THE ROLE OF EDUCATION IN EXPLAINING RACIAL/ETHNIC ALLOSTATIC LOAD DIFFERENTIALS IN THE UNITED STATES

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ABSTRACT

This study expands on earlier findings of racial/ethnic and education-allostatic load associations by assessing whether racial/ethnic differences in allostatic load persist across all levels of educational attainment. This study used data from 4 recent waves of the National Health and Nutrition Survey (NHANES). Results from this study suggest allostatic load differs significantly by age ($p<0.001$), race/ethnicity ($p<0.001$) and educational attainment for all adults ($p<0.001$). Results for tests of an education-race/ethnicity interaction were significant ($p<0.05$). Additionally, education stratified models suggest that allostatic load levels do not differ by race/ethnicity for individuals low education, rather the largest allostatic load differentials for Mexican-Americans ($p<0.05$) and non-Hispanic Blacks ($p<0.01$) are observed for individuals with a college degree or more. These findings add to the growing evidence that differences in socioeconomic opportunities by race/ethnicity are likely a consequence of differential returns to education, which contribute to higher stress burdens among minorities compared to non-Hispanic Whites.

Keywords: Stress biomarkers, Chronic stress, Allostatic load, Educational attainment

INTRODUCTION

Recent research in the areas of chronic stress and aging has begun to uncover important mechanisms linking socioeconomic conditions to health and mortality outcomes. One pathway linking socioeconomic conditions to health and mortality is known as allostatic load, which is a measure of the cumulative biological ‘wear and tear’, or dysregulation, resulting from exposure to chronic stress (McEwen, 1998b, 2003; McEwen & Seeman, 1999). Recent research has found evidence linking measures of socioeconomic position (SEP), such as poverty (Crimmins et al., 2009), income (Seeman et al., 2008) and educational attainment (Seeman et al., 2010; Seeman et al., 2008), as well as age (Crimmins et al., 2003; A.T. Geronimus et al., 2006) and race/ethnicity (A.T. Geronimus et al., 2006; Peek et al., 2010; Seeman et al., 2008) to levels of allostatic load. Based on such findings a clearer picture is beginning to emerge regarding how social conditions get into the body through biological stress responses to ultimately affect health and longevity.

It has been noted that racial/ethnic differences in health outcomes often persist even when multivariable regression models adjust for confounders, such as age, sex, income, poverty status, and educational attainment (Aday, 2001; Barr, 2008; A.T. Geronimus et al., 2006; Haas et al., 2003; Hummer et al., 1999; LaVeist, 2002; Peek et al., 2010; Seeman et al., 2008). Three competing explanations for the persistence of racial/ethnic differences include (1) biological susceptibility (Haiman et al., 2006), (2) weathering, the accelerated aging of racial/ethnic minorities as the result of persistent exposure to stress brought about by racial discrimination (A. T. Geronimus, 1992; A.T. Geronimus et al., 2006), and (3) differential returns on social capital (Crimmins & Saito, 2001; Crosnoe, 2005; Farmer & Ferraro, 2005; Kimbro et al., 2008; Masters et al., 2012; Roscigno & Ainsworth-Darnell, 1999).

Under the biological susceptibility hypothesis, one would expect to see racial/ethnic differences persist across levels of other socioeconomic variables, such as education and income. Likewise, under the weathering hypothesis one might also expect to observe racial/ethnic differentials across all levels of socioeconomic variables, but through mechanisms of social stratification and discrimination. In contrast, the differential returns hypothesis suggests that observed differences are the result of (1) racial/ethnic minorities benefitting less from health protective socioeconomic factors than whites, and (2) the misspecification of statistical models in which interaction terms between socioeconomic variables and race/ethnicity are not included. In fact, one may expect to find no racial/ethnic differences within certain socioeconomic strata. In addition, the fact that measures of SEP often differ across racial/ethnic groups complicates attempts to assess racial/ethnic differences, because comparisons are not being made between similar groups (LaVeist, 2005; LaVeist et al., 2007). In many cases, the use of interaction terms and stratification in statistical models can help overcome such issues by creating subsets of analysis that are more alike in the distributions of other covariates (Brambor et al., 2005; Schmoor et al., 2008).

Yet, much is still unknown about such interactions between fundamental socio-demographic variables, such as racial/ethnic background and education, which potentially impact allostatic load by establishing, typically by early adulthood, different trajectories for stress exposure and health over the life course (Hayward & Gorman, 2004; Link & Phelan, 1995; Seeman et al., 2010). The purpose of this study was to expand on earlier findings of racial/ethnic and education-allostatic load (AL) associations by (1) testing the biological susceptibility and differential returns hypotheses to determine whether or not racial/ethnic differences in AL persist across all levels of educational attainment, and (2) exploring how other demographic and socioeconomic factors are associated with AL within different educational attainment strata. The central hypothesis of this study is that racial/ethnic differences in allostatic load arise from differential returns on educational attainment.

The patterning of SEP by educational attainment, however, is complicated by racial/ethnic confounding, particularly in studies seeking to tease apart racial/ethnic disparities in health outcomes because observed associations between race/ethnicity, measures of SEP and health often do not operate in the same way for all individuals in similar educational levels (LaVeist, 2005; LaVeist et al., 2007). For example, fewer Mexican-Americans and African-Americans are represented in higher educational categories than non-Hispanic Whites. Likewise minorities may not receive the same return on investment in higher education in terms of comparable salaries or potential long-term wealth as non-Hispanic Whites. As a result, it is important to examine racial/ethnic and SEP associations to health outcomes within like groups.

While recent studies have found evidence of significantly higher levels of allostatic load for racial/ethnic minorities (Crimmins & Saito, 2001; A.T. Geronimus et al., 2006; Kaestner et al., 2009; Peek et al., 2010; Seeman et al., 2010) and for individuals with low educational attainment (Hickson et al., 2012; Seeman et al., 2010; Seeman et al., 2008), none have addressed race/ethnicity-education interactions explicitly. As a result, it remains unclear whether or not the presence of differential returns to education may explain racial/ethnic differences in allostatic load.

