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# Neighborhood socioeconomic status and food environment: a 20-year longitudinal latent class analysis among CARDIA participants

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## Abstract

Cross-sectional studies suggest neighborhood socioeconomic (SES) disadvantage is associated with obesogenic food environments. Yet, it is unknown how exposure to neighborhood SES patterning through adulthood corresponds to food environments that also change over time. We used latent class analysis (LCA) to classify participants in the US-based Coronary Artery Risk Development in Young Adults study [n=5,114 at baseline 1985-1986 to 2005-2006] according to their longitudinal neighborhood SES residency patterns (upward, downward, stable high and stable low). For all classes of residents, the availability of fast food and non-fast food restaurants and supermarkets and convenience stores increased ($p<0.001$). Yet, socioeconomically



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disadvantaged neighborhood residents had fewer fast food and non-fast food restaurants, more convenience stores, and the same number of supermarkets in their neighborhoods than the advantaged residents. In addition to targeting the pervasive fast food restaurant and convenient store retail growth, improving neighborhood restaurant options for disadvantaged residents may reduce food environment disparities.

### Keywords

Geographic Information Systems; Environment; Neighborhood food availability; Neighborhood socioeconomics; Longitudinal study

## INTRODUCTION

From the mid-1980's to the 2000's, obesity increased dramatically in developed countries, such as the U.S., U.K., New Zealand, and Canada(World Health Organization 2011) with socioeconomically disadvantaged populations disproportionately affected (Ministry of Health 2004; McLaren 2007). Disparities in obesity have lead researchers to investigate the degree to which disadvantaged neighborhoods have poor food environments that promote the over-consumption of unhealthy foods (Zick, Smith et al. 2009; Block, Christakis et al. 2011; Caspi, Kawachi et al. 2012; Author et al. 2012). Identifying modifiable features of the food environment hypothesized to influence individual-level diet behaviors could lead to effective policies that will improve health in disadvantaged populations. However, the largely cross-sectional evidence base about socioeconomic disparities in the food environment is mixed with positive and negative findings (Diez Roux and Mair 2010; Feng, Glass et al. 2010; Walker, Keane et al. 2010; Giskes, van Lenthe et al. 2011). Complexities resulting from temporal patterns in neighborhood modifications and residential mobility may underlie existing equivocal evidence.

Several large international obesity literature reviews recognize the need for comprehensive strategies and systems models(Foresight 2007; World Health Organization 2013) and attention to wider environmental and societal factors in efforts to reduce obesity disparities. Nonetheless, socioeconomically disadvantaged subpopulations in developed countries remain disproportionately affected by obesity(World Health Organization 2000). Thus, there is growing interest by researchers in the U.S. and other developed countries on the role of socioeconomic factors in temporal declines in healthy food environments(Burgoine, Lake et al. 2009; Pearce and Day 2010; Filomena, Scanlin et al. 2013; Smith, Cummins et al. 2013). But findings are mixed and studies examining temporal patterns in food environments are sparse [see review(Mackenbach, Rutter et al. 2014)]. There is a large gap in long-term, population-based research in racially diverse samples with detailed time-varying food environment data.

In particular, two major gaps in the literature limit our understanding of inequities in the food environment. First, how does exposure to socioeconomic aspect of neighborhoods change through the life course? Second, do patterns of change in the neighborhood SES environment also reflect changes in exposure to different types of food resources? Understanding the relationships between these two aspects of longitudinal neighborhood exposures may shed insight on how to effectively modify food environments for socioeconomically disadvantaged populations to improve diet and reduce obesity.

Complex relationships between neighborhood SES and the food environment are difficult to capture. Neighborhood SES cannot be explicitly measured. Instead it is a latent construct comprised of multiple SES domains such as income and wealth, education, occupation, and housing. Multiple aspects of neighborhood SES may track together over time, such as poverty and unemployment. However, there may also be other aspects of neighborhood SES that drive commercial zoning policies or economic incentives for food retailers. For instance, supermarket owners may be more likely to locate in a low income neighborhood with vacant housing because the property taxes are lower than in a low income neighborhood with no vacant housing (Michigan 2005).

Another layer of complexity underlying relationships between neighborhood SES and the food environment is that, as individuals experience neighborhood SES changes over time, heterogeneities and similarities may develop within and across socioeconomic domains. For example, at the community-level vacant housing and the number of residents living in poverty may increase steadily in one neighborhood over time, while in another neighborhood, residents may attain higher levels of education but community-level household income may not increase until after graduates have entered the workforce. As an individual-level exposure, people may experience such neighborhood SES changes over time as they live within or move across neighborhoods. In addition, depending on neighborhood SES, food environments may improve or worsen over time. Therefore, a single snapshot in time may not capture patterns of socioeconomic characteristics that drive greater or reduced access to different types of food stores and restaurants.

