
Abstract
This study investigated the independent association between neighborhood racial/ethnic diversity and metabolic syndrome in the United States, and focused on how individual and neighborhood characteristics (i.e., race/ethnicity, sex, age, urbanicity, neighborhood poverty) moderated this association. Individual-level data from 2003-2008 National Health and Nutrition Examination Survey (NHANES) were linked to census-tract profiles from 2000 decennial census. Stratified multilevel random intercept logistic regression models were estimated to examine the contextual effects of tract-level racial/ethnic diversity on individual risks of metabolic syndrome. Results showed that increasing racial/ethnic diversity within a neighborhood was associated with decreasing risks of being diagnosed metabolic syndrome, particularly among blacks and younger adults. The findings point to the potential benefits of neighborhood racial/ethnic diversity on individual health risks. Study implications are discussed.

Keywords: Racial diversity; Residential segregation; Biomarkers; Metabolic syndrome; Neighborhoods
Background

Biological risk factors, also known as biomarkers, refer to measurable and quantifiable physiological parameters (e.g., blood pressure, cholesterol level, blood sugar) that serve as early indices for morbidity and mortality. Metabolic Syndrome (MetSyn) includes a specific cluster of biomarkers that can directly prompt individual risks for developing health problems such as cardiovascular diseases and diabetes. These biomarkers include a large waistline, a high tryglyceride level, a low HDL cholesterol level, high blood pressure, and high fasting blood sugar. Individuals with MetSyn are twice likely to develop heart disease and five times likely to have type 2 diabetes (National Heart, Lung, and Blood Institute 2011). Common factors for developing MetSyn are abdominal obesity, physical inactivity, atherogenic diet, and insulin resistance (Grundy et al. 2005). Much of these underlying risks are behavioral and lifestyle factors, suggesting that public health efforts can be made to prevent individuals from MetSyn.

Prevalence of MetSyn is high among the US adult population and has increased over the past decades. Nationwide analyses showed that age-adjusted prevalence was 29.2% during the years 1988-1994, but rose to 34.2% during 1999-2006 (Mozumdar and Liguori 2011). Further examination by demographic subgroups revealed that Mexican Americans had higher prevalence of MetSyn than non-Hispanic whites and non-Hispanic blacks, and younger women had seen the greatest increase (Mozumdar and Liguori 2011). Another national study suggested the observed racial/ethnic differences in MetSyn prevalence were not substantially attenuated by individual predictors (Karlamangla et al. 2010). There is much need to look beyond individual characteristics and to explore
whether contextual or environmental mechanisms may possibly shape these disparities at the population level (Kawachi and Berkman 2003).

Neighborhood Effects on MetSyn

Neighborhoods constitute an important dimension of the living environment. Recent scholarship has attended to characteristics within residential neighborhoods to examine whether they assert contextual influences on individual risks of MetSyn. Existing evidence has mostly focused on neighborhood socioeconomic status (SES) as a key contributory factor. One study of white and black adults ages 45 to 64 years in the Atherosclerosis Risk in Communities Study found that both individual and neighborhood SES were inversely associated with respondents having MetSyn (Chichlowska et al. 2008). The same pattern was also observed in other similar studies (Clark et al. 2013; Keita et al. 2014). There is, however, scarce evidence from nationally representative sample such as NHANES to explore the neighborhood-MetSyn link. It is also worth noting that two of the above studies only found the link between neighborhood SES and MetSyn to be existent among women; neither did they show any substantial racial differences in this link. Besides MetSyn, research on other biomarker outcomes such as allostatic load and cardiometabolic risks also revealed the significance of neighborhood SES (Bird et al. 2010; King, Morenoff, and House 2011; Laraia et al. 2012).

Several explanations have been proposed to explain the link between neighborhood adversity and individual biomarkers. One strand of research concerns with neighborhood physical characteristics, including food environment and recreational facilities. Residents living in adverse neighborhoods are less likely to have safe and
favorable open space where they can engage in physical activities (Franzini et al. 2010; Giles-Corti 2002); they are also more exposed to unhealthy food environment including the domination of fast food chains and longer distance to grocery stores (Larson, Story, and Nelson 2009). Lack of physical activity and consumption of atherogenic diet are both key risk factors elevating cardiovascular disease risks and MetSyn. The second strand of explanations centers on psychosocial pathways through which residential environment affects multiple regulatory physiological systems (Gee and Payne-Sturges 2004). Neighborhood disorder and repeated exposure to violence are such environmental stressors that affect residents living in disadvantaged neighborhoods (Hill, Ross, and Angel 2005; Ross and Mirowsky 2001; Schulz et al. 2013).

