at all (Pearce et al. 2008). Discrepancies in past results may be due in part to the use of narrow, objective food-environment measures—e.g. the presence of, or measured distance to, specific foods or food sources,(Cheadle et al. 1991; Franco et al. 2009; Laraia et al. 2004; Pearce et al. 2008; Pearce et al. 2009; Pearson et al. 2005; Timperio et al. 2008) or the calculated density of stores or restaurants in residential areas (Franco et al. 2009; Morland et al. 2002; Timperio et al. 2008). Such objective measures are limited because, for example, even if two neighborhoods have the exact same number of stores, located the exact same distance from residents' homes, if the stores in one neighborhood do not sell fresh produce, are not near public transportation routes, or tend to stock inferior products, then food availability, accessibility, and quality in that neighborhood may be very different from in the other neighborhood where superior food-environment conditions may exist. To better capture such differences missed by limited objective measures, researchers have suggested examining more subjective measures of the food environment like peoples' perceptions (Moore et al. 2008a; Moore et al. 2008b).

How people's perceptions of their food environments relate to their dietary patterns has been part of the aims of several recent studies. These studies assessed how perceptions of availability (Caldwell et al. 2009; Dibsdall et al. 2003; Giskes et al. 2009; Inglis et al. 2008; Moore et al. 2008b; Zenk et al. 2009) and/or quality(Giskes et al. 2009; Moore et al. 2008b; Zenk et al. 2009) of produce relate to fruit-and-vegetable (Caldwell et al. 2009; Dibsdall et al. 2003; Giskes et al. 2009; Inglis et al. 2008; Moore et al. 2008b; Zenk et al. 2009) and/or fast-food consumption;(Inglis et al. 2008; Moore et al. 2008b) or how perceived fast-food accessibility relates to healthy and unhealthy-food consumption (Moore et al. 2009). Only one of these studies considered how each of perceived availability, accessibility, and quality related to both fast-food and fruit-and-vegetable consumption (Inglis et al. 2008). This study examined associations at the individual level, neglecting potentially important neighborhood-level effects (Inglis et al. 2008). Given a host of individual and neighborhood-level factors that may be at play in relationships between food environments and dietary behaviors, research in this area should ideally use multi-level approaches. Multi-level approaches could allow elucidation of whether neighborhood food environments—and peoples' perceptions thereof—influence dietary behaviors.

In our study, we sought to evaluate whether people's perceptions about neighborhood produce availability, supermarket accessibility, and grocery quality were associated with both fruit-and-vegetable and fast-food consumption, controlling for both individual and neighborhood-level factors. To achieve these aims, we used mixed-effects multi-level models.

Methods

Dataset

We used data from the Public Health Management Corporation's (PHMC) 2004 Household Health Survey (HHS) (Philadelphia Health Management Corporation 2004). The 2004 HHS used a random-digit-dialing telephone methodology to reach adult respondents (≥18 years of age) in 10,450 households in five contiguous counties in Southeastern Pennsylvania. Forty-two percent of households were in urban Philadelphia county (comprised entirely of the city of Philadelphia); the remaining households were in four surrounding suburban counties: Bucks, Montgomery, Chester, and Delaware. A market research firm administered the survey between June and September 2004. Stratified sampling helped ensure sufficient representation of socio-demographic subpopulations.

Many of the HHS questions come from national health surveys (e.g. the National Health Interview Survey and Behavior Risk Factor Surveillance System) (Philadelphia Health Management Corporation 2004). Some HHS questions change from one biennial administration to the next. The 2004 administration included questions about the local food environment and dietary consumption; questions not asked previously or thereafter.

Conceptual framework

Our conceptual framework, as described here and in the sections below, appears in Fig. 1. By our conceptualization, individuals' perceptions of their food environment reflect objective food-environment conditions (unmeasured in this study); individuals' food-environment perceptions influence individual dietary consumption; the relationships between individual perceptions and consumption are

