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Neighborhood Features and Physiological Risk: An Examination of Allostatic Load

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Abstract

Poor neighborhoods may represent a situation of chronic stress, and may therefore be associated with health-related correlates of stress. We examined whether lower neighborhood income would relate to higher allostatic load, or physiological well-being, through psychological, affective, and behavioral pathways. Using data from the Biomarker Project of the Midlife in the United States (MIDUS) study and the 2000 Census, we demonstrated that people living in lower income neighborhoods have higher allostatic load net of individual income. Moreover, findings indicate that this relation is partially accounted for by anxious arousal symptoms, fast food consumption, smoking, and exercise habits.

Keywords

United States; allostatic load; neighborhoods; socioeconomic status; anxious arousal

Introduction

Low socioeconomic (SES) neighborhoods are associated with higher rates of mental and physical health problems (for a review see Diez Roux & Mair, 2010), with recent evidence suggesting greater cumulative damage to the body's physiological regulatory systems (e.g., Bird et al., 2010; Merkin et al., 2009; Schulz et al., 2013). This cumulative physiological damage may result from psychological, affective, or behavioral mechanisms. For example, residents' perceptions of neighborhood safety (Meyer, Castro-Schilo, & Aguilar-Gaxiola, 2014) and cohesion (neighbors are less trusting of and helpful to one another; for a review

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see Murayama, Fujiwara, & Kawachi, 2012) are associated with poor health outcomes for their inhabitants. Moreover, low income neighborhoods are sometimes perceived as less cohesive (Cagney, Browning, & Wen, 2005), and less cohesive neighborhoods are often perceived as less safe (e.g., Greene, Gilbertson, & Grimsley, 2002). Additionally, life in low SES neighborhoods may be chronically stressful, and chronic stress is often associated with negative mood states (Hammen, Kim, Eberhart, & Brennen, 2011) and greater engagement in health-compromising behaviors (Ng & Jeffery, 2003).

In the current study, we examined whether these factors may serve as psychological, affective, or behavioral pathways linking the SES of the neighborhood where an individual lives to his or her level of allostatic load. Allostatic load is a composite measure posited to capture a person's functioning across multiple physiological systems, with greater allostatic load representing physiological damage and risk for the development of later health problems (McEwen, 1998). Based on prior research, we predicted that allostatic load would be higher in lower SES neighborhoods, even after adjusting for individual SES and other sociodemographic factors. We further hypothesized that individual perceptions of neighborhood safety and cohesion, as well as self-reported levels of perceived stress and anxious arousal, and health behaviors (exercise, fast food consumption, and smoking) would partially account for this relation.

Neighborhood SES and Health

People who reside in low SES neighborhoods report worse health than those living in more affluent neighborhoods (e.g., Browning & Cagney, 2003; Carpiano, 2008; Do, 2009; Giatti, Barreto, & Cesar, 2010; Hou & Myles, 2005). Associations between neighborhood SES and self-rated health have been observed when using various neighborhood socioeconomic indicators, including income, affluence or other wealth measures, and the percentage of residents living in poverty (Subramanian, Kubzansky, Berkman, Fay, & Kawachi, 2006). A number of chronic health conditions are reported more often among people living in poor, compared to wealthy, neighborhoods. Low neighborhood SES is related to higher rates of obesity (Dragano et al., 2007; Grafova, Freedman, Kumar, & Rogowski, 2008; Stimpson, Ju, Raji, & Eschbach, 2007; Mondon, van Lenthe, & Machenbach, 2006), hypertension (Dragano et al., 2007; Johnson, Corley, Starr, & Deary, 2011; Matthews & Yang, 2010), and coronary heart disease (e.g., Diez Roux et al., 2001). Other studies have found associations between low neighborhood SES and chronic conditions such as arthritis, cardiovascular disease, diabetes, stroke, respiratory infections, cancer, and the metabolic syndrome (Clark et al., 2013; Johnson et al., 2011; Mustard, Derksen, Bethelot, & Wolfson, 1999), as well as asthma, heart problems, arthritis, and diabetes (Matthews & Yang, 2010).

Several studies have identified physiological characteristics linked to low neighborhood SES, such as elevated cholesterol (Johnson et al., 2011; Matthews & Yang, 2010), blunted diurnal cortisol patterns (Hajat et al., 2015; Karb, Elliott, Dowd, & Morenoff, 2012), greater inflammation (Nazmi, Diez Rouz, Ranjit, Seeman, & Jenny, 2010), and higher triglyceride levels (Stimpson et al., 2007). These physiological states may underlie the associations between health conditions and neighborhood SES. An intervention found that people who moved from high to low poverty areas had lower glycated hemoglobin than those who

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remained in high poverty areas, suggesting a causal role that neighborhoods play in pathophysiological processes related to the development of diabetes (Ludwig et al., 2011).

