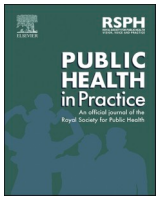
Public Health in Practice 6 (2023) 100425

Contents lists available at ScienceDirect

Public Health in Practice

journal homepage: www.sciencedirect.com/journal/public-health-in-practice



Allostatic load in the US general population: Race and educational intersection

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ARTICLE INFO

Keywords:
Educational attainment
Social determinants
Race
Allostatic load

ABSTRACT

Objectives: Educational attainment is a protective factor against poor health, but high educational attainment has a weaker effect on black people than on white people; this pattern has been called marginalization-related diminished returns (MDRs). Using a national sample of white people and black people 25 years and above, this study estimates the association between high educational attainment and allostatic load between black people and white people, and within each group.

Study design: This cross-sectional study uses data from the National Health and Nutrition Examination Survey (NHANES) between 1999 and 2016, including 2761 black people and 7058 white people. The outcome variable of interest was the Allostatic Load Scale (AL). We created the allostatic load scale by using 8 biomarkers, then created a binary variable (if ALS≥4 as 1 and ALS<4 as 0) to present elevated AL.

Methods: We used several weighted modified Poisson regression models controlling for educational attainment (a predictor) and race (a moderator variable), age, sex, and marital status. We also controlled the models for smoking and drinking status as health behavior variables. As a sensitivity analysis, we ran several sets of regression analysis using the AL scale as a continuous outcome variable.

Results: We found an inverse association between AL and educational attainment. The interaction between race and education has resulted in an inverse association between AL and educational attainment, with a weaker association in black people than in white people. We found similar findings by running regression models with AL as a continuous variable.

Conclusions: We observed a weaker association between educational attainment and AL in black people than in white people, suggesting that educational attainment has more robust protection against allostatic load for white people than black people.

1. Background

Educational attainment is one of the major social and economic factors that reduce the risk of adverse health outcomes [1–4]. There is a robust body of work showing the association between high educational attainment and improved health outcomes [5–8]. Individuals who obtain higher education are more likely to have better health literacy, to have better access to health resources, and better socioeconomic status [6] including higher pay, and better jobs [8,9]. Conversely, individuals with lower educational attainment are more likely to live in poverty [5], economic difficulty [6], have increased stress [7], have increased trauma [8], and to live in conflict [9,10]. Educational attainment and the benefits associated with it have been found to reduce exposure to stress [11–15]; yet, the extent to which this translates into protections concerning the consequences of chronic stress remains vastly under-addressed.

Allostatic load, an index of physiological dysregulation, reflects the "wear and tear" observed in the body following exposure to chronic stress [16,17]. Individuals who experience repeated exposure to stressful life events constantly experience an increase in allostatic load, which is associated with worse health outcomes [17].

Studies have shown that black people with high educational

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https://doi.org/10.1016/j.puhip.2023.100425
Received 12 April 2023; Received in revised form 26 August 2023; Accepted 5 September 2023
Available online 6 September 2023

attainment may still report high levels of stress [18–20], lower income and wealth [21], and limited access to health care [11]. Similarly, education is of lower quality in area with a higher proportion of black people [12]; thus, the return on education may also be weaker for black people than white people. Black people also tend to experience less health benefits from socioeconomic resources such as income and education compared to white people [22]. In addition, as high SES black people are likely to move to white neighborhoods, they may become more exposed and more sensitive to discrimination due to proximity to white people [13]. All these mechanisms suggest that the health returns of education may be smaller for black people than white people, and it is important to continue exploring whether the association between educational attainment and chronic stress differs by race.

Very little is known about racial variation in the association between educational attainment and allostatic load across diverse populations. The dearth of studies on race/ethnicity, educational attainment, and allostatic load have investigated as separate or additive effects of race/ethnicity and education; thus, we are unaware whether race/ethnicity moderates the association between SES and allostatic load. Most research shows that white people are less likely to have high allostatic load than black people [14], other studies have also shown that high educational attainment is associated with lower allostatic load [15]. An increase in allostatic load among black people is also seen as one of the mechanisms and indicators of racial health disparities between black and white peoples [14,16]. By understanding the mechanisms for such racial variation, policy and solutions may be proposed for a wider range of health inequalities, and such information may be useful for reducing health disparities [17].