DATA AND METHODS

Sample

Public-use data from 4 waves of the National Health and Nutrition Examination Survey (NHANES), collected from 2003 through 2010, were compiled for this study (National Center for Health Statistics, 2005, 2007, 2009, 2011a). A set of 10 biomarkers was used to calculate allostatic load scores for each participant. Of particular importance is the fact that the lipid panel used to measure triglycerides is only administered to the fasting subset of the total NHANES sample (National Center for Health Statistics, 2011b). As a result, this study was limited to the fasting subset of the NHANES from each of the 4 waves. The total sample size for the fasting subsample for the 4 waves of NHANES is 14,282 adults.

Several data restrictions were imposed on the total fasting dataset due to a number of important considerations. Individuals were excluded if 1) they were less than 25 years of age; 2) not non-Hispanic White, non-Hispanic Black, or Hispanic (National Center for Health Statistics, 2006); 3) pregnant at the time of the survey or examination; or 4) had non-positive survey weight values. After applying each of these exclusions, the final total fasting sample used for this study was 6,990.

Measures

Allostatic Load

Following from previous research using population-based samples, such as NHANES, allostatic load was calculated using a 10-biomarker algorithm with clinically determined threshold cut-points for defining high-risk for each biomarker (Crimmins et al., 2009; Juster et al., 2010; Seeman et al., 2008). The 10 biomarkers include: diastolic blood pressure, the mean of 4 measurement attempts, (Chobanian et al., 2003); systolic blood pressure, the mean of 4 measurement attempts; (Chobanian et al., 2003), resting pulse rate (Seccareccia et al., 2001); total cholesterol (National Cholesterol Education Program (NECP) Expert Panel, 2001); highdensity lipoprotein (HDL) cholesterol (National Cholesterol Education Program (NECP) Expert Panel, 2001); triglycerides (National Cholesterol Education Program (NECP) Expert Panel, 2001); glycated hemoglobin (Golden et al., 2003; Osei et al., 2003); albumin (Visser et al., 2005); and C-reactive protein (Ridker, 2003). To calculate each individual's allostatic load score, each biomarker exceeding the clinically-determined threshold for high-risk was assigned a value of 1 and 0 otherwise. These values were then summed across each of the 10 biomarkers, which resulted in a score ranging from 0, no high-risk biomarkers present, to 10, all biomarkers are high-risk (Crimmins et al., 2009; A.T. Geronimus et al., 2006; Seeman et al., 2008). The interpretation of the allostatic load score is that the higher the score the more biological risk an individual has accumulated.

Missing cases for each biomarker were imputed using multiple regression procedures (Shrive et al., 2006). Typically less than 5% of the sample had missing cases for each measure except for HDL cholesterol. Table 1 provides a listing of each biomarker, basic descriptive statistics with and without imputation, the clinically-determined high-risk threshold and the percentage of the sample falling outside of these cut-points. Comparisons of imputed and un-imputed means and standard errors for each biomarker suggest that imputation had little to no effect on the underlying distributions for each biomarker, and did not significantly affect results of subsequent analyses.

----- TABLE 1 ABOUT HERE -----

Demographic, Socioeconomic, and Health Behavior Measures

Of primary interest in this study were the variables race/ethnicity and educational attainment. Race/ethnicity was measured as the following categories, (1) Mexican-American, (2) non-Hispanic White (reference group), and (3) non-Hispanic Black. Educational attainment was measured as a categorical variable representing the highest educational level completed: (1) Less than high school, (2) High school graduate or equivalent, (3) Some college, (4) College degree or higher. Additional demographic and socioeconomic variables were also included, including age (25-40, 41-60, and 60 and older), sex, nativity (US or foreign born), family income (<$20,000, $20,000-$64,999, and $65,000 and more) and marital status (married, divorced/separated/widowed, never married, and cohabitating.

Two measures of potentially negative health behaviors were included: current smoking status (non-smoker/never smoked, current smoker, and former smoker) and alcohol consumption (non-drinker, 1 drink per week or less, more than 1 drink per week, and don't know/refused/missing. For each of the independent variables there were less than 1% of cases for which respondents answered don't know, refused, or were otherwise missing. These cases were treated as missing values, which were recoded to imputed values using regression based methods (Shrive et al., 2006). Sensitivity analysis suggested that imputed values did not significantly change the observed results.

Lastly, since this study involves the pooling of 4 separate waves of NHANES data, a survey wave indicator variable was created to control for period effects. Period effects can create bias when changes in important variables under study change over time, independent of other covariates. To account for period effects, a categorical variable was created as (1) Wave 2003-2004 (reference group), (2) Wave 2005-2006, (3) Wave 2007-2008, and (4) Wave 2009-2010.

Statistical Analysis

While prior studies of allostatic load have used Ordinary Least Squares (OLS) and Ordinal Logistic Regression (OLR) techniques, hypothesis tests for this study were conducted using multivariable negative binomial regression models for the allostatic load outcome. This statistical method was chosen for two reasons. First, the nature of the allostatic load measure is that it is a count outcome following a Poisson-like distribution; and second, the observed distribution is over-dispersed, such that Poisson regression assumptions were not met (Ismail & Jemain, 2007; Land et al., 1996; Tabachnick & Fidell, 2007). The distributions of count outcomes typically do not follow a normal distribution (Ismail & Jemain, 2007). Figure 1, panels A and B, illustrates the univariate distribution of allostatic load within the sample. OLS regression is not desirable in such cases, because it assumes a continuous outcome following a normal distribution, which is clearly not the case for this variable. Similarly, while allostatic load is certainly an ordered outcome, it is ordered in a manner that represents a count where there is a known distance of 1 for each increment. Furthermore, an initial test of the proportional odds assumption for OLR indicated that the assumption was violated in these data. In this case, the observed data, see Figure 1 and Table 2 below, suggest that allostatic load is best fit with the negative binomial functional form:

$$AL = \exp\{\ln a + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \alpha\}$$

where a is a constant, β_1 through β_n are coefficients for model covariates, X_1 through X_n represent the values for each model covariate and α represents the dispersion parameter (Land et al., 1996).