Race-based residential segregation is arguably a fundamental cause of racial disparities in health in the US (Williams and Collins 2001). Empirical research on neighborhood racial/ethnic contexts and biomarkers, however, are very limited. One study analyzing 1988-1994 NHANES data found that both the unequal distribution of minority groups and the degree of potential social contact between minority and majority group members were associated with allostatic load (Bellatorre et al. 2011). The authors pointed out that both whites and blacks paid a health penalty for racial residential segregation. Another study on hypertension using 2005 Behavior Risk Factor Surveillance Survey data also confirmed the deleterious effects of metropolitan-level segregation on hypertension, net of individual and spatial SES (Jones 2013). These studies suggest that neighborhood racial/ethnic contexts do play a role in shaping individual biomarkers.
The Role of Neighborhood Racial/ethnic Diversity

Racial/ethnic diversity is on the rise in both urban and rural America. Logan and Zhang (2010) analyzed census data from 1980 to 2000 showing that growth of Hispanic and Asian populations had been blurring the traditional black-white color line in US metropolis. “From the perspective of intergroup exposure, the good news is a powerful trend toward representation of all four main racial/ethnic groups in highly diverse neighborhoods.” (Logan & Zhang, 2010:1102) In rural areas, racial/ethnic diversity was particularly witnessed during the post-2000 period. Lichter (2012) has offered two explanations driving this pattern. One is white out-migration that has reduced the absolute numbers of women of reproductive age. Another contributory factor is growing Hispanics, which accounted for over half of all non-metropolitan population growth between the years 2000 and 2010.

Increasing racial/ethnic diversity in the US population calls for other angles to look at neighborhood racial/ethnic contexts beyond the traditional black-white racial line. This shift is emphasized by social demographers in their recent scholarship on theorizing and operationalizing additional measures of multi-group composition or segregation (Hao and Fong 2011; Iceland 2004; Reardon and Firebaugh 2002). Racial/ethnic heterogeneity, which takes into account the relative size and number of multiple groups to reflect diversity in racial/ethnic composition in the population, is one such measure that warrants investigation but has received much less scholarly attention in studying neighborhood effects.

In other research arenas concerning racial and ethnic relations at the societal level, the Chicago School scholars have proposed long ago that racial diversity or ethnic
heterogeneity reflects social disorganization (Shaw and Mckay 1942), and there is evidence suggesting that increasing ethnic heterogeneity might deteriorate social solidarity or social cohesion in community life (Putnam 2007). Not surprisingly, social or demographic differentiation based on physical attributes or cultural preferences can easily lead to this conclusion as individuals are supposed to have more trust on or befriend with others who share similar values or look more like themselves (McPherson, Smith-Lovin, and Cook 2001). Re-examination of social disorganization theory, however, has provided evidence against the assertion that increasing racial/ethnic diversity and inflow of immigrants have endangered communities in Western societies. These evidence on homicide and violence (Graif and Sampson 2009; MacDonald, Hipp, and Gill 2012; Stansfied 2014) and social cohesion (Letki 2008; Portes and Vickstrom 2011) suggest that Western communities have actually benefited from diversity in many aspects.

With regard to health, there are a number of reasons why racially and culturally diverse neighborhoods may protect individuals from health risks. Net of area deprivation and neighborhood adversity, racially diverse areas in urban cities may provide more diverse housing types and mixed land use, both being favorable factors for physical activity (Durand et al. 2011). Besides energy expenditure, local food environment also shapes residents’ energy intake, another determinant of individuals’ energy balance. Neighborhoods with larger share of immigrants tend to have healthier food environment (Osypuk et al. 2009). This may be attributable to immigrants’ low energy-dense diet in their original cultures, which results in the availability of healthier ethnic food surrounding ethnic neighborhoods. Residents in less segregated and immigrant-
concentrated neighborhoods both witnessed beneficial dietary intake (Osypuk et al. 2009; Yi et al. 2014).

In addition to physical presence of health-promoting resources, neighborhood subcultural orientation may also influence residents’ health behavior decisions (Macintyre, Ellaway, and Cummins 2002). For instance, percentage of residents walking to work and percentage being obese in a neighborhood were both associated with obesity risks (Wen and Kowaleski-Jones 2012; Wen and Maloney 2011). If racially diverse neighborhoods have more residents engaging in transportation-related or other types of physical activity, or obesity prevalence is lower in these neighborhoods, it is possible that such pro-health environment can influence residents’ behaviors and lifestyle choices. From the psychosocial perspective, increasing share of the minority populations within residential neighborhoods may prevent the minorities from discrimination and reduce their exposure to such stressors that are likely to heighten their physiological dysfunction (Bécares, Nazroo, and Stafford 2009).

Taken together, these mechanisms suggest that neighborhood racial diversity may prevent individuals from MetSyn-related risk factors including physical inactivity, atherogenic diet intake, and stress. In fact, one recent study did find that ethnic heterogeneity was associated with lower obesity risks, net of a range of individual and neighborhood controls (Wen and Kowaleski-Jones 2012). More empirical research is warranted to further explore the role of racial diversity on health risks as compared to other contextual predictors.

