BMJ open

Are neighborhood food resources distributed inequitably by income and race? Epidemiologic findings across the urban spectrum

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000698
Article Type:	Research
Date Submitted by the Author:	20-Dec-2011
Complete List of Authors:	Richardson, Andrea; UNC Chapel Hill, Nutrition Boone-Heinonen, Janne; Oregon Health & Science University, Public Health & Preventive Medicine Popkin, Barry; UNC Chapel Hill, Nutrition Gordon-Larsen, Penny; UNC Chapel Hill,
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	NUTRITION & DIETETICS, PUBLIC HEALTH, STATISTICS & RESEARCH METHODS

Are neighborhood food resources distributed inequitably by income and race?

Epidemiologic findings across the urban spectrum

Andrea S. Richardson[1], Janne Boone-Heinonen[2], Barry M. Popkin[1], and Penny Gordon-Larsen[1]

[1] Department of Nutrition, University of North Carolina at Chapel Hill; Carolina Population Center, 123 West Franklin St. Campus Box 8120, Chapel Hill, NC USA

[2] Public Health & Preventive Medicine, Oregon Health & Science University; 3181 SW Sam Jackson Park Road, Mail Code CB 669, Portland, OR 97239-3098, USA

Please Address Correspondence & Reprint Requests To:

Penny Gordon-Larsen

University of North Carolina at Chapel Hill

Carolina Population Center

123 West Franklin St. CB#8120

Chapel Hill, NC 27516-3997, USA

Phone: (W) 919-843-9966; Fax: 919-966-9159

Keywords (MeSH*): Epidemiology, United States, *Diet, Geographic Information Systems, Environment, Environment Design, Fast Foods, Restaurants, Young Adult

Abstract 295 words

Text 3056 words excluding title page, abstract, references, and tables

SUMMARY

1) Article Focus
   - Most research on socioeconomic inequities in neighborhood food environments are conducted in dense, urban areas, focus on supermarkets, and do not address the potential joint role of neighborhood race/ethnic composition and neighborhood income.
   - In a national sample, we examine inequities in neighborhood food availability according to joint combinations of neighborhood poverty and minority population across non-urban, low-density, and high-density urban areas.

2) Key Messages
   - Sociodemographic inequities in grocery/supermarket, convenience store, and fast-food restaurant availability were most pronounced in low density urban (largely suburban) areas.
   - In high density urban areas, higher neighborhood poverty was associated with greater availability of all food resources.
   - While many state and national efforts focus on providing healthy eating options in poor, inner-city neighborhoods, our results suggest that less urban areas might benefit from similar policies.

3) Strengths and Limitations
   - This study benefits from several innovations and depth of coverage that has been heretofore unaddressed in a large, geographically diverse study.
   - While secondary food environment data from business records may have introduced error and do not provide foods sold at each establishment, these limitations are outweighed by the ability to address comparable data across the full US (i.e., thousands of census blocks groups).
   - The most significant strength of the study is the ability to examine variation in neighborhoods across the US, which enables comparisons across multiple sociodemographic and urban strata within a single study.
   - Other strengths include the attention to a variety of food resources, two dimensions of neighborhood socioeconomic status, and examination of small neighborhood areas within the context of a national geographic scope.

Abstract

Objective. While there is much recent policy attention to inequities in availability of healthy food stores and restaurants, there is little understanding of how such inequities vary across neighborhood poverty, race, and urbanicity. Largely this gap is due to lack of large studies that capture diverse geographic and sociodemographic populations. Using a national sample, we examined disparities in neighborhood food availability across non-urban, low- and high-density urban areas.

Design. Cross-sectional data from a national, observational epidemiologic cohort study.

Participants. Using neighborhood characteristics of participants in the National Longitudinal Study of Adolescent Health (Wave III, 2001-02; n=13,995 young adults representing 7,588 US block groups), we examined associations between neighborhood poverty and race/ethnicity with neighborhood food resources in urbanicity-stratified multivariable linear regression.

Primary and Secondary outcome measures: Neighborhood availability of grocery/supermarkets, convenience stores, and fast food restaurants (measured as number of outlets per 100 km roadway).

Results. Neighborhood race and income disparities were most pronounced in low density urban areas, where high poverty/high minority areas had lower availability of grocery/supermarkets [beta coefficient (beta)= -1.91; 95% confidence interval (CI) -2.73, -1.09] and convenience stores (beta=-2.38, CI: -3.62, -1.14) and greater availability of fast food restaurants (beta=4.87, CI: 2.26, 7.48) than low poverty/low minority areas. However, in the dense, urban areas, high poverty/low minority neighborhoods had comparatively greater availability of grocery/supermarkets (beta=8.05, CI: 2.52, 13.57), convenience stores (beta=2.89,

CI: 0.64-5.14), and fast food (beta=4.03, CI: 1.97, 6.09), relative to low poverty/low minority areas.

Conclusions. In addition to targeting disproportionate fast food availability in disadvantaged dense urban areas, our findings suggest that policies should also target disparities in grocery/supermarket and fast food restaurant availability in low density areas. To better inform policy, distinct social and economic drivers of food resource allocation across urban, suburban, and rural areas should be explored.

INTRODUCTION

National, state, and local policies increasingly focus on improving availability of healthy foods in disadvantaged neighborhoods. Expectations that such policies will improve diets in low income and race/ethnic minority populations stem from evidence that inequitable access to healthy foods may underlie differentials in diet quality [1-3], obesity [4], and related diseases by income and race/ethnicity (see reviews [5-8]). However, understanding the extent to which inequities in different types of food resources exist in different types of U.S. communities is limited by several factors.

First, research has focused on "food deserts", generally defined as areas with limited access to affordable fresh foods from supermarkets (see reviews [5-8]). Subsequently, "food swamps" [9], characterized as neighborhoods with disproportionate access to convenient, energy dense, nutrient poor foods sold by convenience stores and fast food restaurants, emerged as important dimensions of the food environment. Thus, attention to a variety of food resources, such as supermarkets, convenience stores, and fast food restaurants, may be a more useful approach to examining neighborhood food access [8, 10].

Second, most existing food access initiatives target low income, dense urban areas, yet suburban and rural areas may be even more sensitive to the food environment due to shifting demographic compositions and car-dependent infrastructure. Yet few studies examine variation in availability of food resources by urbanicity [6, 11-13].

Third, allocation of food resources according to income has received the most focus, with some examination of race/ethnic differences. Patterning by race/ethnicity may further compound patterning according to income and would underscore the importance of culturally sensitive

policies. However, the joint role of neighborhood race/ethnic composition and neighborhood income has received little attention.

Our GIS-derived neighborhood characteristics from a national sample of 13,995 young adults living throughout the US captured many types of food resources and provided variation in individual-level and neighborhood-level characteristics required to examine disparities in food resource availability according to income, race/ethnicity, and urbanicity. With our unique data, we characterize food resource availability as the count of several types of resources per roadway distance within a 3 kilometer street network buffer, which represents access to resources relative to the street network potentially reflecting routes of travel [14]. To address vast variation in measures of the food environment across published studies, we present findings using different neighborhood definitions and density calculations to facilitate comparisons with published literature.

We examined the joint role of neighborhood race/ethnic composition and neighborhood income across non-urban, low density urban, and high density urban areas. Specifically, we tested if individuals living in neighborhoods comprised of populations with high proportions of low income and minority residents had lower availability of grocery/supermarkets and greater availability of fast-food restaurants and convenience stores (compared to areas with high proportion of high income and non-minority populations), and whether this distribution varied across less urban and more urban areas.

METHODS

Study population and data sources

Our study sample is derived from respondents aged 18 to 24 years who participated in Wave III (2001-02) of the National Longitudinal Study of Adolescent Health (Add Health), a nationally representative, prospective cohort study of adolescents of the US school-based population in grades 7 to 12 (11-22 years of age) in 1994-95 who are followed into adulthood (wave III). Subjects eligible for inclusion in the analytic sample included 14,322 Wave III young adults with sample weights. The Add Health sample was collected under protocols approved by the Institutional Review Board at the University of North Carolina. The survey design and sampling frame have been discussed elsewhere [15, 16]. The authors have no conflicts of interest to declare and have each made 1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

We used the Add Health Obesity and Neighborhood Environment database (ONEdata), a Geographic Information System that includes time-varying, community-level data geographically-linked to respondent residential addresses geocoded with street-segment matches (n=13,039), global positioning system (GPS) measurements (n=1,204), and ZIP/ZIP+4/ZIP+2 centroid match (n=685). Attributes of areas within 1, 3, 5, and 8.05 km of each respondent location (neighborhood buffers) and block group, tract, and county attributes from time-matched U.S. Census and other federal sources were merged with individual-level Add Health interview responses [17]. The number of census block groups (n=7,588) represents 3.6% of 2000 US Census block groups.

Of 14,322 Wave III respondents with sample weights, 327 (2.3%) with missing food environment or US census data were excluded, leaving an analytic sample of 13,995.

Study variables

GIS-derived neighborhood data

For our central analysis we used residential locations linked to attributes of areas within 3 km straight line distance (Euclidean buffer) and along the street network for (street network buffer) surrounding each respondent's residential location in the Wave III (2001). The 3 km buffer has been shown to be relevant for assessing associations between neighborhood resources and individual level behavior [18]. Comparative analyses were conducted with 1 and 8 km buffers. Neighborhood food environment, sociodemographic, and urban indicator data were merged with individual-level Add Health interview data.

Food environment

Food resource data were obtained from Dun and Bradstreet, a commercial dataset of US businesses. Food resources were classified according to 4- and 8-digit Standard Industrial Classification (SIC) codes. Three categories of food resources were used: 1) fast-food restaurants, defined as fast-food chain and non-chain restaurants, excluding food stands and cafeterias; 2) grocery stores and supermarkets, defined as independent and chain grocery stores and supermarkets; and 3) convenience stores, defined as variety & convenience stores and food stores attached to gasoline filling stations. Full details are described in Appendix A.

Given the importance of scaling resources by general urban development, we created measures of resources per kilometers of secondary/connecting and local, neighborhood and rural

roads using street data obtained from StreetMap Pro (July 2003, v.5.2) data from Environmental Systems Research Institute (ESRI, www.esri.com) in Redlands, CA. We selected the 3km street network buffer after evaluating associations with resource availability and sensitivity of buffer size. We thus defined food resource availability as the number of outlets per 100 kilometer of roadway within a 3 km network buffer to account for differences in food resource counts according to the amount of commercial activity in an area.

Neighborhood sociodemographics

Census block groups were used to define neighborhoods because smaller units are more likely to adhere to individually perceived neighborhood boundaries [19] and are more sociodemographically homogeneous. Using the federal definition of "poverty area" [20, 21], we dichotomized neighborhood poverty into >20% or ≤20% of population below the federal poverty level. We defined neighborhood minority population as percent of population of non-Hispanic white race/ethnicity and neighborhood-level education as percent of population ≥25 years with college or greater education. To evaluate potential interaction of neighborhood poverty status with minority population we created a categorical variable: 1) low poverty/low minority, 2) high poverty/low minority, 3) low poverty/medium minority, 4) high poverty/medium minority, 5) low poverty/high minority, 6) high poverty/high minority.

Neighborhood Urbanicity

US Census-defined urbanized areas (UA) were used to classify residential locations as non-urban (outside UA) or urban (inside UA). Within urban areas, we used Fragstats [22] software with US Geologic Survey National Landcover Data to distinguish: 1) low density [≤95% (75th percentile) developed land cover] and 2) high density [>95% developed land cover]

urban areas based on the area of developed land as a proportion of total area within 3km after excluding water and ice. Our measure of developed land cover provides an indicator of urban development that is independent of population density and correctly classifies areas as within or outside of a UA (Receiver Operating Characteristic curve area=0.937).

Statistical analysis

Descriptive analysis

Availability of food resources and sociodemographic characteristics were compared across non-urban, low density urban, and high density urban strata. We examined urbanicity-specific tertiles of neighborhood minority population (Table 1) to address non-linear associations with food resource availability measures. All statistical analyses were weighted for national representation and corrected for complex survey design using Stata 11.1 (Stata Corp, College Station, TX).

Multivariable regression analysis

We fit multivariable linear regression models to predict food resource availability as a function of neighborhood poverty and minority population where our constructed variable combining neighborhood poverty (high and low) with levels of minority population (low, medium, high) explicitly estimates interactions relative to the theoretically most advantaged neighborhoods (low poverty/low minority). Given that food resources and neighborhood sociodemographics varied dramatically across urbanicity, comparability across sociodemographic and geographic subpopulations was difficult, even with our large sample size. Nonetheless, we have large samples of individuals and block groups across urbanicity strata, with adequate variation across neighborhood sociodemographics (Table 1). All models were weighted for national

representation, corrected for clustering on our primary sampling unit (schools) and controlled for continuous neighborhood-level education and population density dichotomized into urbanicity-specific quantiles. Given that schools and census block groups are not geographically nested, we did not use multi-level analysis. Further, multi-level analysis of unbalanced, sparse data within census block groups can result in biased estimates [23].

To aid interpretation of the model results, we used the estimated model coefficients to predict food resource availability across levels of neighborhood-level poverty and minority population within the low density-urban stratum, where the strongest disparities were observed.

Comparative analyses

In order to assess whether different neighborhood buffer sizes were needed in urban versus non-urban areas, we compared and found similar patterns for the 1 km buffer in urban areas and the 8 km buffer in non-urban areas. In addition, we assessed alternate measures of food resource availability to compare our main measure findings with commonly used though conceptually different metrics: count per population [2] and distance to nearest outlet [1, 10, 24]. Specifically, we contrasted our roadway-scaled measure with: 1) density of food resources per 10,000 population within 3 km Euclidean buffer; and 2) minimum distance to the single nearest food resource within 8 km Euclidean buffer. We repeated identical multivariable regression models with alternate measures, except models with population density measures did not control for population density. Results for food resources per 100 kilometer of roadway within a 3 km network buffer are presented in text, while results for all other measures are shown in the Appendices B-C.

