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Long-Term Neighborhood Poverty Trajectories and Obesity in a Sample of California Mothers

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Abstract

Neighborhoods (and people) are not static, and are instead shaped by dynamic long-term processes of change (and mobility). Using the Geographic Research on Wellbeing survey, a population-based sample of 2,339 Californian mothers, we characterize then investigate how long-term latent neighborhood poverty trajectories predict the likelihood of obesity, taking into account short-term individual residential mobility. We find that, net of individual and neighborhood-level controls, living in or moving to tracts that experienced long-term low poverty was associated with lower odds of being obese relative to living in tracts characterized by long-term high poverty.

Keywords

Obesity; Neighborhoods; Mothers; California; Poverty

Obesity has reached epidemic levels in the United States. Recent estimates indicate that more than one in three American adults have a Body Mass Index (kg/m^2 : hereafter BMI) of 30 or greater, the clinical threshold for obesity (Ogden et al. 2014). Being obese has serious implications for health such as elevated risks for diabetes, hypertension, and ultimately premature death (Masters et al. 2013; Mokdad et al. 2003; Surgeon General 2001; Thompson et al. 1999). The obesity epidemic also has serious economic implications, as a recent meta-analysis estimated that direct health care costs associated with obesity totaled more than \$149.4 billion dollars in 2014 alone (Kim and Basu 2016).

Women are more likely to be obese than men (Ogden et al. 2014), potentially due to biological differences in fat storage (Karastergiou et al. 2012). In addition to higher prevalence rates, the consequences and implications of being obese are generally more

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severe for women. For example, women have increased perception of weight-based discrimination (Puhl, Andreyeva, and Brownell 2008) and face a disproportionate burden of obesity-related disease than men (Hu 2003; Muennig et al. 2006). Obesity is not equally distributed among women as women of color and women with low socioeconomic status have significantly higher levels of obesity than non-Hispanic white women and women with higher socioeconomic status (Wang and Beydoun 2007). Additionally, women's obesity and its behavioral proximate determinants, dietary habits and physical activity, are strongly correlated with their offspring's risk of obesity, making it especially important to understand the factors related to obesity among mothers (Catalano and Ehrenberg 2006; Drake and Reynolds 2010). Due to substantial and unequal obesity rates among women and the implications of being obese for women and their children, it is critical to improve our understanding of the determinants of obesity among women in general and mothers in particular in order to stem the epidemic.

As obesity rates have continued to climb, researchers have turned to more distal or "upstream" determinants of obesity such as neighborhood environments (Black and Macinko 2008). Indeed, while much of the previous research and policy initiatives have focused on individual-level risk factors for obesity such as diet and physical activity, these factors have proven difficult to change, partially because neighborhoods can not only restrict behavioral health decisions but also dampen the potential impact of behavioral responses to individual health conditions (Gordon-Larsen et al. 2006; Morland, Roux, and Wing 2006). For example, neighborhoods can be obesogenic when they are comprised of unhealthy, calorie-dense, food options (Mirowsky and Ross 2015), when they limit the access to healthy food (Black et al. 2010), when they limit the ability to be physically active or because of more distal factors (for an overview see Black and Macinko 2008). Women in particular have been shown to be especially vulnerable to neighborhood factors in relation to obesity risk (Alvarado 2016; Lippert 2016; Robert and Reither 2004).

While the existing neighborhood effects research on obesity has produced compelling results and delineated plausible pathways between neighborhood environments and obesity (Berke et al. 2007; Black et al. 2010; Larson, Story, and Nelson 2009), several key gaps in the existing literature prevent our understanding of the impact of neighborhoods on obesity. First, prior work has almost exclusively measured neighborhood disadvantage and other characteristics using single point-in-time (i.e., cross-sectional) measures. This work has shown that those who live in disadvantaged neighborhoods have higher odds of being obese after accounting for important individual-level confounding factors (for an overview see: Black and Macinko 2008). Neighborhoods, however, are by no means static and as such, cross-sectional measures of neighborhood characteristics may not accurately reflect dynamic obesogenic neighborhood circumstances which have been unfolding over the course of decades. For example, using only cross-sectional measures of neighborhood characteristics makes it difficult, if not impossible, to capture meaningful and dynamic urban processes (Kirk and Laub 2010) such as "white flight," gentrification, or a concentration of poverty—and their influence on obesity. Indeed, research examining other health outcomes such as self-reported health (Do 2009), atherosclerosis (Murray et al. 2010), and preterm birth (Margerison-Zilko et al. 2015) has found strong evidence that long-term neighborhood poverty is associated with negative health outcomes. As such, we propose that long-term

socioeconomic factors shape a neighborhood's obesogenic characteristics, and thus the propensity of mothers to be obese, and should be measured accordingly.