------ FIGURE 1 ABOUT HERE ------

Multivariable negative binomial regression models were constructed in two stages. First, an overall model of allostatic load was estimated in order to address the hypotheses relating to (1) whether educational attainment is associated with allostatic load scores while controlling for other possible confounding factors and (2) whether the education-allostatic load association differs by race/ethnicity. Second, education stratified models were estimated to determine to what extent the education-allostatic load association by race/ethnicity also differs across age groups. All models were adjusted for potential confounding factors including sex, marital status, family income, smoking, alcohol use, and period effects. SAS software (version 9.3) was used for data management and descriptive statistics, and Stata software (version 12.1) was used for all survey (SVY) regression analysis procedures to account for complex survey design (SAS Institute, 2011; Stata Software, 2013).

RESULTS

Descriptive statistics are presented below in Table 2. The mean allostatic load score for the total sample is 1.72 (SE=0.028), with a variance of 5.48. These data suggest that mean allostatic load scores tend to be significantly higher for racial/ethnic minorities than for non-Hispanic Whites. More specifically, mean allostatic load scores are 1.84 (SE=0.057) for Mexican-Americans, 1.95 (SE=0.049) for non-Hispanic Blacks, and 1.67 (SE=0.034) for non-Hispanic Whites. Similarly, the data from Table 2 indicate that all demographic, socioeconomic, and health behavior characteristics examined in this study also differ significantly by race/ethnicity.

----- TABLE 2 ABOUT HERE -----

Results from the first stage of the multivariate analysis are presented in Table 3. Two models of allostatic load were estimated, (1) an overall model without an interaction term for educational attainment by race/ethnicity, and (2) an overall model with an interaction term for educational attainment by race/ethnicity. Both models were adjusted for confounders including age, sex, nativity, marital status, family income, smoking, alcohol use, and period effects. The dispersion parameter, α, is significant in both models, suggesting that the negative binomial model is the appropriate functional form for these data.

The results for model 1 indicate that age, race/ethnicity and educational attainment are significantly associated with allostatic load levels. Age, for example, is positively related to allostatic load ($p<0.001$). Individuals aged 41-60 years have allostatic load levels that are 28% higher than individuals aged 25-40 years, and individuals aged 61 and older have allostatic load levels that are 33% higher than individuals aged 25-40 years. Similarly, Mexican-Americans and non-Hispanic Blacks have higher allostatic load levels than non-Hispanic Whites.

----- TABLE 3 ABOUT HERE -----

More specifically, Mexican-Americans are estimated to have allostatic load levels that are 10% higher than non-Hispanic Whites ($p<0.01$), and non-Hispanic Blacks have allostatic load levels that are 11% higher than non-Hispanic Whites ($p<0.001$). This suggests that, overall, Mexican-Americans and non-Hispanic Blacks have similar allostatic load profiles compared to non-Hispanic Whites. With respect to educational attainment, the results suggest that, while education is an important predictor of allostatic load, its effect is only significant for individuals who have attained a 4-year college degree or higher compared to individuals with less than a high school diploma ($p<0.001$). Allostatic load levels for individuals with a high school diploma and some college do not differ significantly from individuals with less than a high school education. For individuals with a 4-year college degree or more, however, the results suggest that allostatic load is 29% lower than individuals with less than a high school diploma, controlling for other covariates.

In model 2, the interaction between educational attainment and race/ethnicity was added into the model. The inclusion of this interaction term did not affect the estimated effects for age substantially, but it does, however, help clarify the observed racial/ethnic differences in allostatic load. For example, in model 1 the effects for Mexican-Americans and non-Hispanic Blacks were significant, indicating a difference between these two racial/ethnic minority groups and non-Hispanic Whites, even when educational attainment was included in the model as a covariate. By including the interaction between education and race/ethnicity, the results suggest that racial/ethnic differences in allostatic load do not exist at the lowest level of educational attainment. Rather, racial/ethnic differences in allostatic load appear to increase as educational attainment increases. In fact, the data in Table 3 and Figure 1 suggest that the gap in allostatic load levels between Mexican-Americans, non-Hispanic Blacks and non-Hispanic Whites is greatest for individuals with a college degree or more.

----- FIGURE 2 HERE -----

Given that the results of the first stage of the analysis support the differential returns to education hypothesis, additional questions regarding the extent to which associations between race/ethnicity, socio-demographic, behavioral variables and allostatic load are consistent across educational attainment strata remain. To address these questions a second set of education stratified negative binomial models were estimated. These models were separated into (1) low (less than high school), (2) moderate (high school graduate and some college), and high (college graduate or more) levels of educational attainment. The results of these models are presented in Table 4.

----- TABLE 4 ABOUT HERE -----

The results for model 1 suggest that individuals with less than a high school education have little differentiation in terms of allostatic load levels, particularly with respect to socioeconomic and racial/ethnic factors. Age, sex and smoking status are the only statistically significant variables for individuals at this lowest level of educational attainment.

For high school graduates and individuals with some college, age differences in allostatic load are observed, which are similar to individuals with less than high school education. More importantly, however, racial/ethnic and socioeconomic differences begin to emerge for individuals with moderate levels of educational attainment. Specifically, non-Hispanic Blacks are estimated to have allostatic load levels that are 9% higher than non-Hispanic Whites, and foreign born individuals are estimated to have allostatic load levels that are 18% lower than U.S. born individuals. Alcohol consumption is significantly associated with allostatic load for individuals with moderate levels of educational attainment.