RESULTS

Availability of grocery/supermarkets, convenience stores, and fast food restaurants varied dramatically across non-urban, low density urban and high density urban areas, with more resources in high density urban areas (Table 2).

In multivariable analysis, availability of grocery/supermarkets and convenience stores for low density urban residents did not differ according to neighborhood poverty; rather, lower availability of food stores was observed with greater minority populations (Table 3). Food stores were more equitably allocated in non-urban neighborhoods. Interestingly, greater availability of food stores was often found in high density urban areas with high proportions of low income residents, but this relationship with neighborhood income did not hold in neighborhoods with high proportion of minority residents.

Fast food availability was greater for residents in high poverty neighborhoods, with strongest associations in low and high density urban areas (Table 3). Among those living in neighborhoods with high poverty, greater minority population incurred additional inequities in food resource availability, particularly in low density urban areas. In a notable exception, in high density urban, high minority areas, fast food was *less* available in high poverty neighborhoods.

Figure 1 presents predicted food resource availability (based on the Table 3 models) and more clearly illustrates the differential associations with poverty versus race/ethnicity in non-urban, low density urban, and high density urban areas.

In general, estimated patterns of disparities were very similar between roadway-scaled, population density and distance measures (Appendices B-C).

DISCUSSION

We assessed inequities in grocery/supermarket, convenience store, and fast-food restaurant availability by neighborhood poverty and minority population in a large, diverse national sample of residential neighborhoods of young adults, representing 7,588 census block groups (3.6% of 2000 US Census block groups). Our findings suggest that inequities in food availability do exist, but not always where prior research suggests. In particular, racial and income disparities in availability of grocery/supermarkets were far more apparent in low density urban areas than in high density urban areas, where food deserts have been shown to exist [25-28]. In an unexpected finding, areas with high poverty and high minority population also have lower availability of convenience stores, which typically provide largely energy dense, nutrient poor foods [29, 30]. Greater availability of fast food in areas with high poverty rates and high minority population was more consistent across non-urban, low density urban and high density urban areas.

Differences in availability of grocery/supermarkets, convenience stores, and fast-food restaurants were most consistent in low density urban areas, which include the largest proportion of our sample and theoretically captures suburban America. In the US, we also note that the distribution of poverty has shifted away from the dense inner cities. Data from the 2010 census reports suggest that counter to the assumption of "White Flight" out of inner cities, racial minorities, foreign-born, and low income people were more likely to live in metropolitan suburbs in 2010 than the cities they lived in during 2008 [31]. Thus, the income and race/ethnic disparities in availability of healthy and unhealthy foods observed in low density urban areas in our 2001 data may become much more important as poor and minority populations increasingly reside in suburban neighborhoods. Our findings suggest that in addition to increasing grocery

store availability and limiting fast food availability in disadvantaged dense urban areas, rural and suburban areas should be targeted for food environment improvements. While this idea has been suggested by a series of studies in rural Texas [12], our national study further supports more focus on rural and suburban food environments.

Relationships between food resource availability, neighborhood poverty, and minority population were notably distinct in high density urban areas. First, our finding of *greater* availability of grocery stores and convenience stores in high versus low poverty areas, but only in areas with predominately white populations, suggests the presence of complex economic and social drivers in where food stores choose to locate. Second, fast food availability was generally greater in high poverty, high minority areas, but this was not true in high minority, high density urban areas. This finding is consistent with prior evidence [8, 32] that perceived or real racial tensions or safety concerns may also influence opening and closure of food establishments.

Findings using our main roadway scaled measures and population density measures were nearly identical as they likely capture resources scaled by commercialization and development indicated by population and roadways. Slight inconsistencies in results for the minimum distance measures and may reflect increased variation that results from using a single data point (nearest outlet) to characterize availability compared to incorporating data from multiple resources within an area. Minimum distance measures also do not account for differential distribution of food resources according to population and development density.

Strengths and limitations

This study did not look at extreme poverty nor consider a large array of other factors linked with urbanicity. It is possible that disparities in food resources in dense, urban areas may

be evident only under extreme neighborhood poverty that we did not examine in our analysis. More refined analyses of dynamic effects among social and economic environments and food resources are beyond the scope of the present analysis though they certainly warrant further attention. Moreover, other factors such as crime [32], aesthetics [32], travel time [33], or proximity to other resources [32] could also relate to actual or perceived access to food resources.

The benefit of business record data, which provides comparative national food resource data, must be balanced with their limitations. Neighborhood audits (street-by-street data collection by researchers) may better capture food environment features that contribute to healthy food access, but they are not feasible for large national samples across thousands of census blocks groups. These intense audits are generally performed in smaller geographic areas, and thus preclude broad comparisons across neighborhood type and sociodemographics. We were unable to ascertain food sold at each establishment and relied on generalizations regarding healthy (grocery/supermarket) versus unhealthy (convenience store, fast food restaurant) types of establishments. In addition, this is a cross-sectional study and thus does not capture changes in food environments over time. Further, due to lower participation of illegal immigrants in the census, US census data may underestimate neighborhood minority population and poverty. Finally, our 3 km network residential neighborhood buffer may not accurately reflect food purchasing areas for different urban settings and sociodemographic subgroups; this is a topic worthy for future study.

Despite these limitations, our study is an essential step in understanding the allocation of theoretically healthy and less healthy food resources across social and geographic space over the entire US, and our findings can inform measurement and design in future individual-level and

longitudinal studies. Our study benefits from the variation in neighborhoods of a large population that enables comparisons across multiple sociodemographic and urban strata within a single study. Further, our study capitalizes upon national data with roadway scaled measures of food availability within 3 km residential network buffers for each observation. In addition, we used more detailed measures of urbanicity derived both from US census and landcover data allowing a more refined urban/rural classification than the traditional urban/rural dichotomy. In sum, our study benefits from several innovations and depth of coverage that has been heretofore unaddressed in a large, geographically diverse study.

Policy implications

Many state and national efforts focus on providing healthy eating options for poor inner-city neighborhoods, many with high minority populations. Strategies include providing produce carts in low income neighborhoods in New York City [34], directly or indirectly subsidizing supermarkets [35-38], banning fast-food restaurant construction in selected urban areas [39], as well as legislation considered at the national level [40]. Our results suggest that less urban areas might benefit from similar policies.

Conclusion

Our findings suggest that common assumptions regarding income and race-ethnic subpopulation disparities in food resources may not be universally true across the spectrum of urbanicity. We observed an association between greater neighborhood poverty and minority population with greater availability of fast-food restaurants in urban areas. Conversely, disparities in grocery/supermarkets were primarily observed in low density urban areas. Our

findings suggest that poverty and race may play distinct roles in how food resources are allocated and that underlying social complexities should be further explored in dense urban, suburban, and rural areas.

ACKNOWLEDGEMENTS

The authors would like to thank Brian Frizzelle, Marc Peterson, Chris Mankoff, James D. Stewart, Phil Bardsley, and Diane Kaczor of the University of North Carolina, Carolina Population Center (CPC) and the CPC Spatial Analysis Unit for creation of the environmental variables. The authors also thank Ms. Frances Dancy for her helpful administrative assistance. There were no potential or real conflicts of financial or personal interest with the financial sponsors of the scientific project.

This work was funded by National Institutes of Health grant R01HD057194 and R01 HD041375, R01 HD39183, a cooperative agreement with the Centers for Disease Control and Prevention (CDC SIP No. 5-00). The authors are also grateful to R24 HD050924 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) for broad support of the authors, although no funding was provided by this grant. Analysis and manuscript preparation was supported by the Interdisciplinary Obesity Training postdoctoral fellowship (T32MH075854-04).

Data sharing: This research uses data from Add Health, a program project designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris, and funded by a grant P01-HD31921 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, with cooperative funding from 17 other agencies. Special acknowledgment is due Ronald R. Rindfuss and Barbara Entwisle for assistance in the original design. Persons interested

in obtaining data files from Add Health should contact Add Health, CPC, 123 W. Franklin Street, Chapel Hill, NC 27516-2524 (addhealth@unc.edu). No direct support was received from grant P01-HD31921 for this analysis.

Contributorship:

All authors significantly contributed to the

1) conception and design, acquisition of data or analysis and interpretation of data

2) drafting the article or revising it critically for important intellectual content.

3) final approval of the version published

Table 1. Urbanicity-specific [a] neighborhood demographics, National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995.

	Non-urban	Low density urban	High density urban
Count (census block groups)	1,530	4,132	1,935
Count (Add Health respondents)	3,779	6,676	3,549
% College educated or above[b] - mean (SD)	16.6 (0.8)	25.5 (1.1)	22.2 (1.8)
Population density (persons/km^2)[c] - range			
Low	0.2-80.4	15.4-981.3	555.2-2651.2
High	80.7-2299.9	981.4-26514.7	2651.5-22952.4

[a] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.
[b] Census block group
[c] Within 3km Euclidean buffer around individual residence

Table 2. Means and (SD) of food resources[a] (Count per 100 km secondary and local road within 3 km network buffer around each individual residence)[b,] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicity[c]

Neighborhood					
Percent poverty[d,e] within 3k	Percent minority population[d,f] within 3k	N	Grocery/ supermarket	Convenience stores	Fast food
				Non-urban	
Low	Low	545	0.22 (0.08)	0.91 (0.42)	2.48 (0.47)
	Medium	954	0.14 (0.03)	0.34 (0.07)	2.04 (0.23)
	High	1024	0.05 (0.02)	0.22 (0.05)	1.43 (0.24)
High	Low	715	0.33 (0.20)	2.00 (1.21)	3.22 (0.53)
	Medium	306	0.08 (0.04)	0.17 (0.08)	5.03 (0.72)
	High	232	0.12 (0.06)	0.27 (0.14)	1.68 (0.91)
	Total	3,779	0.15 (0.05)	0.62 (0.27)	2.33 (0.21)
				Low density urban	
Low	Low	1320	3.47 (0.39)	4.57 (0.66)	5.71 (0.39)
	Medium	1757	1.90 (0.17)	2.77 (0.19)	5.30 (0.21)
	High	2078	0.84 (0.15)	1.55 (0.27)	4.32 (0.18)
High	Low	910	3.81 (0.58)	4.20 (0.46)	6.48 (0.36)
	Medium	477	2.25 (0.47)	3.18 (0.43)	9.40 (0.50)
	High	129	1.28 (0.38)	1.91 (0.45)	10.31 (1.24)
	Total	6,676	2.06 (0.22)	2.86 (0.26)	5.58 (0.19)
				High density urban	
Low	Low	767	8.21 (2.96)	7.47 (0.81)	6.83 (1.33)
	Medium	786	8.06 (2.55)	9.74 (1.12)	7.32 (1.17)
	High	870	7.19 (1.82)	11.31 (1.85)	6.71 (0.85)
High	Low	418	15.97 (5.46)	10.08 (1.80)	9.70 (2.45)
	Medium	400	9.70 (4.22)	9.69 (1.92)	7.12 (2.13)
	High	307	7.09 (1.46)	9.95 (0.65)	7.10 (1.20)
	Total	3,549	8.72 (2.31)	7.24 (1.08)	10.18 (1.14)

[a] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food
[b] Means and SD corrected for clustering and weighted for representation.
[c] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.
[d] Census block group
[e] Greater than 20% of population below the federal poverty level
[f] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-100%)

Table 3. Associations between high neighborhood poverty[a] and urbanicity-specific minority composition[b] and high neighborhood and food resource[c] availability [beta coefficient (95% CI)][d] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicity[e]

Food resource (count per 100 km secondary and local road within 3 km network buffer)	Neighborhood: Percent poverty[a,f] within 3k	Neighborhood: Percent minority popula-tion[b,f] within 3k	Non-urban: beta coefficient (95% Confidence Interval)	Low density urban: beta coefficient (95% Confidence Interval)	High density urban: beta coefficient (95% Confidence Interval)
Grocery/super market					
	Low	Low	0.0	0.0	0.0
		Medium	-0.09 (-0.23, 0.05)	-1.17 (-1.72, -0.63)*	-2.11 (-7.54, 3.31)
		High	-0.13 (-0.28, 0.01)	-1.76 (-2.39, -1.13)*	1.70 (-2.38, 5.77)
	High	Low	0.09 (-0.21, 0.40)	0.26 (-0.70, 1.21)	8.05 (2.52, 13.57)†
		Medium	-0.18 (-0.37, 0.00)	-1.35 (-2.36, -0.33)*	4.96 (-1.74, 11.65)†
		High	0.00 (-0.18, 0.18)†	-1.91 (-2.73, -1.09)*	-0.72 (-5.68, 4.24)*
Convenience store					
	Low	Low	0	0	0
		Medium	-0.54 (-1.26, 0.17)	-1.38 (-2.44, -0.32)*	-0.53 (-3.07, 2.01)
		High	-0.51 (-1.20, 0.17)	-2.05 (-3.17, -0.93)*	1.56 (-0.41, 3.53)
	High	Low	1.01 (-0.69, 2.71)	-0.43 (-1.69, 0.84)	2.89 (0.64, 5.14)†
		Medium	-0.86 (-1.76, 0.04)†	-1.58 (-3.06, -0.11)*	2.19 (-0.92, 5.31)†
		High	-0.27 (-0.92, 0.39)	-2.38 (-3.62, -1.14)*	0.64 (-1.61, 2.88)
Fast food					
	Low	Low	0	0	0
		Medium	-0.68 (-1.37, 0.01)	-0.01 (-0.63, 0.61)	0.39 (-1.77, 2.54)
		High	-0.47 (-1.07, 0.14)	-0.44 (-1.12, 0.24)	4.36 (1.44, 7.28)*
	High	Low	0.44 (-0.34, 1.23)	0.73 (-0.08, 1.53)	4.03 (1.97, 6.09)†
		Medium	1.80 (0.75, 2.86)*†	3.47 (2.31, 4.64)*†	4.85 (2.13, 7.57)†
		High	0.82 (-0.62, 2.26)	4.87 (2.26, 7.48)*†	1.56 (-1.39, 4.50)

[a] Greater than 20% of population below the federal poverty level

[b] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-100%)

[c] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food

[d] Linear regression models, controlling for percent college educate and population density

[e] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.