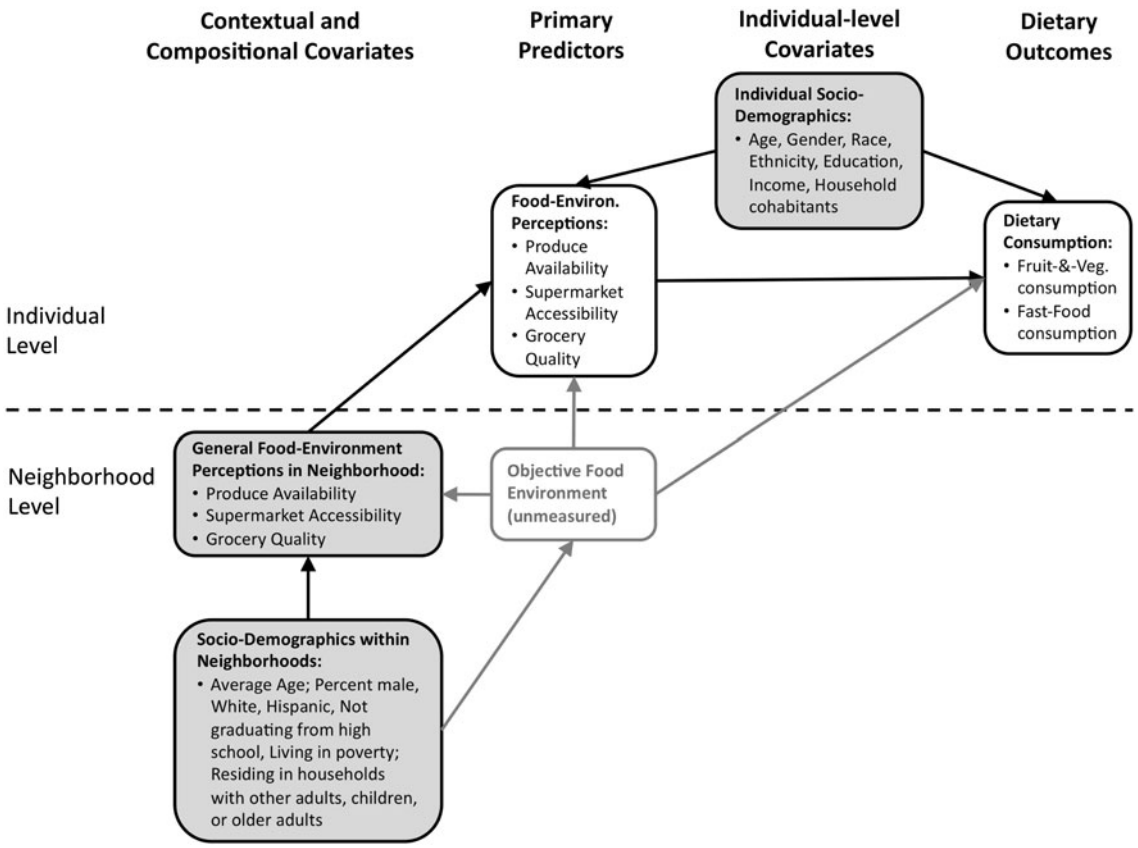

Fig. 1 Conceptual framework for how perceptions of the food environment relate to fruit-and-vegetable and fast-food consumption. This framework provides a conceptual overview and is bounded by available data. The figure does not include the universe of potentially relevant factors. For instance, food-environment perceptions might also include the price of produce or the availability or advertising of fast foods; these relevant factors were unmeasured in our study. *Arrows* show the presumed dominant direction of influence between variables and ignore the complex relationships among and between covariates that may also include mediation and moderation in some cases. We hypothesized that lacking food environments—and the negative food-environment perceptions that follow therefrom—are associated with greater fast-food consumption and lesser fruit-and-vegetable consumption

affected by a variety of socio-demographic factors at the individual level; and those relationships are contributed by both general food-environment perceptions in the neighborhood (influencing individual perceptions) and neighborhood socio-demographics (influencing both the objective food environment and individual perceptions). We hypothesized that the more negatively people perceived their food environment to be, the more fast food they would eat and the less fruits and vegetables they would eat after controlling for individual and neighborhood-level factors.

Primary predictors

To measure individual perceptions of the food environment—and considering these perceptions from a negative frame—we created the following dichotomous variables from HHS questions: *Poor Availability* (How easy or difficult is it for you to find fruits and vegetables in your neighborhood? [difficult/very difficult vs. easy/very easy]), *Poor Accessibility* (Do you HAVE to travel outside of your neighborhood to go to a supermarket? [Yes vs. No]), and *Poor Quality* (How would you rate the overall quality of groceries available in the stores in your neighborhood? [fair/poor/absent vs. excellent/good]).

Dietary outcomes

For dietary "outcomes", we created the following count variables from HHS questions: *Fruit-and-Vegetable Consumption* (How many servings of fruits and vegetables do you eat on a typical day? A serving of a fruit or vegetable is equal to a medium apple, half a cup of peas, or half a large banana), and *Fast-Food Consumption* (In the past seven days, how many times did you eat food from a fast-food restaurant, such as McDonalds, Pizza Hut or Crown Fried Chicken?).

Multi-level modeling

For our primary analysis, we used multi-level mixed-effects models (Rabe-Hesketh 2006; Rabe-Hesketh 2008) to investigate associations between food-environment perceptions and dietary outcomes, controlling for a variety of individual and neighborhood-level factors. To define *neighborhoods*, we followed the lead of other researchers who conduct small-area food-environment studies in the U.S.(Franco et al. 2009; Moore et al. 2008b; Morland et al. 2002) and chose *census tracts* (small, relatively permanent, statistical subdivisions of State counties) (U.S. Census Bureau - Geography Division 2000). Census tracts served as our nesting variable. There are 991 census tracts in the five Southeastern Pennsylvania counties, 381 of which are in Philadelphia. We included all 991 census tracts in our analyses.