Effect Modification by Social Groups
Current research has provided some evidence concerning whether individual characteristics modify the neighborhood and health link (Diez Roux and Mair 2010). The most researched effect modification regards sex differences. Many previous studies showed that neighborhood effects were stronger and more robust among women across a wide range of health outcomes. A widely accepted explanation is that women tend to spend more time at home than men do, so they are more exposed to, hence are more influenced by, various aspects of neighborhood environment. Still, how neighborhood effects differ between men and women can be dependent on the specific contextual predictors and health outcomes one would look into. For example, research on obesity among middle-aged and older adults suggested that built environment was more salient for women while economic and social environment mattered more for men (Grafova et al. 2008). Specific to neighborhood racial diversity and biomarkers, it is not clear whether this association differs by sex. One prior study inquired into the possible modification of sex in the association between neighborhood SES and allostatic load, but did not find any significant difference between men and women (Bird et al. 2010). Other research examining racial segregation (Kershaw, Albrecht, and Carnethon 2013) and racial/ethnic concentration (Chang, Hillier, and Mehta 2009; Wen and Maloney 2011) and obesity provided evidence showing that women were indeed more affected than men were.

Age is another crucial individual characteristic worth exploring, because identifying the environment by age interaction can further our understanding about how residential neighborhood impacts individuals differentially over the life course. One prior study analyzing two national surveys in the US showed that the relationship between neighborhood and physical health, specifically chronic conditions and self-rated health,
was stronger among older age groups, whereas this association was nonexistent or very weak among younger adults (Robert and Li 2001). Different from the health outcomes examined in the above study, biomarkers are considered pre-disease conditions and usually reach to a risky level well ahead of actual physiological change; thus biological risks can be prevailing among younger adults when the actual morbidity process has not yet occurred. In the association between neighborhood racial diversity and MetSyn, it is possible that the contextual influences would be stronger among younger adults.

Aside from the variations by individual characteristics, different types of neighborhood may also witness differential associations between racial diversity and MetSyn. Neighborhood SES, in particular, is shown not only to directly impact individual health itself, but can also condition the effects of other contextual predictors on health. A study of blacks living in New York City found that black concentration was detrimental for physical health and life satisfaction when neighborhood income was low, but this association was reversed in high income black neighborhoods (Roy, Hughes, and Yoshikawa 2012). Another ecological study in Texas also showed that the association between Hispanic concentration and obesity prevalence varied by county-level educational attainment (Salinas et al. 2012). Although there has not been enough evidence to aid in hypothesizing how racial diversity and MetSyn will differ by neighborhood SES, Sampson (2009) offered some justification in his study of linguistic diversity and rates of neighborhood violence. He found that the protective effects of linguistic diversity on neighborhood violence were stronger in high disorder and high poverty neighborhoods, and implied that diversity and immigration might have re-energized historically disadvantaged neighborhoods.
Finally, given different patterns of racial and demographic composition in urban and rural areas, we expect that the association between racial diversity and MetSyn is likely to differ by levels of urbanization in the US. Because the hypothesized mechanisms linking racial diversity and MetSyn are largely concerned with health-promoting resources such as built and food environment, with greater variations in urban areas, we may observe stronger contextual effects of racial diversity in urban neighborhoods as compared to rural areas.

In sum, as the US has seen and is still expecting increasing minority populations and immigrants, there is clear need to investigate residential ethnoracial diversity and pre-disease biomarkers such as MetSyn to further our understanding of how changing demographic patterns at the societal level shape health risks, and how these social forces impact various subgroups differentially. We specifically ask the following two questions. Is neighborhood racial/ethnic diversity associated with MetSyn in the US? If so, does this association differ by individual-level (i.e., race, sex, age groups) or neighborhood-level (i.e., poverty, and urbanity) factors?

Methods

Data

Individual-level data in the current study were drawn from the 2003-2008 National Health and Nutrition Examination Survey (NHANES), a series of pooled cross-sectional surveys of about 5,000 American children and adults conducted each year by the National Center for Health Statistics of the Centers for Disease Control and Prevention. NHANES combines both interviews and physical examinations; thus it not
only provides self-reported demographic, socioeconomic, and health-related information, but also contains unique and much-needed objective data on medical and physiological measurements. For example, objectively measured biomarker data for MetSyn, which are rarely found in other nationwide surveys, are available in the NHANES data.

The NHANES survey design is based on stratified, multistage probability sampling of the civilian non-institutionalized US residents. More detailed sampling and data collection procedures are provided on the NHANES website: http://www.cdc.gov/nchs/data/series/sr_02/sr02_161.pdf Because NHANES is a nationally representative survey, results are generalizable to the whole US population. In the analytical sample, we excluded pregnant women and only included respondents ages 20 to 64 years.

