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Are neighbourhood food resources distributed inequitably by income and race in the USA? Epidemiological findings across the urban spectrum

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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 neighbourhood racial composition and across the range from rural to urban settings is limited, largely due to lack of large, geographically and socio-demographically diverse study populations. Using a national sample, the authors examined differences in neighbourhood food resource availability according to neighbourhood-level poverty and racial/ethnic population in non-urban, low-density urban 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 neighbourhood characteristics of participants in the National Longitudinal Study of Adolescent Health (Wave III, 2001–2002; n=13 995 young adults aged 18–28 years representing 7588 US block groups), the authors examined associations between neighbourhood poverty and race/ethnicity with neighbourhood food resource availability in urbanicity-stratified multivariable linear regression.

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

Results: Neighbourhood race and income disparities were most pronounced in low-density urban areas, where high-poverty/high-minority areas had lower availability of grocery/supermarkets (β coefficient (β)=−1.91, 95% CI −2.73 to −1.09) and convenience stores (β=−2.38, 95% CI −3.62 to −1.14) and greater availability of fast-food restaurants (β=4.87, 95% CI 2.26 to 7.48) than low-poverty/low-minority areas. However, in high-density urban areas, high-poverty/low-minority neighbourhoods had comparatively greater availability of grocery/supermarkets (β=8.05, 95% CI 2.52 to 13.57), convenience stores (β=2.89, 95% CI 0.64 to 5.14) and fast-food restaurants (β=4.03, 95% CI 1.97 to 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.

ARTICLE SUMMARY

Article focus

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

Key messages

- Socio-demographic inequities in neighbourhood food resource availability were most pronounced in low-density urban (largely suburban) areas.
- In high-density urban areas, higher neighbourhood 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.

Strengths and limitations of this study

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

INTRODUCTION

National, state and local policies increasingly focus on improving availability of healthy foods in disadvantaged neighbourhoods. 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 the US 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] characterised as neighbourhoods 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 neighbourhood food access.[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,[16 17] perhaps due to differences in travel times to community resources[18] and population density. Yet few studies examine how inequities in availability of food resources might vary by urbanicity,[9 19–21] and limited understanding relies on comparisons across small geographically specific study populations (eg, New Orleans compared with Texas colonias). Generalisable 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 neighbourhood socioeconomic status alone has not yielded consistent results,[15 22–24] which suggest that other neighbourhood 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 neighbourhood race/ethnic composition and neighbourhood income has received little attention.[25]

Using Geographic Information Systems-derived neighbourhood characteristics from a national sample of 13 995 young adults across the USA provides variation and sufficient sample size to examine disparities in neighbourhood food resource availability according to income, race/ethnicity and urbanicity. We examined the joint role of neighbourhood race/ethnic composition and neighbourhood poverty across non-urban, low-density urban and high-density urban areas. Specifically, we tested whether individuals living in neighbourhoods composed 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 with 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 18–24 years who participated in Wave III (2001–2002) 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 7–12 (11–22 years of age) in 1994–1995 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]

We used the Add Health Obesity and Neighbourhood 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 measurements (n=1204) 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 (neighbourhood buffers) and block group, tract and county attributes from time-matched US Census and other federal sources were merged with individual-level Add Health interview responses.[28] The number of census block groups (n=7588) 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 the US census data were excluded, leaving an analytic sample of 13 995.

Study variables

Geographic Information Systems-derived neighbourhood 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 Wave III (2001). The 3 km buffer was designed to capture distances readily accessible by walking and driving to neighbourhood diet- and activity-related resources.[2 3 29 30] Comparative analyses were conducted with 1 and 8 km buffers. Neighbourhood food environment, socio-demographic 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 data set of the US businesses. Food resources were classified according to 4- and 8-digit Standard Industrial Classification 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 and convenience stores and food stores attached to gasoline filling stations. Full details are described in online appendix A.