[f] Census block group

* Statistically different (alpha=0.05) than low minority population, within poverty status stratum

† Statistically different (alpha=0.05) than low poverty status, within minority population stratum

REFERENCES

1. Timperio A, Ball K, Roberts R, Campbell K, Andrianopoulos N, Crawford D. Children's fruit and vegetable intake: associations with the neighbourhood food environment. Prev Med 2008;**46**(4):331-5 doi: S0091-7435(07)00491-4 [pii]

10.1016/j.ypmed.2007.11.011[published Online First: Epub Date]|.

2. Boone-Heinonen J, Gordon-Larsen P, Kiefe CI, Shikany JM, Lewis CE, Popkin BM. Fast food restaurants and food stores: longitudinal associations with diet in young to middle-aged adults: the CARDIA study. Arch Intern Med 2011;**171**(13):1162-70 doi: 171/13/1162 [pii]

10.1001/archinternmed.2011.283[published Online First: Epub Date]|.

3. Richardson AS, Boone-Heinonen J, Popkin BM, Gordon-Larsen P. Neighborhood fast food restaurants and fast food consumption: a national study. BMC Public Health 2011;**11**:543 doi: 1471-2458-11-543 [pii]

10.1186/1471-2458-11-543[published Online First: Epub Date]|.

4. Zick CD, Smith KR, Fan JX, Brown BB, Yamada I, Kowaleski-Jones L. Running to the store? The relationship between neighborhood environments and the risk of obesity. Soc Sci Med 2009;**69**(10):1493-500 doi: S0277-9536(09)00570-X [pii]

10.1016/j.socscimed.2009.08.032[published Online First: Epub Date]|.

5. Beaulac J, Kristjansson E, Cummins S. A systematic review of food deserts, 1966-2007. Prev Chronic Dis 2009;**6**(3):A105 doi: A105 [pii][published Online First: Epub Date]|.

6. Institute of Medicine and National Research Council. Workshop on the public health effects of food deserts: Workshop summary. In: Medicine Io, ed. Washington D.C.: National Academy, 2009.

7. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. Am J Prev Med 2009;**36**(1):74-81 doi: S0749-3797(08)00838-6 [pii]

10.1016/j.amepre.2008.09.025[published Online First: Epub Date]|.

8. Walker RE, Keane CR, Burke JG. Disparities and access to healthy food in the United States: A review of food deserts literature. Health Place 2010;**16**(5):876-84 doi: S1353-8292(10)00058-4 [pii]

10.1016/j.healthplace.2010.04.013[published Online First: Epub Date]|.

9. Rose D, Bodor NJ, Swalm CM, Rice JC, Farley TA, Hutchinson PL. DESERTS IN NEW ORLEANS? ILLUSTRATIONS OF URBAN FOOD ACCESS AND IMPLICATIONS FOR POLICY. University of Michigan National Poverty Center/USDA Economic Research Service Research "Understanding the Economic Concepts and Characteristics of Food Access". New Orleans: Tulane University, 2009.

10. USDA. Access to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences. Report to Congress: Economic Research Service, 2009.

11. Sharkey JR, Horel S. Neighborhood socioeconomic deprivation and minority composition are associated with better potential spatial access to the ground-truthed food environment in a large rural area. J Nutr 2008;**138**(3):620-7 doi: 138/3/620 [pii][published Online First: Epub Date]|.

12. Sharkey JR, Horel S, Han D, Huber JC, Jr. Association between neighborhood need and spatial access to food stores and fast food restaurants in neighborhoods of colonias. Int J Health Geogr 2009;**8**:9 doi: 1476-072X-8-9 [pii]

10.1186/1476-072X-8-9[published Online First: Epub Date]|.

13. Smith DM, Cummins S, Taylor M, et al. Neighbourhood food environment and area deprivation: spatial accessibility to grocery stores selling fresh fruit and vegetables in urban and rural settings. Int J Epidemiol 2010;**39**(1):277-84 doi: dyp221 [pii]

10.1093/ije/dyp221[published Online First: Epub Date]|.

14. Oliver LN, Schuurman N, Hall AW. Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands. Int J Health Geogr 2007;**6**:41 doi: 1476-072X-6-41 [pii]

10.1186/1476-072X-6-41[published Online First: Epub Date]|.

15. Miller WC, Ford CA, Morris M, et al. Prevalence of chlamydial and gonococcal infections among young adults in the United States. JAMA 2004;**291**(18):2229-36 doi: 10.1001/jama.291.18.2229

291/18/2229 [pii][published Online First: Epub Date]|.

16. Resnick MD, Bearman PS, Blum RW, et al. Protecting adolescents from harm. Findings from the National Longitudinal Study on Adolescent Health. JAMA 1997;**278**(10):823-32

17. Boone-Heinonen J, Evenson KR, Song Y, Gordon-Larsen P. Built and socioeconomic environments: patterning and associations with physical activity in U.S. adolescents. Int J Behav Nutr Phys Act 2010;**7**:45 doi: 1479-5868-7-45 [pii]

10.1186/1479-5868-7-45[published Online First: Epub Date]|.

18. Boone-Heinonen J, Popkin BM, Song Y, Gordon-Larsen P. What neighborhood area captures built environment features related to adolescent physical activity? Health Place 2010;**16**(6):1280-6 doi: S1353-8292(10)00090-0 [pii]

10.1016/j.healthplace.2010.06.015[published Online First: Epub Date]|.

19. Boone-Heinonen J, Gordon-Larsen P. What is the relevant neighborhood area for detecting built environment relationships with physical activity? submitted to Health & Place 2010

20. Subramanian SV, Chen JT, Rehkopf DH, Waterman PD, Krieger N. Racial disparities in context: a multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. Am J Public Health 2005;**95**(2):260-5 doi: 95/2/260 [pii]

10.2105/AJPH.2003.034132[published Online First: Epub Date]|.

21. U.S. Census Bureau. Statistical Brief- Poverty Areas. Secondary Statistical Brief- Poverty Areas 1995. http://www.census.gov/population/socdemo/statbriefs/povarea.html.

22. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. [program], 2002.

23. Clarke P. When can group level clustering be ignored? Multilevel models versus single-level models with sparse data. J Epidemiol Community Health 2008;**62**(8):752-8 doi: 62/8/752 [pii]

10.1136/jech.2007.060798[published Online First: Epub Date]|.

24. Jago R, Baranowski T, Baranowski JC, Cullen KW, Thompson D. Distance to food stores & adolescent male fruit and vegetable consumption: mediation effects. Int J Behav Nutr Phys Act 2007;**4**:35 doi: 1479-5868-4-35 [pii]

10.1186/1479-5868-4-35[published Online First: Epub Date]|.

25. Morland K, Filomena S. Disparities in the availability of fruits and vegetables between racially segregated urban neighbourhoods. Public Health Nutr 2007;**10**(12):1481-9 doi: S1368980007000079 [pii]

10.1017/S1368980007000079[published Online First: Epub Date]|.

26. Block JP, Scribner RA, DeSalvo KB. Fast food, race/ethnicity, and income: a geographic analysis. Am J Prev Med 2004;**27**(3):211-7 doi: 10.1016/j.amepre.2004.06.007

S0749-3797(04)00139-4 [pii][published Online First: Epub Date]|.

27. Wang MC, Kim S, Gonzalez AA, MacLeod KE, Winkleby MA. Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. J Epidemiol Community Health 2007;**61**(6):491-8 doi: 61/6/491 [pii]

10.1136/jech.2006.051680[published Online First: Epub Date]|.

28. Zenk SN, Powell LM. US secondary schools and food outlets. Health Place 2008;**14**(2):336-46 doi: S1353-8292(07)00066-4 [pii]

10.1016/j.healthplace.2007.08.003[published Online First: Epub Date]|.

29. Borradaile KE, Sherman S, Vander Veur SS, et al. Snacking in children: the role of urban corner stores. Pediatrics 2009;**124**(5):1293-8 doi: peds.2009-0964 [pii]

10.1542/peds.2009-0964[published Online First: Epub Date]|.

30. Lucan SC, Karpyn A, Sherman S. Storing empty calories and chronic disease risk: snack-food products, nutritive content, and manufacturers in Philadelphia corner stores. J Urban Health;**87**(3):394-409 doi: 10.1007/s11524-010-9453-5[published Online First: Epub Date]|.

31. The Brookings Institution Metropolitan Policy Program. State of Metropolitan America: on the front lines of demographic transformation. In: The Brookings Institution Press, ed. Washington DC: The Brookings Institution, 2010.

32. Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built environments and obesity in disadvantaged populations. Epidemiol Rev 2009;**31**:7-20 doi: mxp005 [pii]

10.1093/epirev/mxp005[published Online First: Epub Date]|.

33. Raja S, Ma C, Yadav P. Beyond Food Deserts: Measuring and Mapping Racial Disparities in Neighborhood Food Environments. Journal of Planning Education and Research 2008;**27**:469-82

34. NYC Department of Health and Mental Hygiene. NYC Green Cart. Secondary NYC Green Cart 2008. http://www.nyc.gov/html/doh/html/cdp/cdp_pan_green_carts.shtml.

35. The Reinvestment Fund. Commercial Real Estate: Supermarkets. Secondary Commercial Real Estate: Supermarkets 2010. http://www.trfund.com/financing/realestate/supermarkets.html.

36. Lombino D, Patterson J. New York City Industrial Development Agency Approves Incentives for First Two Supermarkets Under the Fresh Program. Secondary New York City Industrial Development Agency Approves Incentives for First Two Supermarkets Under the Fresh Program 2010. http://www.nycedc.com/PressRoom/PressReleases/Pages/IDAApprovesIncentivesforSupermarkets.aspx.

37. Stephens C. State of Louisiana Approves $7 Million for Fresh Food Initiative in New Orleans. Secondary State of Louisiana Approves $7 Million for Fresh Food Initiative in

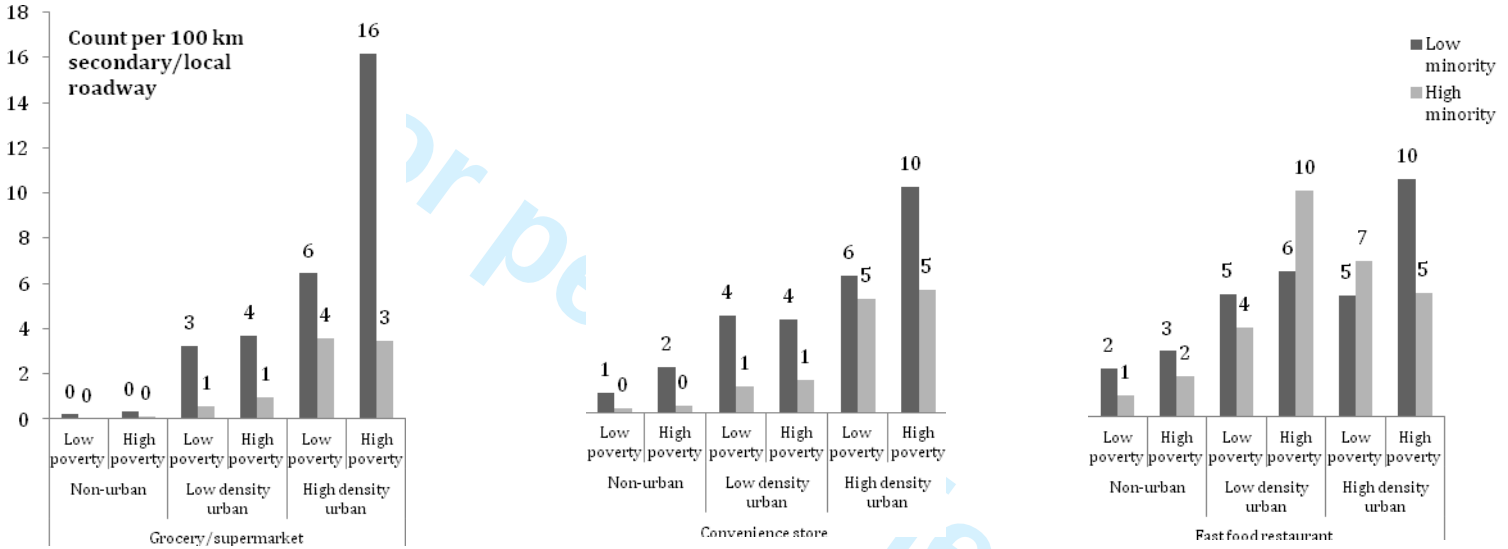
New Orleans 2009. http://www.lra.louisiana.gov/index.cfm?md=newsroom&tmp=detail&articleID=582.

38. The Food Trust. Pennsylvania Fresh Food Financing Initiative. Secondary Pennsylvania Fresh Food Financing Initiative 2004. http://www.thefoodtrust.org/php/programs/fffi.php.

39. Los Angeles City Clerk. FAST FOOD RESTAURANTS / INTERIM CONTROL ORDINANCE / WEST-ADAMS-BALDWIN HILLS-LEIMERT, SOUTH AND SOUTHEAST LOS ANGELES. Secondary FAST FOOD RESTAURANTS / INTERIM CONTROL ORDINANCE / WEST-ADAMS-BALDWIN HILLS-LEIMERT, SOUTH AND SOUTHEAST LOS ANGELES 2008. http://cityclerk.lacity.org/lacityclerkconnect/index.cfm?fa=ccfi.viewrecord&cfnumber=07-1658&CFID=16806974&CFTOKEN=73b760e131fb720-4A7614CB-C1C7-C84F-F1E8474351348CDC&jsessionid=f030cb1129cc179c6eed6440245a58561e87.

40. letsmove.gov. Accessing Healthy & Affordable Food. Secondary Accessing Healthy & Affordable Food 2010. http://letsmove.gov/accessing/index.html.