We built six separate multi-level Poisson regression models to assess associations between each of the two diet outcomes and each of the three food-environment perceptions. We also built separate multi-level logistic models to investigate associations between the three binary perceived-environment "predictors". All models included an individual-level outcome, an individual-level predictor, and conceptually-relevant variables at both the individual and neighborhood level. We used face validity of covariates (supported by past literature (Ball et al. 2006; Booth et al. 2001; Dibsdall et al. 2003; Diez-Roux et al. 1999; Franco et al. 2009; Kamphuis et al. 2006; Morland et al. 2002; Pearson et al. 2005; Rolls et al. 1991; Turrell et al. 2004; Westenhoefer 2005; Wetter et al. 2001)) and statistical criteria ($p < 0.20$ for bivariable analyses) to determine the inclusion of covariates. Table 1 shows frequency distributions and crude associations for variables included in our multi-level regression models (regressing diet outcomes on food-environment perceptions).

Individual-level covariates

Covariates at the individual-level included: age, race/ethnicity (operationalized as Black, White, Asian, Other; and Hispanic or not), gender, education (< high-school grad, high-school grad, some college, college grad, post-college), income level (<100% Federal Poverty Level [FPL], 100–200% FPL, > 200% FPL), having children (any children in the home), marital status (other adults in the home), older adults (adults > 60 years old in the home), and household size (children, other adults, or older adults in the home). Such socio-demographic factors have been associated with dietary intake and/or food-environment perceptions in past studies (Ball et al. 2006; Dibsdall et al. 2003; Diez-Roux et al. 1999; Franco et al. 2009; Kamphuis et al. 2006; Morland et al. 2002; Pearson et al. 2005; Rolls et al. 1991; Turrell et al. 2004; Westenhoefer 2005).

Neighborhood compositional covariates

Neighborhood-level covariates included *compositional variables*, in this case variables characterizing differences based on who lives in a neighborhood (Diez Roux 2003; Subramanian et al. 2009). Compositional variables allowed us to control for how living among certain kinds of neighbors might affect an individual's food-environment perceptions and dietary consumption. For instance, living in an area with a higher percentage of minorities, low-income residents, and/or children, might affect both the objective food environment (e.g. through higher concentrations of fast-food outlets (Neckerman et al. 2010)) and neighborhood perceptions thereof. By our conceptual framework, objective conditions and neighbors' perceptions could then affect both individuals' perceptions and individual dietary consumption.

Compositional variables included neighborhood correlates of individual-level covariates (e.g. average age and the percent of neighborhood residents that were White, Hispanic, not graduating from high school, living in poverty, and residing in households with other adults, children, or older adults). Compositional variables were obtained from the U.S Census Bureau's American FactFinder Census 2000 Summary Files (U.S. Census Bureau 2000). These variables were proxies for other variables that we also felt were important to consider—e.g. social, cultural, and environmental.(Booth et al. 2001; Wetter et al. 2001) For instance, age and gender were proxies for social habits and trends, race and ethnicity were proxies for cultural values and identities, and percents living in poverty and not graduating high school were proxies for neighborhood deprivation and socioeconomics. Importantly, our objective was not to develop explanatory models, nor to explore the likely complex relationships among and between neighborhood variables. Rather, our objective was to control for the influence of neighborhood-level covariates in quantifying the relationship between food-environments perceptions and dietary intake.

Neighborhood contextual covariates

Other neighborhood-level covariates included *contextual*, or *derived group-level*, *variables.* (Diez Roux 2003; Subramanian et al. 2009) These variables included general perceptions of the food environment in a neighborhood, such as residents' average perception of produce availability. For instance, if an individual's neighbors generally believe it is hard to find produce in the neighborhood, then that impression could bias the individual both towards having an

Table 1 Frequency distributions for variables and crude incident rate ratios for associations with reported fruit-and-vegetable consumption and fast-food consumption (Southeastern Pennsylvania Household Health Survey 2004)