We characterised neighbourhood food resource availability as the count of each type of resource per roadway distance within a 3 km 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 (eg, count per population, distance to nearest outlet).

Given the importance of scaling resources by general urban development, we created measures of resources per 100 km of secondary/connecting and local neighbourhood and rural roads using street data obtained from StreetMap Pro (July 2003, V.5.2) data from Environmental Systems Research Institute (http://www.esri.com) in Redlands, California, USA. We selected the 3 km street network buffer after evaluating associations with resource availability and sensitivity of buffer size. We thus defined neighbourhood food resource availability as the number of outlets per 100 km 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.

Neighbourhood socio-demographics

Census block groups were used to define neighbourhoods because smaller units are more likely to adhere to individually perceived neighbourhood boundaries[34] and are more socio-demographically homogeneous. Using the federal definition of 'poverty area',[35 36] we dichotomised neighbourhood poverty into >20% or ≤20% of population below the federal poverty level. We defined neighbourhood minority population as percentage of population of non-Hispanic white race/ethnicity and neighbourhood-level education as percentage of population ≥25 years with college or greater education. While other studies have used a neighbourhood deprivation index to provide an 'empirical summary of total area-level variance explained by the census variables',[37] we investigated neighbourhood 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 neighbourhood 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 and (6) high poverty/high minority.

Neighbourhood urbanicity

Most studies characterise urbanicity based on population density.[19] We improve on such traditional definitions by using the US Census-defined urbanised areas (UAs) that were used to classify residential locations as non-urban (outside UA) or urban (inside UA). Within urban areas, we used Fragstats[38] software with the 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 3 km 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 the UA (receiver operating characteristic curve area=0.937).

Statistical analysis

Descriptive analysis

Availability of food resources and socio-demographic characteristics were compared across non-urban, low-density urban and high-density urban strata. We examined urbanicity-specific tertiles of neighbourhood minority population (table 2) 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 V.11.1 (Stata Corp).

Multivariable regression analysis

We fit multivariable linear regression models to predict food resource availability as a function of neighbourhood poverty and minority population where our constructed variable combining neighbourhood poverty (high and low) with levels of minority population (low, medium, high) explicitly estimates interactions relative to the theoretically most advantaged neighbourhoods (low poverty/low minority). Given that food resources and neighbourhood socio-demographics varied dramatically across urbanicity, comparability across socio-demographic and geographic subpopulations was difficult, even with our large sample size. Nonetheless, we have large samples of individuals and block groups

Table 1 Urbanicity-specific* neighbourhood demographics, National Longitudinal Study of Adolescent Health, Wave III (2001–2002) (n=13 995)

	Non-urban	Low-density urban	High-density urban
Count (census block groups)	1530	4132	1935
Count (Add Health respondents)	3779	6676	3549
% College educated or above†, mean (SD)	16.6 (0.8)	25.5 (1.1)	22.2 (1.8)
Population density (persons/km^2)‡, 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

*Non-urban: distance to urbanised area (UA) >0; low-density urban: distance to UA=0 and % developed land cover, excluding water and ice (land developed) ≤95%; high-density urban: distance to UA=0 and % land developed >95%.
†Census block group.
‡Within 3 km Euclidean buffer around individual residence.

across urbanicity strata, with adequate variation across neighbourhood socio-demographics (table 1). All models were weighted for national representation, corrected for clustering on our primary sampling unit (schools) and controlled for continuous neighbourhood-level education and population density dichotomised into urbanicity-specific quantiles. Given that schools and census block groups are not geographically nested, we did not use multilevel analysis. Furthermore, multilevel 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 neighbourhood-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 neighbourhood 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 km of roadway within a 3 km network buffer are presented in text, while results for all other measures are shown in online appendices B and C.

RESULTS

Neighbourhood 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 neighbourhood poverty; rather, lower availability of food stores was observed with greater minority populations (table 3). Food stores were more equitably allocated in non-urban neighbourhoods. 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 neighbourhood income did not hold in neighbourhoods with high proportion of minority residents.