The individual-level data were then linked to the 2000 decennial US census, where census-tract socioeconomic and demographic profiles were obtained. The size of residential boundaries has always been a debated issue in researching neighborhood and health, because variations in spatial scale may encompass different contextual processes underlying health risks. While contextual features of small aggregation such as census tract may be more salient on individual behaviors as they represent more immediate and relevant social and built environment, larger geographic units like county and Metropolitan Statistical Area (MSA) can better capture structural forces resulting from policy influences and levels of social hierarchy. Empirical evidence suggested that contextual influences such as income inequality and residential segregation were indeed more robust in larger contexts (Bellatorre et al. 2011; Kershaw et al. 2011; Walton 2009; Wilkinson and Pickett 2006). However, because we speculate that local physical and
social environment are the primary pathways linking racial diversity and MetSyn through behavioral and lifestyle factors (Chaix et al. 2010), the present study used census tract as the unit of analysis at the neighborhood level.

**Outcome Variable**

MetSyn. Following the criteria proposed by the American Heart Association and National Heart, Lung, and Blood Institute (Grundy et al. 2005), clinical diagnosis of MetSyn was determined if a respondent had at least three of the following five biological risk factors:

1. Elevated blood pressure (systolic blood pressure $\geq 130$ mm/Hg or diastolic blood pressure $\geq 85$ mm/Hg);
2. Central adiposity (waist circumference $\geq 102$ cm for men; $\geq 88$ cm for women);
3. Low serum HDL ($< 40$ mg/dL for men; $< 50$ mg/dL for women);
4. Elevated triglycerides ($\geq 150$ mg/dL);
5. Elevated fasting glucose ($\geq 100$ mg/dL).

Thus the outcome variable used in this study was a binary measure indicating whether a respondent had MetSyn (coded 1 for Yes and 0 for No).

**Key Neighborhood-level Variables**

**Racial Diversity.** The index of racial/ethnic heterogeneity was used to represent racial diversity. It was defined as $1 - \sum p_i^2$, where $p_i$ is the fraction of the population in a given group. This index takes into account both the relative size and number of groups in the populations, with a value of one reflecting maximum diversity, and a value
approaching zero reflecting the presence of only one racial/ethnic group within census tracts. The calculation of the index was based on proportions of non-Hispanic whites, non-Hispanic blacks, Asians/Pacific Islander, Hispanics, American Indians/Alaska Natives, and Others in a census tract.

_Poverty Concentration._ Neighborhood poverty concentration served as both a control variable and a moderating factor in the current study. We chose to focus on poverty instead of other indicators of neighborhood SES because spatial concentration of poverty oftentimes intertwined with residential segregation and individual poverty among racial/ethnic minorities (Massey and Denton 1993; Quillian 2012). Following the categorization of US Census Bureau, poverty concentration was dichotomously measured by having at least 20 percent of residents living below the poverty line (U.S. Census Bureau).

_Urbanity._ The US Department of Agriculture (USDA) 2000 primary rural-urban commuting areas (RUCA) codes were used to distinguish urban and rural neighborhoods in this study. The RUCA codes were based on measures of population density, urbanization and daily commuting, and classified census tracts into ten categories, with categories 1-3 being metropolitan tracts (areas with 50,000 or more people), categories 4-6 being micropolitan tracts (areas between 10,000 and 49,999 people), categories 7-9 being small towns (areas between 2,500 and 10,000 people), and category 10 being small rural (areas less than 2,500 people) (U.S. Department of Agriculture 2013). The use of RUCA codes allowed the creation of both the census and the White House Office of Management and Budget (OMB) definitions of urbanity at the census tract level. In the
present study, we followed the OBM definition and defined urban neighborhoods as all metropolitan tracts with RUCA codes between categories 1 and 3.

**Individual-level Control Variables**

**Socio-demographic Characteristics.** They included age, sex, race/ethnicity, marital status, nativity status, educational attainment, and household income. In addition to the continuous measure of age, we included an age-squared term in the models to account for possible curvilinear relationship between age and biomarkers. The binary variable for age groups used in age-stratified analyses distinguished younger adults (ages ≥20 but <45) from middle-aged adults (ages ≥45 but ≤64). Sex (male vs. female), marital status (married or living with partner vs. single, separated, divorced or widowed), nativity (US born vs. foreign born) were all coded as binary variables. Race and ethnicity included non-Hispanic whites, non-Hispanic blacks, US-born Hispanics, and foreign-born Hispanics. Respondents identified themselves as other racial/ethnic categories were excluded in the analysis. We specifically distinguished nativity status among Hispanics because prior studies suggested that US-born Hispanics had higher biological risks than foreign-born Hispanics (Crimmins et al. 2007). Educational attainment also included four categories: less than high school, high school graduate, some college, and college degree or higher. Besides educational attainment, a continuous variable of household poverty income ratio was included in the analysis as another indicator of individual socioeconomic status.

**Prescribed Medication Use.** Because patients whose biomarkers were diagnosed at risky levels were likely to use drug treatment to control their elevated risks, all models
adjusted for medication use available in the NHANES interview data. This included self-reported responses to the survey questions asking whether the respondent was taking prescribed medicine to control for high blood pressure or high cholesterol level (both coded 1 for Yes and 0 for No).