To overcome these gaps in the literature, we capitalized on a geographic information system (GIS)-derived dataset in the United States (U.S.) spatially and temporally linked to Coronary Artery Risk Development in Young Adults (CARDIA) respondent residential locations at each of five exam years occurring over a 20-year period. We examined how individuals were exposed to different patterns of multiple neighborhood SES characteristics (e.g., occupation, poverty, and education) during young to middle adulthood using Latent Class Analysis (LCA). The result was a classification of CARDIA participants according to 20 years of their time-varying neighborhood SES characteristics. During a period when adult obesity increased rapidly in the U.S. we examined how neighborhood fast food restaurants, non-fast food restaurants, supermarkets, and convenience stores compared over time for adults across longitudinal neighborhood SES patterns. We hypothesized that participants with a 20-year history of living in socioeconomically disadvantaged neighborhoods were exposed to worse food environments (i.e., few supermarkets and more fast food restaurants) that deteriorated over time compared to those with a history of living in advantaged neighborhoods.

# METHODS

## Data

CARDIA is a longitudinal cohort with detailed diet, physical activity, environmental, demographic and socioeconomic data collected for 5,114 white or black U.S. adults aged 18-30 years originally from 4 centers: Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA. Participants were selected in 1985-86 with approximately equal numbers by race, gender, education (high school or less versus more than high school), age (18-24 years versus 25-30 years) within each center, and followed over 5 exams during 1992-93 (Year 7), 1995-96 (Year 10), 2000-01 (Year 15), and 2005-06 (Year 20). Retention rates were 81% , 79% , 74% , and 72% , respectively, of the surviving cohort.

We used data from 5 exam years (0, 7, 10, 15, and 20) and a GIS-derived dataset of time-varying neighborhood-level food resources and U.S. Census data were spatially and temporally linked to CARDIA respondent residential locations at each exam year.

## Area-level socioeconomic indicators

U.S. Census block groups were not available in the 1980 census data (year 0) so census tracts were used to define neighborhoods at all years. Census tract measures have been shown to identify health disparities as well as, if not better than, block groups(Krieger, Chen et al. 2002; Krieger, Chen et al. 2003). The geographic area of U.S. Census tracts depends on population density, with an optimum size tract of 4,000 people, although census tracts range from 1,200 to 8,000 people(United States Census Bureau 2012). At baseline, the catchment area of the four CARDIA centers comprised 799 Census tracts, by 2005-06 as individuals moved out of the original four field site cities, the catchment increased to include 2,800 tracts. We included multiple measures of socioeconomic disadvantage that addressed the domains of income, education, race, employment, and housing value (Table 1). Population density was calculated as tract population per square kilometer of land excluding water; it was not included in the LCA but was included as a covariate in multivariable models to adjust for area-level development.

## Neighborhood food environment

Counts of chain fast-food restaurants (hereafter referred to as fast food restaurants), all other restaurants not classified as chain fast food (hereafter referred to as non-fast food restaurants), supermarkets, and convenience stores were obtained from Dun and Bradstreet (D&B), a commercial dataset of U.S. business records. They were classified according to 8-digit Standard Industrial Classification (SIC) codes (Supplemental Table 1) for years 7, 10, 15, and 20. Year 0 SIC codes were 4 digits; this limited the specificity of restaurant classification, so fast food restaurants were identified by matching business names with fast food restaurants at years 1991-1996 and by SIC code. Fast food restaurants, non-fast food restaurants, supermarket, and convenience stores were aggregated as counts within 3 kilometers (km) of each respondent’s residential location (Euclidean buffer). The 3 km buffer was chosen to capture distances readily accessible by walking and driving to neighborhood diet-related resources as supported by several studies (Boone-Heinonen, Gordon-Larsen et al. 2011; Hillier, Cannuscio et al. 2011; Author et al. 2011). Food resource densities were derived as counts per 10 km secondary roadway (roads used to connect smaller towns, subdivisions, and neighborhoods) and local roadway (roads used for local traffic, usually with a single lane of traffic in each direction), resulting in a measure of concentration of food resources along streets representing overall commercial activity(Romley, Cohen et al. 2007; Richardson, Boone-Heinonen et al. 2011). Roadway lengths were calculated from street networks extracted from StreetMap 2000 (v. 9.0) for years 7 (1993) and 10 (1996), from StreetMap Pro 2005 (v. 5.2) for year 15 (2001), and from StreetMap Pro 2010 (v. 7.2) for year 20. Street network source datasets were obtained from Environmental Systems Research Institute (ESRI, www.esri.com: Redlands, CA). We opted for the roadway-scaled measures rather than raw food resource counts because count measures can introduce spurious associations between neighborhood SES and food stores and restaurants. For example, low SES neighborhoods may have more convenience stores because they have more businesses in general, due to roadway structures and commercial development. Using raw counts would then reflect commercial development differences by neighborhood SES and thus might obscure disparities in the food environment by neighborhood SES. While we did not use network buffers, we addressed differences in food resources according to overall commercial activity by scaling counts by roadway length while holding Euclidean area constant across geographic areas varying in terrain and network distances. Thus, the resources relative to roadway lengths provides measures relative to road network, whereas the Euclidean buffers provide the salient geographic area of focus.