Finally, for individuals with high levels of educational attainment, a college degree or more, age, race/ethnicity, nativity, family income and alcohol consumption have significant associations with allostatic load. The relationship between age and allostatic load follows a consistent pattern, in which allostatic load levels are 30% higher for individuals aged 41-60 years, and 44% higher for individuals aged 61 years and older, compared to individuals aged 25-40 years. More interesting, though, is that it is at the highest level of education that the largest racial/ethnic gaps in allostatic load are present. Specifically, allostatic load levels are 38% higher for Mexican-Americans and 25% higher for non-Hispanic Blacks, compared to non-Hispanic Whites. Foreign born individuals have allostatic load levels that are 33% lower than U.S. born individuals at this level of education, a much larger difference in allostatic load than is observed at moderate and low levels of educational attainment. Likewise, individuals with family incomes of $65,000 or more have allostatic load levels that are 40% lower than individuals with family incomes of $20,000 or less. These findings suggest that the health benefits typically associated with higher educational attainment, as it relates specifically to allostatic load, are realized to a much greater extent by non-Hispanic Whites than for racial/ethnic minorities.

DISCUSSION

The results from this study suggest that educational attainment is an important pathway through which socioeconomic conditions affect allostatic load levels for adults in the United States, and that the health benefits associated with education differ by race/ethnicity. Overall, these findings indicate that the association between educational attainment and allostatic load operates as a threshold effect, where the benefit of education seems to matter primarily for individuals who obtain a 4-year college degree or higher. This may be due to less stressful work conditions and the typically higher income associated with jobs requiring a college degree (Baum et al., 2006; Lantz et al., 2005; Wamala et al., 2000).

The data illustrate clear differences in socioeconomic conditions between the 3 racial/ethnic groups, whereby non-Hispanic Whites have advantages in terms of both family income and educational attainment compared to Mexican-Americans and non-Hispanic Blacks. This is perhaps most noticeable in the two tails of the income and education distributions. For instance, the percentage of individuals in the lowest income category, less than $20,000, for both Mexican-Americans and non-Hispanic Blacks is roughly 14%, but it is approximately half this level, 7%, for non-Hispanic Whites. Similarly, the percentage of individuals in the highest income category, those making $65,000 or more, is approximately 7% for Mexican-Americans and just under 10% for non-Hispanic Blacks. Yet, the percentage of non-Hispanic Whites who make $65,000 or more is approximately 18%.

The differences in educational attainment are even starker. Over half of Mexican-Americans (52.60%) have less than a high school diploma, while only 25.29% of non-Hispanic Blacks and 12.79% of non-Hispanic Whites have less than a high school diploma. On the upper end of educational attainment, it is a similar story. Only 8.03% of Mexican-Americans have a college degree or more, but twice as many non-Hispanic Blacks (16.93%) and almost 4 times as many non-Hispanic Whites (31.05%) have a college degree or more.

----- FIGURE 3 HERE -----

While individuals who obtain at least a 4-year college degree benefit from significantly lower allostatic load levels, the degree of benefit depends on racial/ethnic background. This finding is consistent with the differential returns hypothesis, and contradicts the biological susceptibility hypothesis. As Figure 2 illustrates, for individuals with less than a high school education, there are no observed racial/ethnic differences in allostatic load. These findings suggest that at the lowest levels of educational attainment individuals are positioned in similar socioeconomic conditions, characterized by lower levels of income and access to resources, which result in similar patterns of stress exposure regardless of race/ethnicity and nativity (Baum et al., 2006; Lantz et al., 2005; Link & Phelan, 1995; Wamala et al., 2000).

Non-Hispanic Blacks and Mexican-Americans have slightly higher allostatic load levels at moderate levels of education, 9% and 8% respectively. However, at high levels of educational attainment, racial/ethnic differences are large. For example, allostatic load is 25% higher for non-Hispanic Blacks and 38% higher for Mexican-Americans, compared to non-Hispanic Whites, for individuals with a college degree or more. These results indicate that there is not only a large gap in the level of educational attainment between each racial/ethnic groups, but also that the mechanisms of subsequent socioeconomic and health benefits which typically result from high levels of educational attainment do not transfer equally to racial/ethnic minorities in the United States, at least as it relates to levels of allostatic load.

Rather than resulting from any inherent biological differences, these results point to the existence of structural factors that perpetuate socioeconomic disadvantages for racial/ethnic minorities, even at high levels of educational attainment, which ultimately translate into large allostatic load differentials. Residential segregation is one mechanism in particular that has been linked to racial/ethnic educational (Charles et al., 2004; Crosnoe, 2005; Roscigno et al., 2006), socioeconomic (Fischer & Massey, 2000; Massey, 1990), and health (LaVeist et al., 2007; White & Borrell, 2011; Williams & Collins, 2001) disparities, which may explain how differential returns to education arise and affect health. Racial/ethnic minorities tend to be concentrated in low-SEP neighborhoods and in schools characterized by fewer resources, larger class sizes, high poverty, and low levels of teacher experience, which creates early inequities in educational quality that persist throughout the educational experience, with long-lasting consequences (Crosnoe, 2005; Roscigno et al., 2006). In fact, such structurally based educational inequalities may last well into college and beyond, which may affect college entrance and performance as well as subsequent socioeconomic opportunities (Charles et al., 2004). Individuals from such backgrounds may eventually receive lower compensation in the labor market for equivalent levels of educational attainment, which may limit employment and income opportunities leading to higher levels of stress exposure (Baum et al., 2006; Cohen et al., 2006; Fry & Taylor, 2013). Evidence is also beginning to emerge regarding the role of gender inequalities, which also contributes to differential returns to education, whereby minority women fare even more poorly in the job market and in terms of wages than do minority men (Budig et al., 2013). Given that more women than men over 25 years of age have a college degree or higher within both the Hispanic and non-Hispanic Black populations, a situation that is reversed for non-Hispanic Whites, it is likely that gender inequalities also add to observed racial/ethnic differences in educational returns (Kim, 2011).