A second important limitation in some previous research on neighborhoods and obesity is that it is unable to account for residential mobility of individuals (i.e., moving to a new home). Specifically, it is difficult for cross-sectional research designs to account for residential mobility, and as such cross-sectional analyses may implicitly assume equal neighborhood effects for differential lengths of exposure to neighborhoods (Smoyer-Tomic et al. 2008). Researchers are aware of exposure, or duration lived in a neighborhood, and residential mobility, or moving between neighborhoods, and their potential influence on obesity and other health outcomes (Kravitz-Wirtz 2016; Lippert 2016; Powell-Wiley et al. 2015; Richardson et al. 2014), however to the best of our knowledge, no previous research has examined the influence both of long-term neighborhood poverty *and* residential mobility on obesity. Critically, even when research has accounted for inter-neighborhood moves, it is impossible using cross-sectional specifications of neighborhood characteristics to distinguish between individuals who are exposed to poor neighborhoods (that have been persistently poor) because they remain in these neighborhoods or because they moved to a neighborhood which just became poor. Thus, we build on previous research by analyzing the influence of long-term neighborhood poverty trajectory classes on obesity while accounting for short-term (5–10 years) inter-neighborhood residential mobility among a sample of Californian mothers.

Long-Term Neighborhood Poverty and Obesity

Many of the proposed direct mechanisms through which impoverished neighborhood environments may be obesogenic do not develop overnight or instantaneously before a decennial census. Instead, these mechanisms take years, if not decades, to emerge and are more likely to be concentrated in neighborhoods that are *consistently* impoverished. For example, food availability and retail offerings respond to perceived or real demand, often in congress with the shifting socioeconomic-demographic profile of a neighborhood (Filomena, Scanlin, and Morland 2013; Maguire, Burgoine, and Monsivais 2015). Compared with more affluent neighborhoods, poorer neighborhoods that have seen decades of “disinvestment” have more fast food restaurants which serve energy-dense food (Zenk et al. 2005), food that is engineered to be cheap, easily shipped, marketed, and cooked quickly with little attention given to the nutritious quality or implications for the weight of the consumers (Mirowsky and Ross 2015). Impoverished neighborhoods also have fewer options for fresh nutrient-rich food from grocery stores than more advantaged neighborhoods (Sharkey et al. 2009; Smoyer-Tomic et al. 2008), and when healthy food is available, it is generally more expensive in disadvantaged neighborhoods (Zenk et al. 2005).

Notably, over time, neighborhoods that are *consistently* impoverished evolve to have few food options except for calorie-dense fast food or corner shops (Taylor et al. 2006). Indeed, in a 20-year study of CARDIA participants, researchers found that those who consistently lived in socioeconomically disadvantaged neighborhoods had fewer restaurant options but more convenience store options over time compared to those who lived in more advantaged neighborhoods (Richardson et al. 2014). Other researchers found that after Hurricane

Katrina grocery stores reemerged less quickly in disadvantaged neighborhoods of New Orleans (Mundorf, Willits-Smith, and Rose 2015) and that grocery stores experienced greater long-term instability in poorer neighborhoods of Brooklyn (Filomena et al. 2013). In other words, previous research has found that obesogenic food environments emerge *dynamically* especially in neighborhoods which are consistently impoverished, findings which stress the importance of using longitudinal neighborhood socioeconomic characteristics when investigating neighborhood determinants of obesity.

The ability to burn calories through exercise within a neighborhood is also somewhat contingent upon dynamic *long-term* socioeconomic processes. Just as food options respond to shifting demand based on the sociodemographic profile of neighborhoods so too do facilities where physical activity can take place, such as outdoor spaces, gyms, parks, or dance studios (Cohen 2008). Previous research finds less access to such places and lower levels of physical activity in impoverished neighborhoods (Gordon-Larsen et al. 2006; Powell et al. 2006; Yen and Kaplan 1998). Consistently impoverished neighborhoods also lack the four major components of walkability: functionality, safety, aesthetics and destinations (Neckerman et al. 2009). For example, Pikora et al.'s (2003) research in New York City showed that poorer neighborhoods had fewer landmarked buildings, restaurants, and trees, but more crime, pollution, and vehicle crashes than more advantaged neighborhoods. The factors which encourage or discourage walking take time to develop (e.g. trees take time to grow). Other research has shown that impoverished neighborhoods are more likely to lack developed walking infrastructure such as sidewalks (Gibbs et al. 2012); and when impoverished neighborhoods have sidewalks, they are lower quality and more likely to be damaged (Kelly et al. 2007). This prolonged under-investment in the built environment may deter walking and outdoor exercise in impoverished neighborhoods (Papas et al. 2007; Taylor et al. 2006), and because these factors take time to emerge or be degraded, presumably more so in *consistently* impoverished neighborhoods.

There are also more distal reasons to anticipate greater prevalence of obesogenic factors in neighborhoods that have been consistently impoverished. Neighborhoods which have seen chronic poverty for decades can also have higher levels of crime (Stretesky, Schuck, and Hogan 2004). Previous research has suggested crime is concentrated most heavily in areas of cities which have been consistently impoverished (Freeman, Grogger, and Sonstelie 1996; Massey 1995). Crime may not only deter exercise and time spent outside (For inconsistent findings please see Foster and Giles-Corti 2008) but may also elevate stress leading to unhealthy coping mechanisms such as drinking alcohol and overeating (Boardman et al. 2001; Dallman, Pecoraro, and la Fleur 2005; Vicennati et al. 2009). While tautological, poorer neighborhoods also have higher concentrations of obesity, potentially due to more permissive social norms around being overweight (Boardman et al. 2005). All these factors also take time to emerge and are presumably more prevalent in neighborhoods that have been consistently impoverished.