### Individual-level characteristics

Individual-level sociodemographics were used to describe the study population throughout the study period. Sociodemographics were collected at each exam year by a structured interview or self-administered questionnaire. Sex, race (white/black), exam attendance, and center were time-invariant variables. Time-varying individual-level characteristics included working full-time (yes, no), marital status (married, not married), maximum reported number of years of schooling completed by the exam year (less than high school, high school, some college, college degree or above), and mean household income inflated to U.S. dollars at year 20 (2005-06) using the Consumer Price Index. Income was not collected in year 0, so the closest measurement (year 5) was used for year 0.

### Statistical Analyses

All descriptive analyses and multivariable models were performed using Stata 13.0 (StataCorp, College Station, TX).

**Descriptive statistics—**To describe the study population and their neighborhoods over exam years 0, 7, 10, 15, and 20, we calculated means and standard deviations (continuous variables) and percentiles (categorical variables) of individual-level sociodemographics. Medians and interquartile ranges were calculated for neighborhood-level characteristics.

**Latent class analysis: derivation of longitudinal neighborhood SES classes—** We performed LCA models with Mplus (Muthen LK and BO 2010) to classify CARDIA respondents into longitudinal neighborhood SES latent classes according to Census demographics. All variables used in the LCA were transformed to year-specific standard normal deviates [(X-mean)/SD] (hereafter referred to as Z-scores) to facilitate convergence of the LCA models. The variables related to housing were transformed to Z-scores specific to CARDIA study center, to account for the large cost of living differences between centers. Residential mobility was not included in these analyses because our aim was to quantify exposure to patterns of neighborhood SES over time, regardless of mobility.

A two-class model was estimated first with maximum likelihood methods and then models were considered with additional classes. We used the following criteria determine the number of k latent classes for our final model: 1) the Bayesian Information Criteria (BIC) (model fit and parsimony across models whereby smaller values indicate better fit); 2) the interpretability of model solution with assessment of size and uniqueness of each class; and 3) Lo-Mendell-Rubin (LMR) p-value ($k$ vs. $k - 1$ class). A significant LMR p-value indicates that the k-class solution is significantly different from the (k-1)-class solution, suggesting that k-class solution is preferred. Using these criteria, interpretability, and verifying model fit with BIC, we selected 4 SES classes.

Each individual was assigned to the single longitudinal neighborhood SES class for whom they had the highest posterior class membership probability. A minimum number of follow-up visits was not an inclusion criteria and on average respondents attended most follow-up visits (mean=3.98, SD=1.39). Class results are illustrated by plotting the mean Z-score for the component variables at each of the exam years. For greater detail, interquartile ranges were calculated for all components and food resource measures by class.

**Relationship between longitudinal neighborhood SES classes with food environment measures—**Next, we compared changes in neighborhood food resources over time experienced by participants across the four longitudinal neighborhood SES classes. Longitudinal multilevel random effects regression models estimated each neighborhood food resource density relative to roadway length separately as a function of SES class indicators (referent was class with largest sample size), exam year (continuous), interaction of class indicators by exam year, and a random effect for each participant. Population density [which can vary across roadway structure(Levinson 2012), rural and urban areas(United States Census Bureau 2010)] and commercial development were each independently associated with geographic food resource distribution and were not highly correlated in our data p=0.35. Therefore, we addressed population density (representing area-level development and population) and counts per roadway (representing commercial development) in our modeling. Time trends were statistically significant if the p-value of the estimated marginal year effect within class was less than 0.05. Linear contrasts (Stata’s ‘lincom’ command) compared food resource densities relative to roadway length by year and for each class pair and marginal predictions estimated mean food resource densities relative to roadway length by class and year.

Food environment model results are presented as: 1) plots of the estimated mean densities relative to roadway length for each type of neighborhood restaurant and food store by class and year; 2) table of beta coefficients from the multivariable random effects models for each food resource; and 3) table of the linear contrasts by year and for each class pair.

## RESULTS

### Descriptive statistics

Across 20 years of CARDIA exams, participant educational attainment, income, and proportion married increased over time (Table 2). Overall, the neighborhoods in which CARDIA participants lived improved over time in terms of economic and social environment indicators (Table 3). Counts of neighborhood fast food restaurants and convenience stores increased, non-fast food restaurants decreased, and supermarkets remained fairly stable.

### Latent class analysis

CARDIA participants were classified into four latent classes of longitudinal neighborhood SES based on BIC =610725 and LMR (p=0.04 for four vs. three classes compared to p=0.72 for five vs four classes classes): downwardly mobile neighborhood SES residents (n=1,014); stable low neighborhood SES residents (n=1,581); upwardly mobile neighborhood SES residents (n=665); and stable high neighborhood SES residents (n=1,854) (Figure 1). The average posterior probability within each class was > 0.97. In general, the LCA components that indicated neighborhood advantage (e.g., income, aggregate housing value) tracked together over time, as did the indicators of disadvantage (e.g., unemployment, vacancy). Medians and interquartile ranges of neighborhood SES and food resource measures are presented by longitudinal neighborhood SES class in Supplemental Table 2.