These findings also point to important policy implications regarding both education and health policy. Because college-graduate level educational attainment is associated with significant reductions in allostatic load overall, it follows that investments in education aimed at decreasing high school dropout rates and increasing college enrollment and graduation rates are also investments in better health at the population level. Therefore, continued efforts to increase levels of educational attainment should be bolstered, especially programs focused on increasing educational attainment for racial/ethnic minorities. As a case in point, at least one recent study concludes that educational attainment has been increasing among Latinos in recent years to the extent that Latino high school graduates have surpassed non-Hispanic Whites in college enrollment (Fry & Taylor, 2013). The same study indicates that non-Hispanic Blacks have also experienced an increase in educational attainment, in terms of college enrollment, but still lag non-Hispanic Whites (Fry & Taylor, 2013). While recent trends in educational attainment for racial/ethnic minorities are promising, continued efforts to increase educational attainment without also addressing the structural factors which may contribute to lower returns on education for non-Whites, including residential and educational system segregation, may not have the desired health effects in the long run (Crosnoe, 2005; Link & Phelan, 1995; Roscigno & Ainsworth-Darnell, 1999).

While this study has shed more light on the complex interrelationships between educational attainment, race/ethnicity, and allostatic load, there are several limitations which should be noted. First, as mentioned above, because NHANES is cross-sectional, and the waves used in this analysis were collected within a narrow period of time, between 2003 and 2010, it is not clear whether or not the effects of age groups, as measured in this study, reflect effects of being a given age or if they represent cohort effects. In order to better address this question, more waves of data over longer periods of time, and preferably longitudinal data, would be required. Second, other potential mediators and modifiers of the education-allostatic load association, such as employment status, type of occupation, and measures of cultural differences, were not included in this analysis, but may also be important in disentangling the manner in which education establishes trajectories for socioeconomic and health outcomes throughout the life course. Third, this study is limited to only 3 racial/ethnic groups due to sampling limitations within NHANES. Fourth, contextual variables, such as measures of segregation, were not included in this study. In order to gain a more comprehensive understanding of the pathways through which education and other measures of SEP operate to affect levels of allostatic load, future research should strive to expand similar analyses to other racial/ethnic groups and focus on the role of segregation and other structural factors affecting education-health associations using multi-level modeling approaches.

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Table 1. Weighted descriptive statistics for 10 allostatic load biomarkers with and without imputation.

Biomarker	Without Imputed Values n	Without Imputed Values Mean	Without Imputed Values Std. Error	With Imputed Values n	With Imputed Values Mean	With Imputed Values Std. Error	Clinically-Based AL Threshold	Clinically-Based AL % of Sample
Cardiovascular Markers								
Diastolic blood pressure (mmHg)	6,715	69.93	0.276	6,990	69.93	0.269	>= 90	4.34
Systolic blood pressure (mmHg)	6,715	122.12	0.349	6,990	122.18	0.342	>= 140	14.29
Pulse rate at 60 seconds	6,765	71.43	0.278	6,990	71.46	0.271	>= 90	7.89
Metabolic Markers								
Total cholesterol (mg/dL)	6,909	200.51	0.728	6,990	200.51	0.721	>= 240	16.18
HDL cholesterol (mg/dL)	5,339	54.61	0.327	6,990	54.57	0.251	< 40	12.25
Triglycerides (mg/dL)	6,920	139.31	2.021	6,990	139.29	1.997	>= 150	30.23
Glycohemoglobin (%)	6,967	5.57	0.015	6,990	5.57	0.015	>= 6.4	7.20
Body mass index (kg/m2)	6,881	28.92	0.109	6,990	28.92	0.108	>= 30	35.69
Inflammation Markers								
Albumin (g/dL)	6,910	4.21	0.007	6,990	4.21	0.007	< 3.8	6.90
C-reactive protein (mg/dL)	6,961	0.43	0.011	6,990	0.43	0.011	>= 0.3	37.30

[1]All figures were adjusted for complex survey design using SDMVPSU, SDMVSTRA, and WTSAF8YR variables.

Table 2. Weighted descriptive statistics by race/ethnicity.

			Race/Ethnicity					
	Total		Mexican American		Non-Hispanic White		Non-Hispanic Black	
Variable	**Mean or %**	**Std. Error**	**Mean or %**	**Std. Error**	**Mean or %**	**Std. Error**	**Mean or %**	**Std. Error**
	n=6990		*n=1465*		*n=4039*		*n=1486*	
Outcome								
Allostatic Load Score***	1.72	0.028	1.84	0.057	1.67	0.034	1.95	0.049
Demographic and Socioeconomic								
Age***	49.82	0.328	42.80	0.522	50.99	0.386	47.02	0.411
Age Group***								
25-40 years	32.17	0.895	52.04	1.750	29.27	1.043	37.26	1.159
41-60 years	42.50	0.825	35.81	1.381	42.99	0.988	43.95	1.218
61 years and older	25.33	0.844	12.15	1.063	27.74	1.004	18.79	0.994
Sex***								
Male	47.99	0.556	54.84	1.329	47.83	0.698	44.27	1.177
Female	52.01	0.556	45.16	1.329	52.17	0.698	55.73	1.177
Nativity***								
US Born	95.10	0.623	71.24	2.704	97.52	0.570	95.94	1.079
Foreign Born	4.90	0.623	28.76	2.704	2.48	0.570	4.06	1.079
Marital Status***								
Married	61.67	0.927	63.43	1.669	65.03	1.042	38.40	1.963
Divorced/Separated/Widowed	20.33	0.613	16.69	1.286	19.55	0.761	28.03	1.199
Never Married	10.98	0.670	11.41	1.205	9.11	0.704	23.01	1.248
Cohabiting	6.90	0.524	8.47	1.003	6.18	0.645	10.52	1.035
DK/Refused	0.12	0.064	0.00	0.000	0.14	0.080	0.04	0.042
Family Income***								
Less than $20,000	8.82	0.551	14.19	2.564	7.36	0.832	14.59	1.146
$20,000 - $64,999	74.07	1.253	76.62	2.703	73.72	1.641	74.53	2.053
$65,000 or More	16.15	1.012	7.03	1.201	18.11	1.246	9.65	1.391
DK/Refused	0.97	0.014	2.16	0.597	0.80	0.154	1.23	0.311
Education***								
Less than HS Diploma	17.68	0.814	52.60	1.422	12.79	1.032	25.29	1.615
High School Diploma	25.37	0.815	19.79	1.143	25.89	0.986	25.84	1.269
Some College	29.48	0.750	19.41	1.380	30.21	0.927	31.78	1.206
College Degree	27.39	1.161	8.03	1.017	31.05	1.519	16.93	1.274
DK/Refused	0.08	0.038	0.17	0.077	0.06	0.045	0.16	0.095
Health Behaviors								
Smoking***								
Non-Smoker	50.52	1.022	61.53	2.103	48.13	1.178	58.52	1.599