Some researchers posit that macro-level factors such as a neighborhood's SES relate to health through the built environment and social context (Schulz & Northridge, 2004). By differentially investing or disinvesting in certain communities, there is an unequal distribution of public physical and social resources across neighborhoods varying in SES. Poorer physical and social environments are related to a greater number of stressors, fewer opportunities for social cohesion and engagement, and poorer health behaviors among those inhabitants. These factors increase the risk for poorer mental and physical health. Others (Daniel, Moore, & Kestens, 2008) have argued the importance of biological mechanisms, stating that inferences of causation require attention to physiological stress processes that explain links between neighborhoods and health. Building on these models, we examined whether neighborhood income relates to a physiological pathway to health, captured by allostatic load, as well as some of the psychological, affective, or behavioral factors that may account for this relation.

Neighborhood SES is typically derived from the SES of its residents. Therefore, researchers have questioned whether associations between neighborhood SES and health simply reflect the risk conferred by low individual SES, such as poor access to healthcare, low health literacy, greater frequency of engagement in health damaging behaviors, or other risk factors associated with lower individual SES. However, some studies have found that greater neighborhood socioeconomic deprivation is associated with poorer health even after statistically adjusting for individual education level (e.g., Lang, Hubbard, Andrew, Llewellyn, Melzer, & Rockwood, 2009). Identifying unique effects of neighborhood SES on factors that influence individual health thus requires adjusting for individual SES (e.g., income, education, or occupation; Oaks, 2004), a strategy that will be used in the present analyses.

Neighborhood SES and Allostatic Load

Allostatic load represents a summary score of individuals' physiological assessments that together produce an indicator of future risk for poor health and mortality (McEwen, 1998). Scores typically incorporate information on the structure and functioning of the body's key regulatory systems that are often disrupted by psychosocial stress, including the cardiovascular, sympathetic and parasympathetic nervous, neuroendocrine, immune and glucose and lipid metabolic systems (e.g., Gruenewald et al., 2012; Seeman, Singer, Rowe, Horwitz, & McEwen, 1997). Data on an array of biomarker indicators of these systems are aggregated into a composite risk score reflecting evidence of wear and tear (e.g., low or high resting state levels or hypo- or hyper-reactivity of biomarker indicators) across these multiple systems.

Researchers hypothesize that allostatic load reflects the cumulative wear and tear on the body's physiological regulatory systems that results from the body's chronic attempts to regulate optimal functioning under conditions of challenge or demand (McEwen, 1998; Seeman et al., 1997). In the short term, physiological arousal is adaptive as it facilitates a biological response to a stressor. Repeated or prolonged arousal, on the other hand, can be

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damaging to the body and place people at risk for higher rates of morbidity and mortality (McEwen, 1998).

Low SES neighborhoods have been characterized as a source of many psychosocial (crime, violence) and physical (poor quality housing, poor street connectivity) hazards (Diez Roux & Mair, 2010). Exposure to these environments may elicit allostatic processes, and with repeated or prolonged exposure, allostatic load. For instance, individuals living in neighborhoods with a higher degree of psychosocial hazards such as crime had greater odds of a history of cardiovascular events (e.g. myocardial infarction; Augustin, Glass, James, & Schwartz, 2008). Examining allostatic load in the context of neighborhood SES has the potential for identifying individuals at the greatest risk for later health problems, and therefore early detection and intervention. Indeed, a few studies have linked higher neighborhood SES with lower allostatic load (Bird et al., 2010; Brody, Lei, Chen, & Miller, 2014; Merkin et al., 2009; Theall, Drury, & Shirtcliff, 2012) and similar measures of cumulative physiological risk (Schulz et al., 2013), even after adjusting for individual SES.

Neighborhood SES may relate to allostatic load through multiple pathways. Researchers have posited that low SES neighborhoods are related to health through physical and social contextual features. These features are, in turn, related to residents' exposure to stressors, ability to form social supports, and engage in various health behaviors. Allostatic load is not only posited to increase in response to repeated stressors (McEwen, 1998), but also has documented associations with health behaviors (Gruenewald et al., 2012). In general, engaging in fewer health-compromising behaviors (smoking, consuming fast food and alcohol) is associated with lower allostatic load, indicating less physiological risk for the development of chronic health conditions. Similarly, having greater contact with friends and family is related to lower allostatic load. Taken together, we aimed to examine multiple pathways linking neighborhood income to allostatic load in the present study. We hypothesized that both neighborhood- (safety appraisals and perceptions of social cohesion) and individual-level (perceived stress and health behaviors) factors would partially account for this relationship.

Psychological, Affective and Behavioral Pathways

Low neighborhood SES may put residents at greater risk for physiological damage through psychological, social, and physical means (Cutrona, Wallace, & Wesner, 2006). Some researchers suggest that psychological factors such as residents' perceptions of their neighborhoods partially explain the neighborhood SES and health relationship. For example, low SES neighborhoods are sometimes less cohesive (Cagney et al., 2005; but see Qadeer & Kumar, 2006) and sometimes less safe (Greene et al., 2002) than higher SES neighborhoods. Furthermore, perceptions of both neighborhood safety and cohesion are related to various health outcomes (e.g., Meyer et al., 2014; Murayama et al., 2012). Perceptions of neighborhood characteristics (e.g., observed and perceived crime and disorder) and personal safety, and to a lesser degree social cohesion, are also associated with physiological functioning and risk (Mair, Cutchin, & Peek, 2011; Mujahid et al., 2008; Schulz et al., 2013).

