Does transportation mode modify associations between distance to food store, fruit and vegetable consumption, and BMI in low-income neighborhoods?[1–4]

Daniel Fuller, Steven Cummins, and Stephen A Matthews

ABSTRACT

Background: A consistent body of research has shown that the neighborhood food environment is associated with fruit and vegetable (F&V) consumption and obesity in deprived neighborhoods in the United States. However, these studies have often neglected to consider how transportation can moderate associations between food accessibility and diet-related outcomes.

Objective: This study examined associations between distance to primary food store, fruit and vegetable consumption, and BMI and whether mode of transportation to the primary food store moderates this relation.

Design: Cross-sectional data from the baseline wave of the Philadelphia Neighborhood Food Environment Study were used. A telephone survey of adult (≥18 y of age) household primary food shoppers residing in 2 Philadelphia neighborhoods was conducted (n = 1440).

Results: In a bivariate linear regression analysis, distance to primary food store did not predict F&V consumption (β = 0.04; 95% CI: −0.00, 0.09). Linear regression analysis stratified by transportation mode to the main F&V store showed no difference in F&V consumption between car, public, and multimodal transportation users. Compared with respondents using multimodal transportation, those using public transit had a significantly lower BMI (β = −1.31; 95% CI: −2.50, −0.10), whereas those using an automobile did not (β = −0.41; 95% CI: −1.36, 0.54).

Conclusions: The assumption that using an automobile to access food stores results in increased F&V consumption was not confirmed. Significant associations were found for the relation between transportation mode and BMI. Theory-based mechanisms explaining relationships between the primary transportation mode used to access food stores and BMI should be further explored. *Am J Clin Nutr* 2013;97:167–72.

INTRODUCTION

Diets rich in fruit and vegetables (F&Vs) play an important role in the prevention of chronic diseases such as obesity, heart disease, and some cancers (1). Health promotion initiatives to increase intakes of F&Vs have traditionally been focused on the individual, but in recent years a consistent body of research has shown that the neighborhood food environment may be an important determinant of F&V consumption in the United States (2–6). Low-income neighborhoods and neighborhoods with high proportions of African Americans have been found to have poorer physical access to F&Vs, and residents of these areas may have higher rates of obesity and diet-related chronic disease (2, 7, 8). However, recent longitudinal studies do not support this relation and suggest that other mechanisms may influence the hypothesis that limited access to F&V consumption is related to obesity (9, 10).

Studies investigating the role of the neighborhood food environment on diet do not usually consider the influence of transportation on food accessibility. A small body of research has begun to examine the interaction between access to healthy food and transportation in predicting healthy eating or diet-related chronic disease outcomes (11–15). Auchincloss et al (11) showed that the association between access to healthy food and insulin resistance was stronger for those who did not own an automobile and shopped within walking distance of their home than for those who owned a car and shopped further away. Burns and Inglis (12) found that areas of lower socioeconomic advantage had closer access to fast-food outlets and that access to healthy food was primarily dependent on owning an automobile. Inagami et al (14) found that respondents with greater access to fast food and who did not own vehicles weighed 1.2 kg more than did those residing in the same areas who owned a motor

[1] From the Centre de Recherche du Centre Hospitalier de l'Université de Montréal and Département de Médecine Sociale et Préventive, Université de Montréal, Montréal, Canada (DF); the Healthy Environments Research Programme, School of Geography, Queen Mary University of London, London, United Kingdom (SC); and the Departments of Sociology and Anthropology and Population Research Institute, Pennsylvania State University, University Park, PA (SAM).

[2] The views and opinions expressed herein are those of the author and do not necessarily reflect those of the National Institute of Environmental Health Sciences, the UK National Institutes of Health Research, or the UK Department of Health.

[3] Supported by the Philadelphia Neighborhood Food Environment Study, funded by the National Institute of Environmental Health Sciences award R21-ES014211 (SC and SM), and the Population Research Institute, which receives core funding from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development Award R25-HD41025 (SM). SC was supported by a UK National Institutes of Health Research Senior Fellowship. DF was supported by a Michael Smith Foreign Study supplement from the Canadian Institutes of Health Research.