In sum, neighborhoods and their attendant obesogenic factors are shaped by dynamic processes but typically measured cross-sectionally. While the importance of dynamically changing neighborhoods seems conceptually well understood and noted by previous scholars (Roux 2004; Subramanian 2004; Tienda and Stier 1991), less research has actually analyzed

the association between long-term neighborhood characteristics and obesity. Instead, research has used cross-sectional measures. Cross-sectional measures can also be more prone to measurement error than employing multiple time points (Bound, Brown, and Mathiowetz 2001) and can potentially obfuscate complex and meaningful poverty histories of neighborhoods that may influence the risk of obesity. We address this gap by analyzing the association between long-term neighborhood latent poverty trajectories and obesity in a representative sample of Californian mothers, while accounting for inter-neighborhood residential mobility.

Residential Mobility

Cross-sectional research that aims to identify how neighborhoods may influence obesity is also typically unable to account for neighborhood mobility (Jackson and Mare 2007). Neighborhood mobility is problematic for analyzing neighborhood influences on obesity for multiple reasons. First, residential mobility limits the exposure to specific neighborhoods, and the attendant risk factors for becoming obese (Burgoine et al. 2016). That is, because weight gain is generally gradual (Mirowsky and Ross 2015), the obesogenic effects of neighborhood environments are likely greater for someone who has lived in a particular neighborhood their whole life than for someone who has just moved to that neighborhood. Second, people may select to live in, or move to, specific neighborhoods based on their lifestyles, perceived needs, or out of necessity, which may subsequently influence the propensity to gain weight or become obese. Previous research has found strong evidence that neighborhood effects on obesity can be overestimated when not accounting for selection and residential mobility (Smith et al. 2011). Thus, researchers have put forth considerable effort in accounting for residential mobility and neighborhood exposure (Kravitz-Wirtz 2016; Lippert 2016; Richardson et al. 2014). For example, Lippert (2016) and Kravitz-Wirtz (2016) employed classification schemes which measured the exposure to specific types of neighborhoods while also allowing mobility between types of neighborhoods.

We suspect that just as the length of a neighborhood's exposure to poverty may influence its obesogenic properties, the length of an individual's exposure to an impoverished neighborhood may influence his/her probability of being obese. This is particularly relevant in the most disadvantaged neighborhoods, because those who live in them, particularly blacks, are less likely to leave such neighborhoods in general and their current neighborhood in particular (Quillian 2003). Of course, residential inequality and segregation is often replicated by residential mobility (Sampson and Sharkey 2008; Sharkey 2012). The lack of mobility among those who live in the poorest neighborhoods (and replication through mobility) implies that the negative and cumulative exposures of living in long-term concentrated poverty are amplified by exposure to these neighborhoods (Lippert 2016). To address this issue, we characterize women's neighborhood using geocoded addresses at two time points, allowing us to gauge whether mothers have been consistently exposed to long-term neighborhood poverty and also to document upward or downward mobility.

Objectives

Our overall objective is to analyze whether long-term latent neighborhood poverty trajectory classes and short-term inter-class residential mobility predicts obesity among a sample of mothers. We accomplish these objectives by employing the following protocol. First, we estimate a latent class growth model to determine long-term poverty trajectories of neighborhoods in California, using U.S. Census and American Community Survey data from 1970 until 2009 for all Californian census tracts. Next, we descriptively characterize the obesogenic conditions for mothers in each of the long-term classes. We then create a variable that measured both long-term neighborhood poverty classes and inter-class mobility. Finally, we analyze how long-term neighborhood poverty-class and inter-class mobility combine to predict obesity in a traditional multivariate framework. These multivariate models progressively control for important individual and neighborhood level confounders.

Data & Methods

Data

The individual level (mother) data for this investigation came from the Geographic Research on Wellbeing (GROW) study. Conducted from 2012–2013, the GROW study was a follow-up survey of women (N=3,016) who participated in the California Maternal and Infant Health Assessment (hereafter MIHA) from 2003–2007. MIHA is an annual, statewide-representative survey of roughly 3,500 Californian women who have recently given birth with annual response rates exceeding 70% (Cubbin et al. 2002). GROW is a population-based follow-up study of MIHA participants, conducted 5–10 years after women gave birth. GROW included women who lived in six largely urbanized California counties (Alameda, Los Angeles, Orange, Sacramento, San Diego, and Santa Clara) who agreed to be re-contacted for a potential future survey. With weighting GROW is therefore representative of those counties. Respondents from these counties represented 55% of the respondents in MIHA. For more detailed information regarding the GROW study please see: Cubbin (2015). Our sample of mothers aged 21–57, included all the respondents from GROW who still lived in the six urban Californian counties at the time of GROW, were not currently pregnant, provided valid responses for height and weight, and whose address geocoded accurately to a census tract (N=2,339). We found that those excluded had slightly higher than average reported BMI than those in the sample, but this was largely attributable to our exclusion of pregnant mothers. Reassuringly, the proportion of our analytical sample that was obese (24%) was consistent with other recent state-level estimates of female adult obesity in California (also estimated at 24%) (Wolstein, Babey, and Diamant 2015).