Fast-food availability was greater for residents in high-poverty neighbourhoods, with strongest associations in low- and high-density urban areas (table 3). Among those living in neighbourhoods 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 neighbourhoods.

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 (online appendices B and C).

DISCUSSION

We assessed inequities in grocery/supermarket, convenience store and fast-food restaurant availability by neighbourhood poverty and minority population in a large diverse national sample of residential neighbourhoods of young adults, representing 7588 census block groups (3.6% of 2000 US Census block groups). Our findings suggest that inequities in neighbourhood food resource availability do exist, but not always where prior research suggests. In particular, racial and income disparities in availability of grocery/supermarkets were

Table 2 Means (SD) of food resources* (count per 100 km secondary and local road within 3 km network buffer around each individual residence)†, National Longitudinal Study of Adolescent Health, Wave III (2001–2002) (n=13 995), by urbanicity‡ and neighborhood povertyx { and minority populationx **

Neighbourhood Per cent poverty§ ¶ within 3 km	Per cent minority population§ ** within 3 km	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	3779	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	6676	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	3549	8.72 (2.31)	7.24 (1.08)	10.18 (1.14)

*See online appendix A for Standard Industrial Classification codes for grocery/supermarkets, convenience stores and fast food.
†Means (SD) corrected for clustering and weighted for representation.
‡Non-urban: distance to urbanised area (UA) >0; low-density urban: distance to UA=0 and % developed land cover, excluding water and ice (land developed) ≤95%; high-density urban: distance to UA=0 and % land developed >95%.
§Census block group.
¶Greater than 20% of population below the federal poverty level.
**Per cent 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%).

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 USA, 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 neighbourhood 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 neighbourhoods. 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, neighbourhood 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 (1935 high-density urban vs 4132 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

Table 3 Associations between high neighbourhood poverty* and urbanicity-specific minority composition† and high neighbourhood and food resource‡ availability (β coefficient (95% CI))§ National Longitudinal Study of Adolescent Health, Wave III (2001–2002) (n=13 995), by urbanicity¶

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

*Greater than 20% of population below the federal poverty level.
†Per cent 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%).
‡See online appendix A for Standard Industrial Classification codes for grocery/supermarkets, convenience stores and fast food.
§Linear regression models, controlling for per cent college educate and population density.
¶Non-urban: distance to urbanised area (UA) >0; low-density urban: distance to UA=0 and % developed land cover, excluding water and ice (land developed) ≤95%; high-density urban: distance to UA=0 and % land developed >95%.
**Census block group.
††Statistically different (α=0.05) than low-minority population, within poverty status stratum.
‡‡Statistically different (α=0.05) than low-poverty status, within minority population stratum.