[4] Address correspondence to D Fuller, Département de Médecine Sociale et Préventive, CP 6128, Succursale Centre-ville, Université de Montréal, Montréal, QC, Canada H3C 3J7. E-mail: daniel.lavergne.fuller@umontreal.ca.

Received February 3, 2012. Accepted for publication October 10, 2012.

First published online November 28, 2012; doi: 10.3945/ajcn.112.036392.

vehicle. The limited literature therefore suggests that motor vehicle ownership may buffer the effect of poor access to high-quality neighborhood food environments. In this study, we extended this work by examining associations between distance to primary food store, F&V consumption, and BMI and by determining whether the mode of transportation respondents used to access their primary food store moderated these associations. We also conducted a sensitivity analysis in a subsample of respondents by examining associations between distance to primary F&V store, F&V consumption, and BMI and by determining whether the mode of transportation respondents used to access their primary F&V store moderated these associations.

SUBJECTS AND METHODS

Study population

Cross-sectional data from the baseline wave of the Philadelphia Neighborhood Food Environment Study were used. This study is a controlled before-and-after study of how changes in the local food environment affect dietary habits in 2 predominantly African American neighborhoods in Philadelphia. A baseline telephone survey of residents in these 2 neighborhoods was conducted in 2006. Respondents were contacted with a prenotification letter along with a cash incentive of $1. After the prenotification letter was sent, a telephone survey was completed with the primary food shopper of the household, which elicited responses to questions relating to diet, psychological well-being, perceptions of food access, food shopping behavior, transportation, and a range of sociodemographic data. To be eligible for the study, households were required to be located in either of the 2 neighborhoods and to have one primary food shopper 18 y of age or older residing within the home. Respondents received $20 for participation. Approval for the study was secured from Pennsylvania State University's Office of Research Protection (Institutional Review Board no. 34283).

The final study sample included 1440 respondents. The response rate [response rate no. 2 defined by the American Association for Public Opinion Research (16)] was 47.2%. The sample eligible for analysis in the current study consisted of 1266 respondents (87.9% of the final sample of 1440); those with missing address information for their primary food store or BMI data were excluded. The final sample for analysis did not differ from the eligible sample on key variables, including daily F&V consumption, distance to the primary food store, and modes of transportation. Sensitivity analysis was conducted on a subsample of 933 respondents whose primary food store was their primary F&V store.

Measures

Primary outcomes were total portions of F&V consumption per day and BMI. F&V consumption was assessed by using the Block food-frequency questionnaire (FFQ) (17, 18). This tool captured the consumption of 10 fruits and 12 vegetables over the past month. Standardized algorithms were used to compute the total daily F&V consumption (19). The Block FFQ has good concurrent validity when compared with dietary records (20). Consistent with past research, and to limit the influence of outliers, the Block FFQ was truncated at 15 F&Vs per day in these analyses (21). BMI was calculated by using the standard equation for adults [weight (kg)/height (m)^2] based on self-reported height and weight.

The primary exposure variables were road network distance (km) and mode of transportation to the respondent's primary food store. Primary food store was measured by asking the main household food shopper "what is the name and location of the main 'store' where you do your major food shopping?" Respondents were subsequently asked "Is your primary food store the same store that you buy most of your fruit and vegetables from? Most (73.5%) of the analysis sample used their primary food store to purchase their F&Vs. If the respondents were unsure of the precise address, they could provide store names and intersections, which were matched by using the Geographic Information System based on a listing of all commercial and publicly available data for known store names and addresses in Philadelphia. Distance was operationalized as a road network distance between the respondent's home and primary food store. Mode of transportation was ascertained by asking the respondents "What mode of transport do you use for the major shopping trip"? The respondents had the option of ticking more than 1 of 7 possible responses: car/van/truck (own), car/van/truck (other family/friend), taxi, bus (public transportation), bicycle, walk, or other. Transportation mode was operationalized as a 3-category variable representing automobile (own or other family/friend, taxi), public transit, or multiple modes. The sociodemographic covariates were age, sex, race (white, black, other), household income (≥$40,000 or <$40,000), employment (full-time or not full-time), household size (number of people residing in the household), and education (>high school or <high school).