The key neighborhood level data come from a latent class growth model conducted on census tracts. Census tracts are a commonly-used method of classifying neighborhoods (Morland and Evenson 2009; Morland et al. 2006; Rundle et al. 2007) as they are designed to represent neighborhoods, made to be homogenous in terms of the sociodemographic profile and living conditions of an area, and are based on physical features (Iceland and Steinmetz 2003). While they are not without problems, previous research has shown they are reasonably reliable in measuring the impact of neighborhoods (Kravitz-Wirtz 2016;

Sampson 2013; Sharkey and Faber 2014). Using the neighborhood change database (Geolytics, Inc., East Brunswick, NJ), which provides census tract-level data from 1970–2000 (harmonized to 2000 census boundaries), we then compiled census tract poverty rates for each tract in California from five time points (the 1970, 1980, 1990, and 2000 censuses, and the 2005–2009 American Community Survey). Due to the nature of sampling of the ACS compared to the Census, the ACS has more uncertainty and less accuracy; however, we used the 5-year ACS which has the smallest margin of error. Of note, the 2010 U.S. decennial census does not include a measure of poverty and is based on different geographic boundaries, thus we used the 5-year ACS.

Measures

Body Mass Index and Obesity—Our dependent variable, obesity, was based on the self-reported height and weight of the mother, which we converted to BMI. Consistent with clinical definitions (Ogden et al. 2014) we coded the obesity variable “1” if the respondent’s BMI was 30 or above, and “0” if the respondent’s BMI was below 30. To gauge the sensitivity of results based on the dichotomous measure, we also left BMI as continuous and fit Ordinary Least Squares models; the substantive results were similar and presented in Appendix Table 4. While BMI has its own limitations as a measure; for example, it does not account for muscle mass or fat distribution, at the population level having a BMI over 30 is associated with serious health problems and increased risk of death (Masters et al. 2013).

Long-Term Neighborhood Poverty Class and Inter-Class Mobility—Our key independent variable was derived from a latent class growth model based on the percentage of residents below the poverty level in each tract from 1970 until 2009. To construct our classes, we followed the protocol of previous research (Margerison-Zilko et al. 2015) using a latent class growth model (LCGM) of the percentage of residents in each tract below the federal poverty line from five time points (the 1970, 1980, 1990, and 2000 censuses, and the 2005–2009 American Community Survey). LCGM is a nonparametric technique to identify distinct subgroups of neighborhoods that exhibit similar latent trajectories (Andruff et al. 2009). We found that a three-class model was optimal based on Bayesian Information Criteria, entropy, and log likelihood-based tests. These results are consistent with a prior study that used California census tracts to measure poverty trajectories (Margerison-Zilko et al. 2015). The four-class model also fit the data well, but produced one class with a very small number of tracts (2.0%) that would have led to small cells, complicating further analysis. We classify these tracts as (1) long-term high poverty, (2) long-term moderate poverty, and (3) long-term low poverty.

We next examined the validity of this classification, by predicting latent class membership using other measures that are traditionally used to gauge neighborhood disadvantage. We used the tract measures from the 2005–2009 ACS of percentage of renters, percentage of those with less than a high school education, percentage black, percentage multi-unit housing and percentage receiving public assistance. The results operated in anticipated directions suggesting that the 3-class model is a valid typology of neighborhood disadvantage and poverty trajectories. We present the full results of the latent class analysis (Appendix Table 1) and our validation analysis (Appendix Table 2) in the online supplement.

To further characterize the obesogenic characteristics of these classes we descriptively display tract level information of the mothers from the 2005–2009 ACS stratified by long-term poverty class. Specifically, we show: percentage below poverty line, percentage white, percentage black, percentage Latino, median household income, and population density. We also show geo-referenced characteristics of the mother's home address at GROW including measures of density, distance, and size: number of convenience stores within 0.5 miles, number of grocery stores within 0.5 miles, street network distance to the nearest grocery store (KM), street network distance to the nearest fast food restaurant (KM), number of intersections within 0.5 miles, Euclidian distance to the nearest park (KM), and the size of the nearest park (acres). To compile this data, we used 74,145 business records from infogroup (www.infogroup.com) collected in 2011 and supplemented their records with park data from the California Protected Areas Database and county parks departments, and street data from Census TIGER files. More information regarding the coding and data compilation can be found in Cubbin (2015). Additionally, we compared our long-term measure with the census classification of poverty areas ($\leq 20\%$ and $>20\%$), a classification that has been used by previous researchers (Jargowsky and Bane 1991; Lippert 2016; South and Crowder 1997; Timberlake 2007). We also compared the long-term measure to a three-class measure (0%–4.99%, 5%–19.99% and $\leq 20\%$) employed by previous researchers (Margerison-Zilko et al. 2015) and found similar substantive results.