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Perceptions of neighborhood safety may be associated with physiological functioning in that people living in such neighborhoods maintain a heightened sense of vigilance and mistrust of their surroundings. Conversely, perceiving one's neighborhood as cohesive may have similar stress-buffering effects as those observed among individuals with higher levels of perceived social support from friends and family members (Rook, August, & Sorkin, 2011). Indeed, people living in neighborhoods perceived as less cohesive display greater affective reactivity to daily stressors (Robinette, Charles, Mogle, & Almeida, 2013). The degree to which people react to daily stressors, in turn, is theorized to associate with physiological wear and tear (McEwen, 1998). Living in neighborhoods perceived as having low levels of social cohesion is related to worse reported health (Bures, 2003; Rios, Aiken, & Zautra, 2012). Whether neighborhood cohesion is associated with wear and tear across multiple physiological systems, as captured by allostatic load, will be examined in the current study.

In addition to neighborhood-specific levels of psychological distress, affective experiences, including perceived stress and anxiety, may further explain links between neighborhood SES and allostatic load. Low SES neighborhoods have been characterized as the source of many psychological (e.g., residential instability) and physical (e.g., poor walkability) stressors (Diez Roux & Mair, 2010). It is plausible that exposure to a myriad of stressors could, over time, increase residents' level of general affective distress. Recent evidence substantiates this theory in that people living in low SES neighborhoods reported greater distress (Rios et al., 2012), and distress has been found to partially account for observations of higher levels of allostatic load among those with lower individual SES (Gruenewald et al., 2012). Further research in neighborhood SES is needed to examine whether levels of affective distress might similarly serve as another pathway to health.

Lastly, it is possible that relations between neighborhood SES and health are partially explained by health behaviors. A plethora of studies demonstrate that residents of poorer neighborhoods engage in health-compromising behaviors, such as smoking, eating fast food more, and exercising less (e.g., Chuang et al., 2005; Hanson & Chen, 2007). These behaviors are associated with cardiovascular health problems, many of which are disproportionality represented among individuals living in lower SES neighborhoods. Furthermore, these behaviors are associated with higher allostatic load (Friedman, Karlamanga, Gruenewald, Koretz, & Seeman, 2015) and partially account for associations between lower individual SES and greater allostatic load (Gruenwald et al., 2012).

The Present Study

Few researchers have examined allostatic load, a measure of physiological health, in the context of neighborhood SES. Building on the finding that allostatic load appears to be elevated among individuals living in low SES neighborhoods (Bird et al., 2010), we sought to test three potential pathways explaining this relation. First, we examined a psychological pathway. Although other researchers have demonstrated that crime rates (Theall et al., 2012) and other safety issues (theft; Schulz, Mentz, Lachance, Johnson, Gaines, & Israel, 2012) may be associated with allostatic load, we examined associations between neighborhood SES, perceptions of neighborhood safety (and therefore a more direct assessment of neighborhood-specific psychological fear), and allostatic load. Our analyses represent a first

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examination of these questions using a large national sample of midlife men and women. We also examined whether perceptions of neighborhood cohesion might explain associations between neighborhood SES and allostatic load. Second, we examined an affective pathway; specifically, whether indicators of psychological distress, including perceived stress and anxiety, may partially account for the relation between neighborhood SES and allostatic load. Finally, we examined a behavioral pathway, hypothesizing that exercise, fast food consumption, and smoking would partially explain hypothesized links between neighborhood SES and allostatic load. We included individual SES and age in all of our models to rule out their role as potential confounds, as both factors are associated with higher allostatic load (Crimmins, Johnston, Hayward, & Seeman, 2006; Gruenewald et al., 2012; Seeman & Gruenewald, 2006) and neighborhood features.

Method

Sample and Procedures

The Midlife in the United States (MIDUS) longitudinal study included a telephone and self-administered questionnaire survey of a large sample of U.S. adults. A large portion of this sample was drawn from random digit dialing procedures, with siblings or twins of these participants representing the remainder of the sample (75% response rate). The aim of the MIDUS survey was to assess the behavioral, psychological, and social factors that explain age-related differences in mental and physical well-being. MIDUS II, conducted 10 years after the baseline assessment, successfully retained 4963 participants from the main telephone and questionnaire study. At the second wave of this study (MIDUS II), a subset of the original MIDUS participants ($N = 1043$) also completed the Biomarker Substudy which consisted of an overnight stay in one of three General Clinical Research Centers (GCRC; at University of California, Los Angeles; University of Wisconsin; and Georgetown University; Love, Seeman, Weinstein, & Ryff, 2010). All MIDUS I participants were considered eligible for the Biomarker Substudy as long as they were able, and willing, to travel to one of the data collection sites (39.3 % response rate). The participant pool included those from the random digit dialing sample, twins, and siblings added at Wave II. Biomarker participants provided blood, urine, and saliva samples in addition to a full physical exam. This information allowed for the assessment of an array of biomarker indicators of the cardiovascular, sympathetic nervous, parasympathetic nervous, hypothalamic pituitary adrenal axis, inflammatory, lipid metabolism, and glucose metabolism systems. Allostatic load variable were calculated for those with data available for at least half of the biomarkers in the physiological system. Some participants ($n = 309$) were siblings (including twin pairs). The study was completed using ethical guidelines with the approval of each of review boards of the institutions involved.