	Median or percentage[b]	IRR for fruit-and-veg consumption	*p* value	IRR for fast-food consumption	*p* value
Individual-level predictors (n = 10,450 individuals)					
Perceived poor produce availability[a]	4.7%	0.90	0.005	1.37	0.001
Perceived poor supermarket accessibility[a]	31.6%	0.99	0.92	1.08	0.09
Perceived poor grocery quality[a]	13.9%	0.91	<0.001	1.56	<0.001
Individual-level covariates (n = 10,450 individuals)					
Age[b]	47	1.01	<0.001	0.97	<0.001
Male	34.1%	0.83	<0.001	1.33	<0.001
Race					
Black	21.4%	0.79	<0.001	1.77	<0.001
Asian	6.9%	0.89	<0.001	1.49	<0.001
Other	5.5%	0.91	0.07	1.62	<0.001
Hispanic	4.8%	0.85	0.001	1.33	0.002
Education					
College grad	23.7%	0.89	<0.001	1.32	<0.001
Some college	19.4%	0.83	<0.001	1.55	<0.001
High-school grad	32.3%	0.74	<0.001	1.56	<0.001
<High-school grad	8.8%	0.63	<0.001	1.43	<0.001
Income level (poverty status)					
100–200% FPL	17.2%	0.82	<0.001	1.16	0.005
<100% FPL	7.9%	0.80	<0.001	1.40	<0.001
One or more child at home	31.9%	0.97	0.07	1.29	<0.001
Other adult(s) at home	35.2%	1.08	<0.001	1.06	0.15
Older adult(s) at home	17.1%	1.06	0.002	0.78	<0.001
Contextual neighborhood covariates (n = 991 neighborhoods [census tracts])					
Mean perceived poor produce availability[a]	0.00%[c]	0.51	<0.001	4.99	<0.001
Mean perceived poor supermarket access[a]	29.2%	0.92	0.04	1.63	<0.001
Mean perceived poor grocery quality[a]	10.0%	0.64	<0.001	3.40	<0.001
Compositional neighborhood covariates (n = 991 neighborhoods [census tracts])					
Median age[b]	36.7	1.01	<0.001	0.96	<0.001
Percent male	52.3%	0.37	<0.001	2.30	0.21
Percent White	87.4%	1.30	<0.001	0.55	<0.001
Percent Hispanic	1.8%	0.61	0.001	2.71	<0.001
Percent non-high-school grads	16.0%	0.42	<0.001	5.19	<0.001
Percent < 100% Federal Poverty Level	7.0%	0.48	<0.001	4.03	<0.001
Percent with One or more child at home	31.7%	1.20	0.02	1.71	0.008
Percent with other adult(s) at home	27.3%	0.73	<0.001	0.99	0.95
Percent with older adult(s) at home	33.0%	0.75	<0.001	0.73	0.12

Referents for dichotomous variables were the opposite values of those listed (e.g. female for male, percent female for percent male). Referents for categorical variables were as follows: race = White, education = post-college education, income = >200% Federal Poverty Level

[a] Perceived poor produce availability = reported difficulty finding produce in neighborhood, perceived poor supermarket accessibility = reported need to travel outside of neighborhood to go to a supermarket, perceived poor grocery quality = reported fair, poor, or absent quality of groceries in neighborhood

[b] For *age,* value is median age; for other individual-level covariates and for predictors, values is percentage among individuals; for *median age*, value is the median of the neighborhood-specific medians for age; for other contextual neighborhood factors and for all compositional neighborhood factors, value is the median of neighborhood-specific percentages

[c] The median of *mean perceived poor produce availability* is 0.00% because in most neighborhoods, no residents had a negative perception of produce availability (thus the mean of individuals' perceptions of poor produce available within the neighborhood was zero)

IRR incident rate ratio, *NA* not applicable, *Veg* vegetable, *Access* accessibility

exaggerated perception of neighborhood fruit-and-vegetable deficiency and towards consuming fewer produce due to a defeatist view about finding them. To define general neighborhood perceptions, we aggregated individual perceptions to the neighborhood level, calculating the simple proportion of survey respondents having a negative perception by neighborhood. *Negative perceptions* included any perceived difficulty finding fruits and vegetables, having to travel outside the neighborhood to get to a supermarket, and reporting fair, poor, or absent grocery quality.

Statistical analysis

No variable had greater than 1.5% missing observations, and most had less than 1% missing observations. Hence, we did not perform imputation and missing observations were left out of the regression analyses.

We used STATA SE (version 11.0, 2009, StataCorp LP, College Station, TX) for all statistical analyses. For mixed-effects multi-level models, we used *xtpoisson* for Poisson regressions and *xtlogit* for logistic regressions. We report incident rate ratios (IRRs) from Poisson models, and odds ratios (ORs) from logistic regression models, both of which derive naturally by exponentiating the beta coefficients in the respective regressions. We also report corresponding 95% confidence intervals and/or p-values for all statistical ratios (i.e., IRRs and ORs).

Results

Respondents had a mean *Fruit-and-Vegetable Consumption* of 2.8 daily servings, with a 1–99 percentile range of 0–9 servings. About 4% of respondents reported eating no fruits or vegetables on a typical day, with only 15.6% of individuals reporting five or more typical daily servings. This level of fruit-and-vegetable consumption is likely lower than that for Pennsylvania as a whole (where 35.5% of adults eat two or more daily servings of fruits, and 25.1% eat three or more daily servings of vegetables) and the U.S (where the percentage of adults eating $\geq$2 daily servings of fruits and $\geq$3 daily servings of vegetables are 32.5 and 26.3% respectively) (Centers for Disease Control and Prevention 2010). Respondents had a mean *Fast-Food Consumption* of 0.77 times in the past seven days, with a 1–99 percentile range of 0–7 times. About 33.5% of individuals reported eating fast food 1 or 2 times in the past week, whereas 58.7% reported eating no fast food in past week.

Table 1 shows frequency distributions for other variables included in multi-level models. Respondents were mostly of middle age, women, White, non-Hispanic, high-school graduates, with incomes > 200% Federal Poverty Level, and living alone. Only a minority of respondents had poor perceptions of their neighborhood food environments, and most respondents lived in neighborhoods where fellow residents generally shared their food-environment perceptions. Overall, demographics of neighborhoods mirrored demographics of individual respondents.