Based on the neighborhood classification model we coded our key independent variable, “long-term neighborhood poverty class and inter-class mobility” as the following categorical variable that is consistent with the coding of previous research (Lippert 2016; Richardson et al 2014). If the respondent indicated living in a long-term high poverty tract at both survey periods (MIHA and GROW) they were coded high-high poverty; (1) (reference category); if the respondent lived in a long-term moderate tract at both time periods they were coded as moderate-moderate poverty (2); if the respondent lived in a long-term low poverty tract at both time periods they were coded as low-low poverty; (3); if the respondent moved to a tract that experienced long-term lower poverty they were coded as upwardly mobile; (4); finally, if the respondent moved to a tract that experienced long-term higher poverty they were coded as downwardly mobile (5). An important limitation of the data and our classification scheme is that we only have the mother's address at the time of the two surveys, and thus cannot account for any moves that occur in-between surveys. However, prior work using this sample has demonstrated that there is relatively little residential mobility among mothers immediately after they give birth, and, importantly, women who do move tend to do so between neighborhoods of similar socioeconomic status (and thus likely poverty-class) (Margerison-Zilko et al. 2016).

Individually Reported Controls—In our multivariate analyses, we controlled for important individual-level demographic, psychosocial, socioeconomic factors and reports of neighborhood conditions. We began by accounting for basic demographic factors. First, we controlled for the respondents' age in years at the time of the GROW survey, the number of births, race/ethnicity of the mother, MIHA year, and current county. The number of births, race/ethnicity and first geographic location were reported in MIHA, the rest of the information comes from GROW.

We next included an additional set of individual level controls. To account for important psychosocial factors, we included measures of stress (Dallman et al. 2005), adverse childhood experiences (Friedman et al. 2015), perception of racial discrimination (Cozier et al. 2014), and self-efficacy (Kontinen et al. 2009). All of these variables have been shown to be important for obesity. We also included four important (Wang and Beydoun 2007) measures of socioeconomic status: educational attainment, household income, marital status and home ownership. In addition to the individual-level variables, we also controlled for subjectively reported measures of the respondent's neighborhood. As neighborhood walkability, has previously been associated with obesity (Frank et al. 2006; Rundle et al. 2007), we included two self-reported measures of walkability. We finally included a categorical variable which measured the respondents' satisfaction with the neighborhood. More detailed information regarding the wording of the question and our coding of these variables can be found in the Appendix.

We also included objectively-measured neighborhood characteristics derived from the geocoded address of the mother at GROW. We added the intersection density of the address within a half mile (higher density indicates more connected streets and thus higher walkability) (Lopez 2007), distance to the nearest park in kilometers (KM), and food availability: distance to the nearest fast food restaurant (KM), and nearest grocery store (KM).

Methods

We first descriptively document the obesogenic factors for mothers in each of the latent classes, comparing our results with a commonly used cross-sectional specification of poverty. Next, we analyze the association between long-term neighborhood poverty class and inter-class mobility and obesity among mothers by employing the following protocol. We fit a series of progressively-adjusted multivariate logistic models predicting individual-level obesity enabling us to examine the impacts of variables that may be either mediators or confounders. There was little overlap in tract residence which precluded multi-level modeling, so we used traditional logistic models. In the first model, we examined the extent to which long-term neighborhood poverty class and inter-class mobility predicted obesity, net of demographic factors. In the next model, we added individual-level psychosocial factors and socioeconomic status (SES) and self-reported neighborhood factors. In the final model, we included measures of objectively-measured neighborhood characteristics. We followed the same protocol in estimating Ordinary Least Squares models predicting continuous BMI values, the results of which are presented in Appendix Table 4. All models are weighted to be representative of the sampling frame using Stata's "svy" suite.

Results

Table 1 shows demographic and obesogenic characteristics of neighborhoods lived in by the mothers stratified by long-term poverty class and a widely used cross-sectional demarcation of neighborhood poverty (20% or more residents in poverty versus less than 20% of residents in poverty). We find that the long-term high poverty tracts had higher average levels of poverty (33.2%) than the long-term moderate (20.3%), or long-term low (7.2%)

poverty tracts but also higher levels of poverty than the cross-sectional specification for high-poverty (29.0%). The long-term high poverty tracts had comparably high concentrations of black (17.8%) and Latino (68.3%) residents and relatively low household incomes (\$31,321) at least compared to the long-term low poverty neighborhoods which had higher household incomes (\$93,259) and lower proportions of black (5.0%) and Latino (25.8%) residents. The long-term high poverty neighborhoods were also densely populated, having 20,889 residents per square mile, compared to 6,736 in the long-term low poverty neighborhoods.

The obesogenic characteristics of the long-term high poverty neighborhoods was also reflected in the availability of food with the mothers living in long-term high poverty tracts having 4.4 convenience stores within 0.5 miles of their house. Conversely, mothers who lived in long-term low poverty tracts averaged only 1.0 convenience stores within 0.5 miles of their house. The cross-sectional measure of high poverty also has fewer convenience stores (3.4) within 0.5 miles than the long-term measure. Although mothers in long-term high poverty tracts had more grocery stores nearby (8.7 vs. 1.2 in long-term low poverty tracts), the classification of the type of grocery store makes it difficult to differentiate how many of those are smaller, limited service stores rather than full-service, supermarket types of stores that have a larger selection of healthy affordable foods. The mothers who live in long-term low poverty neighborhoods live a similar distance (0.4 KM) to parks on average than mothers who live in long-term high poverty neighborhoods (0.4 KM) but the parks are much larger on average in the long-term low poverty neighborhoods (31.4 acres versus 11.7 acres). Overall, these results are consistent with the notion that long-term high poverty neighborhoods have more obesogenic characteristics than both long-term low poverty neighborhoods and neighborhoods defined as being high poverty using traditional cut-offs based on cross-sectional data.