Statistical Analysis

We estimated multilevel random intercept logistic regression models to examine the contextual effects of neighborhood racial/ethnic diversity on individual risk of MetSyn, with individual predictors at Level 1 and tract-level predictors at Level 2. Because an important purpose of the present study was to detect whether the racial diversity-MetSyn association differed by race, sex, age, neighborhood poverty and urbanity, interaction models were estimated for these hypothesized moderators. Therefore, we began by estimating a full model without interactions, then subsequently added interactions for each of the above hypothesized moderators. All analyses were performed in SAS software and were remotely accessed through the National Center for Health Statistics Research Data Center.

Results

Descriptive Statistics

Table 1 presented weighted sample characteristics for the full and subsamples. Among the five MetSyn biomarkers, low serum HDL (56.1%) and waist obesity (49.0%) were most prevalent among US adults, and elevated fasting glucose (17.9%) and elevated triglycerides (13.4%) were less prevalent. Prevalence for elevated blood pressure was
about 24.5%. This pattern was similar across subsamples. Overall, about 20.5% respondents had MetSyn, but male, middle-aged adults and rural residents witnessed higher prevalence.

As the NHANES surveys were designed to be nationally representative, socio-demographic characteristics in the analytical sample were largely comparable to the US population. The present study limited respondents to ages 20-64, so the average age was about 41 years old. Our sample consisted slightly more male (50.4%) than female (49.6%). The majority were white respondents (73.4%), and blacks accounted for 12.7%. There were more foreign-born Hispanics (9.1%) than native-born Hispanics (4.9%). At the neighborhood level, most respondents lived in urban areas (75%). The diversity measure of ethnic heterogeneity stood at an average of 0.29 in the full sample, but varies across subsamples. In particular, younger adults (0.30) and urban residents (0.32) lived in neighborhoods with higher ethnic heterogeneity than middle-aged (0.27) and rural residents (0.20), respectively. About 15.4% of respondents lived in census tracts where at least 20% of their neighbors in the same tract were in poverty.

-Table 1 about here-

Multivariate Analyses

Table 2 presented estimates from multilevel random effects logistic regression models. Our full model (Model 1) showed that residents living in racially diverse neighborhoods had significantly lower MetSyn risks ($\beta=-0.35, p<0.05$). Looking at other individual predictors revealed some noteworthy results. Blacks ($\beta=-0.18, p<0.05$) were less likely to have MetSyn ($\beta=-0.18, p<0.05$). Regarding the two socioeconomic
indicators, receiving a college degree had a strong and inverse effect on MetSyn risks ($\beta=-0.37, p<0.001$), and higher income was also associated with lower MetSyn risks ($\beta=-0.05, p<0.05$). In Model 2, adding the binary measure of neighborhood poverty females rendered the effect of ethnic heterogeneity marginally significant (OR=0.68, $p<0.1$), and living in poverty neighborhoods were about 27% more likely to have MetSyn (OR=1.27, $p<0.01$). Results did not show any significant effect of either ethnic heterogeneity or neighborhood poverty for male respondents.

-Table 2 about here-

In Model 2, we tested the interaction effects of race/ethnicity. The results suggested that neighborhood racial diversity was associated with lower risks of MetSyn for blacks ($\beta=-0.35, p<0.05$). In other words, blacks had particularly benefited from racial diversity in this health outcome. We also tested interactions for whites and Hispanics, but the results were not statistically significant and were therefore not presented in the table.

In Model 3, we tested the interaction effects of age groups (younger adults VS middle-aged). The results suggested that neighborhood racial diversity was associated with higher risks of MetSyn for middle-aged adults compared to younger adults ($\beta=0.34, p<0.05$). Results from interactions models for other hypothesized moderators (i.e., sex, neighborhood poverty, urbanity) were not significant and were not presented in the table.

**Discussion**

Using objectively measured biomarker data from 2003-2008 NHANES survey, this nationwide study examined the contextual effects of neighborhood racial/ethnic diversity on MetSyn, a particular cluster of risk factors that prompt health problems like
cardiovascular diseases and diabetes. Our analyses particularly focused on differential associations by sex, age, urbanity, and poverty concentration. Results suggested that neighborhood racial diversity, indeed, seemed to exert contextual influences on individual health risks among US adults, net of a range of individual risk factors. In particular, increasing racial/ethnic diversity was associated with lower risks of having MetSyn, particularly for blacks and younger adults.