Statistical analysis

The analyses were conducted by using Stata version 12 (22). A descriptive analysis was conducted for all of the variables. Bivariate linear regression examined the relation between all variables, F&V consumption, and BMI. After bivariate analysis, distance to the primary food store, transportation mode, and relevant covariates were entered in 2 separate linear regression models predicting F&V consumption and BMI. The potential effect modification of transportation mode between the distance to primary food store, F&V consumption, and BMI was tested by using linear regressions predicting F&V consumption and BMI stratified by transportation mode (23). Multivariable analyses controlled for clustering at the census tract level.

The F&V consumption variable was positively skewed. To ensure that results were robust, regressions were also conducted by using square root transformed F&V consumption. β Values and CIs from all analyses using transformed data were similar and did not change the interpretation of the results. For ease of interpretation, untransformed results are presented. The mode of transportation variable was asked with respect to the primary food store and not the primary F&V store. For completeness, we conducted a sensitivity analysis that examined associations between distance to primary F&V store, F&V consumption, and BMI.

RESULTS

The descriptive results for all variables are presented in **Table 1**. The sample was predominately female (78.4%) and black

(85.9%). The mean (±SD) distance to the primary food store was 3.6 ± 3.08 km, and 60.5% of the sample used a car as their primary mode of transportation to their primary food store. Most (89.9%) of the trips to the primary food store originated from home. The mean BMI was 29.4 ± 6.9.

The unadjusted and adjusted regression models with F&V consumption and BMI as separate dependent variables are presented in **Table 2**. In the bivariate analysis, distance was not associated with F&V consumption (β = 0.04; 95% CI: −0.00, 0.09). In both the bivariate and multivariable analyses, no difference in F&V consumption was found between car, public, and multimodal transportation.

The adjusted results from the linear regressions with F&V consumption and BMI, as separate outcomes stratified by mode of transportation, are shown in **Table 3**. Distance was not significantly associated with F&V consumption for any mode of transportation. Automobile users with a high school education or less eat nearly one fewer portion of F&Vs per day (β = −0.84; 95% CI: −1.37, −0.31). For those using public transportation, no significant associations were found between distance to primary food store or sociodemographic characteristics and F&V consumption. Automobile use was significantly associated with BMI for blacks (β = 3.77; 95% CI: 2.57, 4.96) or "other" race (β = 3.39; 95% CI: 1.04, 5.74). Automobile users who were not employed full time had a significantly lower BMI (β = −1.24; 95% CI: −2.04, −0.45). Respondents using public transportation to the primary food store had higher BMIs if they were female (β = 2.71; 95% CI: 1.50, 3.92) or black (β = 5.55; 95% CI: 1.10, 10.00). Multimodal transportation users had significantly higher BMIs if they were black (β = 4.41; 95% CI: 2.67, 6.15) or "other" race (β = 5.34; 95% CI: 1.90, 8.78). However, multimodal transportation users who were not employed full time had significantly lower BMIs (β = −2.26; 95% CI: −4.55, −0.02).

Results of the sensitivity analyses are presented elsewhere (*see* "Supplemental data" in the online issue). β Values and CIs were similar to the results of the analyses with primary food store used as the exposure variable and did not change the interpretation of the results.

TABLE 1
Descriptive statistics for a sample of 1266 respondents residing in 2 Philadelphia neighborhoods

	Value
BMI (kg/m^2)	29.35 ± 6.88[1]
Fruit and vegetables (servings/d)	3.64 ± 2.57
Distance (km)	3.59 ± 3.08
Mode of transport [% (*n*)]	
Car	60.5 (766)
Public transit	17.9 (227)
Multiple modes	21.6 (273)
Sex [% (*n*)]	
Female	78.4 (992)
Male	21.6 (274)
Age (y)	48.95 ± 16.41
Employment [% (*n*)]	
Not full-time	65.3 (827)
Full-time	34.7 (439)
Education [% (*n*)]	
High school or less	16.0 (203)
More than high school	84.0 (1063)
Race [% (*n*)]	
White	8.0 (101)
Black	85.9 (1088)
Other	6.1 (77)
Household income [% (*n*)]	
<$40,000	73.0 (924)
≥$40,000	27.0 (342)
Household size (*n*)	1.91 ± 1.75

[1] Mean ± SD (all such values).