Table 2 provides the weighted descriptive statistics for the GROW sample. Roughly 24% of the sample was obese, which is consistent with other Californian estimates of adult female obesity (Wolstein et al. 2015). The average BMI of our sample was 26.7. 8.3% of the mothers resided in a long-term high poverty tract at both time periods, 18.0% resided in the moderate poverty tracts at both times and 60.5% of the sample resided in the low poverty tracts at both times. There was also some inter-class mobility as 8.3% were upwardly mobile and 5.1% were downwardly mobile. The average age was about 36 years with an average of 2.1 births at MIHA.

Table 3 depicts odds ratios from weighted logistic predicting obesity based on long-term neighborhood poverty class and inter-class mobility. For the sake of parsimony, we show only logistic coefficients from the long-term neighborhood poverty class and inter-class mobility, but the full results from the logistic as well as OLS models predicting BMI, including controls and standard errors, are provided in the online supplement (Appendix Tables 3 and 4 respectively). The first model controls for only demographic factors. We found that the mothers who lived in a low-low poverty tract ($OR=0.58$, $p<0.05$), or who were upwardly mobile ($OR=0.50$, $p<0.01$) had significantly lower odds of being obese than those who lived in the high-high poverty tracts. Model 2 shows the results of a model that additionally includes individual self-reported controls. Net of added individual level

controls, those who lived in a low-low poverty tract at both times (OR=0.61, $p < 0.05$) or who were upwardly mobile (OR=0.46, $p < 0.01$) had significantly lower odds of being obese than those who lived in a high-high poverty tract.

Model 3 progressively added controls for objectively measured neighborhood characteristics that have previously been linked to obesity. After adding these neighborhood factors, the difference between low-low and high-high poverty tracts became marginally significant. Those who were upwardly mobile (OR=0.50, $p < .001$) still had significantly lower odds of becoming obese than those who lived in high-high poverty tracts. The increased odds of obesity of those who lived in high-high tracts has important social and health implications, as women with higher BMI face perceptions of discrimination and have increased risk of chronic diseases (Puhl, Andreyeva and Brownell 2008). As a sensitivity analysis to examine if long-term measures were still significant above and beyond a cross-sectional (ACS) specification of poverty, we controlled for the widely used cross-sectional specification of neighborhood poverty (20% or more compared to less than 20%). When we included this measure in our model our results remained statistically significant (see Appendix Tables 3 and 4, Model 4). It is worth noting that while we have numerous controls, we do not have the ability to fully account for selection, and thus we cannot argue that long-term neighborhood poverty trajectories are causally related to BMI or risk of obesity.

Discussion

Previous research has connected neighborhood factors to obesity. However, this research has often relied on cross-sectional measures and designs that cannot account for the dynamic changing nature of neighborhoods or residential mobility between different neighborhoods. U.S. neighborhoods, particularly urban neighborhoods, have changed dramatically over the past half century, through processes such as gentrification and the concentration of poverty (Kirk and Laub 2010). Americans also move frequently, averaging over 12 residential moves in their life (U.S. Census Bureau 2007). These moves complicate estimates of neighborhood effects on obesity and other health outcomes. We build on this research by characterizing the obesogenic characteristics of long-term poverty class tracts and then examining how long-term neighborhood poverty trajectories are associated with obesity among mothers while accounting for short-term mobility.

Our analysis has three major findings. First, long-term high poverty class tracts are obesogenic environments, as they had high concentrations of convenience stores, fast food restaurants, and small parks. We also find that these obesogenic characteristics are greater in long-term poverty tracts than in tracts as classified by widely used cross-sectional specifications of neighborhood poverty. Second, we find strong associations between living in these long-term classes and the likelihood of being obese as well as BMI values. Those who lived in long-term low poverty tracts during interviews at MIHA (interview years: 2003–2007) and at GROW (interview years: 2012–2013) had lower odds of being obese and lower BMI values than those who lived in long-term high poverty tracts at both interviews. These findings were significant even net of individual-level controls including the respondent's own socioeconomic status, objectively measured neighborhood characteristics, and concurrent neighborhood poverty. The direct and indirect mechanisms through which

neighborhood poverty can influence weight, such as availability of healthy food, and the built environment, can take decades to emerge, slowly changing in congress with the shifting sociodemographic profile of a neighborhood. Our results point to the critical importance of exposure to long-term neighborhood factors above and beyond individual level and other neighborhood factors for predicting obesity.