Measures

Allostatic load—A total of 24 physiological indices were assessed to calculate seven separate scales comprising the cardiovascular, sympathetic nervous, parasympathetic nervous, hypothalamic pituitary adrenal axis, inflammatory, lipid metabolism, and glucose metabolism systems (Gruenewald et al., 2012). Values on each of the 24 biomarker indicators of each separate physiological index were categorized into membership in the highest risk quartile range of the biomarker distribution. For all but two indices, the highest quartile was considered the quartile ‘at risk’ (higher values represent more physiological wear-and-tear). For the two exceptions, DHEA-S and HDL cholesterol, lower scores were more health-compromising, so the lowest quartiles were considered the quartile ‘at risk.’ An average score of the dichotomous (0/1) high-risk indicators was computed for the set of biomarkers representing each system so that the average score essentially represented the proportion of biomarker indicators for which participant values fell into high-risk ranges (i.e., scores could range from 0 to 1, with a score of “0” indicating that no biomarker indicators fell into high-risk ranges, a score of “0.5” indicating that 50% of biomarker indicators fell into high-risk ranges, a score of “1” indicating that all biomarker indicators fell into high-risk ranges, etc.). Average scores were created for each subsystem for which data on at least half of the biomarker indicators of the subsystem was available (the rate of average subsystem scores based on incomplete data for each subsystem was small (range from 0.1 – 1.3% of sample). Likewise, the rate of those missing more than half the biomarker indicators of each system was also small (range from 0.1 – 1.6%) with the exception of missing data for the parasympathetic nervous system for which 8.3% of the sample was missing data on all biomarker indicators due to instrumentation or other challenges during measurement. Using standard protocol (see Gruenewald et al., 2012), scores were then summed across these seven subsystem average scores to create an overall allostatic load score, which ranged from 0 (no physiological systems have any at risk indices) to 7 (all indices within all seven systems are at risk). Allostatic load scores were calculated for those with average scores on at least 6 of the 7 subsystems (101 participants (9.6%) were missing an average score on 1 subsystem; this summary scoring method effectively computed a score of 0 for the missing subsystem).

Neighborhood income—Neighborhood SES was operationalized as median household income at the census tract (CT) level, collected from the 2000 US Census. Although some researchers have argued that administrative boundaries such as the CT do not always reflect people's representation of ‘neighborhood’ (Basta, Richmond, & Wiebe, 2010), others have demonstrated similar results using both CTs and smaller ‘natural’ neighborhoods (Ross, Tremblay, & Graham, 2004). An incremental census tract variable was created so that estimates in our models could be interpreted as the change in allostatic load for every $10,000 increase in census tract income. MIDUS II was conducted between 2004-2006 and the Biomarker Project was conducted between 2004-2009. The time points for these datasets and the US Census decennial data are therefore an imperfect match, yet the closest match possible.

Neighborhood safety—The self-administered questionnaire included two questions assessing safety in the participants’ neighborhoods: I feel safe being out alone in my neighborhood during the daytime; I feel safe being out alone in my neighborhood at night (Keyes, 1998). Using a Likert-type scale, participants rated these questions with 1 = a lot, 2 = a little, 3 = some, and 4 = not at all. Items were reversed coded so that higher mean scores represented more neighborhood safety. Given the strong positive skew of this variable, people were categorized into two groups. Those with a score corresponding to ‘not at all’

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safe (37.84% of the sample) represented the unsafe category, and those who scored greater than a 0 (62.16% of the sample) represented the safe category.

Neighborhood cohesion—Participants were asked two questions assessing their perceptions of neighborhood cohesion: I could call on a neighbor for help if I needed it; People in my neighborhood trust each other (Keyes, 1998). Participants rated these questions along a Likert-type scale with 1 = a lot, 2 = a little, 3 = some, and 4 = not at all. Items were reversed coded so that higher mean scores represented more neighborhood cohesion.

Affective distress—Two measures of distress were examined in analyses. General perceived stress was assessed with the 10-item version of the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983; Cohen & Williamson, 1988). They were asked how often in the last month they had experiences such as, felt nervous and 'stressed,' been upset because of something that happened unexpectedly, and been angered because of things that were outside of your control. Responses were given using a Likert-type scale ranging from 1 = Never to 5 = Very Often. Some items were reverse-coded so that higher scores represented higher distress. Cronbach's alpha for this scale was $\alpha = 0.87$

Additionally, symptoms of anxious arousal were assessed using the Mood and Symptom Questionnaire (Clark & Watson, 1991; Watson, Clark, Weber, Assenheimer, Strauss, & McCormick, 1995a; Watson, Clark, Weber, Assenheimer, Strauss, & McCormick, 1995b). Seventeen items were used to measure people's anxious arousal. Items included experiences, such as startled easily, felt faint, had hot or cold spells, and felt numbness or tingling in body. Participants provided their responses using a Likert-type scale ranging from 1 = Not at All to 5 = Extremely. Cronbach's alpha for this scale was $\alpha = 0.77$.