Figure 1. Predicted neighborhood food resource availability (count per 10,000 population) for various neighborhood poverty[a] and minority population[b] levels[c]



[a] Greater than 20% of population below the federal poverty level

[b] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-10%)

[c] National Longitudinal Study of Adolescent Health Wave III (young adulthood; 2001-02), corrected for clustering and weighted for representation. Estimated from urbanicity-stratified regression modeling food resource availability (within 3k network buffer) as a function of neighborhood poverty status (>20% population below federal poverty level, compared to ≤20% of population below federal poverty level), with neighborhood poverty*neighborhood minority interactions. For simplicity, predictions for medium neighborhood minority population are not reported;

Appendix A. Detailed food resource definitions based on 4- and 8-digit Standard Industrial Classification (SIC) codes

Food Resource Type	SIC subgroup	SIC	Description
Fast food chain & non-chain	Fast food chain (5812)	58120307	Fast-food restaurant, chain
		58120601	Pizzeria, chain
	Fast food non-chain (5812)	58120300	Fast food restaurants and stands
		58120301	Box lunch stand
		58120302	Carry-out only (except pizza) restaurant
		58120303	Chili stand
		58120304	Coffee shop
		58120305	Delicatessen (eating places)
		58120306	Drive-in restaurant
		58120308	Fast-food restaurant, independent
		58120309	Food bars
		58120310	Grills (eating places)
		58120311	Hamburger stand
		58120312	Hot dog stand
		58120313	Sandwiches and submarines shop
		58120314	Snack bar
		58120315	Snack shop
		58120600	Pizza restaurants
		58120602	Pizzeria, independent
Grocery/Supermarkets	Grocery stores chain (5411)	54119904	Grocery stores, chain
	Grocery stores non-chain (5411)	54119905	Grocery stores, independent
	Grocery stores other (5411)	54110000	Grocery stores
		54119900	Grocery stores, nec
		54119903	Frozen food and freezer plans, except meat
		53999903	Country general stores
	Supermarkets smaller (5411)	54110101	Supermarkets, chain
		54110103	Supermarkets, greater than 100,000 square feet (hypermarket)
	Supermarkets larger	54110102	Supermarkets,

	(5411)		independent
		54110104	Supermarkets, 55,000 - 65,000 square feet (superstore)
		54110105	Supermarkets, 66,000 - 99,000 square feet
	Supermarkets other (5411)	54110100	Supermarkets
Convenience stores	Convenience Stores (5411/5331/5541)	53310000	Variety stores
		54110200	Convenience stores
		54110201	Convenience stores, chain
		54110202	Convenience stores, independent
		55410000	Gasoline service stations
		55419900	Gasoline service stations, nec
		55419901	Filling stations, gasoline

Appendix B. Means and (SD) of alternate measures of food resources availability[a,b,] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicity[c]

Neighborhood			Count per 10,000 population- within 3 km Euclidean buffer			Distance to nearest outlet (km)- within 8 km Euclidean buffer		
Percent poverty[d,f] within 3k	Percent minority population[d,e] within 3k	N	Grocery/ supermarket	Convenience stores	Fast food	Grocery/ supermarket	Convenience stores	Fast food
			Non-urban			Non-urban		
Low	Low	545	0.50 (0.17)	1.75 (0.77)	6.38 (1.16)	3.00 (0.56)	2.49 (0.50)	2.09 (0.23)
	Medium	954	0.55 (0.13)	1.17 (0.27)	5.51 (0.48)	3.05 (0.20)	3.25 (0.19)	2.62 (0.16)
	High	1024	0.16 (0.06)	0.94 (0.24)	5.00 (0.53)	3.25 (0.43)	3.71 (0.42)	2.73 (0.17)
High	Low	715	0.58 (0.34)	3.52 (2.10)	7.98 (0.65)	1.46 (0.11)	2.56 (0.88)	1.94 (0.26)
	Medium	306	0.20 (0.10)	0.38 (0.19)	9.67 (0.84)	1.82 (0.60)	2.50 (0.60)	1.48 (0.29)
	High	232	0.42 (0.10)	0.87 (0.20)	4.60 (0.93)	1.61 (0.65)	4.47 (0.80)	3.92 (0.58)
	Total	3,779	0.39 (0.09)	1.46 (0.48)	6.16 (0.34)	2.56 (0.29)	3.17 (0.34)	2.43 (0.12)
			Low density urban			Low density urban		
Low	Low	1320	2.73 (0.28)	3.78 (0.27)	5.48 (0.25)	1.21 (0.13)	1.12 (0.12)	0.80 (0.05)
	Medium	1757	1.89 (0.15)	3.06 (0.20)	6.32 (0.19)	1.80 (0.17)	1.58 (0.11)	0.91 (0.03)
	High	2078	0.99 (0.17)	1.99 (0.34)	6.44 (0.19)	2.53 (0.32)	2.59 (0.32)	1.08 (0.05)
High	Low	910	2.59 (0.28)	3.50 (0.32)	5.97 (0.29)	1.14 (0.16)	1.01 (0.10)	0.73 (0.05)
	Medium	477	1.73 (0.22)	2.72 (0.29)	9.08 (0.95)	1.13 (0.20)	1.28 (0.22)	0.53 (0.04)
	High	129	1.23 (0.32)	1.71 (0.37)	11.52 (1.94)	1.54 (0.44)	1.41 (0.35)	0.56 (0.07)
	Total	6,676	0.39 (0.09)	2.83 (0.21)	6.16 (0.34)	2.56 (0.29)	3.17 (0.34)	2.43 (0.12)
			High density urban			High density urban		
Low	Low	767	3.00 (0.29)	3.43 (0.29)	4.28 (0.42)	0.83 (0.24)	0.56 (0.04)	0.60 (0.06)
	Medium	786	3.11 (0.34)	3.60 (0.26)	4.98 (0.22)	0.87 (0.16)	0.62 (0.06)	0.48 (0.04)
	High	870	2.74 (0.26)	4.29 (0.41)	6.44 (0.18)	1.18 (0.24)	0.81 (0.14)	0.50 (0.02)
High	Low	418	3.85 (0.63)	3.32 (0.43)	4.72 (0.36)	0.94 (0.20)	0.87 (0.18)	0.54 (0.06)
	Medium	400	3.30 (0.83)	3.30 (0.66)	5.17 (0.45)	1.19 (0.42)	0.94 (0.15)	0.57 (0.06)
	High	307	3.42 (0.59)	4.17 (0.53)	6.43 (0.51)	0.93 (0.28)	0.66 (0.11)	0.43 (0.03)
	Total	3,549	3.10 (0.34)	3.84 (0.31)	5.64 (0.21)	1.04 (0.17)	0.76 (0.09)	0.51 (0.03)

[a] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food
[b] Means and SD corrected for clustering and weighted for representation.
[c]Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.
[d] Census block group
[e] Greater than 20% of population below the federal poverty level
[f] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-100%)

Appendix C. Associations between urbanicity-specific neighborhood minority composition[a] and high neighborhood poverty[b] and alternate measures[c] of availability [beta coefficient (95% CI)][d,e] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicityf

Neighborhood Poverty status[a,g]	Neighborhood Minority population [b,g]	Non-urban	Low density urban	High density urban
Grocery/supermarket density (count per 10,000 population) within 3 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-0.04 (-0.40, 0.31)	-0.92 (-1.40, -0.44)	-0.03 (-0.61, 0.55)
	High	-0.35 (-0.69, -0.02)	-1.76 (-2.35, -1.18)	-0.51 (-1.04, 0.02)
High	Low	0.08 (-0.49, 0.66)	-0.03 (-0.55, 0.48)	1.11 (0.04, 2.18)
	Medium	-0.38 (-0.77, 0.01)	-1.14 (-1.78, -0.50)	0.40 (-0.94, 1.74)
	High	-0.01 (-0.42, 0.40)	-1.57 (-2.40, -0.74)	0.17 (-1.21, 1.55)
Distance to nearest grocery/supermarket (km) within 8 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-0.24 (-1.22, 0.74)	0.52 (0.24, 0.81)	0.18 (-0.11, 0.47)
	High	-0.16 (-1.45, 1.12)	1.09 (0.46, 1.71)	0.20 (-0.50, 0.89)
High	Low	-1.43 (-2.47, -0.39)	-0.08 (-0.36, 0.20)	0.08 (-0.33, 0.48)
	Medium	-0.82 (-2.50, 0.85)	0.26 (-0.17, 0.69)	0.26 (-0.28, 0.79)
	High	-1.67 (-3.39, 0.05)	0.66 (0.03, 1.29)	0.12 (-0.52, 0.77)
Convenience store density (count per 10,000 population) within 3 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-0.70 (-2.22, 0.83)	-0.86 (-1.36, -0.35)	0.18 (-0.47, 0.84)
	High	-0.84 (-2.43, 0.75)	-1.84 (-2.58, -1.10)	0.87 (-0.16, 1.89)
High	Low	1.77 (-1.33, 4.87)	-0.09 (-0.65, 0.46)	-0.12 (-0.95, 0.71)
	Medium	-1.48 (-3.06, 0.10)	-1.30 (-2.06, -0.55)	-0.13 (-1.32, 1.06)
	High	-0.79 (-2.39, 0.81)	-2.19 (-3.02, -1.36)	0.76 (-0.44, 1.95)
Distance to nearest convenience store (km) within 8 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	0.34 (-0.35, 1.03)	0.35 (0.11, 0.60)	0.11 (-0.02, 0.24)
	High	0.27 (-0.67, 1.21)	1.12 (0.61, 1.63)	0.16 (-0.13, 0.45)
High	Low	0.33 (-1.01, 1.67)	-0.12 (-0.32, 0.08)	0.32 (0.05, 0.59)
	Medium	-0.04 (-1.22, 1.15)	0.49 (0.02, 0.95)	0.30 (0.04, 0.55)
	High	1.19 (-0.27, 2.64)	0.61 (0.17, 1.06)	0.08 (-0.13, 0.30)
Fast food density (count per 10,000 population) within 3 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-1.59 (-4.05, 0.87)	0.83 (0.28, 1.37)	0.56 (-0.25, 1.37)
	High	-1.52 (-3.93, 0.88)	0.96 (0.33, 1.59)	1.91 (1.03, 2.79)
High	Low	1.62 (-0.61, 3.84)	0.51 (-0.09, 1.10)	0.71 (-0.21, 1.63)
	Medium	2.67 (-0.08, 5.41)	3.59 (1.57, 5.60)	0.99 (-0.17, 2.16)
	High	-1.22 (-3.83, 1.40)	6.04 (2.11, 9.97)	1.89 (0.62, 3.17)

Distance to nearest fast food restaurant (km) within 8 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	0.32 (-0.06, 0.71)	0.03 (-0.06, 0.12)	-0.08 (-0.18, 0.02)
	High	0.07 (-0.40, 0.54)	0.10 (0.00, 0.21)	-0.14 (-0.24, -0.04)
High	Low	-0.20 (-0.49, 0.08)	-0.05 (-0.16, 0.05)	-0.07 (-0.14, 0.00)
	Medium	-0.44 (-0.89, 0.01)	-0.24 (-0.36, -0.13)	-0.09 (-0.22, 0.05)
	High	0.51 (-0.33, 1.34)	-0.30 (-0.46, -0.13)	-0.17 (-0.28, -0.07)

[a] Greater than 20% of population below the federal poverty level

[b] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-10%)

[c] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food

[d] Linear regression models, controlling for percent college educate and population density (except model of count per population measure)

[e] Dashes represent un-estimated associations; 1) measure within network 8km in low and high-density urban areas 2) measure within network 1km in non-urban areas.

[f] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.

[g] Census block group

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7
Objectives	3	State specific objectives, including any pre-specified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-10
Bias	9	Describe any efforts to address potential sources of bias	11, 12
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	11
		(*b*) Describe any methods used to examine subgroups and interactions	11
		(*c*) Explain how missing data were addressed	8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	8

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	12
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	19
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	20
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	20
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	21
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Appendices B-C
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ open

Are neighborhood food resources distributed inequitably by income and race in the United States? Epidemiologic findings across the urban spectrum

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000698.R1
Article Type:	Research
Date Submitted by the Author:	08-Mar-2012
Complete List of Authors:	Richardson, Andrea; UNC Chapel Hill, Nutrition Boone-Heinonen, Janne; Oregon Health & Science University, Public Health & Preventive Medicine Popkin, Barry; UNC Chapel Hill, Nutrition Gordon-Larsen, Penny; UNC Chapel Hill,
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health, Nutrition and metabolism
Keywords:	NUTRITION & DIETETICS, PUBLIC HEALTH, STATISTICS & RESEARCH METHODS

Are neighborhood food resources distributed inequitably by income and race in the United States? Epidemiologic findings across the urban spectrum

Andrea S. Richardson[1], Janne Boone-Heinonen[2], Barry M. Popkin[1], and Penny Gordon-Larsen[1]

[1] Department of Nutrition, University of North Carolina at Chapel Hill; Carolina Population Center, 123 West Franklin St. Campus Box 8120, Chapel Hill, NC USA

[2] Public Health & Preventive Medicine, Oregon Health & Science University; 3181 SW Sam Jackson Park Road, Mail Code CB 669, Portland, OR 97239-3098, USA

Please Address Correspondence & Reprint Requests To:

Penny Gordon-Larsen

University of North Carolina at Chapel Hill

Carolina Population Center

123 West Franklin St. CB#8120

Chapel Hill, NC 27516-3997, USA

Phone: (W) 919-843-9966; Fax: 919-966-9159

Keywords (MeSH*): Epidemiology, United States, *Diet, Geographic Information Systems, Environment, Environment Design, Fast Foods, Restaurants, Young Adult

Abstract 299 words

Text 3,725 words excluding title page, abstract, references, and tables

SUMMARY

1) **Article Focus**

- **Using national data, we examined whether neighborhood food resource availability exhibits joint race and socioeconomic inequities across levels of urbanicity.**

2) **Key Messages**

- **Sociodemographic inequities in neighborhood food resource availability were most pronounced in low density urban (largely suburban) areas.**
- **In high density urban areas, higher neighborhood poverty was associated with *greater* availability of all food resources.**
- **Whereas policy has focused on dense, urban settings, less urban areas might also benefit from policies addressing food access**

3) **Strengths and Limitations**

- **While business records provide comparable data across the US, these data may contain error and do not indicate availability of specific foods.**
- **National coverage enabled examination of the joint role of neighborhood race and socioeconomic status across urban strata within a single study.**

Abstract

Objective. Many recent policies focus on socioeconomic inequities in availability of healthy food stores and restaurants. Yet understanding of how socioeconomic inequities vary across neighborhood racial composition and across the range from rural to urban settings is limited, largely due to lack of large, geographically and sociodemographically diverse study populations. Using a national sample, we examined differences in neighborhood food resource availability according to neighborhood-level poverty and racial/ethnic population in non-urban, low- and high-density urban areas.