Table 1 also shows crude IRRs between variables included in multi-level models and the two diet outcomes. Greater fruit-and-vegetable consumption and lesser fast-food consumption were associated with respondents who were—and neighborhoods that were substantially—older, female, White, non-Hispanic, better educated, not poor, and with more-positive perceptions of produce availability, supermarket accessibility, and grocery quality. Living with other adults, older adults, and children showed mixed associations.

Table 2 shows results from multi-level models. Despite statistically significant crude associations, after controlling for individual and neighborhood-level factors, there were no meaningful associations between the perceived food-environment variables and *Fruit-and-Vegetable Consumption* (Models 1–3). Conversely, there were statistically significant relationships between all perceived food-environment variables and *Fast-Food Consumption* (Models 4–6). In fact, for individuals in the five Southeastern Pennsylvania counties, negative perceptions of produce availability, supermarket accessibility, and grocery quality translated to a 31, 6, and 20% greater number of times consuming fast food during the past week respectively ($p < 0.001$, 0.04, < 0.001). Given the level of fast-food consumption in our sample, having a negative food-environment perception could equate to eating fast food up to 12.4 more times per year (or more than one additional time per month) on average in our sample.

In re-running all models for each of the five counties separately, values did not differ meaningfully from the five-county aggregate values; nor was there a substantive difference between urban and suburban counties (data not shown). Most neighborhood-level covariates were significantly associated with *Fast-Food Consumption* in models. Re-running models without neighborhood-level covariates (i.e. running exclusively individual-level models) resulted in point estimates for IRRs that were slightly higher than those obtained in full multi-level models (data not shown).

Full multi-level models evaluating associations between "predictors" (the three negative perceptions of the food environment; all dichotomous variables) showed each was highly associated with the others (ORs 3.42–8.31, $p < 0.001$ for all).

Discussion

Our study used multi-level modeling to demonstrate associations between people's perceptions of their food

Table 2 Multi-level Poisson models investigating associations among and between negative perceptions of the food environment and reported dietary consumption for individuals ($n = 10{,}450$) nested in census tracts ($n = 991$) (Southeastern Pennsylvania Household Health Survey 2004)

Model	Outcome	Predictor	IRR	95% CI
1	Fruit-and-veg consumption	Poor produce availability	0.99	0.93–1.06
2	Fruit-and-veg consumption	Poor supermarket accessibility	1.01	0.98–1.04
3	Fruit-and-veg consumption	Poor grocery quality	1.01	0.97–1.05
4	Fast-food consumption	Poor produce availability	1.31	1.19–1.45**
5	Fast-food consumption	Poor supermarket accessibility	1.06	1.00–1.11*
6	Fast-food consumption	Poor grocery quality	1.20	1.12–1.28**

Each model included the listed predictor (e.g. an individual's perception of produce availability), the corresponding contextual variable at the neighborhood level (i.e. the average perception of produce availability within the neighborhood), individual-level sociodemographics (i.e. age, race, ethnicity, gender, education, income, household cohabitants), and neighborhood sociodemographics (i.e. median age, percent male, percent White, percent Hispanic, percent not graduating high school, percent in poverty, and percent of households with more than one adult, any children, or any older adults)

Fruit-and-veg consumption = reported servings of fruits and vegetables eaten on typical day, Fast-food consumption = reported times eating fast food in past week, Poor Produce availability = reported difficulty finding produce in neighborhood (difficult/very difficult vs. easy/very easy), Poor supermarket accessibility = reported need to travel outside of neighborhood to go to a supermarket (yes vs. no), Poor grocery quality = reported fair, poor, or absent quality of groceries in neighborhood (fair/poor/absent vs. good/excellent), IRR = incident rate ratio, CI = confidence interval

* p value 0.044, ** p value < 0.001

environment and specific dietary consumption, controlling for a host of relevant individual and neighborhood-level factors. Specifically, we showed that perceptions of poor produce availability, poor supermarket accessibility, and poor grocery quality were each associated with greater consumption of fast foods in five Southeastern Pennsylvania counties (one urban and four suburban counties). Our analyses also showed that perceptions of three different aspects of the food environment were all highly associated with each other.

Other studies have demonstrated relationships between the perceived food environment and dietary patterns in the U.S. (Caldwell et al. 2009; Moore et al. 2009; Moore et al. 2008b; Zenk et al. 2009) and other countries (Dibsdall et al. 2003; Giskes et al. 2009; Inglis et al. 2008). Yet few studies have used multi-level approaches (Caldwell et al. 2009; Giskes et al. 2009; Moore et al. 2008b; Zenk et al. 2009)—often considered the *gold standard* for quantitative assessments as these approaches incorporate the complex influences of both individual factors and environmental contexts that may influence individual behavior (Diez-Roux 1998; Subramanian et al. 2009). Among multi-level studies, two studies support that positive food-environment perceptions are associated with greater fruit-and-vegetable intake (Caldwell et al. 2009; Moore et al. 2008b). A third study, like ours, found little evidence for such an association (Zenk et al. 2009). A fourth had mixed results (Giskes et al. 2009). Discrepancies between studies may be partially due to differences in included covariates. Indeed, in our unadjusted analyses, fruit-and-vegetable consumption was strongly associated with both produce availability and grocery quality (associations that disappeared with adjustment for individual and neighborhood-level factors). Discrepancies between studies may also be contributed by different measures of both food-environment perceptions and dietary consumption, and different populations under study. Future research should build on nascent work to incorporate both self-report and objective data into more robust, reliable, and generalizable measures (Freedman and Bell 2009; Moore et al. 2008a; Moore et al. 2008b).