Current Smoker	21.93	0.860	17.15	1.428	21.95	0.978	25.18	1.464
Former Smoker	27.49	0.910	21.17	1.237	29.90	1.047	16.11	0.852
DK/Refused	0.06	0.027	0.16	0.130	0.03	0.027	0.19	0.100
Alcohol Consumption***								
Non-Drinker	32.60	1.105	36.88	1.575	30.53	1.439	43.17	1.572
1 Drink per week	42.14	0.773	48.79	1.433	42.11	0.914	37.64	1.350
> 1 Drink per week	25.26	0.943	14.33	1.389	27.36	1.163	19.18	1.244

* p<0.05 | ** p<0.01 | *** p<0.001

[1]Categorical variables tested using Rao-Scott χ^2 test. [2]Continuous variables tested using F test.
[3]All figures and statistical tests were adjusted for complex survey design using SDMVPSU, SDMVSTRA, and WTSAF8YR variables.

Table 3. Results of weighted negative binomial regression on allostatic load with and without education by race/ethnicity interaction term.

	Model 1 *n=6990*					Model 2 *n=6990*				
	Coeff.		95% CI			Coeff.		95% CI		
Variable	(β)	p	Lower	Upper	Exp. β	(β)	p	Lower	Upper	Exp. β
Age Group										
25-40 years (Ref)										
41-60 years	0.24780	<0.001	0.18322	0.31238	1.28	0.25440	<0.001	0.18776	0.32104	1.29
61 years and older	0.28762	<0.001	0.21484	0.36041	1.33	0.32080	<0.001	0.24989	0.39171	1.38
Race/Ethnicity										
non-Hispanic White (Ref)										
Mexican-American	0.09653	0.008	0.02658	0.16649	1.10	0.07625	0.107	-0.01699	0.16949	1.08
non-Hispanic Black	0.10462	<0.001	0.04913	0.16011	1.11	0.06082	0.222	-0.03778	0.15941	1.06
Education										
Less than high school (Ref)										
High school diploma	-0.02450	0.357	-0.07727	0.02828	0.98	-0.04751	0.177	-0.11702	0.02200	0.95
Some college	-0.06305	0.059	-0.12847	0.00237	0.94	-0.09761	0.016	-0.17634	-0.01889	0.91
College degree or higher	-0.34598	<0.001	-0.43565	-0.25630	0.71	-0.43077	<0.001	-0.53798	-0.32356	0.65
Race/Ethnicity * Education Interaction										
Mexican-American										
Less than high school (Ref)										
High school diploma						-0.02890	0.715	-0.18647	0.12868	0.97
Some college						0.02723	0.675	-0.10211	0.15657	1.03
College degree or higher						0.24900	0.062	-0.01246	0.51046	1.28
non-Hispanic Black										
Less than high school (Ref)										
High school diploma						0.02515	0.724	-0.11646	0.16677	1.03
Some college						0.03237	0.591	-0.08751	0.15225	1.03
College degree or higher						0.20801	0.041	0.00884	0.40718	1.23

Constant	0.54717	<0.001	0.42099	0.67335	0.53192	<0.001	0.41012	0.65373
α	0.12310	<0.05	0.09768	0.15514	0.13209	<0.05	0.10595	0.16468
Fit statistics:	DF=(21,42)				DF=(23,40)			
	F=13.94				F=11.17			
	p<0.0001				p<0.0001			

[1]All figures and statistical tests were adjusted for complex survey design using SDMVPSU, SDMVSTRA, and WTSAF8YR variables.

[2]Adjusted for the covariates age, sex, race/ethnicity, nativity, marital status, family income, smoking, alcohol use, and period effects.

Table 4. Results of education stratified, weighted negative binomial regression on allostatic load.