DISCUSSION

The objective of this study was to examine associations between mode of transportation to the primary food store and a proximal (F&V consumption) and distal (BMI) outcome and whether distance to the store moderated this relation. Results suggest that access (operationalized as distance to primary food store) was not related to F&V consumption in the 2 sampled neighborhoods. This is contrary to past cross-sectional studies in the United States, which showed that poor access is related to F&V consumption (24, 25) but is consistent with recent longitudinal studies (9, 10).

The analyses showed nonsignificant associations between mode of transportation to the primary food store and distance in predicting F&V consumption. Interestingly, similar to past research, those using public transit had a mean BMI 1.2 units lower than that of those using multiple modes of transportation and a mean BMI 0.8 points lower than that of those using automobiles as their mode of transportation to their primary food store. F&V consumption was not significantly negatively related to BMI (11–15). The results of the stratified analyses examining effect modification suggest that automobile and multimodal transportation to the primary food store are associated with a higher BMI for the lowest socioeconomic groups, except for respondents who were not employed full time. Significant positive associations between BMI and being not black or white and having less than a high school education for automobile and multimodal transportation are not present for public transportation.

Given that the results for the outcomes F&V consumption (proximal) and BMI (distal) are not consistent, potential explanatory mechanisms are unclear. Past research using outcomes such as BMI and insulin resistance suggests that access and automobile ownership may be protective of health because automobile owners are better able to access healthy food, and this access results in a reduction in BMI (14, 26). However, the current study did not confirm the hypothesized pathway, ie, that automobile use increases access to foods, which results in an increase in F&V consumption and a subsequent reduction in BMI. This suggests that other mechanisms may explain the relation between transportation, distance to food store, and BMI. A plausible explanation is that automobile users are less physically active; however, this explanation could not be tested because detailed physical activity data were not available. Further analysis should test theory-based pathways that could explain the relation between access to food, mode of transportation, and BMI (how automobile use and multimodal transportation may increase detrimental associations between socioeconomic variables and BMI). In addition, future research should include a more diverse set of neighborhoods to improve the generalizability of findings and consider how both network distance and estimated travel times by different modes of transportation may influence access to healthy food.

TABLE 2
Bivariate and multivariate linear regression associations between F&V consumption, BMI, distance to primary food store, mode of transport, and sociodemographic characteristics in a sample of 1266 respondents from 2 Philadelphia neighborhoods[1]

	β (95% CI)	
	Bivariate association	Multivariable association
Dependent variable: FV consumption		
Distance (km)	0.04 (−0.00, 0.09)	0.04 (−0.01, 0.09)
Mode of transport		
Multiple modes (reference)	1.00	1.00
Car	−0.08 (−0.04, 0.28)	−0.21 (−0.52, 0.09)
Public transit	−0.32 (−0.78, 0.12)	−0.19 (−0.60, 0.21)
Sex		
Male (reference)	1.00	1.00
Female	0.26 (−0.08, 0.60)	0.14 (−0.19, 0.46)
Race		
White (reference)	1.00	1.00
Black	0.34 (−0.19, 0.86)	0.22 (−0.28, 0.71)
Other	0.52 (−0.24, 1.29)	0.55 (0.01, 1.10)*
Employment		
Full-time (reference)	1.00	1.00
Not full-time	−0.05 (−0.35, 0.25)	−0.10 (−0.37, 0.17)
Education		
More than high school (reference)	1.00	1.00
High school or less	−0.21 (−0.60, 0.18)	−0.27 (−0.65, 0.11)
Household income		
≥$40,000 (reference)	1.00	1.00
<$40,000	0.31 (−0.01, 0.63)	0.22 (−0.13, 0.58)
Household size (*n*)	0.12 (0.34, 0.20)*	0.18 (0.07, 0.29)*
Age (y)	0.00 (0.00, 0.02)*	0.02 (0.01, 0.04)*
Dependent variable: BMI		
F&V consumption (servings/d)	−0.03 (−0.17, −0.12)	−0.09 (−0.22, 0.03)
Distance (km)	0.02 (−0.10, 0.15)	0.04 (−0.08, 0.15)
Mode of transport		
Multiple modes (reference)	1.00	1.00
Car	−0.29 (−1.24, 0.66)	−0.42 (−1.28, 0.45)
Public transit	−1.17 (−2.38, 0.04)	−1.22 (−2.29, −0.16)*
Sex		
Male (reference)	1.00	1.00
Female	1.94 (1.02, 2.85)*	1.37 (0.63, 2.12)*
Race		
White (reference)	1.00	1.00
Black	4.89 (3.51, 6.27)*	4.19 (3.36, 5.03)*
Other	3.67 (1.67, 5.67)*	3.48 (1.78, 5.19)*
Employment		
Full-time (reference)	1.00	1.00
Not full-time	−0.33 (−1.13, 0.46)	−1.27 (−2.03, −0.50)*
Education		
More than high school (reference)	1.00	1.00
High school or less	1.67 (0.64, 2.67)*	1.26 (0.05, 2.47)*
Household income		
≥$40,000 (reference)	−0.77 (−1.63, 0.09)	1.00
<$40,000		−0.83 (−1.68, 0.02)
Household size (*n*)	0.24 (0.02, 0.46)*	0.31 (0.11, 0.51)*
Age (y)	0.04 (0.01, 0.06)*	0.04 (0.02, 0.07)*