### Relationship between longitudinal neighborhood SES classes with food environment

The plotted mean food resource densities relative to roadway length and time trends are presented by class and year for restaurants (Figure 2) and food stores (Figure 3). In general, time trends in each type of food resource were similar for all residents regardless of their neighborhood SES class. Neighborhood densities of fast food restaurants, supermarkets, and convenience stores relative to roadway length increased over time for all classes of neighborhood SES residents. Neighborhood non-fast food restaurant density relative to roadway length increased over time for all residents except the upwardly mobile neighborhood SES residents, who experienced little change in neighborhood non-fast food restaurant density relative to roadway length over time.

Beta coefficients from the multivariable random effects models for each food resource are presented in Supplemental Table 3. Linear contrasts for each class pair are presented by year and food resource in Supplemental Table 4. In contrast to the time trends, fast food and non-fast food restaurant densities relative to roadway length varied markedly across classes of neighborhood SES residents, and the differences were stable over time (Supplemental Table 4). The participants belonging to the upwardly mobile and stable high neighborhood SES residential classes had more non-fast food restaurants in their neighborhoods at all observed years than those in the downwardly mobile or stable low SES neighborhood classes. Likewise, stable high neighborhood SES residents and upwardly mobile neighborhood SES residents consistently had more fast food restaurants in their neighborhoods than downwardly mobile and stable low SES neighborhood residents. In sum, advantaged neighborhood (stable high SES or upwardly mobile) residents consistently had more of both types of restaurants than the disadvantaged neighborhood (stable low SES or downwardly mobile) residents.

At most years, all residents had similar supermarket density relative to roadway length in their neighborhoods, regardless of their neighborhood SES resident class (Supplemental Table 4). While neighborhood convenience store densities relative to roadway length were relatively similar for all residents in the mid-1980's over time, the downwardly mobile neighborhood SES residents had more convenience stores in their neighborhoods than all other classes of residents.

## DISCUSSION

Using a unique set of data covering 20 years of residential histories and latent class analysis methods, we found that neighborhood restaurant and food store availability increased for all residents. Further, the more advantaged neighborhood SES residents had greater neighborhood restaurant availability and less convenience store availability at any given time. Our approach addressed two gaps in the literature: 1) How does exposure to socioeconomic aspects of neighborhoods change through the life course? Indeed, we successfully classified CARDIA participants into four distinct patterns of longitudinal neighborhood SES: downwardly mobile neighborhood SES residents, stable low neighborhood SES residents, upwardly mobile neighborhood SES residents, or stable high neighborhood SES residents. 2) Are patterns of change in the neighborhood SES environment also associated with changes in exposure to different types of food resources? We found that blacks and whites who lived in neighborhoods of low or declining SES during young to middle adulthood, had consistently more convenience stores and fewer restaurant options over time than individuals living in socioeconomically advantaged neighborhoods.

During a period when obesity prevalence increased significantly in the U.S. (Flegal, Carroll et al. 2002; Flegal, Carroll et al. 2010), neighborhood fast food restaurant, non-fast food restaurant, convenience store and supermarket availability also increased for most CARDIA participants. Such trends are consistent with national reports (Economic Research Service - USDA 2004; National Association of Convenience Stores (NACS) 2011; The Reinvestment Fund 2011; Lenard 2012; National Restaurant Association 2013) and reflect macroeconomic shifts in the retail food industry.

Two decades of residential histories in our large sample reveal disparities in how such national trends in food retail were experienced for subpopulations with different longitudinal neighborhood SES patterns. At any given time, those consistently living in socioeconomically disadvantaged neighborhoods had lower neighborhood density of non-fast food restaurants relative to roadway length than those consistently living in socioeconomically advantaged neighborhoods. Socioeconomically advantaged neighborhood residents had more fast food *and* non-fast food restaurants in their neighborhoods; therefore, they had a greater variety of restaurant options to choose from than socioeconomically disadvantaged neighborhood residents. However, non-fast food restaurants, as defined here, are a heterogeneous group of restaurants and does not necessarily represent restaurants that only sell healthy options.

Residential mobility could have resulted in more dramatic changes in food environment exposures for individuals who moved versus those who remained in the same residential location over the follow-up, if changes in food environment were greater among those who moved residences. In our data, only 378 (7%) participants stayed in the same residential location throughout the study period and the changes in neighborhood SES were actually larger in non-movers versus movers ($P<0.001$). Among the 378 non-movers, 50% were classified into one of the upwardly (7%) or downwardly (43%) mobile SES residency classes, compared to only 31% of the movers (13% upward; 18% downward). Changes in the food environment were similar for movers and non-movers, except that non-movers had greater temporal increases in numbers of non-fast food restaurants and convenience stores ($P<0.001$). Given that residential mobility did not predict greater changes in neighborhood SES or food environment it is unlikely that residential mobility biased our findings.

Our findings contradict prior research showing that low income and high minority population neighborhoods have more fast food and fewer full-service restaurants than socioeconomically advantaged neighborhoods (Block, Scribner et al. 2004; Lewis, Sloane et al. 2005; Baker, Schootman et al. 2006). However, our results concur with a large national study that found that predominantly black neighborhoods had fewer full-service and fast food restaurants than predominantly white neighborhoods (Powell, Chaloupka et al. 2007).