This study extends current literature in several important ways. First, it is among the first to systematically examine the independent effect of racial diversity in the neighborhood and health literature. Past research has unanimously used single-group segregation indices or co-ethnic concentration, and largely ignored the multi-group context in racial/ethnic composition. The present study used the measure of ethnic heterogeneity to operationalize multi-group composition, and provided a different angle looking at the racial and ethnic context within residential neighborhoods. In comparing different measures in the racial/ethnic context, studying racial diversity or homogeneity across census tracts allows the opportunity to assess the influence of immediate residential environment that is largely distinct from structural forces as a result of metropolitan-level segregation. In this sense, finding from this study is a well supplement to the past literature suggesting the detrimental effects of racial segregation on health outcomes in the US.

Second, this study utilized objectively measured biomarker data available in a nationally representative survey. Incorporating biomarker data is of great value to studying social determinants of health (Crimmins, Kim, and Vasunilashorn 2010), because they provide objective and quantified measures, thus serve as a reliable
alternative to supplement existing subjective measures such as self-rated health, which oftentimes suffer from group-specific bias and recall bias (Su, Wen, and Markides 2013). The surging scholarly interests in biomarkers are also due to the fact that they can well capture the biological “wear and tear” processes underlying social constructs of individual characteristics (Das 2012) or social environment (Bird et al. 2010). The present study found that racial diversity within residential neighborhoods indeed played a role in the individual biological “wear and tear” process, and this role was independent of neighborhood adversity and other individual risk factors. Assessing neighborhood racial/ethnic diversity and MetSyn, in this sense, provides a more comprehensive view in understanding neighborhood effects on individual physiological change.

Third, we systematically examined effect modification in the neighborhood-health link across several hypothesized modifiers. This was motivated by the lack in previous research in exploring interactions effects, especially a few understudied modifiers such as age and urbanity. Neighborhood effects are complex, and it is crucial to test whether the effects of one contextual predictor would change according to other independent variables (Sharkey and Faber 2013). A unique contribution of the current study is to test such interactions by both individual-level and neighborhood-level characteristics. Our results were partially consistent with the hypotheses in that the beneficial effect of racial diversity and MetSyn were stronger among blacks. But compared to younger adults, neighborhood racial diversity seemed to be positively associated with MetSyn for middle-aged adults. Results shown here should be one step further in disentangling the intricate relationship between neighborhood racial/ethnic composition and health.
Current racial discourse and ongoing debate on immigration in the US have stimulated a soaring scholarship to examine influences of neighborhood racial/ethnic composition on various aspects of social life and population well-being in general. Much discrepancy within this strand of research surrounds the fundamental question of whether increasing minority populations bring in positive or negative consequences to residential communities. In their study of spatial heterogeneity and neighborhood homicide rates, Graif and Sampson (2009) called for a need for reformulation of the traditional negative connotation of racial/ethnic heterogeneity following the social disorganization tradition. Their interpretation of the beneficial effects of immigrant concentration on neighborhood violence specifically distinguished two equally important aspects associated with the immigration, the component of segregation and the component of diversity. The component of diversity, “brought about by the influx of new cultures, skills, and worldviews into urban neighborhoods,” (Graif & Sampson, 2009:258) as they suggested, is a primary driving force benefiting and re-energizing urban neighborhoods.

Cities are back. In his further discussion on the diversity effect, Sampson (2009) has offered insights into the new urbanism where diversity is valued and appreciated rather than being disparaged. Within the new generation of urban neighborhoods, artistic tastes in favor of “neo-bohemia” and “grit as the new glamour” have replaced the traditional impression of decaying and disordered inner cities or ethnic enclaves. More and more people, particularly the younger generation, are drawn into these neighborhoods in seek of diversity and social differences. Moreover, Sampson posited that diversity in urban neighborhoods is attracting those “against race” and against the homogenization dominant in suburban sprawl. In summary, Sampson believed that
increasing diversity, driven largely by immigration, has revitalized many inner-city neighborhoods, both economically and socially (Sampson 2008).

This study is not without limitations. First, the cross-sectional design of this analysis has limited the possibility in handling endogeneity as a result of the nonrandom nature of individuals’ neighborhood choice, thus disallowing any causal inference of contextual influences on MetSyn risks. Such selection bias may vary systematically across social groups leading to differential effects of racial diversity among different groups. Second, although we have speculated several underlying mechanisms linking neighborhood racial diversity and MetSyn, such as local built environment and healthy food accessibility, this study only focused on effect modification and did not directly test potential mediators.

More than one hundred years ago, Du Bois stated that “the problem of the twentieth century is the problem of the color line.” (Du Bois 1903: V) Yet racial and ethnic matters have never receded from the center of public attention. As the US is moving towards a minority-majority society, it will undoubtedly expect continuing debates surrounding race and immigration. This study joins others (e.g., Graif and Sampson 2009; Portes and Vickstrom 2011) and provides fresh and important evidence confirming the salutary effect of racial diversity. Findings from this research can serve as an important basis for relevant policy makers, public health practitioners, and urban designer in their efforts to prevent chronic diseases while incorporating multi-dimensional societal factors and demographic changes.
References


Keita, Akilah Dulin et al. 2014. “Associations of Neighborhood Area Level Deprivation with the Metabolic Syndrome and Inflammation among Middle- and Older- Age Adults.” *BMC Public Health* 14(1):1319.