Health behaviors—Participants were asked about their fast food consumption with one question, 'In an average week, how often do you eat at a fast food restaurant or order food for takeout or delivery?' Response options ranged from 1 (Never) to 5 (7 or more times per week). Another question asked participants whether or not (0 = no, 1 = yes) they regularly engage in light (e.g., light housekeeping, easy walking), moderate (e.g., leisurely sports, brisk walking), or vigorous (e.g., competitive sports, running) exercise for 20 minutes or more at least three times per week. Participants were classified as current smokers, ex-smokers, or having never smoked on the basis of whether they reported having ever, or currently, regularly smoked cigarettes. Participants with a history of cigarette smoking were asked to indicate the age they began smoking cigarettes regularly, and the year they stopped smoking cigarettes regularly if they were ex-smokers. A pack-years cigarette exposure variable was created by multiplying the years that the participant regularly smoked cigarettes by the number of reported packs of cigarettes smoked per day (estimated as number of cigarettes smoked per day divided by typical pack size of 20 cigarettes) during the heaviest year of cigarette usage. Never-smokers were given a pack-years score of 0.

Individual SES—The median household income variable we used to capture individual SES represented a composite of self-reported income from personal wages, pensions, social security, and government assistance for both the participant and his or her spouse combined from the MIDUS II survey. We created an incremental individual income variable to interpret changes in allostatic load based on $10,000 increments.

Additional Covariates—Several sociodemographic variables associated with allostatic load in prior research were included as covariates. A five-year incremental age variable was created to estimate difference in allostatic load based on five-year age differences. Gender was dichotomized with 1 = male and 2 = female.

Statistical Analyses

We tested all of our hypotheses with generalized estimating equations (GEE). The use of GEEs allowed for adjustment of any sibling dependency in the data. Participants in our study were residing in a total of 979 census tracts around the United States, with 24 of these tracts including more than one participant. Of those 24 census tracts, 23 census tracts contained two participants and one census tract contained three participants. As such, there was not a sufficient amount of clustering of participants within census tracts to warrant any adjustment for potential cluster-related dependency in the data. We first tested the hypothesis that higher neighborhood income would be associated with lower allostatic load, independent of individual income, age, and gender (Model 1). To examine our hypothesized psychological pathway, we added perceptions of neighborhood safety and perceptions of neighborhood cohesion to the model (Model 2). In Model 3 we tested our hypothesized affective pathway by alternatively including perceived stress and symptoms of anxious arousal. In Model 4 we included tobacco, fast food consumption and exercise habits[1] to examine whether these represent a behavioral pathway between neighborhood income and allostatic load. Lastly, Model included all potential pathways simultaneously.

Results

Of the 1043 Biomarker participants, 995 were included in the analyses. Of the 44 participants who were excluded, six were missing addresses making it impossible to link census tract-level income data. An additional 30 participants were excluded because they were missing household income information. The remaining eight were excluded because they either did not respond to the questions assessing fast food consumption ($n = 1$), smoking ($n = 4$), perceptions of safety or cohesion in their neighborhoods ($n = 4$), perceived stress ($n = 1$), or anxious arousal ($n = 2$). The majority (93.35%) of the analytic sample was white, ranging from 34 to 84 years old ($M = 55$ years, $SD = 12$ years), and 54.47% were women.

Table 1 displays means and standard deviations for the main variables used in the analyses. Neighborhood and individual income levels spanned wide ranges. In general, participants reported fairly high levels of cohesion in their neighborhoods and low levels of anxious arousal. The majority of the sample reported exercising regularly, and 577 participants (58%) reported having not consumed any tobacco (scores of 0). On average, participants

[1]Although we intended to include alcohol consumption as an additional covariate in our models, 320 (32%) of participants were missing information on this variable. We therefore excluded this variable. However, when we ran a model with the alcohol variable included, the relationship between neighborhood income and allostatic load (est = −0.04, $p = .0016$ without alcohol, est = −0.04, $p = .0048$ with alcohol) remained significant.

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reported eating fast food between two and three times per week. Participants lived in their current neighborhoods for an average of 15 years.

Table 2 lists the physiological indices used in the calculation of allostatic load and reports the quartile cut-offs used in the present study for classifying physiological indices as ‘at risk.’ Consistent with previous studies (Gruenewald et al., 2012), a physiological index was considered to be ‘at risk’ if the value were at or above the 75th percentile for that index (except in the case of DHEA and HDL cholesterol for which the ‘at risk’ quartile was at or below the 25th percentile for that index). Clinical cut-offs, where available, are also reported. Comparison of the quartile and clinical cut-offs indicates that the values used in the present study for classifying an index as ‘at risk’ were similar to those used in clinical practice. Table 2 also reports the percentage of participants with one or more indices ‘at risk’ in each of the seven physiological systems. Additional information regarding assay, measurement methods, and indices used in the calculation of allostatic load variables can be found in a published supplement (Gruenewald et al., 2012).

Table 3 shows the bivariate correlations between neighborhood income and each of the additional predictor variables. Higher neighborhood income was significantly associated with greater perceptions of neighborhood cohesion, lower levels of anxious arousal, and being a non-smoker.