Although there is some evidence regarding social determinants of allostatic load [23–26], there is a need to learn more about the impact of educational differences and AL. Knowing that stress is a risk factor for allostatic load, and as stress remains consistently high in the life course for black people [14,22,27], it is plausible to expect diminished returns of educational attainment on allostatic load for black people than for white people. Although knowledge regarding racial differentials in the association between SES and stress and health are overwhelming [28], there is still a need to study whether there are racial differences in the association between educational attainment and allostatic load, variation in the inverse association between educational attainment and allostatic load may have implications for public health practice, research, and policy. Such knowledge could potentially improve researchers' and public health experts' ability to reduce disparities in allostatic load in diverse groups of people. While knowledge is key to designing effective policies and practices, what protects communities of white people may not be equally protective for communities of color. Race and ethnic differences in exposures, vulnerabilities, and historical experiences may alter the relevance of educational attainment as a protective factor against elevated allostatic load in communities of color. In, this study we determined the racial variations in allostatic load and estimated the association between high educational attainment and allostatic load between white and black peoples.

2. Methods

2.1. Design and setting

This cross-sectional study was a secondary analysis of the National Health and Nutrition Examination Survey (NHANES) data. The analysis only used NHANES data from years between 1999 and 2016.

2.2. Sample

The NHANES included 25+ year old American adults to allow people time (in age) to complete their degrees. The NHANES studies enrolled adults from all US states. In the present study, we included only White Non-Hispanic (hereinafter "white people") and Black NH (hereinafter "black people"); Latino, Asian American, and other racial/ethnic groups were all excluded. We excluded other racial/ethnic groups such as Asian Americans and Native Americans and mixed-race for two reasons: (1) to reduce complexity due to measurement and conceptualization of race; (2) Before 2013, the NHANES reported Asian Americans and Native Americans and mixed-race as one category, and it may create bias in results. The NHANES reported them as Mexican American and other Hispanics; to avoid potential bias, we excluded this population as well. The study sample included 9820 (7473 white people and 2995 black people), after removing all missing values.

2.3. Outcome

Allostatic load was treated as a binary outcome. Using the approach suggested by Chyu and Upchurch (2011), we created the allostatic load scale by using 8 biomarkers, including the following: systolic blood pressure (mm Hg), diastolic blood pressure (mm Hg), pulse rate (beats/min), body mass index (kg/m2), glycohemoglobin (%), direct HDL-cholesterol (mg/dL), total cholesterol (mg/dL), and serum albumin (g/dL) [29]. We defined biomarkers with values above the 75th percentile as high risk except for HDL and serum albumin; for those two variables, the values below the 25th percentile were defined as high risk [30]. The included biomarkers provide some clinical measures for cardiovascular, metabolic, and inflammatory markers but will not incorporate neuroendocrine mediators [29]. This approach has been used previously [31]. The literature has reported differences in morbidity and mortality when allostatic load scales reached above 3 or 4, so we used the cut point (AL$\geq$4) that has been used widely; the binary variable sowed the "elevated AL" (if ALS$\geq$4 as 1) [32–37]. We used this binary variable to run the modified Poisson regression models.

2.4. Education

Our key variable of interest is educational attainment. In the NHANES, educational attainment is collected as 'less than 9th grade', '9-11th drade (includes 12th grade with no diploma)', 'high chool grad/GED or equivalent', 'some college or associate in arts (AA) degree' and 'college draduate or above'. This variable was included in our analyses as a four-level categorical variable indicating the highest level of education reached by respondents. The four possible levels were: 'Less than a high school diploma', 'high school diploma/GED', 'some college or AA degree', and 'college degree or higher'.

2.5. Race

In the NHANES, race and ethinciy are reported as Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Other Race - Including Multi-Racial before 2011. After 2011, Non-Hispanic Asian was added to the race and ethnicity category. For this analysis, we included white people and black people. Black people were coded as 1 and white people were coded as 0. As such, the interaction term was indicative of the difference in the return of educational attainment for black people compared to white people.