	Less than High School *n=1989*					High School Graduate/Some College *n=3585*					4-Year College Degree or More *n=1416*				
	Coeff.		95% CI			Coeff.		95% CI			Coeff.		95% CI		
Variable	(β)	p	Lower	Upper	Exp. β	(β)	p	Lower	Upper	Exp. β	(β)	p	Lower	Upper	Exp. β
Age Group															
25-40 years (Ref)															
41-60 years	0.25461	0.001	0.104	0.4053	1.29	0.24634	<0.001	0.1641	0.3286	1.28	0.26172	0.001	0.1051	0.4184	1.30
61 years and older	0.20665	0.001	0.0918	0.3215	1.23	0.28733	<0.001	0.1844	0.3902	1.33	0.36542	<0.001	0.1874	0.5434	1.44
Sex = Female vs. Male (Ref)	0.15022	0.001	0.0625	0.2380	1.16	-0.03379	0.332	-0.1029	0.0353	0.97	-0.11735	0.062	-0.2410	0.0063	0.89
Race/Ethnicity															
Non-Hispanic White (Ref)															
Mexican-American	0.00996	0.842	-0.0894	0.1094	1.01	0.07708	0.089	-0.0120	0.1661	1.08	0.32320	0.017	0.0587	0.5877	1.38
Non-Hispanic Black	0.07394	0.128	-0.0218	0.1696	1.08	0.08725	0.006	0.0255	0.1490	1.09	0.22338	0.005	0.0689	0.3779	1.25
Nativity = Foreign Born vs. US Born (Ref)	-0.02807	0.695	-0.1707	0.1145	0.97	-0.19703	0.033	-0.3772	-0.017	0.82	-0.40345	0.002	-0.6585	-0.1484	0.67
Family Income Level															
Less than $20,000 (Ref)															
$20,000 - $64,999	-0.07006	0.255	-0.1919	0.0518	0.93	-0.09551	0.107	-0.2121	0.0211	0.91	-0.27440	0.068	-0.5693	0.0205	0.76
$65,000 or More	-0.21223	0.143	-0.4980	0.0736	0.81	-0.13319	0.055	-0.2693	0.0030	0.88	-0.50547	0.002	-0.8131	-0.1979	0.60
Marital Status															
Married (Ref)															
Divorced/Separated/Widowed	0.00618	0.906	-0.0979	0.1102	1.01	0.06421	0.092	-0.0107	0.1392	1.07	0.03033	0.739	-0.1506	0.2113	1.03
Never Married	0.01928	0.808	-0.1387	0.1772	1.02	-0.02556	0.614	-0.1265	0.0754	0.97	0.15831	0.132	-0.0490	0.3656	1.17
Cohabiting	-0.01698	0.864	-0.2144	0.1805	0.98	0.03413	0.645	-0.1134	0.1817	1.03	-0.12741	0.487	-0.4917	0.2369	0.88
Smoking															
Non-Smoker (Ref)															
Current Smoker	-0.03705	0.510	-0.1487	0.0746	0.96	0.06368	0.145	-0.0225	0.1499	1.07	0.12187	0.192	-0.0628	0.3066	1.13
Former Smoker	0.13547	0.006	0.0406	0.2303	1.15	0.07466	0.054	-0.0014	0.1507	1.08	0.13514	0.077	-0.0150	0.2853	1.14
Alcohol Consumption															

Non-Drinker (Ref)															
1 Drink per week	-0.04562	0.324	-0.1374	0.0462	0.96	-0.06983	0.035	-0.1346	-0.0050	0.93	-0.11222	0.135	-0.2602	0.0358	0.89
> 1 Drink per week	-0.12793	0.088	-0.2754	0.0195	0.88	-0.22267	<0.001	-0.3211	-0.1243	0.80	-0.36940	<0.001	-0.5147	-0.2241	0.69
<u>Period Effects</u>															
2003-2004 (Ref)															
2005-2006	0.11700	0.115	-0.0292	0.2632	1.12	0.13412	0.004	0.0443	0.2240	1.14	-0.04183	0.663	-0.2331	0.1494	0.96
2007-2008	0.15809	0.040	0.0076	0.3086	1.17	0.03749	0.510	-0.0757	0.1507	1.04	-0.35083	0.002	-0.5649	-0.1368	0.70
2009-2010	0.02208	0.799	-0.1505	0.1947	1.02	0.07855	0.127	-0.0230	0.1801	1.08	-0.32140	0.002	-0.5252	-0.118	0.73
Constant	0.44532	<0.001	0.2712	0.6195		0.49031	<0.001	0.3582	0.6224		0.68633	<0.001	0.4289	0.9438	
α	0.04828	<0.050	0.0189	0.1235		0.09931	<0.05	0.0709	0.1391		0.25112	<0.05	0.1792	0.3519	
Fit statistics:	DF=62					DF=62					DF=62				
	F(18,45)=4.13					F(18,45)=7.87					F(18,45)=7.63				
	p<0.0001					p<0.0001					p<0.0001				

[1]All figures and statistical tests were adjusted for complex survey design using SDMVPSU, SDMVSTRA, and WTSAF8YR variables.

[2]Adjusted for the covariates age, sex, race/ethnicity, nativity, marital status, family income, smoking, alcohol use, and period effects.

Figure 1. Distribution of allostatic load scores by race/ethnicity (Panel A) and educational attainment (Panel B).