In our study, supermarket availability was similar for socioeconomically disadvantaged compared to advantaged neighborhood residents throughout most of two decades. At the same time, the most socioeconomically disadvantaged neighborhood residents had more convenient food shopping options than the other neighborhood SES class residents. These results contrast with the prevailing view that neighborhood disadvantage has been associated with reduced access to supermarkets/grocery stores. However, associations have varied by neighborhood racial composition (Morland, Wing et al. 2002; Zenk, Schulz et al. 2005; Baker, Schootman et al. 2006; Author et al. 2012).

In addition to the cross-sectional design, most of the above studies were geographically limited or did not control for area-level development. Socioeconomically deprived neighborhoods in dense urban areas may have many fast food restaurants as a consequence of commercial development; thus, not accounting for such area-level development can create spurious associations between neighborhood disadvantage and disparities the food environment. In this study, respondents lived in mainly urban areas however, population density can vary across urban areas (United States Census Bureau 2010). Population density and commercial development are correlated and independently associated with dietary behaviors (Lopez 2007). We addressed commercial density by scaling food resource measures by roadway length and controlling for population density in regression models.

Our findings suggest that overall fast food industry growth may have a greater impact on diet behaviors among persons living in the most disadvantaged neighborhoods because they have less access to alternative away-from-home eating options. Greater total food outlet density has been inversely associated with BMI, perhaps because greater density typically offers a wider array of food options or lower prices so that residents can make healthier food purchases (Stark, Neckerman et al. 2013) despite rising fast food availability (Economic Research Service - USDA 2004). Conversely, lower BMI in areas with high food outlet density may reflect overall dietary preferences of the residents (Poti, Duffey et al. 2013). Alternatively, lower BMI and high food outlet density may both be consequences of living in a more privileged environment, without one causing the other.

At the same time fast food availability increased, neighborhood convenience store availability increased for all participants. Participants with a history of living in socioeconomically declining neighborhoods at most years had more convenience stores in their neighborhoods than the other residents. Psychological distress due to neighborhood deprivation and disorder has been identified as an important mechanism of poor diet (Burdette and Hill 2008). Compared to people living in neighborhoods with low but stable SES, residents exposed to increasing signs of neighborhood decay may experience more stress. Therefore, the combination of experiencing greater neighborhood deprivation and greater access to convenient neighborhood food shopping options may be a potent promoter of poor diet.

Our study has some limitations. The electronic business record D&B data are widely used in other neighborhood environment research studies and are currently the only option for retrospective longitudinal studies spanning multiple decades. Yet these data are vulnerable to misclassification error including geospatial inaccuracy, missing data, and classification inaccuracy (Bader, Ailshire et al. 2010; Fleischhacker, Rodriguez et al. 2012; Han, Powell et al. 2012). We were unable to retrospectively field validate the historical food environment data from Exam Years 0-15 but other studies provide field validation of the D&B data from 2009(Liese, Colabianchi et al. 2010; Powell, Han et al. 2011; Rossen, Pollack et al. 2012). It is possible that increases in numbers of food resources over time could reflect temporal improvements in complete business listings. However, data on U.S. food industry trends confirm the nature and direction of the increase in food stores and restaurants that we observed (Economic Research Service - USDA 2004; National Association of Convenience Stores (NACS) 2011; National Restaurant Association 2013). Powell et al. conducted a ground-truthed study in Chicago and some surrounding suburban/rural Census tracts(Powell, Han et al. 2011), finding higher validity between D&B business listings and ground-truthed locations was higher in white versus predominantly black race Census tracts. Thus there may be more database inaccuracies in disadvantaged versus advantaged neighborhoods(Powell, Han et al. 2011). However, findings from two other validation studies set in Chicago(Bader, Ailshire et al. 2010) and Baltimore(Rossen, Pollack et al. 2012), suggest that neighborhood socioeconomics were not associated with disagreement between business lists and field observations. Powell's larger study(Powell, Han et al. 2011) included non-urban tracts compared to the latter two studies that were set in urban areas. Other studies also suggest validity may be poor in rural compared to urban areas(Kravets and Hadden 2007; Boone, Gordon-Larsen et al. 2008; Longacre, Primack et al. 2011; McGuirt, Jilcott et al. 2011; Fleischhacker, Rodriguez et al. 2012; Han, Powell et al. 2012). Nonetheless, CARDIA participants were recruited from four major U.S. cities and after 20 years, over 90% of them were still living either in or less than a mile away from an urban area. Therefore, differential misclassification in our data by urbanicity is not likely. Another limitation of all secondary business data sources is that lists capture only a snapshot and may not be updated frequently enough to capture new food retail outlets. However, our data are spatially and temporally matched to each exam year so we capture changes over time. In addition, we lacked data regarding the quality of the foods sold that might differ over time and by neighborhood SES. The decennial Census data, which are not precisely matched to exam year is another limitation. Despite these limitations we took advantage of a large and unique GIS that captured multiple types of neighborhood food resources, time-varying data on food environment characteristics and community-level sociodemographics for black and white men and women during their young to middle adulthood.