Third, our results corroborate previous research which has stressed the importance of neighborhood mobility as an important factor for influencing the effects of neighborhoods on obesity (Kravitz-Wirtz 2016; Lippert 2016; Smith et al. 2011). We find that those who were upwardly mobile were less likely to be obese and had lower BMI values than those who lived in a long-term high poverty tract at both times. In ancillary analyses, we also found that those who were upwardly mobile were significantly less likely to be obese (OR: .60, $p < .05$) than the mothers who lived in moderate-moderate tracts, even with the fully adjusted model. However, it remains unclear whether the lower odds of becoming obese for those who moved to a more advantaged neighborhood was due to factors related to neighborhood selection, less exposure to poorer neighborhoods, or both. Of course, the decision to live in a new neighborhood may be determined more by the perception of a neighborhood's trajectory rather than its current status, which could influence obesity. Indeed, given the structure of our data, analysis, and inability to fully measure nor manipulate selection we cannot claim that long-term neighborhood poverty has a causal relationship with the risk of obesity. Our results support the recommendation that future research that analyzes the influence of neighborhoods on obesity should strive to account for mobility and selection into specific neighborhoods.

Like any research, there are some other limitations that the reader should consider. First, these results are only generalizable to urban Californian mothers. Future research should analyze the relationship between long-term poverty trajectories and obesity in more diverse samples, including non-Californians, men, rural residents and non-mothers. Second, while an important issue, it is beyond the scope of our paper to fully address issues of selection into neighborhoods based on obesity. Research designs are needed that track individuals over time to examine who moves to which types of neighborhoods and whether people move prior to or after becoming obese. Third, while we have the addresses of the respondent at two time periods, we only use their self-reported height and weight at their current address at the second interview. Because of this we could not track obesity or BMI changes over time in relation to neighborhood of residence. We also are unable to examine residential mobility prior to pregnancy or in between the two-time points in this study, but as mentioned above this is a time (after giving birth) with comparably few residential moves (Margerison-Zilko et al. 2016). Height and weight are reported by the respondent rather than objectively measured. However, previous research focused on women found that reported height and weight are "reasonably reliable," but those who are obese may underestimate their weight (Lin et al. 2012).

Conclusion

Our research finds that mothers who live in neighborhoods that have been consistently poor have greater odds of obesity than mothers who live in or move to neighborhoods that have

undergone less long-term poverty. The long-term neighborhood determinants of obesity are important for the health of mothers, placing them at higher risk for conditions such as diabetes and heart disease (Hu 2003; Muennig et al. 2006). Additionally, given the correlation between mother and child obesity (Catalano and Ehrenberg 2006; Drake and Reynolds 2010, living in these neighborhoods also likely increases the odds of obesity among their children. The increased odds of obesity among children negatively impacts their lifelong health (Kelsey et al. 2014) and other outcomes such as academic achievement (Datar, Sturm, and Magnabosco 2004; Hollar et al. 2010) and thus long-term neighborhood poverty can reinforce social inequality.

Neighborhoods are not static and research that analyzes the influence of neighborhood factors on health outcomes should attempt to account for the changing nature of neighborhoods. This research should use multiple measures of neighborhood change and combine measures from the census with other objective measures such as neighborhood walkability, access to food, and other measures of the built environment. Additionally, future research should explore how selection into new neighborhoods may be based on the perceptions of a neighborhood's trajectory, and how these selection processes may influence health. By better understanding how changing neighborhood circumstances can influence obesity and other health outcomes, researchers will be better equipped to understand the influence of neighborhoods and policymakers will be better equipped to recommend interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- We estimate the influence of long-term neighborhood poverty on obesity
- We also take into account short-term residential mobility
- Mothers who live in long-term poor neighborhoods have higher odds of obesity
- Mothers who live in long-term low poverty neighborhoods have lower odds of obesity
- Future research should consider using long-term measures of neighborhood factors

Descriptive Statistics: Obesogenic Characteristics of Neighborhoods Lived in by Mothers, Stratified by Long-Term Poverty Class, 1970–2000 Decennial Censuses, 2005–2009 American Community Survey, and Geographic Research on Wellbeing Survey Respondents, 2012–2013.

Table 1

	Long-Term Poverty Class ^{ab}			Cross-Sectional Classification of Poverty ^b		
	High Poverty	Moderate Poverty	Low Poverty	20% or Above	Below 20%	
	Mean or Percentage	Mean or Percentage	Mean or Percentage	Mean or Percentage	Mean or Percentage	
American Community Survey: Tract Characteristics^{bc}						
Percent Below Poverty Line	33.2%	20.3%	7.2%	29.0%	8.3%	
Percent Whites	6.0%	14.9%	49.0%	10.6%	44.1%	
Percent Black	17.8%	12.1%	5.0%	15.0%	5.9%	
Percent Latino	68.3%	60.6%	25.8%	64.7%	30.7%	
Median Household Income (Dollars)	\$31,321	\$45,724	\$93,259	\$36,754	\$87,132	
Population Density (People/Square Mile)	20,889	14,245	6,736	17,226	7,839	
Geo-Referenced Mother Characteristics^c						
Food Environment						
Number of Grocery Stores Within 0.5 Miles	8.7	3.8	1.2	6.1	1.5	
Number of Convenience Stores Within 0.5 Miles	4.4	2.5	1.0	3.4	1.2	
Distance to Nearest Fast Food Restaurant (KM)	0.7	0.7	1.1	0.7	1.1	
Distance to Nearest Grocery Store (KM)	0.4	0.7	1.4	0.6	1.3	
Walkability and Outdoor Space						
<i>Walkability</i>						
Average Intersection Density Within 0.5 Miles	187.6	171.2	142.2	174.7	147.4	
<i>Parks</i>						
Distance to Nearest Park (KM)	0.4	0.5	0.4	0.5	0.4	
Nearest Park Size (Acres)	11.7	14.0	31.4	12.3	29.1	

^aData from 1970–2000 Decennial Censuses.