Design. Cross-sectional data from an observational cohort study representative of the US middle and high school-aged population in 1994 followed into young adulthood.

Participants. Using neighborhood characteristics of participants in the National Longitudinal Study of Adolescent Health (Wave III, 2001-02; n=13,995 young adults **18-28 years of age** representing 7,588 US block groups), we examined associations between neighborhood poverty and race/ethnicity with **neighborhood food resource availability** in urbanicity-stratified multivariable linear regression.

Primary and Secondary outcome measures: Neighborhood availability of grocery/supermarkets, convenience stores, and fast food restaurants (measured as number of outlets per 100 km roadway).

Results. Neighborhood race and income disparities were most pronounced in low density urban areas, where high poverty/high minority areas had lower availability of grocery/supermarkets [beta coefficient (beta)= -1.91; 95% confidence interval (CI) -2.73, -1.09] and convenience stores (beta=-2.38, CI: -3.62, -1.14) and greater availability of fast food

restaurants (beta=4.87, CI: 2.26, 7.48) than low poverty/low minority areas. However, in **high density**, urban areas, high poverty/low minority neighborhoods had comparatively greater availability of grocery/supermarkets (beta=8.05, CI: 2.52, 13.57), convenience stores (beta=2.89, CI: 0.64-5.14), and fast food (beta=4.03, CI: 1.97, 6.09), relative to low poverty/low minority areas.

Conclusions. In addition to targeting disproportionate fast food availability in disadvantaged dense urban areas, our findings suggest that policies should also target disparities in grocery/supermarket and fast food restaurant availability in low density areas.

INTRODUCTION

National, state, and local policies increasingly focus on improving availability of healthy foods in disadvantaged neighborhoods. Expectations that such policies will improve diets in low income and race/ethnic minority populations stem from evidence that inequitable access to healthy foods may underlie differentials in diet quality **[1-4],** obesity [5], and related diseases by income and race/ethnicity (see reviews **[6-11**]). However, understanding the extent to which inequities in different types of food resources exist in different types of U.S. communities is limited by several factors.

First, research has focused on "food deserts", generally defined as areas with limited access to affordable fresh foods from supermarkets (see reviews [8-11]). Subsequently, "food swamps" **[12, 13],** characterized as neighborhoods with disproportionate access to convenient, energy dense, nutrient poor foods sold by convenience stores and fast food restaurants, emerged as important dimensions of the food environment. Thus, attention to a variety of food resources, such as supermarkets, convenience stores, and fast food restaurants, may be a more useful approach to examining neighborhood food availability **[11, 14, 15].**

Second, most existing food access initiatives target low income, dense urban areas, yet inequities in access to healthy foods may be even more pronounced in suburban and rural areas due to greater dispersion of resources and car-dependent infrastructure [14]. In addition, geographic distribution of food outlets relative to homes, transportation infrastructure, and other resources differs across urbanicity [20, 21], perhaps due to differences in travel times to community resources [22] and population density. Yet few studies examine how inequities in availability of food resources might vary by urbanicity [9, 16-18], and limited understanding relies on comparisons across small, geographically

specific study populations (e.g. New Orleans compared to Texas colonias). Generalizable understanding requires large, national study populations.

Third, allocation of food resources according to income has received the most focus, with some examination of race/ethnic differences. **Consideration of neighborhood socioeconomic status alone has not yielded consistent results [15, 22-24], which suggests that other neighborhood characteristics underlie food resource allocation.** Patterning by race/ethnicity may further compound patterning according to income and would underscore the importance of culturally sensitive policies. However, the joint role of neighborhood race/ethnic composition and neighborhood income has received little attention **[25].**

Using GIS-derived neighborhood characteristics from a national sample of 13,995 young adults across the US provides variation and sufficient sample size to examine disparities in neighborhood food resource availability according to income, race/ethnicity, and urbanicity. We examined the joint role of neighborhood race/ethnic composition and neighborhood poverty across non-urban, low density urban, and high density urban areas. Specifically, we tested whether individuals living in neighborhoods comprised of populations with high proportions of impoverished and minority residents had lower availability of grocery/supermarkets and greater availability of fast-food restaurants and convenience stores (compared to lower poverty areas with high proportion of non-Hispanic white populations), and whether this distribution varied across less urban and more urban areas.

METHODS

Study population and data sources

Our study sample is derived from respondents aged 18 to 24 years who participated in Wave III (2001-02) of the National Longitudinal Study of Adolescent Health (Add Health), a nationally representative, prospective cohort study of adolescents of the US school-based population in grades 7 to 12 (11-22 years of age) in 1994-95 who are followed into adulthood (wave III). Subjects eligible for inclusion in the analytic sample included 14,322 Wave III young adults with sample weights. The Add Health sample was collected under protocols approved by the Institutional Review Board at the University of North Carolina. The survey design and sampling frame have been discussed elsewhere [26, 27]. The authors have no conflicts of interest to declare and have each made 1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

We used the Add Health Obesity and Neighborhood Environment database (ONEdata), a Geographic Information System that includes time-varying, community-level data geographically linked to respondent residential addresses geocoded with street-segment matches (n=13,039), global positioning system (GPS) measurements (n=1,204), and ZIP/ZIP+4/ZIP+2 centroid match (n=685). Attributes of areas within 1, 3, 5, and 8.05 km of each respondent location (neighborhood buffers) and block group, tract, and county attributes from time-matched U.S. Census and other federal sources were merged with individual-level Add Health interview responses [28]. The number of census block groups (n=7,588) represents 3.6% of 2000 US Census block groups.

Of 14,322 Wave III respondents with sample weights, 327 (2.3%) with missing food environment or US census data were excluded, leaving an analytic sample of 13,995.

Study variables

GIS-derived neighborhood data

For our central analysis we used residential locations linked to attributes of areas within 3 km straight line distance (Euclidean buffer) and along the street network (street network buffer) surrounding each respondent's residential location in the Wave III (2001)**. The 3 km buffer was designed to capture distances readily accessible by walking and driving to neighborhood diet- and activity-related resources [2, 3, 29, 30]**. Comparative analyses were conducted with 1 and 8 km buffers. Neighborhood food environment, sociodemographic, and urban indicator data were merged with individual-level Add Health interview data.

Food environment

Food resource data were obtained from Dun and Bradstreet, a commercial dataset of US businesses. Food resources were classified according to 4- and 8-digit Standard Industrial Classification (SIC) codes. Three categories of food resources were used: 1) fast-food restaurants, defined as fast-food chain and non-chain restaurants, excluding food stands and cafeterias; 2) grocery stores and supermarkets, defined as independent and chain grocery stores and supermarkets; and 3) convenience stores, defined as variety & convenience stores and food stores attached to gasoline filling stations. Full details are described in Appendix A.

We characterized neighborhood food resource availability as the count of each type of resource per roadway distance within a 3 kilometer street network buffer, which

represents availability to resources relative to the street network and potentially reflects routes of travel [31]. **While others have used measures such as the modified retail food environment index [32], which measures the availability of healthy relative to unhealthy food stores, ratio measures may obscure differential variation across food outlet types. Since this is a major focus of the current study, we use absolute measures of fast food, convenience stores and supermarkets and examine each resource type separately. In addition, by controlling for population density we capture resources relative to what might be expected with respect to population distribution. Given the variation in classification of the food environment in the literature (see review [33]), we present findings across several different food environment measures (e.g., count per population, distance to nearest outlet).**

Given the importance of scaling resources by general urban development, we created measures of resources per 100 kilometers of secondary/connecting and local, neighborhood and rural roads using street data obtained from StreetMap Pro (July 2003, v.5.2) data from Environmental Systems Research Institute (ESRI, www.esri.com) in Redlands, CA. We selected the 3km street network buffer after evaluating associations with resource availability and sensitivity of buffer size. We thus defined neighborhood food resource availability as the number of outlets per 100 kilometer of roadway within a 3 km network buffer to account for differences in food resource counts according to the amount of commercial activity in an area.

Neighborhood sociodemographics

Census block groups were used to define neighborhoods because smaller units are more likely to adhere to individually perceived neighborhood boundaries [34] and are more sociodemographically homogeneous. Using the federal definition of "poverty area" [35, 36], we dichotomized neighborhood poverty into >20% or ≤20% of population below the federal poverty

level. We defined neighborhood minority population as percent of population of non-Hispanic white race/ethnicity and neighborhood-level education as percent of population ≥25 years with college or greater education. **While other studies have used a neighborhood deprivation index to provide an "empirical summary of total area-level variance explained by the census variables" [37], we investigated neighborhood race/ethnicity and income as *separate* constructs. We focus on these two specific characteristics to address the theoretical processes of resource placement in areas with greater purchasing power (income) and political leverage associated with the majority race.** To evaluate potential interaction of neighborhood poverty status with minority population we created a categorical variable: 1) low poverty/low minority, 2) high poverty/low minority, 3) low poverty/medium minority, 4) high poverty/medium minority, 5) low poverty/high minority, 6) high poverty/high minority.

Neighborhood Urbanicity

Most studies characterize urbanicity based on population density [19]. We improve on such traditional definitions by using US Census-defined urbanized areas (UA) to classify residential locations as non-urban (outside UA) or urban (inside UA). Within urban areas, we used Fragstats [38] software with US Geologic Survey National Landcover Data to distinguish: 1) low density [≤95% (75th percentile) developed land cover] and 2) high density [>95% developed land cover] urban areas based on the area of developed land as a proportion of total area within 3km after excluding water and ice. Our measure of developed land cover provides an indicator of urban development that is independent of population density and correctly classifies areas as within or outside of a UA (Receiver Operating Characteristic curve area=0.937).

Statistical analysis

Descriptive analysis

Availability of food resources and sociodemographic characteristics were compared across non-urban, low density urban, and high density urban strata. We examined urbanicity-specific tertiles of neighborhood minority population (Table 1) to address non-linear associations with food resource availability measures. All statistical analyses were weighted for national representation and corrected for complex survey design using Stata 11.1 (Stata Corp, College Station, TX).

Multivariable regression analysis

We fit multivariable linear regression models to predict food resource availability as a function of neighborhood poverty and minority population where our constructed variable combining neighborhood poverty (high and low) with levels of minority population (low, medium, high) explicitly estimates interactions relative to the theoretically most advantaged neighborhoods (low poverty/low minority). Given that food resources and neighborhood sociodemographics varied dramatically across urbanicity, comparability across sociodemographic and geographic subpopulations was difficult, even with our large sample size. Nonetheless, we have large samples of individuals and block groups across urbanicity strata, with adequate variation across neighborhood sociodemographics (Table 1). All models were weighted for national representation, corrected for clustering on our primary sampling unit (schools) and controlled for continuous neighborhood-level education and population density dichotomized into urbanicity-specific quantiles. Given that schools and census block groups are

not geographically nested, we did not use multi-level analysis. Further, multi-level analysis of unbalanced, sparse data within census block groups can result in biased estimates [39].

To aid interpretation of the model results, we used the estimated model coefficients to predict food resource availability across levels of neighborhood-level poverty and minority population within the low density-urban stratum, where the strongest disparities were observed.

Comparative analyses

In order to assess whether different neighborhood buffer sizes were needed in urban versus non-urban areas, we compared and found similar patterns for the 1 km buffer in urban areas and the 8 km buffer in non-urban areas. In addition, we assessed alternate measures of food resource availability to compare our main measure findings with commonly used though conceptually different metrics: count per population [2] and distance to nearest outlet [4, 14, 40]. Specifically, we contrasted our roadway-scaled measure with: 1) density of food resources per 10,000 population within 3 km Euclidean buffer; and 2) minimum distance to the single nearest food resource within 8 km Euclidean buffer. We repeated identical multivariable regression models with alternate measures, except models with population-scaled measures did not control for population density. Results for food resources per 100 kilometer of roadway within a 3 km network buffer are presented in text, while results for all other measures are shown in Appendices B-C.

RESULTS

Neighborhood availability of grocery/supermarkets, convenience stores, and fast food restaurants varied dramatically across non-urban, low density urban and high density urban areas, with greater availability in high density urban areas (Table 2).

In multivariable analysis, availability of grocery/supermarkets and convenience stores for low density urban residents did not differ according to neighborhood poverty; rather, lower availability of food stores was observed with greater minority populations (Table 3). Food stores were more equitably allocated in non-urban neighborhoods. Interestingly, greater availability of food stores was often found in high density urban areas with high proportions of low income residents, but this relationship with neighborhood income did not hold in neighborhoods with high proportion of minority residents.

Fast food availability was greater for residents in high poverty neighborhoods, with strongest associations in low and high density urban areas (Table 3). Among those living in neighborhoods with high poverty, greater minority population incurred additional inequities in food resource availability, particularly in low density urban areas. In a notable exception, in high density urban, high minority areas, fast food was *less* available in high poverty neighborhoods.

Figure 1 presents predicted food resource availability (based on the Table 3 models) and more clearly illustrates the differential associations with poverty versus race/ethnicity in non-urban, low density urban, and high density urban areas.

In general, estimated patterns of disparities were very similar between roadway-scaled, population density and distance measures (Appendices B-C).