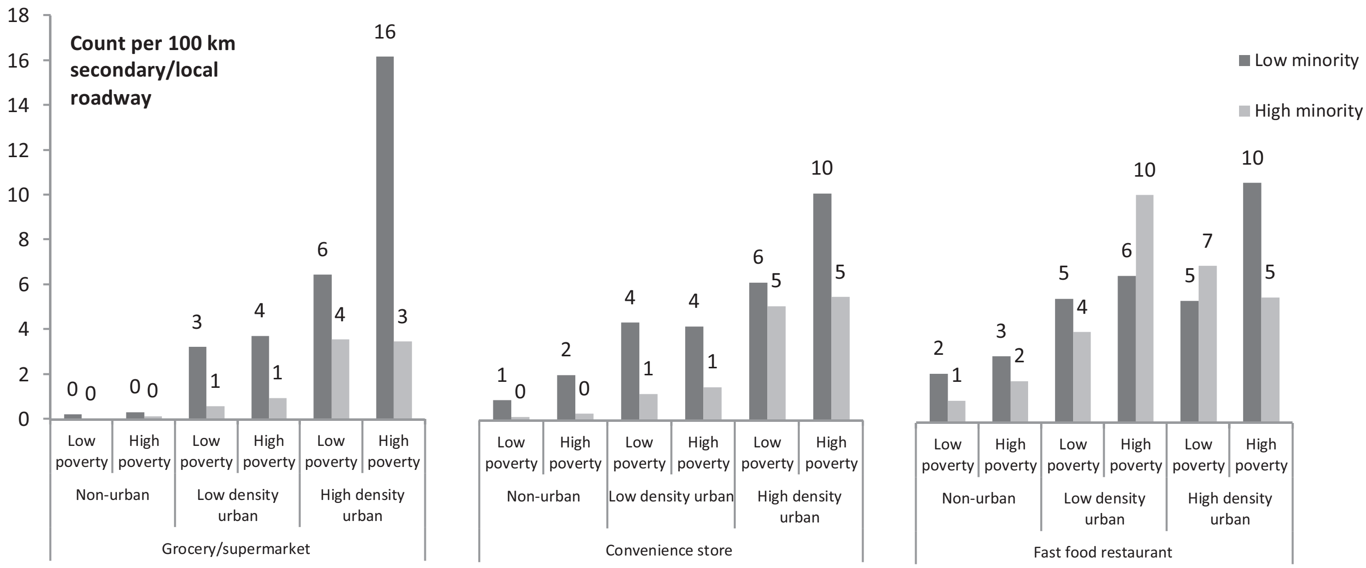

Figure 1 Predicted neighbourhood food resource availability (count per 10 000 population) for various neighbourhood poverty* and minority population† levels‡. *Greater than 20% of population below the federal poverty level. †Per cent non-Hispanic White population. Non-urban (low: 0%–74.7%, medium: 74.8%–96.3%, 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%). ‡National Longitudinal Study of Adolescent Health Wave III (young adulthood: 2001–2002), corrected for clustering and weighted for representation. Estimated from urbanicity-stratified regression modelling food resource availability (within 3 km network buffer) as a function of neighbourhood poverty status (>20% population below federal poverty level compared with ≤20% of population below federal poverty level) and percent non-Hispanic White population. Non-urban (Low:0-74.7%, High: 96.4-100%), Low density urban (Low: 0-70.7%, High: 90.6-100%) High density urban (Low: 0-31%, High: 63.8-10%) For simplicity, predictions for medium neighbourhood minority population are not reported.

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 commercialisation and development indicated by population and roadways. Slight inconsistencies in results for the minimum distance measures may reflect greater variation that results from using a single data point (nearest outlet) to characterise availability compared with incorporating data from multiple food resources within an area. Minimum distance measures also do not account for differential distribution of food resources according to the 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 neighbourhood 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 contain error, which can bias results either towards 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 socio-demographics and/or urbanicity.[49–53] Neighbourhood 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 neighbourhood type and socio-demographics. We were unable to ascertain food sold at each establishment and relied on generalisations regarding healthy (grocery/supermarket) versus unhealthy (convenience store, fast-food restaurant) types of establishments.

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

Furthermore, due to lower participation of illegal immigrants in the census, the US census data may underestimate neighbourhood minority population and poverty. Our 3 km network residential neighbourhood buffer may not accurately reflect food purchasing areas for different urban settings and socio-demographic 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 USA, and our findings can inform measurement and design in future individual-level and longitudinal studies. Our study benefits from the variation in neighbourhoods of a large population that enables comparisons across multiple socio-demographic and urban strata within a single study. Furthermore, our study capitalises upon national data with roadway-scaled measures of neighbourhood food resource availability within 3 km residential network buffers for each observation. In addition, we used detailed measures of urbanicity derived both from the US census and land cover 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 neighbourhoods, many with high-minority populations. Strategies include providing produce carts in low-income neighbourhoods in New York City,[55] directly or indirectly subsidising 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.

Conclusions

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 neighbourhood 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.

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