[1] F&V, fruit and vegetable. *$P < 0.05$.

Strengths and limitations

The strengths of the study include the use of proximal (F&V consumption) and distal (BMI) outcomes to examine the interaction between automobile use and distance to primary food store and the use of actual mode of transportation to the primary food store rather than a proxy such as car ownership. The most important limitation was that approximately one-third of respondents shopped at multiple locations for their F&Vs. Use of primary food store may not have captured the dynamic nature of food shopping and incorrectly estimated the relation between the true environmental exposure to food stores and F&V consumption (5). Limitations of the study included neighborhood

TABLE 3
Multivariable linear regression associations between F&V consumption, BMI, distance to primary food store, and sociodemographic characteristics stratified by mode of transport to the primary store in a sample of 1266 respondents from 2 Philadelphia neighborhoods[1]

	β (95% CI)		
	Car	Public transit	Multiple modes
Dependent variable: F&V consumption			
Distance (km)	0.03 (−0.03, 0.10)	−0.06 (−0.22, 0.09)	0.13 (−0.01, 0.27)
Sex			
Male (reference)	1.00	1.00	1.00
Female	0.02 (−0.26, 0.29)	0.16 (−0.72, 1.05)	0.35 (−0.52, 1.21)
Race			
White (reference)	1.00	1.00	1.00
Black	0.49 (−0.07, 1.05)	0.63 (−0.64, 1.90)	−0.70 (−1.50, 0.10)
Other	0.79 (−0.18, 1.75)	0.05 (−1.60, 1.69)	0.31 (−0.74, 1.37)
Employment			
Full-time (reference)	1.00	1.00	1.00
Not full-time	−0.08 (−0.36, 0.19)	−0.34 (−1.29, 0.62)	0.08 (−0.57, 0.72)
Education			
More than high school (reference)	1.00	1.00	1.00
High school or less	−0.84 (−1.37, −0.31)*	−0.25 (−1.12, 0.62)	0.67 (−0.25, 1.60)
Household income			
≥$40,000 (reference)	1.00	1.00	1.00
<$40,000	0.20 (−0.25, 0.66)	−0.15 (−1.76, 1.46)	0.11 (−0.58, 0.80)
Household size (*n*)	0.18 (0.05, 0.31)*	0.12 (−0.11, 0.35)	0.19 (0.03, 0.35)*
Age (y)	0.02 (0.01, 0.04)*	0.00 (−0.03, 0.04)	0.03 (0.01, 0.05)*
Dependent variable: BMI			
F&V consumption (servings/d)	−0.02 (−0.20, 0.15)	−0.22 (−0.52, 0.07)	−0.24 (−0.56, 0.09)
Distance (km)	−0.02 (−0.13, 0.08)	0.24 (−0.22, 0.70)	0.28 (−0.03, 0.59)
Sex			
Male (reference)	1.00	1.00	1.00
Female	0.99 (−0.02, 2.00)	2.71 (1.50, 3.92)*	0.70 (−1.31, 2.71)
Race			
White (reference)	1.00	1.00	1.00
Black	3.77 (2.57, 4.96)*	5.55 (1.10, 10.00)*	4.41 (2.67, 6.15)*
Other	3.39 (1.04, 5.74)*	2.60 (−1.83, 7.03)	5.34 (1.90, 8.78)*
Employment			
Full-time (reference)	1.00	1.00	1.00
Not full-time	−1.24 (−2.04, −0.45)*	−0.85 (−3.23, 1.54)	−2.26 (−4.55, −0.02)*
Education			
More than high school (reference)	1.00	1.00	1.00
High school or less	1.96 (−0.15, 4.08)	−0.44 (−2.20, 1.32)	1.87 (−0.41, 4.16)
Household income			
≥$40,000 (reference)	1.00	1.00	1.00
<$40,000	−0.74 (−1.72, 0.24)	−1.43 (−4.62, 1.77)	−1.10 (−3.02, 0.82)
Household size (*n*)	0.25 (−0.05, 0.55)	0.38 (−0.33, 1.09)	0.39 (−0.26, 1.04)
Age (y)	0.05 (0.02, 0.08)*	−0.02 (−0.07, 0.03)	0.12 (0.05, 0.18)*