DISCUSSION

We assessed inequities in grocery/supermarket, convenience store, and fast-food restaurant availability by neighborhood poverty and minority population in a large, diverse national sample of residential neighborhoods of young adults, representing 7,588 census block groups (3.6% of 2000 US Census block groups). Our findings suggest that inequities in **neighborhood food resource availability** do exist, but not always where prior research suggests. In particular, racial and income disparities in availability of grocery/supermarkets were far more apparent in low density urban areas than in high density urban areas, where food deserts have been shown to exist [23, 41-43]. In an unexpected finding, areas with high poverty and high minority population also have lower availability of convenience stores, which typically provide largely energy dense, nutrient poor foods [44, 45]. Greater availability of fast food in areas with high poverty rates and high minority population was more consistent across non-urban, low density urban and high density urban areas.

Differences in availability of grocery/supermarkets, convenience stores, and fast-food restaurants were most consistent in low density urban areas, which include the largest proportion of our sample and theoretically captures suburban America. In the US, we also note that the distribution of poverty has shifted away from the dense inner cities. Data from the 2010 census suggest that counter to the assumption of "White Flight" out of inner cities, racial minorities, foreign-born, and low income people were more likely to live in metropolitan suburbs in 2010 than the cities they lived in during 2008 [46]. Thus, the income and race/ethnic disparities in neighborhood food resource availability observed in low density urban areas in our 2001 data may become much more important as poor and minority populations increasingly reside in suburban neighborhoods. Our findings suggest that in addition to increasing grocery store

availability and limiting fast food availability in disadvantaged dense urban areas, rural and suburban areas should be targeted for food environment improvements. While this idea has been suggested by a series of studies in rural Texas [20], our national study further supports more focus on rural and suburban food environments.

Relationships between food resource availability, neighborhood poverty, and minority population were notably distinct in high density urban areas. **It is possible that fewer significant findings in high density urban areas might reflect lower statistical power due to smaller sample size (1,935 high density urban vs. 4,132 low density urban block groups), or greater variability in high density urban relative to other areas. Yet, the pattern of findings suggests variation across the spectrum of urbanicity.** First, our finding of *greater* availability of grocery stores and convenience stores in high versus low poverty areas, but only in areas with predominately white populations, suggests the presence of complex economic and social drivers in where food stores choose to locate. Second, fast food availability was generally greater in high poverty, high minority areas, but this was not true in high minority, high density urban areas. This finding is consistent with prior evidence [11, 47] that perceived or real racial tensions or safety concerns may also influence opening and closure of food establishments.

Findings using our main roadway scaled measures and population density measures were nearly identical as they likely capture resources scaled by commercialization and development indicated by population and roadways. Slight inconsistencies in results for the minimum distance measures and may reflect increased variation that results from using a single data point (nearest outlet) to characterize availability compared to incorporating data from multiple resources within an area. Minimum distance measures also do not account for differential distribution of food resources according to population and development density.

Strengths and limitations

This study did not look at extreme poverty nor consider a large array of other factors linked with urbanicity. It is possible that disparities in food resources in dense, urban areas may be evident only under extreme neighborhood poverty that we did not examine in our analysis. More refined analyses of dynamic effects among social and economic environments and food resources are beyond the scope of the present analysis though they certainly warrant further attention. Moreover, other factors such as crime [47], aesthetics [47], travel time [48], or proximity to other resources [47] could also relate to actual or perceived access to food resources.

The benefit of business record data, which provides comparative national food resource data, must be balanced with their limitations**. Business record data contains error, which can bias results either toward the null if misclassification is non-differential or away from the null in the case of differential misclassification. It is also possible that the accuracy of business records varies by area sociodemographics and/or urbanicity [49-53]. Neighborhood audits (street-by-street data collection by researchers) better capture broader dimensions of food access such as food prices or cultural preferences, but they are not feasible for large national samples across thousands of census blocks groups. These intense audits are generally performed in smaller geographic areas, and thus preclude broad comparisons across neighborhood type and sociodemographics.** We were unable to ascertain food sold at each establishment and relied on generalizations regarding healthy (grocery/supermarket) versus unhealthy (convenience store, fast food restaurant) types of establishments.

Although supercenters have recently gained a significant share of the food retailing market, during the contemporaneous study period supercenters held only a minority proportion of the household purchases compared to grocery stores and supermarkets [54]. Furthermore, access to supercenters often requires driving outside of residential neighborhoods, given their size and placement. For these reasons, supercenters were not addressed.

Further, due to lower participation of illegal immigrants in the census, US census data may underestimate neighborhood minority population and poverty. Our 3 km network residential neighborhood buffer may not accurately reflect food purchasing areas for different urban settings and sociodemographic subgroups; this is a topic worthy for future study. In addition, this is a cross-sectional study and thus does not capture changes in food environments over time.

Despite these limitations, our study is an essential step in understanding the allocation of theoretically healthy and less healthy food resources across social and geographic space over the entire US, and our findings can inform measurement and design in future individual-level and longitudinal studies. Our study benefits from the variation in neighborhoods of a large population that enables comparisons across multiple sociodemographic and urban strata within a single study. Further, our study capitalizes upon national data with roadway scaled measures of neighborhood food resource availability within 3 km residential network buffers for each observation. In addition, we used detailed measures of urbanicity derived both from US census and landcover data allowing a more refined urban/rural classification than the traditional urban/rural dichotomy. In sum, our study benefits from several innovations and depth of coverage that has been heretofore unaddressed in a large, geographically diverse study.

Policy implications

Many state and national efforts focus on providing healthy eating options for poor inner-city neighborhoods, many with high minority populations. Strategies include providing produce carts in low income neighborhoods in New York City [55], directly or indirectly subsidizing supermarkets [56-59], banning fast-food restaurant construction in selected urban areas [60], as well as legislation considered at the national level [61]. Our results suggest that less urban areas might benefit from similar policies.

Conclusion

Our findings suggest that common assumptions regarding income and race-ethnic subpopulation disparities in food resources may not be universally true across the spectrum of urbanicity. We observed an association between greater neighborhood poverty and minority population with greater availability of fast-food restaurants in urban areas. Conversely, disparities in grocery/supermarkets were primarily observed in low density urban areas. Our findings suggest that poverty and race may play distinct roles in how food resources are allocated and that underlying social complexities should be further explored in dense urban, suburban, and rural areas.

ACKNOWLEDGEMENTS

The authors would like to thank Brian Frizzelle, Marc Peterson, Chris Mankoff, James D. Stewart, Phil Bardsley, and Diane Kaczor of the University of North Carolina, Carolina Population Center (CPC) and the CPC Spatial Analysis Unit for creation of the environmental

variables. The authors also thank Ms. Frances Dancy for her helpful administrative assistance. There were no potential or real conflicts of financial or personal interest with the financial sponsors of the scientific project.

This work was funded by National Institutes of Health grant R01HD057194, R01-HL104580, R01 HD041375, R01HD39183, and R01HLI04580, a cooperative agreement with the Centers for Disease Control and Prevention (CDC SIP No. 5-00). The authors are also grateful to R24 HD050924 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) for broad support of the authors, although no funding was provided by this grant. Analysis and manuscript preparation was supported by the Interdisciplinary Obesity Training postdoctoral fellowship (T32MH075854-04).

Data sharing: This research uses data from Add Health, a program project designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris, and funded by a grant P01-HD31921 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, with cooperative funding from 17 other agencies. Special acknowledgment is due Ronald R. Rindfuss and Barbara Entwisle for assistance in the original design. Persons interested in obtaining data files from Add Health should contact Add Health, CPC, 123 W. Franklin Street, Chapel Hill, NC 27516-2524 (addhealth@unc.edu). No direct support was received from grant P01-HD31921 for this analysis.

Table 1. Urbanicity-specific [a] neighborhood demographics, National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995.

	Non-urban	Low density urban	High density urban
Count (census block groups)	1,530	4,132	1,935
Count (Add Health respondents)	3,779	6,676	3,549
% College educated or above[b] - mean (SD)	16.6 (0.8)	25.5 (1.1)	22.2 (1.8)
Population density (persons/km^2)[c] - range			
Low	0.2-80.4	15.4-981.3	555.2-2651.2
High	80.7-2299.9	981.4-26514.7	2651.5-22952.4

[a] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.
[b] Census block group
[c] Within 3km Euclidean buffer around individual residence

Table 2. Means and (SD) of food resources[a] (Count per 100 km secondary and local road within 3 km network buffer around each individual residence)[b,] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicity[c]

Neighborhood					
Percent poverty[d,e] within 3k	Percent minority population[d,f] within 3k	N	Grocery/ supermarket	Convenience stores	Fast food
				Non-urban	
Low	Low	545	0.22 (0.08)	0.91 (0.42)	2.48 (0.47)
	Medium	954	0.14 (0.03)	0.34 (0.07)	2.04 (0.23)
	High	1024	0.05 (0.02)	0.22 (0.05)	1.43 (0.24)
High	Low	715	0.33 (0.20)	2.00 (1.21)	3.22 (0.53)
	Medium	306	0.08 (0.04)	0.17 (0.08)	5.03 (0.72)
	High	232	0.12 (0.06)	0.27 (0.14)	1.68 (0.91)
	Total	3,779	0.15 (0.05)	0.62 (0.27)	2.33 (0.21)
				Low density urban	
Low	Low	1320	3.47 (0.39)	4.57 (0.66)	5.71 (0.39)
	Medium	1757	1.90 (0.17)	2.77 (0.19)	5.30 (0.21)
	High	2078	0.84 (0.15)	1.55 (0.27)	4.32 (0.18)
High	Low	910	3.81 (0.58)	4.20 (0.46)	6.48 (0.36)
	Medium	477	2.25 (0.47)	3.18 (0.43)	9.40 (0.50)
	High	129	1.28 (0.38)	1.91 (0.45)	10.31 (1.24)
	Total	6,676	2.06 (0.22)	2.86 (0.26)	5.58 (0.19)
				High density urban	
Low	Low	767	8.21 (2.96)	7.47 (0.81)	6.83 (1.33)
	Medium	786	8.06 (2.55)	9.74 (1.12)	7.32 (1.17)
	High	870	7.19 (1.82)	11.31 (1.85)	6.71 (0.85)
High	Low	418	15.97 (5.46)	10.08 (1.80)	9.70 (2.45)
	Medium	400	9.70 (4.22)	9.69 (1.92)	7.12 (2.13)
	High	307	7.09 (1.46)	9.95 (0.65)	7.10 (1.20)
	Total	3,549	8.72 (2.31)	7.24 (1.08)	10.18 (1.14)

[a] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food
[b] Means and SD corrected for clustering and weighted for representation.
[c] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.
[d] Census block group
[e] Greater than 20% of population below the federal poverty level
[f] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-100%)

Table 3. Associations between high neighborhood poverty[a] and urbanicity-specific minority composition[b] and high neighborhood and food resource[c] availability [beta coefficient (95% CI)][d] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicity[e]

Food resource (count per 100 km secondary and local road within 3 km network buffer)	Neighborhood: Percent poverty[a,f] within 3k	Neighborhood: Percent minority popula-tion[b,f] within 3k	Non-urban: beta coefficient (95% Confidence Interval)	Low density urban: beta coefficient (95% Confidence Interval)	High density urban: beta coefficient (95% Confidence Interval)
Grocery/super market					
	Low	Low	0.0	0.0	0.0
		Medium	-0.09 (-0.23, 0.05)	-1.17 (-1.72, -0.63)*	-2.11 (-7.54, 3.31)
		High	-0.13 (-0.28, 0.01)	-1.76 (-2.39, -1.13)*	1.70 (-2.38, 5.77)
	High	Low	0.09 (-0.21, 0.40)	0.26 (-0.70, 1.21)	8.05 (2.52, 13.57)†
		Medium	-0.18 (-0.37, 0.00)	-1.35 (-2.36, -0.33)*	4.96 (-1.74, 11.65)†
		High	0.00 (-0.18, 0.18)†	-1.91 (-2.73, -1.09)*	-0.72 (-5.68, 4.24)*
Convenience store					
	Low	Low	0	0	0
		Medium	-0.54 (-1.26, 0.17)	-1.38 (-2.44, -0.32)*	-0.53 (-3.07, 2.01)
		High	-0.51 (-1.20, 0.17)	-2.05 (-3.17, -0.93)*	1.56 (-0.41, 3.53)
	High	Low	1.01 (-0.69, 2.71)	-0.43 (-1.69, 0.84)	2.89 (0.64, 5.14)†
		Medium	-0.86 (-1.76, 0.04)†	-1.58 (-3.06, -0.11)*	2.19 (-0.92, 5.31)†
		High	-0.27 (-0.92, 0.39)	-2.38 (-3.62, -1.14)*	0.64 (-1.61, 2.88)
Fast food					
	Low	Low	0	0	0
		Medium	-0.68 (-1.37, 0.01)	-0.01 (-0.63, 0.61)	0.39 (-1.77, 2.54)
		High	-0.47 (-1.07, 0.14)	-0.44 (-1.12, 0.24)	4.36 (1.44, 7.28)*
	High	Low	0.44 (-0.34, 1.23)	0.73 (-0.08, 1.53)	4.03 (1.97, 6.09)†
		Medium	1.80 (0.75, 2.86)*†	3.47 (2.31, 4.64)*†	4.85 (2.13, 7.57)†
		High	0.82 (-0.62, 2.26)	4.87 (2.26, 7.48)*†	1.56 (-1.39, 4.50)

[a] Greater than 20% of population below the federal poverty level

[b] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-100%)

[c] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food

[d] Linear regression models, controlling for percent college educate and population density

[e] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.

[f] Census block group

* Statistically different (alpha=0.05) than low minority population, within poverty status stratum

† Statistically different (alpha=0.05) than low poverty status, within minority population stratum

REFERENCES

1. de Vet E, de Ridder DT, de Wit JB. Environmental correlates of physical activity and dietary behaviours among young people: a systematic review of reviews. *Obesity reviews : an official journal of the International Association for the Study of Obesity*. [Research Support, Non-U.S. Gov't Review]. 2011 May;12(5):e130-42.