Multivariate Analyses

Model 1 confirmed our first hypothesis that higher neighborhood income was significantly associated with lower allostatic load even after adjusting for individual income, age, and gender (see Table 4 for the results of all models). For every $10,000 increase in neighborhood income there was a 0.05 decrease in allostatic load. Higher individual income and younger age were also associated with lower allostatic load.

After this initial model, our first aim was to examine whether residents’ perceptions of their neighborhoods partially account for the relation between neighborhood income and allostatic load. We did not find support for this hypothesis; perceptions of neighborhood cohesion was not a significant predictor of allostatic load, and perceptions of neighborhood safety was a significant predictor but did not reduce the strength of the association between neighborhood income and allostatic load. Individuals living in neighborhoods perceived as safe had significantly lower allostatic load than those living in neighborhoods perceived as not safe.

In Model 3 we examined whether perceived stress or symptoms of anxious arousal would partially account for the relation between neighborhood income and allostatic load. Results yielded partial support for our hypothesis. Although perceived stress was not significantly associated with allostatic load, people with higher levels of anxious arousal had significantly higher allostatic load. Moreover, the association between neighborhood income and allostatic load was reduced by approximately 12 percent after adding these variables to the model. Results of a Sobel test indicated that anxious arousal significantly mediated the relation between neighborhood income and allostatic load (Sobel's $z.$ = −2.20, $p = 0.02$).

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In Model 4 we examined whether three health behaviors, smoking, exercise, and fast food consumption, partially explains the link between neighborhood income and allostatic load. Our hypothesis was supported; these health behaviors accounted for approximately eight percent of the association between neighborhood income and allostatic load. People who exercised regularly, who had consumed less tobacco, and who reported eating less fast food had significantly lower allostatic load. Results of a Sobel test indicated that smoking significantly mediated the relation between neighborhood income and allostatic load (Sobel's z. = −2.15, $p = 0.03$).

In our last model (Model 5) we included all predictor variables simultaneously. The collection of these variables further reduced the relation between neighborhood income and allostatic load by 14%. Individuals living in neighborhoods perceived as safe had significantly lower allostatic load than their counterparts. Individuals with higher anxious arousal, those who exercise less, those who smoke more, and those who eat fast food more had significantly higher allostatic load.

Discussion

Allostatic load, a measure posited to capture the cumulative effects of wear-and-tear on physiological regulatory systems, has been found to be elevated in those living in low income neighborhoods (Bird et al., 2010; Brody et al., 2014; Merkin et al., 2009; Schulz et al., 2013; Theall et al., 2012). Researchers have examined single factors, such as neighborhood cohesion (Rios et al., 2012) and crime rates (Schulz et al., 2012; Theall et al., 2012), that may explain this relation. In the current report, we examined a combination of psychological, affective, and behavioral pathways that link neighborhood SES with allostatic load. First, our results replicate those of others (Bird et al., 2010; Brody et al., 2014; Merkin et al., 2009; Schulz et al., 2013; Theall et al., 2012), indicating that allostatic load is higher in low income neighborhoods. Second, our results indicated that symptoms of anxious arousal, exercise habits, smoking, and the consumption of fast food partially accounted for this relation. We observed these relationships using a large national sample of men and women spanning a large age range and after adjusting for individual income and other sociodemographic factors.

Psychological pathways

We did not find support for our initial hypothesis that perceptions of neighborhood safety or cohesion would partially explain the relation between neighborhood SES and allostatic load. These null findings may be partially explained by evidence indicating the social heterogeneity of low income neighborhoods (Qadeer & Kumar, 2006). Although some economically disadvantaged neighborhoods are characterized as lacking social cohesion or as lacking in safety (as is often the case in ethnic ghettos), others represent areas with high levels of community-level bonding (as is often the case in ethnic enclaves). Even though our sample was limited by being predominantly white, nonetheless heterogeneity in cohesion and in safety within neighborhoods with similar SES may be the reason for this null finding. More sensitive measures that adjust for these difference may yield different findings.

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Nevertheless, allostatic load was significantly higher among individuals living in neighborhoods perceived as unsafe compared to those who perceived their neighborhoods as safe even after adjusting for the constellation of social and physical factors encompassed in neighborhood SES (captured in the current study as neighborhood income; Cutrona et al., 2006). We interpret these perceptions' unique relation with allostatic load to suggest that living in a neighborhood in which one feels unsafe walking alone during the day or at night represents a chronic stress situation that may continually activate allostatic processes. Living in fear – even in the absence of discrete events with the potential for harm – may elicit a chronic state of vigilance associated with distress and physiological arousal. Our findings support this possibility and indicate that chronic fearfulness in one's neighborhood is related to cumulative physiological damage, as captured by allostatic load.