Table 1. Weighted Descriptive Statistics of Individual and Neighborhood Variables, Full and Subsamples (NHANES 2003-2008)

<table>
<thead>
<tr>
<th>Individual-level Variables</th>
<th>Full Sample</th>
<th>Women</th>
<th>Men</th>
<th>Age 20-44</th>
<th>Age 45-64</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic syndrome</td>
<td>20.48%</td>
<td>19.18%</td>
<td>21.79%</td>
<td>14.56%</td>
<td>28.49%</td>
<td>19.96%</td>
<td>22.04%</td>
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<tr>
<td>Elevated blood pressure</td>
<td>24.47%</td>
<td>20.30%</td>
<td>28.64%</td>
<td>15.17%</td>
<td>37.05%</td>
<td>23.54%</td>
<td>27.27%</td>
</tr>
<tr>
<td>Waist obese</td>
<td>49.02%</td>
<td>57.76%</td>
<td>40.29%</td>
<td>41.48%</td>
<td>59.21%</td>
<td>47.04</td>
<td>54.94%</td>
</tr>
<tr>
<td>Low serum HDL</td>
<td>56.10%</td>
<td>57.04%</td>
<td>55.16%</td>
<td>58.91%</td>
<td>52.28%</td>
<td>56.83%</td>
<td>53.90%</td>
</tr>
<tr>
<td>Elevated triglycerides</td>
<td>13.43%</td>
<td>10.34%</td>
<td>16.52%</td>
<td>11.38%</td>
<td>16.21%</td>
<td>13.51%</td>
<td>13.21%</td>
</tr>
<tr>
<td>Elevated fasting glucose</td>
<td>17.92%</td>
<td>14.35%</td>
<td>21.50%</td>
<td>12.60%</td>
<td>25.12%</td>
<td>19.47%</td>
<td>19.47%</td>
</tr>
<tr>
<td>Age</td>
<td>41.17 (0.25)</td>
<td>41.61 (0.26)</td>
<td>40.74 (0.30)</td>
<td>32.33 (0.18)</td>
<td>53.14 (0.13)</td>
<td>40.63 (0.25)</td>
<td>42.81 (0.49)</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>White</td>
<td>73.37%</td>
<td>73.31%</td>
<td>73.43%</td>
<td>69.15%</td>
<td>79.09%</td>
<td>68.42%</td>
<td>88.21%</td>
</tr>
<tr>
<td>Black</td>
<td>12.65%</td>
<td>13.58%</td>
<td>11.71%</td>
<td>13.27%</td>
<td>11.81%</td>
<td>14.86%</td>
<td>6.01%</td>
</tr>
<tr>
<td>US-born Hispanic</td>
<td>4.87%</td>
<td>5.20%</td>
<td>4.55%</td>
<td>6.09%</td>
<td>3.22%</td>
<td>5.58%</td>
<td>2.76%</td>
</tr>
<tr>
<td>Foreign-born Hispanic</td>
<td>9.11%</td>
<td>7.91%</td>
<td>10.31%</td>
<td>11.49%</td>
<td>5.88%</td>
<td>11.14%</td>
<td>3.02%</td>
</tr>
<tr>
<td>Married</td>
<td>65.41%</td>
<td>63.63%</td>
<td>67.19%</td>
<td>60.99%</td>
<td>71.38%</td>
<td>63.44%</td>
<td>71.33%</td>
</tr>
<tr>
<td>US born</td>
<td>86.10%</td>
<td>87.60%</td>
<td>84.61%</td>
<td>83.68%</td>
<td>89.38%</td>
<td>83.24%</td>
<td>94.70%</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>16.88%</td>
<td>15.52%</td>
<td>18.25%</td>
<td>17.89%</td>
<td>15.52%</td>
<td>16.44%</td>
<td>18.22%</td>
</tr>
<tr>
<td>High school</td>
<td>25.64%</td>
<td>23.93%</td>
<td>27.34%</td>
<td>25.49%</td>
<td>25.84%</td>
<td>28.36%</td>
<td>32.49%</td>
</tr>
<tr>
<td>Some college</td>
<td>32.44%</td>
<td>34.74%</td>
<td>30.14%</td>
<td>32.61%</td>
<td>32.21%</td>
<td>32.12%</td>
<td>33.39%</td>
</tr>
<tr>
<td>College degree or higher</td>
<td>25.04%</td>
<td>25.81%</td>
<td>24.27%</td>
<td>24.01%</td>
<td>26.43%</td>
<td>23.08%</td>
<td>15.90%</td>
</tr>
<tr>
<td>Poverty income ratio</td>
<td>3.10 (0.05)</td>
<td>3.03 (0.05)</td>
<td>3.17 (0.05)</td>
<td>2.84 (0.05)</td>
<td>3.45 (0.06)</td>
<td>3.19 (0.05)</td>
<td>2.82 (0.09)</td>
</tr>
<tr>
<td>Medication for blood pressure</td>
<td>15.03%</td>
<td>15.50%</td>
<td>14.55%</td>
<td>5.25%</td>
<td>28.25%</td>
<td>13.78%</td>
<td>18.76%</td>
</tr>
<tr>
<td>Medication for cholesterol</td>
<td>9.71%</td>
<td>8.99%</td>
<td>10.44%</td>
<td>2.87%</td>
<td>18.97%</td>
<td>9.48%</td>
<td>10.42%</td>
</tr>
<tr>
<td>Neighborhood-level Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnic heterogeneity</td>
<td>0.29 (0.02)</td>
<td>0.29 (0.02)</td>
<td>0.29 (0.02)</td>
<td>0.30 (0.02)</td>
<td>0.27 (0.02)</td>
<td>0.32 (0.02)</td>
<td>0.20 (0.04)</td>
</tr>
<tr>
<td>Poverty concentration</td>
<td>15.37%</td>
<td>15.15%</td>
<td>15.58%</td>
<td>17.56%</td>
<td>12.41%</td>
<td>15.49%</td>
<td>15.01%</td>
</tr>
<tr>
<td>Observations</td>
<td>10,122</td>
<td>5,019</td>
<td>5,103</td>
<td>5,697</td>
<td>4,425</td>
<td>7,986</td>
<td>2,136</td>
</tr>
</tbody>
</table>