The period between 1985-2006 was a time of economic expansion in the U.S.(U.S. Department of State 2011). Yet, our findings suggest that neighborhood SES did not improve for all Americans, and in fact, declined for some. Over time, we observed an increase in numbers of all types of food resources, however these changes were different by neighborhood SES (despite increasing numbers of total food resources over time, there were consistently more convenience stores and fewer non-fast food restaurant options in disadvantaged neighborhoods). In the U.S., residential segregation persists perhaps due in part, to past and present discrimination and policies that are exacerbated by gentrification and suburbanization(Kwate 2008). All of these factors could underlie the geographic distribution and changes over time in numbers of restaurants and convenience stores. Similar socioeconomic processes and patterning exist outside the U.S. such that the World Health Organization argued that urban development, housing and transport infrastructure are health determinants, and consequently, important health policy targets(World Health Organization 2013). In our paper, we provide evidence that Americans exposed to socioeconomically worsening neighborhoods were additionally burdened by worsening food environments, potentially playing a role in widening health disparities over time.

## CONCLUSION

From 1985 to 2006, when obesity prevalence significantly increased among U.S. adults, those living in socioeconomically disadvantaged neighborhoods had less variety in away-from-home eating options compared to those living in advantaged neighborhoods. All respondents had relatively similar numbers of supermarkets in their neighborhoods, whereas residents of socioeconomically disadvantaged neighborhoods had more convenience food shopping options than those in other neighborhood SES classes. As fast food restaurant and convenience store industries grow nationally, disadvantaged populations may be at higher risk than advantaged populations to buy the abundant cheap and convenient food retail options that are high in calories, fat, and sugar. Reducing convenience store and fast food restaurant access while increasing the variety of nutritious restaurant options may improve obesity related disparities in disadvantaged populations.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## Research highlights

- We examined 20-year residential neighborhood SES patterns and food retail disparities.

- Overall neighborhood restaurant and food store availability increased.

- Stable low/declining neighborhood SES consistently predicted few restaurant options.

- Declining neighborhood SES consistently predicted high convenience store density.

- As food availability changes, disparities across neighborhood SES may affect health.

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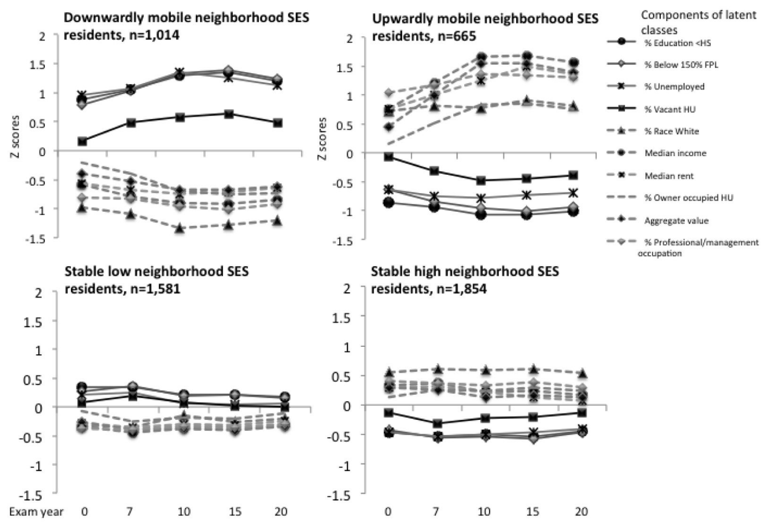


**Figure 1.**

Temporal changes in neighborhood SES characteristics[a], by 4 classes[b] of longitudinal neighborhood SES resident characteristics: the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985-2006.

[a]U.S. Census-tract level data spatially and temporally linked to CARDIA exam years (Year 0, 1980; Years 7 and 10, 1990; Year and Year 20, 2000); percent of education below HS is among persons aged 16 years and over, aggregate value is among owner-occupied HU

[b]Derived from latent class analysis using Mplus version 7(Muthen LK and BO 2010) of Census tract-level data from exam years 0, 7, 10, 15, and 20: percent race white, percent education <HS, percent poverty (below 150% FPL), percent unemployed, percent professional/management occupation, median income, percent vacant housing, aggregate housing value, percent owner occupied, median rent. All measures were normalized to Z-scores and percent vacant housing units, aggregate housing value, percent owner occupied, median rent were normalized by center.

Abbreviations: SES: socioeconomic status, FPL: federal poverty level, HU: housing units, HS: High School.