2. Boone-Heinonen J, Gordon-Larsen P, Kiefe CI, et al. Fast food restaurants and food stores: longitudinal associations with diet in young to middle-aged adults: the CARDIA study. *Arch Intern Med*. 2011 Jul 11;171(13):1162-70.

3. Richardson AS, Boone-Heinonen J, Popkin BM, et al. Neighborhood fast food restaurants and fast food consumption: a national study. *BMC Public Health*. 2011;11:543.

4. Timperio A, Ball K, Roberts R, et al. Children's fruit and vegetable intake: associations with the neighbourhood food environment. *Prev Med*. 2008 Apr;46(4):331-5.

5. Zick CD, Smith KR, Fan JX, et al. Running to the store? The relationship between neighborhood environments and the risk of obesity. *Soc Sci Med*. 2009 Nov;69(10):1493-500.

6. Giskes K, van Lenthe F, Avendano-Pabon M, et al. A systematic review of environmental factors and obesogenic dietary intakes among adults: are we getting closer to understanding obesogenic environments? *Obesity reviews : an official journal of the International Association for the Study of Obesity*. [Review]. 2011 May;12(5):e95-e106.

7. Fleischhacker SE, Evenson KR, Rodriguez DA, et al. A systematic review of fast food access studies. *Obes Rev*. 2011 May;12(5):e460-71.

8. Beaulac J, Kristjansson E, Cummins S. A systematic review of food deserts, 1966-2007. *Prev Chronic Dis*. 2009 Jul;6(3):A105.

9. Institute of Medicine and National Research Council. Workshop on the public health effects of food deserts: Workshop summary. Washington D.C.: National Academy2009.

10. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med*. 2009 Jan;36(1):74-81.

11. Walker RE, Keane CR, Burke JG. Disparities and access to healthy food in the United States: A review of food deserts literature. *Health Place*. 2010 Sep;16(5):876-84.

12. Rose D, Bodor NJ, Swalm CM, et al. DESERTS IN NEW ORLEANS? ILLUSTRATIONS OF URBAN FOOD ACCESS AND IMPLICATIONS FOR POLICY. University of Michigan National Poverty Center/USDA Economic Research Service Research "Understanding the Economic Concepts and Characteristics of Food Access"2009.

13. Sturm R. Affordability and Obesity: Issues in the Multifunctionality of Agricultural/Food Systems. *J Hunger Environ Nutr*. 2009 Jul 1;4(3-4):454-65.

14. USDA. Access to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences: Economic Research Service2009.

15. Pearce J, Blakely T, Witten K, et al. Neighborhood deprivation and access to fast-food retailing: a national study. *Am J Prev Med*. 2007 May;32(5):375-82.

16. Langellier BA. The food environment and student weight status, los angeles county, 2008-2009. *Preventing chronic disease*. 2012 Feb;9:E61.

17. Ahern M, Brown C, Dukas S. A national study of the association between food environments and county-level health outcomes. *J Rural Health*. [Research Support, U.S. Gov't, P.H.S.]. 2011 Sep;27(4):367-79.

18. Pearce J, Witten K, Hiscock R, et al. Regional and urban ^ rural variations in the association of neighbourhood deprivation with community resource access: a national study. *nvironment and Planning A*. 2008(40):2469-89.

19. Sharkey JR, Horel S. Neighborhood socioeconomic deprivation and minority composition are associated with better potential spatial access to the ground-truthed food environment in a large rural area. *J Nutr*. 2008 Mar;138(3):620-7.

20. Sharkey JR, Horel S, Han D, et al. Association between neighborhood need and spatial access to food stores and fast food restaurants in neighborhoods of colonias. *Int J Health Geogr*. 2009;8:9.

21. Smith DM, Cummins S, Taylor M, et al. Neighbourhood food environment and area deprivation: spatial accessibility to grocery stores selling fresh fruit and vegetables in urban and rural settings. *Int J Epidemiol*. 2010 Feb;39(1):277-84.

22. Macdonald L, Ellaway A, Macintyre S. The food retail environment and area deprivation in Glasgow City, UK. *The international journal of behavioral nutrition and physical activity*. 2009;6:52.

23. Wang MC, Kim S, Gonzalez AA, et al. Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. *J Epidemiol Community Health*. 2007 Jun;61(6):491-8.

24. Wilson K, Eyles J, Ellaway A, et al. Health status and health behaviours in neighbourhoods: a comparison of Glasgow, Scotland and Hamilton, Canada. *Health & place*. [Comparative Study]. 2010 Mar;16(2):331-8.

25. Baker EA, Schootman M, Barnidge E, et al. The role of race and poverty in access to foods that enable individuals to adhere to dietary guidelines. *Prev Chronic Dis*. 2006 Jul;3(3):A76.

26. Miller WC, Ford CA, Morris M, et al. Prevalence of chlamydial and gonococcal infections among young adults in the United States. *JAMA*. 2004 May 12;291(18):2229-36.

27. Resnick MD, Bearman PS, Blum RW, et al. Protecting adolescents from harm. Findings from the National Longitudinal Study on Adolescent Health. *JAMA*. 1997 Sep 10;278(10):823-32.

28. Boone-Heinonen J, Evenson KR, Song Y, et al. Built and socioeconomic environments: patterning and associations with physical activity in U.S. adolescents. *Int J Behav Nutr Phys Act*. 2010;7:45.

29. Zenk SN, Schulz AJ, Matthews SA, et al. Activity space environment and dietary and physical activity behaviors: a pilot study. *Health & place*. [Research Support, N.I.H., Extramural, Research Support, U.S. Gov't, P.H.S.]. 2011 Sep;17(5):1150-61.

30. Hillier A, Cannuscio C, Karpyn A, et al. How Far Do Low-Income Parents Travel to Shop for Food? Empirical Evidence from Two Urban Neighborhoods. *Urban Geography*. 2011;32(5):712-29.

31. Oliver LN, Schuurman N, Hall AW. Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands. *Int J Health Geogr*. 2007;6:41.

32. CDC. Children's Food Environment State Indicator Report: Centers for Disease Control and Prevention2011.

33. Feng J, Glass TA, Curriero FC, et al. The built environment and obesity: a systematic review of the epidemiologic evidence. *Health & place*. [Review]. 2010 Mar;16(2):175-90.

34. Boone-Heinonen J, Gordon-Larsen P. What is the relevant neighborhood area for detecting built environment relationships with physical activity? *submitted to Health & Place*. 2010.

35. Subramanian SV, Chen JT, Rehkopf DH, et al. Racial disparities in context: a multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. *Am J Public Health*. 2005 Feb;95(2):260-5.

36. U.S. Census Bureau. Statistical Brief- Poverty Areas. 1995 [cited 2010 1/19/10]; Available from: http://www.census.gov/population/socdemo/statbriefs/povarea.html.

37. Messer LC, Laraia BA, Kaufman JS, et al. The development of a standardized neighborhood deprivation index. *Journal of urban health : bulletin of the New York Academy of Medicine*. [Research Support, Non-U.S. Gov't, Research Support, U.S. Gov't, Non-P.H.S., Research Support, U.S. Gov't, P.H.S.]. 2006 Nov;83(6):1041-62.

38. McGarigal K., Cushman S.A., Neel M.C., et al. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. In: University of Massachusetts A, editor.2002.

39. Clarke P. When can group level clustering be ignored? Multilevel models versus single-level models with sparse data. *J Epidemiol Community Health*. 2008 Aug;62(8):752-8.

40. Jago R, Baranowski T, Baranowski JC, et al. Distance to food stores & adolescent male fruit and vegetable consumption: mediation effects. *Int J Behav Nutr Phys Act*. 2007;4:35.

41. Morland K, Filomena S. Disparities in the availability of fruits and vegetables between racially segregated urban neighbourhoods. *Public Health Nutr*. 2007 Dec;10(12):1481-9.

42. Block JP, Scribner RA, DeSalvo KB. Fast food, race/ethnicity, and income: a geographic analysis. *Am J Prev Med*. 2004 Oct;27(3):211-7.

43. Zenk SN, Powell LM. US secondary schools and food outlets. *Health Place*. 2008 Jun;14(2):336-46.

44. Borradaile KE, Sherman S, Vander Veur SS, et al. Snacking in children: the role of urban corner stores. *Pediatrics*. 2009 Nov;124(5):1293-8.

45. Lucan SC, Karpyn A, Sherman S. Storing empty calories and chronic disease risk: snack-food products, nutritive content, and manufacturers in Philadelphia corner stores. *J Urban Health*. May;87(3):394-409.

46. The Brookings Institution Metropolitan Policy Program. State of Metropolitan America: on the front lines of demographic transformation. Washington DC: The Brookings Institution2010.

47. Lovasi GS, Hutson MA, Guerra M, et al. Built environments and obesity in disadvantaged populations. *Epidemiol Rev*. 2009;31:7-20.

48. Raja S, Ma C, Yadav P. Beyond Food Deserts: Measuring and Mapping Racial Disparities in Neighborhood Food Environments. *Journal of Planning Education and Research*. 2008;27:469-82.

49. Liese AD, Colabianchi N, Lamichhane AP, et al. Validation of 3 food outlet databases: completeness and geospatial accuracy in rural and urban food environments. *American journal of epidemiology*. [Evaluation Studies, Research Support, N.I.H., Extramural, Validation Studies]. 2010 Dec 1;172(11):1324-33.

50. Hoehner CM, Schootman M. Concordance of commercial data sources for neighborhood-effects studies. *Journal of urban health : bulletin of the New York Academy of Medicine*. [Research Support, N.I.H., Extramural, Research Support, Non-U.S. Gov't]. 2010 Jul;87(4):713-25.

51. Longacre MR, Primack BA, Owens PM, et al. Public directory data sources do not accurately characterize the food environment in two predominantly rural states. *Journal of the American Dietetic Association*. [Research Support, N.I.H., Extramural, Research Support, Non-U.S. Gov't]. 2011 Apr;111(4):577-82.

52. Powell LM, Han E, Zenk SN, et al. Field validation of secondary commercial data sources on the retail food outlet environment in the U.S. *Health & place*. [Research Support, Non-U.S. Gov't, Validation Studies]. 2011 Sep;17(5):1122-31.

53. Cummins S, Macintyre S. Are secondary data sources on the neighbourhood food environment accurate? Case-study in Glasgow, UK. *Preventive medicine*. [Research Support, Non-U.S. Gov't, Validation Studies]. 2009 Dec;49(6):527-8.

54. A.C. Nielsen Company. FMI/ACNielsen Study: Winning Strategies for Your Most Important Shoppers2005.

55. NYC Department of Health and Mental Hygiene. NYC Green Cart. New York City2008 [cited 2010]; Available from: http://www.nyc.gov/html/doh/html/cdp/cdp_pan_green_carts.shtml.

56. The Reinvestment Fund. Commercial Real Estate: Supermarkets. New Jersey2010 [cited 2010]; Available from: http://www.trfund.com/financing/realestate/supermarkets.html.

57. Lombino D, Patterson J. New York City Industrial Development Agency Approves Incentives for First Two Supermarkets Under the Fresh Program. New York City2010 [cited 2010]; Available from: http://www.nycedc.com/PressRoom/PressReleases/Pages/IDAApprovesIncentivesforSupermarkets.aspx.

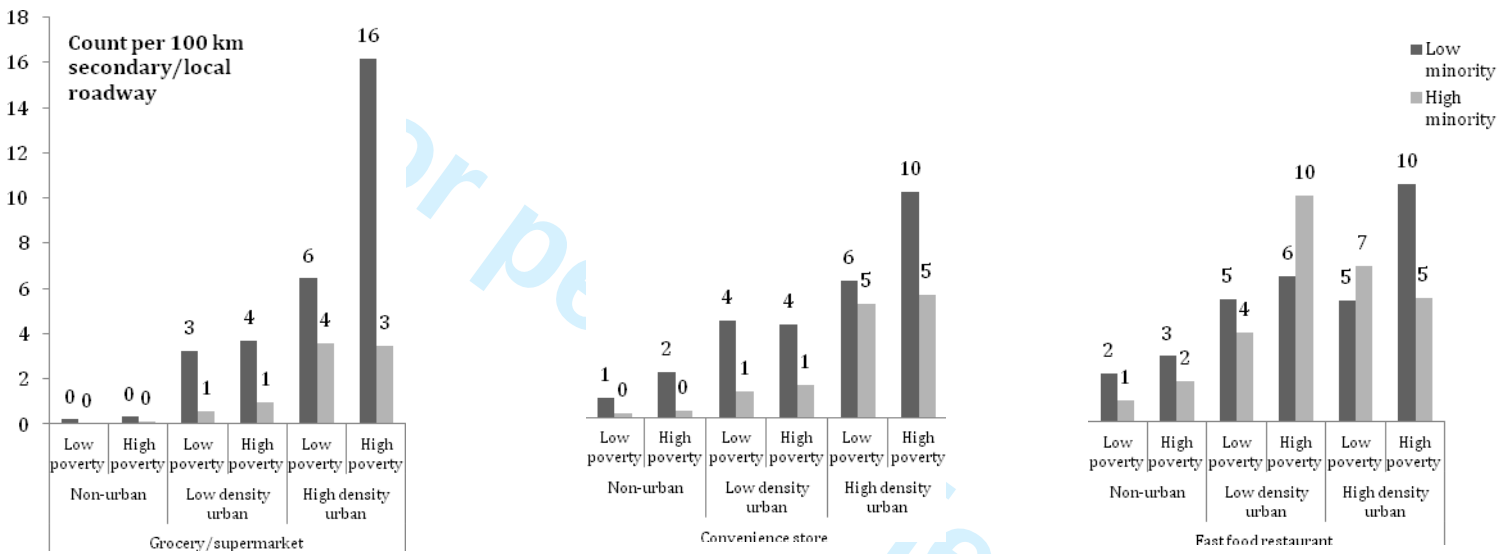
58. Stephens C. State of Louisiana Approves $7 Million for Fresh Food Initiative in New Orleans. Louisisana2009 [cited 2010]; Available from: http://www.lra.louisiana.gov/index.cfm?md=newsroom&tmp=detail&articleID=582.