^bData from 2005–2009 American Community Survey, linked to mothers' tracts at GROW.

^cData from geo-referenced Information from address of mother at GROW, 2012–2013.

Table 2

Descriptive Statistics, Urban Californian Mothers, Aged 21–57 (n=2,339), Geographic Research on Wellbeing Study, 2012–2013.

	Mean or Proportion	SE	Min	Max
Body Mass Index				
Obese	23.6%			
Self-Reported BMI	26.7	0.1	14.9	62.2
Neighborhood Poverty/Mobility				
High-High Poverty (Ref)	8.3%			
Moderate-Moderate Poverty	18.0%			
Low-Low Poverty	60.5%			
Upwardly Mobile	8.3%			
Downwardly Mobile	5.1%			
Age	36.4	0.1	21	57
Number of Births At MIHA	2.1	0.0	1	12
Race/Ethnicity				
White	25.4%			
U.S.-Born Latina	17.7%			
Foreign-Born Latina	34.3%			
Asian/Pacific Islander	15.8%			
Black	6.8%			
Psychosocial Factors				
Number of Recent Stressful Events	0.77	0.0	0	9
Number of Adverse Experiences in Childhood	0.86	0.0	0	7
Control Scale (Higher values = less control)	12.61	0.1	7	26
How often experienced Racism				
Very Often	2.4%			
Somewhat Often	12.1%			
Not Very Often	32.5%			
Never	53.0%			
Educational Attainment				
Less than High School	19.5%			
High School Graduate	22.3%			
Some College	23.0%			
College Graduate or More	35.2%			
Household Income as Percent of Federal Poverty Level				
0–100%	30.9%			
101–200%	19.8%			
201–300%	11.4%			
301–400%	8.2%			
>400%	29.7%			
Marital Status				

	Mean or Proportion	SE	Min	Max
Married/Cohabiting	83.2%			
Separated/Divorced/Widowed	6.7%			
Never Married	10.1%			
Owns Home	45.0%			
Subjectively Measured Neighborhood Characteristics				
Walkability of Neighborhood				
Walks most places	4.2%			
Can walk to the store	42.6%			
Neighborhood Satisfaction				
Likes Neighborhood	54.4%			
Ok would like to live in a better place	36.0%			
Want to move	9.6%			
Objectively Measured Neighborhood Characteristics				
Average Intersection Density	155.5	1.4	2.5	527.1
Distance to Nearest Park (KM)	0.5	0.0	0.0	3.8
Distance to Nearest Fast Food Restaurant (KM)	0.9	0.0	0.0	14.1
Distance to Nearest Grocery Store (KM)	1.1	0.0	0.0	18.4
N = 2,339				

Notes: Data are weighted to be representative of Target Population.

Table 3

Odds Ratios from Logistic Models Predicting Being Obese, Urban Californian Mothers, aged 21–57 (n=2,339), Geographic Research on Wellbeing Study, 2012–2013.
Source: Geographic Research on Wellbeing (GROW), 2012–2013.

	Model 1 ^a	Model 2 ^b	Model 3 ^c
	Logistic	Logistic	Logistic
	(obese/not)	(obese/not)	(obese/not)
Odds Ratio	p	Odds Ratio	p
Odds Ratio		Odds Ratio	
Long-Term Poverty and Inter-Class Mobility			
High-High Poverty (Ref)			
Moderate-Moderate Poverty	0.78	0.76	0.78
Low-Low Poverty	0.58 *	0.61 *	0.68 †
Upwardly Mobile	0.50 ***	0.46 ***	0.50 *
Downwardly Mobile	0.95	0.81	0.86

† p < 0.1

* p < 0.05

** p < 0.01

*** p < 0.001

Notes: Data are weighted to be representative of Target Population. Missing data were handled by STATA's multiple imputation suite.

^a Includes Demographic controls: Age, Previous Births, Race/Ethnicity, County, and MIHA Interview Year.

^b Includes controls from ^a and Other Self-Reported Controls: # of Recent Stressors, # of Adverse Childhood Experiences, Control Scale, Perceived Racism, Educational Attainment, Household Income, Marital Status, Home Ownership, Walkability, and Neighborhood Satisfaction.

^c Includes controls from ^a and ^b and Other Neighborhood Controls: Average Intersection Density, Distance to nearest park (KM), Distance to Nearest Grocery Store (KM), and Distance to Nearest fast food restaurant (KM).