[1] F&V, fruit and vegetable. *$P < 0.05$.

race-ethnicity and socioeconomic status being homogeneous, which reduces generalizability. Furthermore, multiple testing could have resulted in spurious associations, the sample size was somewhat small for a stratified analysis, and the Block FFQ may not include all of the culturally relevant foods of the current study population (27). The cross-sectional design did not allow modeling of changes in food store use (28). Self-reported BMI may be prone to systematic error (29), although it has been validated for use in epidemiologic studies of adults (30).

Conclusions

Transportation mode may not moderate associations between distance to primary food store and F&V consumption. The hypotheses suggesting that the use of an automobile to access healthy foods results in increased F&V consumption were not confirmed in this study. However, significant associations were found for the relation between transportation mode and BMI, with public transportation having a small protective effect. Mechanisms other than diet quality (such as physical activity) may therefore explain the relation between transportation mode, distance to grocery stores, and BMI. Alternate theory-based mechanisms that possibly explain relations between BMI and primary transportation mode used to access F&Vs should be further explored.

The authors' responsibilities were as follows—DF, SC, and SAM: designed the research; DF: analyzed the data and had primary responsibility

for the final content; and DF and SC: wrote the manuscript. All authors read and approved the final manuscript. None of the authors reported any conflicts of interest.