In spite of different measures though, prior literature consistently shows that more-positive perceptions of healthy-food availability and/or quality are associated with lesser consumption of unhealthy items like fast food (Inglis et al. 2008; Moore et al. 2008b)[Lucan et al. unpublished data]. Our results reinforce these associations from a negative frame: in our study, all three negative perceptions of the food environment were associated with greater fast-food consumption. Our results also suggest the importance of multi-level consideration, as neglecting neighborhood-level factors could overestimate relationships between food-environment perceptions and dietary intake.

Of the three food-environment perceptions we assessed, perceived accessibility to supermarkets was the least strongly associated with fast-food consumption (and the only perceived-environment measure not strongly associated with either dietary outcome in unadjusted analyses). Modest and borderline-significant association may have been due to missed effect modification. For example, needing to travel outside of the neighborhood to get to a supermarket may only promote eating of fast food if individuals do not have access to transportation and are thus "forced" to eat whatever is immediately available. Unfortunately, our data did not allow us to fully explore

this possibility. However, a subset of our sample (those > 60 years) answered a question about transportation problems getting to a doctor's appointment in the past year. Among those reporting a need to travel outside of their neighborhood to get to a supermarket, those also having transportation problems (i.e. trouble getting to a physician's office) ate disproportionately more fast food than those who did not.

When comparing the need to travel to get to a supermarket with the other distinct aspects of the food environment measured in our study (i.e. produce availability and grocery quality), each was very strongly associated with the others. These associations suggest that a single question about perceptions may provide greater efficiency in future studies involving subjective food-environment assessments (particularly for produce availability and grocery quality which may not suffer from the same problems of effect modification discussed above).

The strengths of our study include considering relationships among and between three separate measures of the food environment, and two specific kinds of dietary intake, in a large, urban and suburban, five-county sample. We also adjusted for potentially relevant covariates not considered in prior studies (Caldwell et al. 2009; Giskes et al. 2009; Moore et al. 2008b; Zenk et al. 2009) (such as the presence and age of household members), and used a multi-level approach that included control for both contextual and compositional factors in neighborhoods.

Potential limitations of our study relate to the use of a single-year, June–September telephone survey. First, due to the cross-sectional design, we are unable to make causal conclusions. While it is likely that food environments influence peoples' dietary behaviors, the reverse may also be true (Franco et al. 2009); that is, dietary behaviors may shape the quality and quantity of foods and food sources in neighborhoods. For example, if there is high consumer demand for fast food in a neighborhood, such demand could conceivably select against the establishment of stores selling fresh-produce there (and thus there would be an association between poor supermarket accessibility and high fast-food consumption as found in our study). Second, as with all telephone surveys there is the potential for sampling bias—e.g. from differential non-response and under- or over-representation of certain groups. Stratified sampling helped guard against such bias, although compared to census averages for the five Pennsylvania counties in our study—and to the U.S. population as a whole—our sample was over-represented by women, minorities, and older respondents (U.S. Census Bureau 2000) and likely ate fewer daily fruits and vegetables (Centers for Disease Control and Prevention 2010). Thus, while our findings are suggestive, they may not be generalizable to other populations. Third, our findings might also not be generalizable to other times of the year. Given our data derived from a survey that occurred mostly during summer months, consumption and perceptions could have conceivably been different than in other seasons.(Giskes et al. 2007; Kamphuis et al. 2006) Fourth, the range and completeness of survey questions limited our analysis. Unfortunately, there were no survey questions about potentially important food-environment issues like the availability of fast food (Moore et al. 2009) or the perceived affordability or advertising of different food items (Grier and Kumanyika 2008). Also, we were are not able to determine if on the occasions when people ate food from a fast-food restaurant, if any of that food was produce (e.g. fast-food salads or pre-cut fruit). Given we found no associations between people's food-environment perceptions and their typical daily produce consumption, it is highly unlikely that found associations to times eating fast food in the past week were in fact due to fruits and vegetables consumed from fast-food restaurants (as opposed to more typical high-fat, high-calorie, high-salt, high-sugar fare). Fifth, we relied on single items for "predictor" and "outcome" measurement that, while perhaps not as precise or nuanced as multi-item instruments, were efficient for examining differences at distributional extremes as was our aim. Using multi-item instruments may have resulted in our finding statistically significant associations between perceptions of the food environment and fruit-and-vegetable consumption as prior studies, our crude results, and intuition would support. Finally, we used census boundaries to delineate neighborhoods. Such delineation has precedent, (Franco et al. 2009; Moore et al. 2008b; Morland et al. 2002) but survey respondents may not have actually viewed their "neighborhoods" as bounded by census lines. While a few census tracts overlap exactly with established neighborhoods in Philadelphia, other census tracts are somewhat smaller or larger than defined neighborhoods (Philadelphia City Planning Commision 2004). Potential discrepancy in definitions of neighborhoods could have introduced imprecision in our estimates. However, given that our results were either highly statistically significant, or near-definitively null, we doubt that the magnitude of this imprecision would meaningfully alter our findings.