Unlike perceptions of neighborhood safety, perceptions of neighborhood cohesion were not significantly associated with allostatic load. This null finding aligns somewhat with others' research (Nazmi et al., 2010) which has indicated that social cohesion only inconsistently related to indices of physiological functioning (i.e., inflammation). In the current study, higher neighborhood income was significantly related to higher perceptions of neighborhood cohesion, but social cohesion was only significantly related to two out of seven of the physiological regulatory systems in our allostatic load variable (data not shown). Perceptions of safety were related to five out of seven systems. More research is needed to provide a clearer pattern of relations between social cohesion and various other health indicators. Additionally, examining social cohesion as rated by third-party raters may increase objectivity of the social cohesion construct, and may yield a different pattern of results that would be more in-line with our current hypotheses.

Affective pathways

Symptoms of anxious arousal were similarly significantly associated with allostatic load; individuals who reported more symptoms of anxious arousal had significantly higher allostatic load. Moreover, inclusion of this affective factor reduced the association between neighborhood SES and allostatic load by approximately 12 percent. This finding provides empirical support for the argument that living in a low SES neighborhood represents a chronic stress situation, and suggests that at least some of the connection between lower neighborhood SES and higher allostatic load can be explained by residents' levels of distress. Moreover, our results suggested that anxious arousal is distinct from perceptions of neighborhood safety. For example, this anxious arousal may stem from other concerns, such as worry about financial stressors, other personal stressors, or of concerns about the quality of water or the local school system. People may be anxious about other community-based factors that may not relate directly to personal safety but which may be more common among lower than higher SES neighborhoods. This finding suggests that even when safe, lower income neighborhoods may compromise residents' mental health and well-being.

Behavioral pathway

We found support for our final hypothesis that health behaviors would represent a behavioral pathway linking low neighborhood SES to allostatic load. People who reported consuming more fast food and tobacco, and those who reported not getting adequate exercise had significantly higher allostatic load than their counterparts. These findings replicate both theoretical (McEwen, 1998) and empirical (Friedman et al., 2015) reports of as association between health behaviors and allostatic load. Taken together, these findings reduced the association between neighborhood SES and allostatic load by approximately eight percent, indicating that the poor physiological well-being observed among residents of lower income neighborhoods is partially explained by engaging in health-compromising behaviors.

Future directions and conclusions

We found evidence for an association between neighborhood income and allostatic load using a U.S. adult sample representing a wide age range living in census tracts with a wide range of income levels. Furthermore, we observed several affective and behavioral pathways partially explaining this link. These results suggest that people's thoughts, feelings, and behaviors may be points for intervention in an effort to reduce the negative association between objective indicators such as neighborhood SES on long-term physiological wear and tear. Nevertheless, lower neighborhood income was still significantly associated with higher allostatic load even after taking into account the partial individual-level affective and behavioral pathways examined in the current study. Future work will need to examine other neighborhood-level factors, such as the local food environment or access to green space that may further explain the relation between neighborhood income and allostatic load. These may be points of community-level interventions, with the ultimate goal of creating environments conducive to health-enhancing behaviors, and thereby lessening the relation between lower neighborhood SES and poorer resident physiological well-being.

Additionally, we used median income of the census tract as a proxy for neighborhood SES. Although this variable is frequently used in neighborhood-health studies, future studies should attempt to replicate our findings using multiple measures of neighborhood SES. Other researchers have already taken this step in examinations of neighborhood SES and self-reported health (Subramanian et al., 2006). Similarly, our findings could be replicated using a more comprehensive assessment of neighborhood safety and cohesion (our measures only consist of two items, respectively). Future research should assess whether individual differences regarding peoples' preferences for cohesion – or the likelihood that people prefer to be with social others in various situations – may play a role for health and health-related outcomes.

Whether this association extends to international samples and samples with younger participants remains unanswered. Cumulative physiological wear-and-tear, or increased allostatic load, as a function of psychosocial and environmental conditions has been observed in children as young as nine years of age (Evans, 2003), but children were not included in this study. Examining replicability of our findings is particularly important in light of concerns raised in the literature regarding the sample-specific construction of allostatic load measures (Gallo, Fortmann, & Mattei, 2014). Many studies, not unlike the current study, use sample-level distributions to operationalize biomarker values considered ‘high’ versus ‘low’ risk, and these values may vary across populations. Although we demonstrated similarity between our cut-offs and those used by clinicians in practice, many physiological indices have no published clinical cut points upon which to compare sample-derived cut point values.

In sum, this study demonstrated that people living in low SES neighborhoods and characterized as low in safety have higher allostatic load, a risk factor for the development of chronic health problems. The association between allostatic load and neighborhood SES was partially explained by individuals' symptoms of anxious arousal and health behaviors, suggesting that intervention efforts focusing on these factors may benefit neighborhood-level physiological well-being. Additionally, our results provide evidence in support of the long-standing contention that living in low SES neighborhoods is chronically stressful with implications for our physical health.