2.6. Demographic characteristics and health behaviors

Our models considered the role of other demographic characteristics and health behaviors in chronic stress by accounting for these characteristics within the empirical models. Covariates included age, sex, and marital status. Sex was collected by self-report indicating respondent's gender. Men were coded as 1 and women were coded as 0. Age was included in the NHANES as a continuous variable indicating age at the time of interview. We recoded age as a categorical variable with four possible levels: 25–35, 35–50, 50–64, 65+. Marital status was collected by NHANES as married, widowed, divorced, separated, never married, and living with partner. For this analysis, we recoded married and living

with partner as married and other marital status as a reference group. Finally, the NHANES collected data on smoking as smoke every day, some day, and smoked at least 100 cigaretts in life, we recoded the smoking stats as never, current, and former. The NHANES collected data on Alcohol consumption as "had at least 12 alcohol drinks/1 year?", "had at least 12 alcohol drinks/lifetime?", and "how often drink alcohol over past 12 months", using thse information we created a categorical variable to show the driniking status as never, current, or former.

2.7. Data analysis

We used descriptive analyses to compare outcome and independent variables. We used *t*-test and chi-square to test significant differences between white people and black people. Because the AL's dichotomas variable was greater than 10% in this sample, we ran several sets of modified Poisson regression models uisng the dichotomous AL variable to report the Prevalance Ratio [38–40].

The first two modified possion regression models were fitted to the pooled sample in the absence and presence of educational attainment by race interaction terms. The first model was a very basic model by including race, education, and year. In Model 2, we controlled for sex, age, marital status, smoking, drinking behaviors, and year. In Model 3, an interaction term was the multiplicative product of race (=1, black people, = 0, white people) and educational attainment. Because the interaction between race and education was significant ($p < 0.001$), we stratified the model by race. As income, health, and behaviors may be the mechanisms that explain why education correlates differently with allostatic load across groups, we did not control for a wide range of mediators or confounders such as trauma, income, etc., to control over-adjustment [41]. However, we controlled for age, sex, marital status, smoking, drinking behaviors, and year.

Before we estimated our models, we ruled out multicollinearity between the study variables. After pooling sample models, we reported the modified Poisson regressions that were stratified by race/ethnicity. We reported the Prevalence Ratio (PR) and weighted Standard Errors (SE).

As a sensitivity analysis, by using the AL scale as a continuous variable, we ran the above-mentioned models. All analyses were weighted using the NHANES individual-level sampling weights for 1999–2016 (NHANES, 2018). We considered all p-values <0.05 as statistically significant, and all tests were two-sided. All statistical procedures were performed using STATA statistical software, version 15.

3. Results

3.1. Descriptive data overall

The present study included 2995 black people and 7473 white people 25 years old or older. The distribution of characteristics by race is compared in Table 1. Black people had a lower percentage of males than white people, with a lower proportion of the population 50+ and a lower percentage of married people than black people. White people had a higher proportion of college and above and a lower proportion of no-diploma than black people, but black people had a higher proportion of high school diplomas and some college or AA degrees than white people. Black people were more likely to be current smokers but less likely to be current drinkers than white people.

Table 2, presents the distribution of AL scales and individual biomarkers between black people and white people. We observed significant differences in all eight elements except pulse rate ($p = 0.650$) between black people and white people. Black people had a higher prevalence of AL scale when compared to white people (3.3. vs. 2.9, $p < 0.001$). Black people also had a higher prevalence of elevated AL (43.4% vs. 332%, $p < 0.001$).

3.2. Distribution of elevated AL between black people and white people

Table 3 compares the distribution of elevated AL between black and white peoples. As presented, elevated AL (AL≥4) was significantly higher in black people than in white people regardless of any characteristics. More specifically, black people experienced higher prevalence of elevated AL in all education's degrees except for college degree, which black people had lower elevated AL than white people (37.6 vs. 37.8, p < 0.001). Fig. 1, plots this distribution by educational categories between black and white peoples.