In spite of limitations, the results of our study clearly show that how people perceive the food environments in their neighborhoods is associated with what they eat. Perceived difficulty finding or accessing produce and high-quality groceries may encourage the eating of more fast food, but may not further reduce produce consumption in populations already typically eating few fruits and vegetables. If perceptions align with objective conditions, then neighborhoods where perceptions are worst may offer targets for food-environment modifications—i.e. interventions designed to improve availability, accessibility, and quality of healthy foods towards shifting consumption

away from fast foods. Future research should examine the relationships between people's perceptions and objective measures, making use of longitudinal data and natural experiments to assess how changes in the food environment may lead to changes in fruit-and-vegetable and fast-food intake. Such research could provide greater insight into how neighborhood food environments may influence individual dietary behaviors, and how environments may be modified to improve people's diets and public health.

Conflict of interest The authors declare that they have no conflict of interest. Faculty salaries funded this work.

References

American Heart Association Risk Factors and Coronary Heart Disease. In. http://www.americanheart.org/presenter.jhtml?identifier=4726 Accessed March 21 2009

Ball K, Crawford D, Mishra G (2006) Socio-economic inequalities in women's fruit and vegetable intakes: a multilevel study of individual, social and environmental mediators. Public Health Nutr 9(5):623–630

Bazzano LA, Serdula MK, Liu S (2003) Dietary intake of fruits and vegetables and risk of cardiovascular disease. Curr Atheroscler Rep 5(6):492–499

Berkey CS, Rockett HR, Field AE, Gillman MW, Colditz GA (2004) Sugar-added beverages and adolescent weight change. Obes Res 12(5):778–788

Booth SL et al (2001) Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. Nutr Rev 59((3 Pt 2)):S21–S39 discussion S57-65

Caldwell EM, Miller Kobayashi M, Dubow W, Wytinck S (2009) Perceived access to fruits and vegetables associated with increased consumption. Public Health Nutr 12(10):1743–1750

Centers for Disease Control and Prevention (CDC) (2010) State-specific trends in fruit and vegetable consumption among adults — United States, 2000–2009. MMWR Morb Mortal Wkly Rep 59(35):1125–1130

Cheadle A et al (1991) Community-level comparisons between the grocery store environment and individual dietary practices. Prev Med 20(2):250–261

Dibsdall LA, Lambert N, Bobbin RF, Frewer LJ (2003) Low-income consumers' attitudes and behaviour towards access, availability and motivation to eat fruit and vegetables. Public Health Nutr 6(2):159–168

Diez Roux A (2003) A Glossary for Multilevel Analysis. Epidemiol Bull 24(3):1–5

Diez-Roux AV (1998) Bringing context back into epidemiology: variables and fallacies in multilevel analysis. Am J Public Health 88(2):216–222

Diez-Roux AV, Nieto FJ, Caulfield L, Tyroler HA, Watson RL, Szklo M (1999) Neighbourhood differences in diet: the Atherosclerosis Risk in Communities (ARIC) Study. J Epidemiol Community Health 53(1):55–63

Franco M et al (2009) Availability of healthy foods and dietary patterns: the Multi-Ethnic Study of Atherosclerosis. Am J Clin Nutr 89(3):897–904

Freedman DA, Bell BA (2009) Access to Healthful Foods among an Urban Food Insecure Population: Perceptions versus Reality. J Urban Health 86(6):825–838

Frieden TR (2010) A framework for public health action: the health impact pyramid. Am J Public Health 100(4):590–595

Giskes K, Kamphuis CB, van Lenthe FJ, Kremers S, Droomers M, Brug J (2007) A systematic review of associations between environmental factors, energy and fat intakes among adults: is there evidence for environments that encourage obesogenic dietary intakes? Public Health Nutr 10(10):1005–1017

Giskes K, van Lenthe FJ, Kamphuis CB, Huisman M, Brug J, Mackenbach JP (2009) Household and food shopping environments: do they play a role in socioeconomic inequalities in fruit and vegetable consumption? A multilevel study among Dutch adults. J Epidemiol Community Health 63(2):113–120

Grier SA, Kumanyika SK (2008) The context for choice: health implications of targeted food and beverage marketing to African Americans. Am J Public Health 98(9):1616–1629

He FJ, Nowson CA, MacGregor GA (2006) Fruit and vegetable consumption and stroke: meta-analysis of cohort studies. Lancet 367(9507):320–326