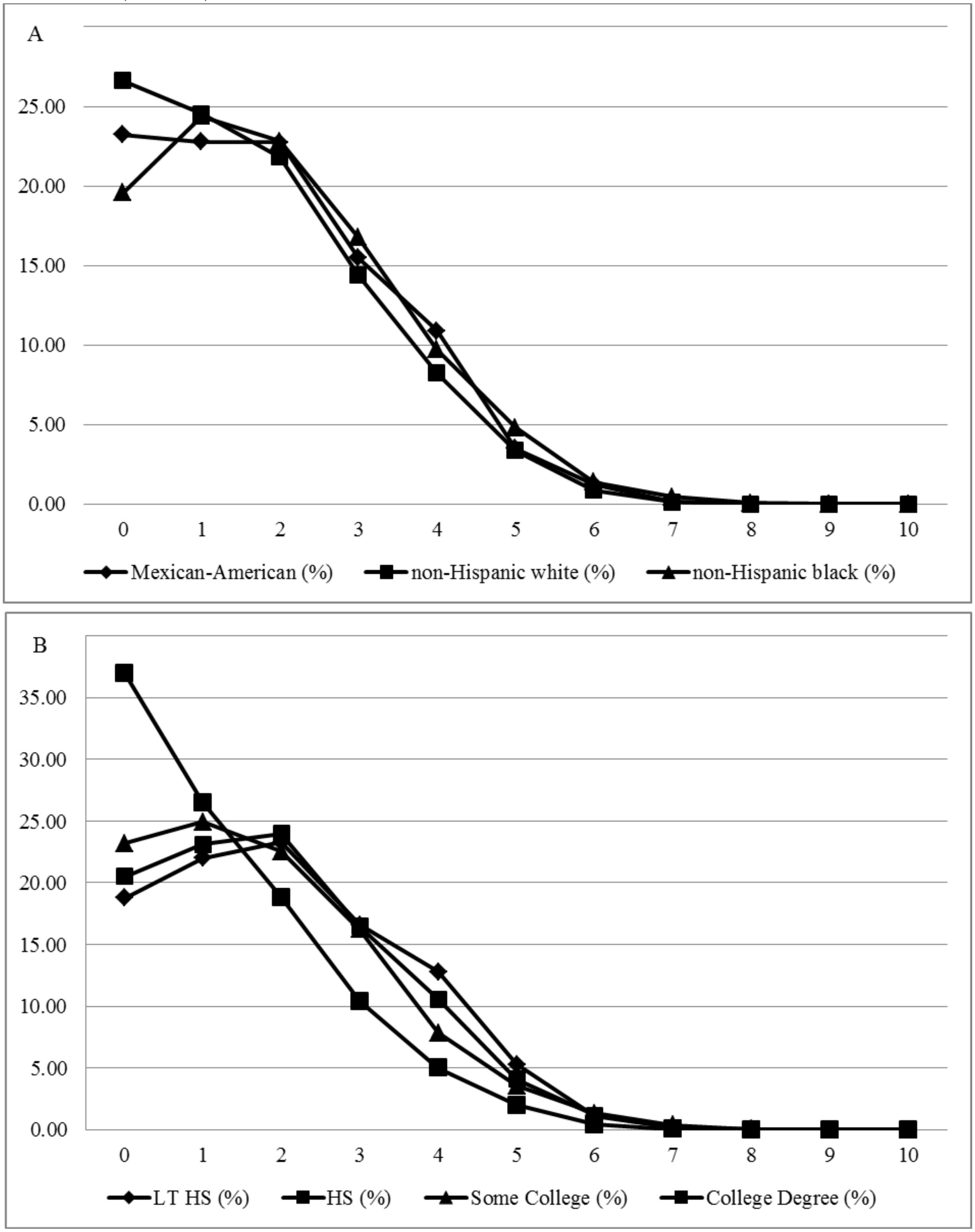

Figure 2. Effect of education on allostatic load by race/ethnicity, adjusted for age, sex, nativity, marital status, family income, smoking, alcohol use, and period effects.

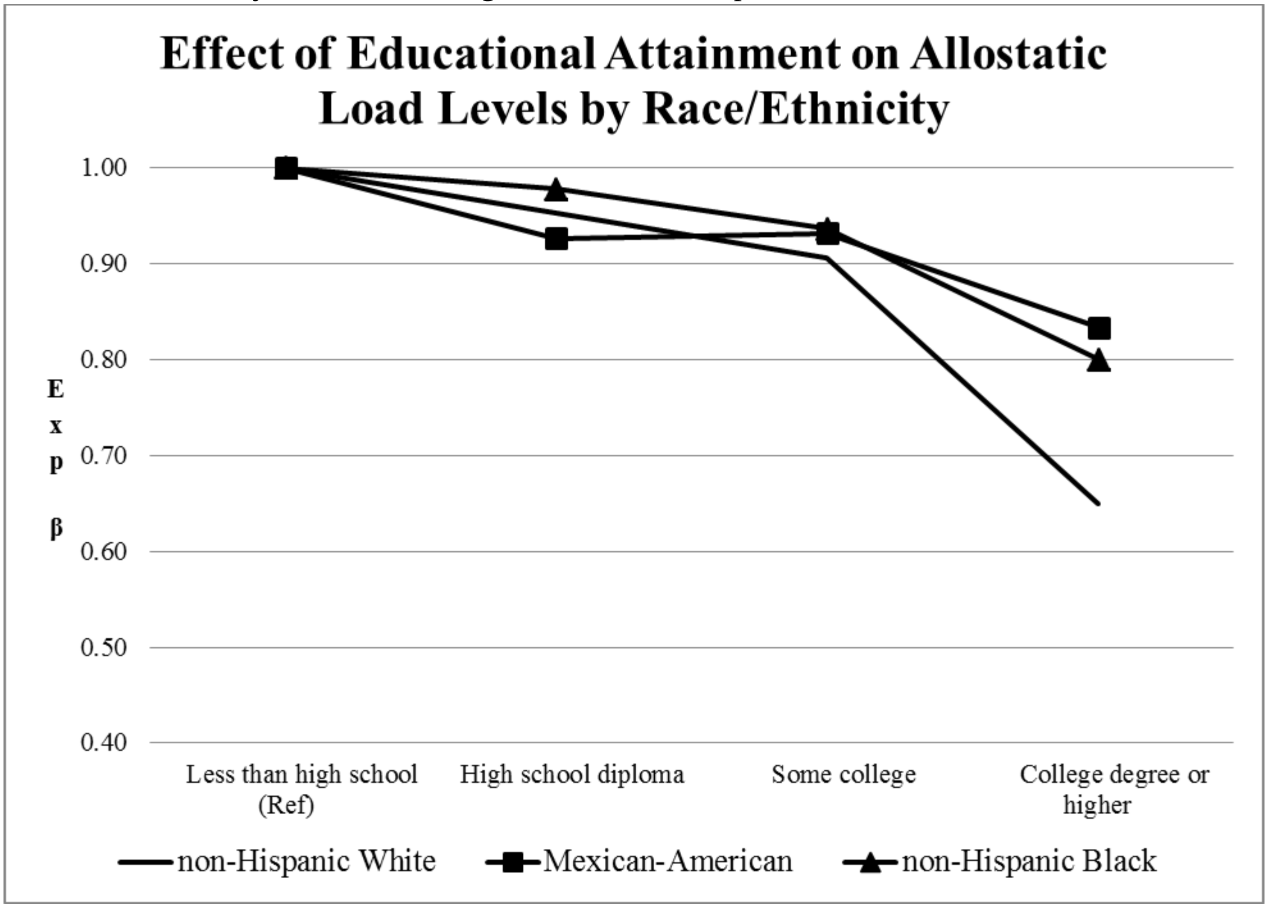

Figure 3. Racial/ethnic differences in allostatic load by educational attainment level, adjusted for age, sex, nativity, marital status, family income, smoking, alcohol use, and period effects.