Note. Descriptive statistics are reported in percentages or means. Standard errors are in parentheses.
Table 2. Estimates from Random Intercept Logistic Models Predicting Metabolic Syndrome (NHANES 2003-2008)

<table>
<thead>
<tr>
<th>Neighborhood-level Variables</th>
<th>Model 1  (Full Model)</th>
<th>Model 2  (Interaction model by Race/ethnicity)</th>
<th>Model 3  (Interaction model by age groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnic heterogeneity</td>
<td>-0.35 (0.15)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poverty concentration</td>
<td>0.17 (0.07)*</td>
<td>0.16 (0.07)*</td>
<td>0.18 (0.07)**</td>
</tr>
<tr>
<td>Urban (vs. Non-urban)</td>
<td>0.10 (0.08)</td>
<td>0.06 (0.08)</td>
<td>-0.02 (0.08)</td>
</tr>
</tbody>
</table>

Interactions

| Ethnic heterogeneity*Blacks | -0.34 (0.15)*         |                                          |                                 |
| Ethnic heterogeneity*Middle-aged |                     | 0.34 (0.08)***                           |                                 |

Individual-level Variables

<table>
<thead>
<tr>
<th>Race/ethnicity (ref. White)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>-0.18 (0.08)*</td>
<td></td>
<td>-0.25 (0.07)**</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.12 (0.08)</td>
<td></td>
<td>-0.04 (0.08)</td>
</tr>
<tr>
<td>Age</td>
<td>0.12 (0.02)***</td>
<td>0.12 (0.02)***</td>
<td></td>
</tr>
<tr>
<td>Age-squared</td>
<td>0.00 (0.00)***</td>
<td>0.00 (0.00)***</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>0.00 (0.05)</td>
<td></td>
<td>-0.03 (0.05)</td>
</tr>
<tr>
<td>Married</td>
<td>0.12 (0.06)***</td>
<td>0.14 (0.06)*</td>
<td>0.23 (0.06)***</td>
</tr>
<tr>
<td>US born</td>
<td>0.19 (0.08)*</td>
<td>0.14 (0.07)*</td>
<td>0.17 (0.08)*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education (ref. High school)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than high school</td>
<td>0.06 (0.07)</td>
<td>0.06 (0.07)</td>
<td>0.11 (0.07)</td>
</tr>
<tr>
<td>Some college</td>
<td>0.01 (0.07)</td>
<td>0.00 (0.07)</td>
<td>0.00 (0.07)</td>
</tr>
<tr>
<td>College degree</td>
<td>-0.37 (0.09)***</td>
<td>-0.38 (0.09)***</td>
<td>-0.37 (0.09)***</td>
</tr>
<tr>
<td>Poverty income ratio</td>
<td>-0.05 (0.02)*</td>
<td>-0.05 (0.02)*</td>
<td>-0.02 (0.02)</td>
</tr>
<tr>
<td>Medication for blood pressure</td>
<td>0.78 (0.07)***</td>
<td>0.76 (0.07)***</td>
<td>1.05 (0.07)***</td>
</tr>
<tr>
<td>Medication for cholesterol</td>
<td>0.28 (0.08)**</td>
<td>0.28 (0.08)**</td>
<td>0.45 (0.08)**</td>
</tr>
</tbody>
</table>

Note. Standard errors are in parentheses.

***p<0.001, **p<0.01, *p<0.05, +p<0.10 (two-tailed test)