Table 1
Descriptive data of black people and white people 25 years and older in National Health and Nutrition Examination Surveys 1999–2016.

	All (n = 9820)		Black people (n = 2761)		White people (n = 7058)		
	Mean/%	SD[a]	Mean/%	SD	Mean/%	SD	*p*-value
Sex (if male)	48.6	(39.3)	45.4	(57.4)	49.1	(35.7)	<0.001
Age categories (%)							
25-34	18.3	(30.4)	24.1	(49.3)	17.5	(27.1)	0.001
35-49	31.7	(36.6)	35.5	(55.2)	31.1	(33.1)	
50-65	28.9	(35.7)	27.1	(51.2)	29.2	(32.5)	
65+	21.1	(32.1)	13.3	(39.1)	22.2	(29.7)	
Marital status (%)							
Married[b]	68.9	(36.4)	48.5	(57.6)	71.8	(32.1)	<0.001
Education (%)							
Less than high school or 9- 11th grade but not diploma	13.7	(27.0)	23.4	(48.8)	12.3	(23.4)	<0.001
High school graduate/GED[c]	24.6	(33.9)	25.7	(50.4)	24.4	(30.7)	
Some college or Associate in Arts (AA) degree	31.0	(36.4)	32.2	(53.8)	30.8	(33.0)	
College graduate or above	30.8	(36.3)	18.7	(45.0)	32.5	(33.4)	
Smoking							
Never	49.4	(39.3)	57.2	(57.0)	48.3	(35.7)	<0.001
Former	28.8	(35.6)	16.8	(43.1)	30.5	(32.9)	
Current	21.8	(32.5)	25.9	(50.5)	21.2	(29.2)	
Drinking							
Never	11.1	(24.7)	16.8	(43.1)	10.3	(21.7)	<0.001
Former	11.6	(25.2)	17	(43.3)	10.8	(22.1)	
Current	77.4	(32.9)	66.2	(54.5)	79	(29.1)	

Notes: A) The Percentages were weighted to the population of US adults aged 25 years or older. B) *P*-values report the results of chi-square tests for black people and white people.

[a] Standard Deviation (SD).

[b] We defined marital status as married (=1), and not married (=0, if not married including divorced, separated, never married, and living with a partner).

[c] GED: high school equivalency diploma.

Table 2
Distribution of individual biomarkers and Allostatic Load Status in Black People and White People in the National Health and Nutrition Examination Surveys 1999–2016.

	All (n = 9820)		Black people (n = 2761)		White people (n = 7058)		Black people vs. White people
Cardiovascular markers (%)	Mean	SD[a]	Mean	SD	Mean	SD	*p*-value[b]
Blood pressure, systolic (mm Hg)	124.5	(14.0)	128.4	(22.3)	123.9	(12.5)	<0.001
Blood pressure, diastolic (mm Hg)	71.3	(9.9)	72.9	(16.1)	71.0	(8.9)	<0.001
Pulse rate (beats/min)	71.9	(9.5)	71.5	(13.9)	71.9	(8.6)	0.650
Metabolic markers (%)							
Body Mass Index (kg/mˆ2)	29.5	(5.3)	31.2	(8.9)	29.2	(4.7)	<0.001
Glycohemoglobin (%)	5.6	(0.7)	5.9	(1.5)	5.6	(0.6)	<0.001
Direct HDL-Cholesterol (mg/dL)	53.6	(13.2)	56.1	(19.8)	53.2	(11.9)	<0.001
Total Cholesterol (mg/dL)	201.9	(33.7)	195.5	(49.1)	202.8	(30.5)	<0.001
Inflammatory markers (%)							
Serum Albumin (g/dL)	4.2	(0.3)	4.1	(0.4)	4.3	(0.2)	<0.001
Allostatic Load Scale	2.9	(1.2)	3.3	(1.8)	2.9	(1.0)	<0.001
Elevated Allostatic Load[c]	33.2	(37.0)	43.4	(57.5)	31.7	(33.1)	<0.001

Notes. a) SD: Standard Deviation. b) p-value reports Adjusted Wald test results. c) Allostatic load scale computed as sum of all markers, existence of a condition considered as 1 and otherwise 0. Values above the 75th percentile were defined as high risk for all the biomarkers, with the exception of HDL and serum albumin, for which values below the 25th percentile were defined as high risk. Elevated AL was based on those men who had 4 or more biomarker considered to be high risk.