REFERENCES

1. World Health Organization. Diet, nutrition and the prevention of chronic diseases: scientific background papers of the joint WHO/FAO expert consultation. Geneva, Switzerland: Public Health Nutrition, 2004.
2. Baker EA, Schootman M, Barnidge E, Kelly C. The role of race and poverty in access to foods that enable individuals to adhere to dietary guidelines. Prev Chronic Dis 2006;3:A76.
3. Cummins S, Macintyre S. Food environments and obesity—neighbourhood or nation? Int J Epidemiol 2006;35:100–4.
4. Kestens Y, Daniel M. Social inequalities in food exposure around schools in an urban area. Am J Prev Med 2010;39:33–40.
5. McKinnon RA, Reedy J, Morrissette MA, Lytle LA, Yaroch AL. Measures of the food environment: a compilation of the literature, 1990-2007. Am J Prev Med 2009;36:S124–33.
6. Zenk SN, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML. Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit. Am J Public Health 2005;95:660–7.
7. Kipke MD, Iverson E, Moore D, Booker C, Ruelas V, Peters AL, Kaufman F. Food and park environments: neighborhood-level risks for childhood obesity in east Los Angeles. J Adolesc Health 2007;40: 325–33.
8. Morland K, Wing S, Diez-Roux A. The contextual effect of the local food environment on residents' diets: the Atherosclerosis Risk in Communities study. Am J Public Health 2002;92:1761–7.
9. Block JP, Christakis NA, O'Malley AJ, Subramanian SV. Proximity to food establishments and body mass index in the Framingham Heart Study Offspring cohort over 30 years. Am J Epidemiol 2011;174: 1108–14.
10. Boone-Heinonen J, Gordon-Larsen P, Kiefe CI, Shikany JM, Popkin BM. Longitudinal associations with diet in young and middle-aged adults: the CARDIA Study. Arch Intern Med 2011;171:1162–70.
11. Auchincloss AH, Diez-Roux AV, Brown DG, Erdmann CA, Bertoni AG. Neighborhood resources for physical activity and healthy foods and their association with insulin resistance. Epidemiology 2008;19: 146–57.
12. Burns CM, Inglis AD. Measuring food access in Melbourne: access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. Health Place 2007;13:877–85.
13. Harrington J, Friel S, Thunhurst C, Kirby A, McElroy E. Obesogenic island: the financial burden of private transport on low-income households. J Public Health (Oxf) 2008;30:38–44.
14. Inagami S, Cohen DA, Brown AF, Asch SM. Body mass index, neighborhood fast food and restaurant concentration, and car ownership. J Urban Health 2009;86:683–95.
15. Inagami S, Cohen DA, Finch BK. Non-residential neighborhood exposures suppress neighborhood effects on self-rated health. Soc Sci Med 2007;65:1779–91.
16. The American Association for Public Opinion Research. Version 7. Available from: http://www.aapor.org/For_Researchers/4683.htm (cited 18 November 2012).
17. Block G, Coyle LM, Hartman AM, Scoppa SM. Revision of dietary analysis software for the Health Habits and History Questionnaire. Am J Epidemiol 1994;139:1190–6.
18. Block G, Hartman AM, Dresser CM, Carroll MD, Gannon J, Gardner L. A data-based approach to diet questionnaire design and testing. Am J Epidemiol 1986;124:453–69.
19. Centers for Disease Control and Prevention. Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/ffqdc_d.pdf (accessed 31 January 2012).
20. Block G, Woods M, Potosky A, Clifford C. Validation of a self-administered diet history questionnaire using multiple diet records. J Clin Epidemiol 1990;43:1327–35.
21. Michels KB, Giovannucci D, Chan AT, Singhania R, Fuchs CS, Willett WC. Fruit and vegetable consumption and colorectal adenomas in the Nurse's Health Study. Cancer Res 2006;66:3942–53.
22. StataCorp. Stata statistical software: release 12. College Station, TX: StataCorp LP, 2011.
23. Rothman KJ, Greenland S. Modern epidemiology. 2nd ed. Philadelphia, PA: Lippincott-Raven Publishers, 1998.
24. Beaulac J, Kristjansson E, Cummins S. A systematic review of food deserts, 1966-2007. Prev Chronic Dis 2009;6:A105.
25. Gordon C, Purciel-Hill M, Ghai NR, Kaufman L, Graham R, Wye GV. Measuring food deserts in New York City's low-income neighborhoods. Health Place 2011;17:696–700.
26. Macintyre S. Deprivation amplification revisited; or, is it always true that poorer places have poorer access to resources for healthy diets and physical activity? Int J Behav Nutr Phys Act 2007;4:32.
27. Grigsby-Toussaint DS, Zenk SN, Odoms-Young A, Ruggiero L, Moise I. Availability of commonly consumed and culturally specific fruits and vegetables in African-American and Latino neighborhoods. J Am Diet Assoc 2010;110:746–52.
28. Widener MJ, Metcalf SS, Bar-Yam Y. Dynamic urban food environments: a temporal analysis of access to healthy foods. Am J Prev Med 2011;41:439–41.
29. Plankey MW, Stevens J, Flegal KM, Rust PF. Prediction equations fo not eliminate systematic error in self-reported body mass index. Obes Res 1997;5:308–14.
30. McAdams MA, Van Dam RM, Hu FB. Comparison of self-reported and measured BMI as correlates of disease markers in US adults. Obesity (Silver Spring) 2007;15:188–96.