Inglis V, Ball K, Crawford D (2008) Socioeconomic variations in women's diets: what is the role of perceptions of the local food environment? J Epidemiol Community Health 62(3):191–197

Kamphuis CB, Giskes K, de Bruijn GJ, Wendel-Vos W, Brug J, van Lenthe FJ (2006) Environmental determinants of fruit and vegetable consumption among adults: a systematic review. Br J Nutr 96(4):620–635

Key TJ et al (1999) Mortality in vegetarians and nonvegetarians: detailed findings from a collaborative analysis of 5 prospective studies. Am J Clin Nutr 70(3 Suppl):516S–524S

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(5):869–875

Michaud CM, Murray CJ, Bloom BR (2001) Burden of disease–implications for future research. JAMA 285(5):535–539

Mokdad AH, Marks JS, Stroup DF, Gerberding JL (2004) Actual causes of death in the United States, 2000. JAMA 291(10):1238–1245

Moore LV, Diez Roux AV, Brines S (2008a) Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment. J Urban Health 85(2):206–216

Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR Jr (2008b) Associations of the local food environment with diet quality–a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. Am J Epidemiol 167(8):917–924

Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR, Franco M (2009) Fast-food consumption, diet quality, and neighborhood exposure to fast food: the multi-ethnic study of atherosclerosis. Am J Epidemiol 170(1):29–36

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(11):1761–1767

National Cancer Institute Fact Sheet - Obesity and Cancer: Questions and Answers. In. http://www.cancer.gov/cancertopics/factsheet/risk/obesity. Accessed March 21 2009

Neckerman KM et al (2010) Disparities in the Food Environments of New York City Public Schools. Am J Prev Med 39(3):195–202

Pearce J, Hiscock R, Blakely T, Witten K (2008) The contextual effects of neighbourhood access to supermarkets and convenience stores on individual fruit and vegetable consumption. J Epidemiol Community Health 62(3):198–201

Pearce J, Hiscock R, Blakely T, Witten K (2009) A national study of the association between neighbourhood access to fast-food outlets and the diet and weight of local residents. Health Place 15(1):193–197

Pearson T, Russell J, Campbell MJ, Barker ME (2005) Do 'food deserts' influence fruit and vegetable consumption?–A cross-sectional study. Appetite 45(2):195–197

Pereira MA et al (2005) Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. Lancet 365(9453):36–42

Philadelphia City Planning Commision (2004) The Political and Community Service Boundaries of Philadelphia. http://www.philaplanning.org/data/boundaries.pdf Accessed 3 Sept 2009

Philadelphia Health Management Corporation (2004) Community Health Data Base - Southeastern Pennsylvania Household Health Survey. http://www.phmc.org/site/index.php?option=com_content&view=article&id=66&Itemid=20

Rabe-Hesketh S, Skrondal A (2006) Multilevel modeling of complex survey data. J Royal Stat Soc Ser A 169:805–827

Rabe-Hesketh S, Skrondal A (2008) Multilevel and longitudinal modeling using Stata, second edn edn. Stata Press, College Station, Texas

Rolls BJ, Fedoroff IC, Guthrie JF (1991) Gender differences in eating behavior and body weight regulation. Health Psychol 10(2):133–142

Rolls BJ, Ello-Martin JA, Tohill BC (2004) What can intervention studies tell us about the relationship between fruit and vegetable consumption and weight management? Nutr Rev 62(1):1–17

Subramanian SV, Jones K, Kaddour A, Krieger N (2009) Revisiting Robinson: the perils of individualistic and ecologic fallacy. Int J Epidemiol 38(2):342–360 author reply 370-3

Timperio A, Ball K, Roberts R, Campbell K, Andrianopoulos N, Crawford D (2008) Children's fruit and vegetable intake: associations with the neighbourhood food environment. Prev Med 46(4):331–335

Turrell G, Blakely T, Patterson C, Oldenburg B (2004) A multilevel analysis of socioeconomic (small area) differences in household food purchasing behaviour. J Epidemiol Community Health 58(3):208–215

U.S. Census Bureau (2000) American FactFinder - Decennial Data Sets. In. http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=DEC&_submenuId=datasets_1&_lang=en Accessed February 1 2009

U.S. Census Bureau - Geography Division (2000) Census Tracts and Block Numbering Areas. In. http://www.census.gov/geo/www/cen_tract.html Accessed October 29 2009

Vainio H, Weiderpass E (2006) Fruit and vegetables in cancer prevention. Nutr Cancer 54(1):111–142

Westenhoefer J (2005) Age and gender dependent profile of food choice. Forum nutr 57:44–51

Wetter AC et al (2001) How and why do individuals make food and physical activity choices? Nutr Rev 59(3 Pt 2):S11–20 discussion S57-65

Zenk SN, Lachance LL, Schulz AJ, Mentz G, Kannan S, Ridella W (2009) Neighborhood retail food environment and fruit and vegetable intake in a multiethnic urban population. Am J Health Promot 23(4):255–264