59. The Food Trust. Pennsylvania Fresh Food Financing Initiative. Philadelphia2004 [cited 2010]; Available from: http://www.thefoodtrust.org/php/programs/fffi.php.

60. Los Angeles City Clerk. FAST FOOD RESTAURANTS / INTERIM CONTROL ORDINANCE / WEST-ADAMS-BALDWIN HILLS-LEIMERT, SOUTH AND SOUTHEAST LOS ANGELES. Los Angeles: LA City Clerk; 2008 [cited 2010]; Available from: http://cityclerk.lacity.org/lacityclerkconnect/index.cfm?fa=ccfi.viewrecord&cfnumber=07-1658&CFID=16806974&CFTOKEN=73b760e131fb720-4A7614CB-C1C7-C84F-F1E8474351348CDC&jsessionid=f030cb1129cc179c6eed6440245a58561e87.

61. letsmove.gov. Accessing Healthy & Affordable Food. Washington, D.C.2010 [cited 2010 4/5/10]; Available from: http://letsmove.gov/accessing/index.html.

Figure 1. Predicted neighborhood food resource availability (count per 10,000 population) for various neighborhood poverty[a] and minority population[b] levels[c]



[a] Greater than 20% of population below the federal poverty level

[b] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-10%)

[c] National Longitudinal Study of Adolescent Health Wave III (young adulthood; 2001-02), corrected for clustering and weighted for representation. Estimated from urbanicity-stratified regression modeling food resource availability (within 3k network buffer) as a function of neighborhood poverty status (>20% population below federal poverty level, compared to ≤20% of population below federal poverty level), with neighborhood poverty*neighborhood minority interactions. For simplicity, predictions for medium neighborhood minority population are not reported;

Appendix A. Detailed food resource definitions based on 4- and 8-digit Standard Industrial Classification (SIC) codes

Food Resource Type	SIC subgroup	SIC	Description
Fast food chain & non-chain	Fast food chain (5812)	58120307	Fast-food restaurant, chain
		58120601	Pizzeria, chain
	Fast food non-chain (5812)	58120300	Fast food restaurants and stands
		58120301	Box lunch stand
		58120302	Carry-out only (except pizza) restaurant
		58120303	Chili stand
		58120304	Coffee shop
		58120305	Delicatessen (eating places)
		58120306	Drive-in restaurant
		58120308	Fast-food restaurant, independent
		58120309	Food bars
		58120310	Grills (eating places)
		58120311	Hamburger stand
		58120312	Hot dog stand
		58120313	Sandwiches and submarines shop
		58120314	Snack bar
		58120315	Snack shop
		58120600	Pizza restaurants
		58120602	Pizzeria, independent
Grocery/Supermarkets	Grocery stores chain (5411)	54119904	Grocery stores, chain
	Grocery stores non-chain (5411)	54119905	Grocery stores, independent
	Grocery stores other (5411)	54110000	Grocery stores
		54119900	Grocery stores, nec
		54119903	Frozen food and freezer plans, except meat
		53999903	Country general stores
	Supermarkets smaller (5411)	54110101	Supermarkets, chain
		54110103	Supermarkets, greater than 100,000 square feet (hypermarket)
	Supermarkets larger	54110102	Supermarkets,

	(5411)		independent
		54110104	Supermarkets, 55,000 - 65,000 square feet (superstore)
		54110105	Supermarkets, 66,000 - 99,000 square feet
	Supermarkets other (5411)	54110100	Supermarkets
Convenience stores	Convenience Stores (5411/5331/5541)	53310000	Variety stores
		54110200	Convenience stores
		54110201	Convenience stores, chain
		54110202	Convenience stores, independent
		55410000	Gasoline service stations
		55419900	Gasoline service stations, nec
		55419901	Filling stations, gasoline

Appendix B. Means and (SD) of alternate measures of food resources availability[a,b,] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicity[c]

Neighborhood			Count per 10,000 population- within 3 km Euclidean buffer			Distance to nearest outlet (km)- within 8 km Euclidean buffer		
Percent poverty[d,f] within 3k	Percent minority population[d,e] within 3k	N	Grocery/ supermarket	Convenience stores	Fast food	Grocery/ supermarket	Convenience stores	Fast food
			Non-urban			Non-urban		
Low	Low	545	0.50 (0.17)	1.75 (0.77)	6.38 (1.16)	3.00 (0.56)	2.49 (0.50)	2.09 (0.23)
	Medium	954	0.55 (0.13)	1.17 (0.27)	5.51 (0.48)	3.05 (0.20)	3.25 (0.19)	2.62 (0.16)
	High	1024	0.16 (0.06)	0.94 (0.24)	5.00 (0.53)	3.25 (0.43)	3.71 (0.42)	2.73 (0.17)
High	Low	715	0.58 (0.34)	3.52 (2.10)	7.98 (0.65)	1.46 (0.11)	2.56 (0.88)	1.94 (0.26)
	Medium	306	0.20 (0.10)	0.38 (0.19)	9.67 (0.84)	1.82 (0.60)	2.50 (0.60)	1.48 (0.29)
	High	232	0.42 (0.10)	0.87 (0.20)	4.60 (0.93)	1.61 (0.65)	4.47 (0.80)	3.92 (0.58)
	Total	3,779	0.39 (0.09)	1.46 (0.48)	6.16 (0.34)	2.56 (0.29)	3.17 (0.34)	2.43 (0.12)
			Low density urban			Low density urban		
Low	Low	1320	2.73 (0.28)	3.78 (0.27)	5.48 (0.25)	1.21 (0.13)	1.12 (0.12)	0.80 (0.05)
	Medium	1757	1.89 (0.15)	3.06 (0.20)	6.32 (0.19)	1.80 (0.17)	1.58 (0.11)	0.91 (0.03)
	High	2078	0.99 (0.17)	1.99 (0.34)	6.44 (0.19)	2.53 (0.32)	2.59 (0.32)	1.08 (0.05)
High	Low	910	2.59 (0.28)	3.50 (0.32)	5.97 (0.29)	1.14 (0.16)	1.01 (0.10)	0.73 (0.05)
	Medium	477	1.73 (0.22)	2.72 (0.29)	9.08 (0.95)	1.13 (0.20)	1.28 (0.22)	0.53 (0.04)
	High	129	1.23 (0.32)	1.71 (0.37)	11.52 (1.94)	1.54 (0.44)	1.41 (0.35)	0.56 (0.07)
	Total	6,676	0.39 (0.09)	2.83 (0.21)	6.16 (0.34)	2.56 (0.29)	3.17 (0.34)	2.43 (0.12)
			High density urban			High density urban		
Low	Low	767	3.00 (0.29)	3.43 (0.29)	4.28 (0.42)	0.83 (0.24)	0.56 (0.04)	0.60 (0.06)
	Medium	786	3.11 (0.34)	3.60 (0.26)	4.98 (0.22)	0.87 (0.16)	0.62 (0.06)	0.48 (0.04)
	High	870	2.74 (0.26)	4.29 (0.41)	6.44 (0.18)	1.18 (0.24)	0.81 (0.14)	0.50 (0.02)
High	Low	418	3.85 (0.63)	3.32 (0.43)	4.72 (0.36)	0.94 (0.20)	0.87 (0.18)	0.54 (0.06)
	Medium	400	3.30 (0.83)	3.30 (0.66)	5.17 (0.45)	1.19 (0.42)	0.94 (0.15)	0.57 (0.06)
	High	307	3.42 (0.59)	4.17 (0.53)	6.43 (0.51)	0.93 (0.28)	0.66 (0.11)	0.43 (0.03)
	Total	3,549	3.10 (0.34)	3.84 (0.31)	5.64 (0.21)	1.04 (0.17)	0.76 (0.09)	0.51 (0.03)

[a] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food
[b] Means and SD corrected for clustering and weighted for representation.
[c]Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.
[d] Census block group
[e] Greater than 20% of population below the federal poverty level
[f] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-100%)

Appendix C. Associations between urbanicity-specific neighborhood minority composition[a] and high neighborhood poverty[b] and alternate measures[c] of availability [beta coefficient (95% CI)][d,e] National Longitudinal Study of Adolescent Health, Wave III (2001-2), n=13,995, by urbanicityf

		Neighborhood		
Poverty status[a,g]	Minority population [b,g]	Non-urban	Low density urban	High density urban
Grocery/supermarket density (count per 10,000 population) within 3 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-0.04 (-0.40, 0.31)	-0.92 (-1.40, -0.44)	-0.03 (-0.61, 0.55)
	High	-0.35 (-0.69, -0.02)	-1.76 (-2.35, -1.18)	-0.51 (-1.04, 0.02)
High	Low	0.08 (-0.49, 0.66)	-0.03 (-0.55, 0.48)	1.11 (0.04, 2.18)
	Medium	-0.38 (-0.77, 0.01)	-1.14 (-1.78, -0.50)	0.40 (-0.94, 1.74)
	High	-0.01 (-0.42, 0.40)	-1.57 (-2.40, -0.74)	0.17 (-1.21, 1.55)
Distance to nearest grocery/supermarket (km) within 8 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-0.24 (-1.22, 0.74)	0.52 (0.24, 0.81)	0.18 (-0.11, 0.47)
	High	-0.16 (-1.45, 1.12)	1.09 (0.46, 1.71)	0.20 (-0.50, 0.89)
High	Low	-1.43 (-2.47, -0.39)	-0.08 (-0.36, 0.20)	0.08 (-0.33, 0.48)
	Medium	-0.82 (-2.50, 0.85)	0.26 (-0.17, 0.69)	0.26 (-0.28, 0.79)
	High	-1.67 (-3.39, 0.05)	0.66 (0.03, 1.29)	0.12 (-0.52, 0.77)
Convenience store density (count per 10,000 population) within 3 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-0.70 (-2.22, 0.83)	-0.86 (-1.36, -0.35)	0.18 (-0.47, 0.84)
	High	-0.84 (-2.43, 0.75)	-1.84 (-2.58, -1.10)	0.87 (-0.16, 1.89)
High	Low	1.77 (-1.33, 4.87)	-0.09 (-0.65, 0.46)	-0.12 (-0.95, 0.71)
	Medium	-1.48 (-3.06, 0.10)	-1.30 (-2.06, -0.55)	-0.13 (-1.32, 1.06)
	High	-0.79 (-2.39, 0.81)	-2.19 (-3.02, -1.36)	0.76 (-0.44, 1.95)
Distance to nearest convenience store (km) within 8 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	0.34 (-0.35, 1.03)	0.35 (0.11, 0.60)	0.11 (-0.02, 0.24)
	High	0.27 (-0.67, 1.21)	1.12 (0.61, 1.63)	0.16 (-0.13, 0.45)
High	Low	0.33 (-1.01, 1.67)	-0.12 (-0.32, 0.08)	0.32 (0.05, 0.59)
	Medium	-0.04 (-1.22, 1.15)	0.49 (0.02, 0.95)	0.30 (0.04, 0.55)
	High	1.19 (-0.27, 2.64)	0.61 (0.17, 1.06)	0.08 (-0.13, 0.30)
Fast food density (count per 10,000 population) within 3 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	-1.59 (-4.05, 0.87)	0.83 (0.28, 1.37)	0.56 (-0.25, 1.37)
	High	-1.52 (-3.93, 0.88)	0.96 (0.33, 1.59)	1.91 (1.03, 2.79)
High	Low	1.62 (-0.61, 3.84)	0.51 (-0.09, 1.10)	0.71 (-0.21, 1.63)
	Medium	2.67 (-0.08, 5.41)	3.59 (1.57, 5.60)	0.99 (-0.17, 2.16)
	High	-1.22 (-3.83, 1.40)	6.04 (2.11, 9.97)	1.89 (0.62, 3.17)

Distance to nearest fast food restaurant (km) within 8 km Euclidean buffer around each individual residence				
Low	Low	0.0	0.0	0.0
	Medium	0.32 (-0.06, 0.71)	0.03 (-0.06, 0.12)	-0.08 (-0.18, 0.02)
	High	0.07 (-0.40, 0.54)	0.10 (0.00, 0.21)	-0.14 (-0.24, -0.04)
High	Low	-0.20 (-0.49, 0.08)	-0.05 (-0.16, 0.05)	-0.07 (-0.14, 0.00)
	Medium	-0.44 (-0.89, 0.01)	-0.24 (-0.36, -0.13)	-0.09 (-0.22, 0.05)
	High	0.51 (-0.33, 1.34)	-0.30 (-0.46, -0.13)	-0.17 (-0.28, -0.07)

[a] Greater than 20% of population below the federal poverty level

[b] Percent non-Hispanic White population. Non-urban (Low:0-74.7%, Medium: 74.8-96.3%, High: 96.4-100%), Low density urban (Low: 0-70.7%, Medium: 70.8-90.5% High: 90.6-100%) High density urban (Low: 0-31%, Medium: 31.1-63.7%, High: 63.8-10%)

[c] See Appendix A for SIC codes for grocery/supermarkets, convenience stores, and fast food

[d] Linear regression models, controlling for percent college educate and population density (except model of count per population measure)

[e] Dashes represent un-estimated associations; 1) measure within network 8km in low and high-density urban areas 2) measure within network 1km in non-urban areas.

[f] Non-urban: distance to Urbanized Area (UA) >0, low density urban: distance to UA=0 & % developed land cover, excluding water and ice (land developed) <=95%, high density urban: distance to UA=0 & % land developed >95%.

[g] Census block group

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7
Objectives	3	State specific objectives, including any pre-specified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-10
Bias	9	Describe any efforts to address potential sources of bias	11, 12
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	11
		(*b*) Describe any methods used to examine subgroups and interactions	11
		(*c*) Explain how missing data were addressed	8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	8

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	12
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	19
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	20
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	20
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	21
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Appendices B-C
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.