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Research Highlights

- Allostatic load is a measure that captures physiological wear and tear
- Individuals living in lower SES neighborhoods have higher allostatic load
- This relation persists after adjusting for individual SES sociodemographics
- Individual levels of anxious arousal and smoking partially mediate this relation

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Table 1

Description of participants (N = 999)

	M (SD)	Range
Allostatic Load	1.71 (1.04)	0-5.03
Household Income	$76,647.33 ($59,977.23)	$0-300,000
Age	55.18 (11.78)	34-84
Gender (% Male)	45.53	
Neighborhood Cohesion	3.37 (0.68)	1-4
Safety (% Safe)	62.21	
Perceived Stress	21.63 (6.14)	10-48
Anxious Arousal	21.62 (4.89)	17-57
Exercise (% Who exercise regularly)[a]	79.20	
Smoking (Max Pack Years)	12.13 (23.09)	0-189
Fast Food[b]	2.44 (0.91)	1-5
Time Lived in Neighborhood (Years)[c]	15.29 (14.09)	0-77
Neighborhood Income	$50,265.85 ($20,934.69)	$10,457-200,001

[a] Compared to those who don't exercise regularly

[b] 1 = never, 2 = less than once a week, 3 = 1-2 times per week, 4 = 4-6 times per week, 5 = 7 or more times per week

[c] 0 indicates less than one year

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Table 2

Physiological indices with 'at risk' values

	Quartile Cut-Offs (Clinical Cut-Offs)	At Least 1 Index 'At Risk' (%)
Cardiovascular		48.74
SBP	≥143.00 (≥140)	
DBP	≥82.00 (≥90)	
HR	≥77.00 (>90)	
HPA		43.22
Cortisol	≥21.00	
DHEA-S	≤51.00	
Inflammatory		63.92
CRP	≥3.18	
Fibrinogen	≥390.00	
IL-6	≥3.18	
e-Selectin	≥50.58	
ICAM-1	≥329.65	
Metabolic Glucose		44.14
Glycosylated Hemoglobin	≥6.10 (≥7)	
Fasting Glucose	≥105.00 (≥126)	
Insulin Resistance (HOMA-IR)	≥4.05	
Metabolic Lipids		64.19
HDL	≤41.37 (<40)	
LDL	≥128.00 (≥160)	
Triglycerides	≥160.00 (≥200)	
BMI	≥32.31 (≥30)	
WTH	≥0.97 (>1)	
Parasympathetic		38.23
Low Frequency Spectral Power	≤113.96	
High Frequency Spectral Power	≤54.16	
Standard Deviation of IBIs	≤23.54	
RMSSD	≤11.83	
Sympathetic		37.09
Epinephrine	≥2.54	
Norepinephrine	≥33.33	

SBP = Systolic Blood pressure; DBP = Diastolic blood pressure; HR = Heart rate; DHEA-S = Dehydroepiandrosterone Sulfate; CRP = C-reactive protein; IL-6 = Interleukin 6; ICAM-1 = Intercellular adhesion molecule 1; HOMA = Homeostatic model assessment; HDL = High density lipoprotein; LDL = Low density lipoprotein; BMI = Body mass index; WTH = Waist to hip; IBI = Inter-beat intervals; RMSSD = Root Mean Square of the Successive Differences (Heart rate variability)

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Table 3

Correlations among predictor variables

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Neighborhood Income	-							
2. Safety	0.00	-						
3. Cohesion	**0.07**	**0.24**	-					
4. Perceived Stress	−0.04	**−0.19**	**−0.23**	-				
5. Anxious Arousal	**−0.11**	**−0.12**	**−0.12**	**0.41**	-			
6. Exercise	0.03	**0.06**	0.05	−0.06	**−0.07**	-		
7. Smoking	**−0.09**	0.04	−0.03	0.04	**0.12**	**−0.11**	-	
8. Fast Food	0.02	0.04	−0.05	0.05	0.02	**−0.10**	**−0.09**	-

Bolded correlations significant at least $p < .05$.

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Table 4

Multivariate models predicting overall allostatic load (regression estimates [SE])

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	0.17 (0.21)	0.48 (0.25)	−0.50 (0.26)	0.14 (0.21)	−0.14 (0.31)
Neighborhood Income	−0.05** (0.01)	−0.05** (0.01)	−0.04* (0.01)	−0.04* (0.01)	−0.04* (0.01)
Individual Income	−0.01* (0.01)	−0.01* (0.01)	−0.01† (0.01)	−0.01* (0.01)	−0.01† (0.01)
Age	0.16*** (0.01)	0.16*** (0.01)	0.16*** (0.01)	0.16*** (0.01)	0.16*** (0.01)
Gender[a]	0.10 (0.06)	0.06 (0.07)	0.07 (0.06)	0.17* (0.06)	0.10 (0.07)
Safety[b]		−0.16* (0.07)			−0.14† (0.07)
Cohesion		−0.05 (0.05)			−0.02 (0.05)
Perceived Stress			0.01 (0.01)		0.00 (0.01)
Anxious Arousal			0.02** (0.01)		0.02* (0.01)
Exercise[c]				−0.22* (0.07)	−0.19* (0.08)
Smoking				0.00* (0.00)	0.00† (0.00)
Fast Food[d]				0.15*** (0.03)	0.15*** (0.03)

[a]Males = 1, Females = 2

[b]Compared to not safe

[c]Compared to those who don't exercise regularly

[d]1 = never, 2 = less than once a week, 3 = 1-2 times per week, 4 = 4-6 times per week, 5 = 7 or more times per week;

†$p < .05$

*$p < .01$

**$p < .001$

***$p < .0001$