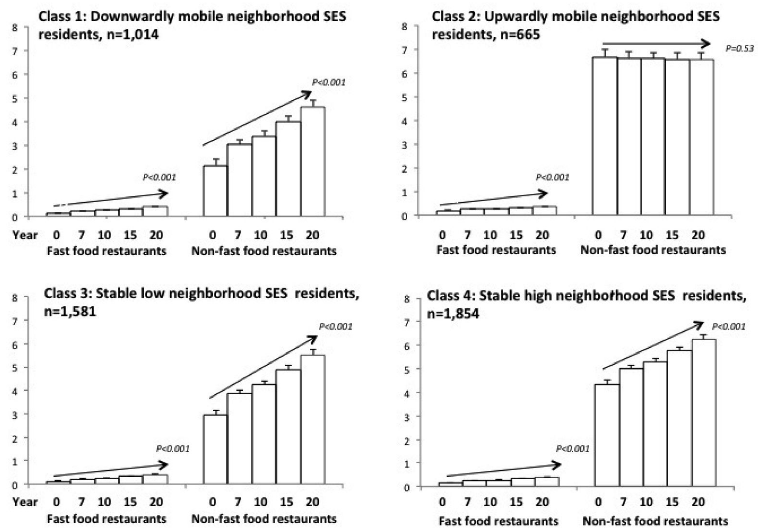


**Figure 2.**

Estimated mean[a] of neighborhood fast food and non-fast food restaurant densities[b] by 4 classes[c] of longitudinal neighborhood SES residents characteristics: the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985-2006.

[a]Multivariable random effects regressions modeling each neighborhood food resource as function of class indicators (referent is stable high neighborhood SES residents), exam year (continuous), interaction of class indicators by exam year, population density, and a random effect for each participant.

[b]Counts of Dunn & Bradstreet food resources within Euclidean 3km buffer per 10 km local and secondary roadways.

[c]Derived from latent class analysis using Mplus version 7(Muthen LK and BO 2010) of Census tract-level data from exam years 0, 7, 10, 15, and 20: percent race white, percent education <HS, percent poverty (below 150% FPL), percent unemployed, percent professional/management occupation, median income, percent vacant housing, aggregate housing value, percent owner occupied, median rent.

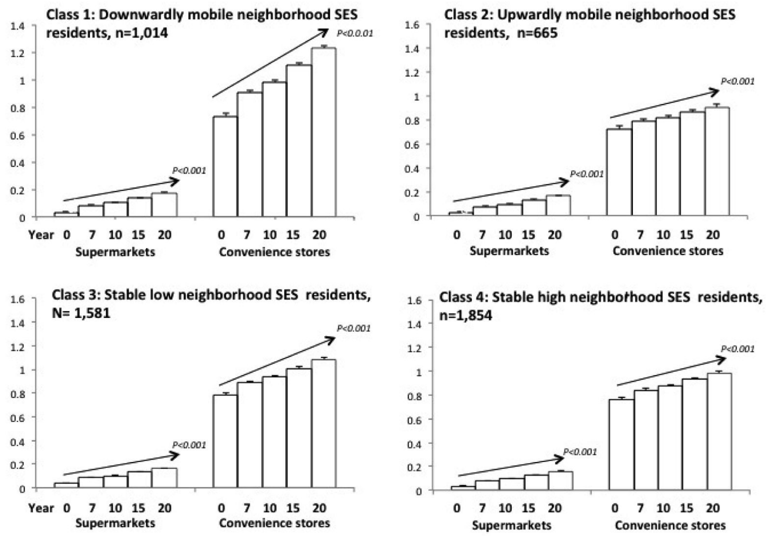


**Figure 3.**

Estimated mean[a] of neighborhood supermarkets and convenience store densities[b] by 4 classes[c] of longitudinal neighborhood SES residents characteristics: the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985-2006.

[a]Derived from latent class analysis using Mplus version 7(Muthen LK and BO 2010) of Census tract-level data from exam years 0, 7, 10, 15, and 20: percent race white, percent education <HS, percent poverty (below 150% FPL), percent unemployed, percent professional/management occupation, median income, percent vacant housing, aggregate housing value, percent owner occupied, median rent. Time trends were derived from class-specific multivariable random effects regression models that included population density wi hin tract, a random effect for each participant, and year.

[b]Counts of Dunn & Bradstreet food resources within Euclidean 3km buffer per 10 km local and secondary roadways.

[c]Multivariable random effects regressions modeling each neighborhood food resource as function of class indicators (referent is stable high neighborhood SES residents) , exam year (continuous), interaction of class indicators by exam year, population density, and a random effect for each participant.

**Table 1**

Neighborhood-level socioeconomic indicators included as components of latent class analysis[a]

| |
|---|
| Percent population race white |
| Percent population education < High School |
| Percent population <150% FPL |
| Median income per $10,000 |
| Percent population professional/management occupation[b] |
| Percent population unemployed[b] |
| Median rent |
| Percent population owner-occupied HU |
| Percent vacant HU |
| Aggregate value HU[c] per $1,000,000 |

FPL: federal poverty level, HU: housing units

[a]U.S. Census-tract level data spatially and temporally linked to respondent residential locations to CARDIA exam years: Year 0, 1980 Census; Years 7 and 10, 1990 Census; Year and 15 20, 2000 Census)

[b]Among census tract population ages 16 years or older

[c]Owner occupied housing units within census tract.

**Table 2**

Individual-level characteristics by year: the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985-2006.

| | Year 0 | Year 7 | Year 10 | Year 15 | Year 20 |
|---|---|---|---|---|---|
| N | 5114 | 4085 | 3949 | 3671 | 3549 |
| Mean age (SD) | 24.8 (0.05) | 32.0 (0.06) | 35.0 (0.06) | 40.2 (0.06) | 45.2 (0.06) |
| Female (%) | 54.5 | 55.1 | 55.6 | 55.9 | 56.7 |
| Race (%) | | | | | |
| Black | 51.6 | 48.3 | 48.8 | 47.1 | 46.5 |
| White | 48.4 | 51.7 | 51.2 | 52.9 | 53.5 |
| Education (%) | | | | | |
| < high school | 8.2 | 4.4 | 4.2 | 3.5 | 3.2 |
| High school | 66.4 | 56.5 | 53.8 | 50 | 48.3 |
| Some college | 20.5 | 27.1 | 28.2 | 29.1 | 29.7 |
| College degree | 4.9 | 12 | 13.9 | 17.5 | 18.9 |
| Married (%) | 22.3 | 44.1 | 48.6 | 53.5 | 55.3 |
| Working full time (%) | 43.6 | 29.6 | 26.7 | 25.8 | 30.3 |
| Mean household income (SD)[a] | 6.3 (0.07) | 5.3 (0.06) | 5.6 (0.06) | 7.2 (0.08) | 8.0 (0.09) |

[a]Income per $10,000, inflated to year 20 and income was not queried at exam year 0 so response at year 5 is used as a proxy.

**Table 3**

Neighborhood-level characteristics [median (interquartile range)] across exam year: the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985-2006.

| | Year 0 | Year 7 | Year 10 | Year 15 | Year 20 |
|---|---|---|---|---|---|
| **Socioeconomics within Census tract[a]:** | | | | | |
| Number of neighborhoods[b] | 799 | 1638 | 2441 | 2606 | 2800 |
| Percent population race white | 60.4 (24.4,86.9) | 59.4 (18.3,86.9) | 74.5 (33.3,91.3) | 60.5 (21.5,84.1) | 64.9 (26.7,86.3) |
| Percent population education < high school | 30.4 (18.4,43.4) | 20.0 (10.1,34.9) | 18.2 (9.6,31.2) | 15.3 (7.4,26.0) | 14.2 (7.2,25.1) |
| Percent population <150% FPL | 28.9 (15.4,41.0) | 23.4 (10.7,37.6) | 17.4 (8.5,32.8) | 17.1 (8.6,33.7) | 15.3 (7.8,30.6) |
| Median income per $1,000 | 14.1 (10.7,18.2) | 27.8 (20.6,37.9) | 31.0 (22.5,41.8) | 43.4 (32.0,59.4) | 45.9 (33.7,61.9) |
| Percent population professional/management occupation[c] | 22.3 (12.9,32.4) | 26.1 (17.4,38.9) | 27.2 (18.3,38.6) | 33.8 (23.6,49.0) | 34.6 (24.4,49.1) |
| Percent population unemployed[c] | 6.8 (4.2,11.0) | 5.6 (3.6,9.9) | 4.7 (3.0,8.1) | 3.2 (2.0,5.4) | 3.0 (1.9,5.2) |
| Median rent | 238 (213,270) | 480 (401,595) | 495 (401,620) | 655 (547,819) | 660 (547,827) |
| Percent population owner-occupied HU | 44.5 (25.7,64.8) | 50.6 (33.7,70.2) | 61.7 (38.9,79.0) | 65.1 (42.5,81.4) | 68.1 (47.2,84.1) |
| Percent population vacant HU | 5.7 (3.5,5.7) | 6.9 (4.2,6.9) | 5.9 (3.7,5.9) | 4.1 (2.5,4.1) | 4.1 (2.5,4.1) |
| Aggregate value HU[d] per $1,000,000 | 21 (10,39) | 47 (20,104) | 69 (30,134) | 120 (51,249) | 134 (59,264) |
| **Counts of food resources within 3 km Euclidean buffer per 10km of local and secondary roadways[e]:** | | | | | |
| Fast food restaurants | 0.2 (0.1,0.2) | 0.2 (0.1,0.3) | 0.2 (0.1,0.3) | 0.2 (0.1,0.3) | 0.4 (0.2,0.6) |
| Non-fast food restaurants | 2.8 (1.4,5.1) | 3.4 (1.5,6.5) | 2.4 (1.2,4.7) | 2.7 (1.4,4.6) | 2.9 (1.5,5.3) |
| Supermarkets | 0.0 (0.0,0.1) | 0.1 (0.1,0.2) | 0.1 (0.0,0.1) | 0.1 (0.0,0.1) | 0.1 (0.1,0.2) |
| Convenience stores | 0.7 (0.5,0.9) | 1.1 (0.7,1.6) | 0.8 (0.5,1.1) | 0.8 (0.5,1.0) | 0.9 (0.6,1.2) |

FPL: federal poverty level, HU: housing units.

[a]U.S. Census-tract level data spatially linked to respondent residential locations and temporally linked to CARDIA exam years (Year 0, 1980; Years 7 and 10, 1990; Year 15 and 20, 2000).

[b]Total number of census tracts.

[c]Among census tract population ages 16 years or older.

[d]Owner occupied Housing Units within census tract.

[e]Counts of Dunn & Bradstreet food resources within Euclidean 3km buffer per 10 km local and secondary roadways.