Table 3
Association between educational attainment and elevated allostatic load in black people and white people 25 years and above in the National Health and Nutrition Examination Survey (NHANES, 1999–2016).

	Model 1 Basic Model (n = 9820)		Model 2 Basic Model (n = 9820)		Model 3 (n = 9820)		Model 4 (n = 9820)	
	PR[a]	SE[b]	PR	SE	PR	SE	PR	SE
Education (Ref. Less than high school)								
High school graduate/GED[c]	0.972	(0.047)	0.995	(0.048)	1.004	(0.048)	0.982	(0.056)
Some college or Associate in Arts (AA) degree	0.853**	(0.046)	0.874*	(0.047)	0.891*	(0.048)	0.871*	(0.056)
College graduate or above	0.611***	(0.033)	0.635***	(0.034)	0.658***	(0.038)	0.628***	(0.041)
Black people (*Ref.* White people)	NA		1.293***	(0.041)	1.295***	(0.043)	1.180*	(0.077)
Age categories (*Ref.* 25–34 year)								
35–49 year	NA		NA		1.704***	(0.112)	1.702***	(0.112)
50–64 year	NA		NA		2.040***	(0.129)	2.043***	(0.129)
65+ year	NA		NA		1.785***	(0.117)	1.786***	(0.117)
Male (*Ref.* Female)					0.961	(0.034)	0.962	(0.034)
Smoking (*Ref.* Never)								
Former	NA		NA		1.006	(0.041)	1.005	(0.041)
Current	NA		NA		0.939	(0.043)	0.938	(0.043)
Drinking (*Ref.* Never)								
Former	NA		NA		1.037	(0.063)	1.036	(0.063)
Current	NA		NA		0.822***	(0.044)	0.824***	(0.045)
Married	NA		NA		0.932*	(0.033)	0.932*	(0.033)
Interaction Race and Education								
Black people with high school graduate/GED	NA		NA		NA		1.086	(0.092)
Black people with Some college or Associate in Arts (AA) degree	NA		NA		NA		1.083	(0.097)
Black people with College graduate or above	NA		NA		NA		1.322**	(0.134)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Notes. NA: Not applicable
[a] Prevalence Ratio after running a modified Poisson regression.
[b] SE: Weighted Standard Error.
[c] GED: high school equivalency diploma. d) NA: Not Applicable.

3.3. Pooled sample models

In the pooled sample and the absence of interaction, educational attainment for people with more than high school was inversely associated with allostatic load.

As presented in Table 3, in Model 1, we found respondents with some college or AA and those with a college degree or higher had a lower prevalence ratio of elevated AL by 0.780 (SE: 0.047) and 0.625 (SE: 0.034), respectively. In Model 2, we incorporated race; black people have higher prevalence ratio of elevated AL (OR = 1.303, SE: 0.042). Still, respondents with some college or AA and those with a college degree or higher had a lower prevalence ratio of elevated AL. In Model 3, we added sex, age, marital status, smoking, and drinking to Model 2. We observed no significant changes in black people; however, the significant association for respondents with some college or AA had faded. Still, people with a college degree or higher had a lower prevalence ratio of elevated AL by 0.639 (SE: 0.041). Also, we found that, compared to younger adults 25–34 years old, older adults 50+ old and over suffered more from elevated AL, and current drinkers (PR = 0.854, SE: 0.047) and married people (PR = 0.926, SE: 0.033) had lower PRs of elevated AL.

In Model 4, we interacted with race and educational attainment. We found that black people with college degrees or higher had higher PRs of elevated AL by 1.333 (0.137).

3.4. Race-specific models

As the interaction between education and race was significant ($p <$

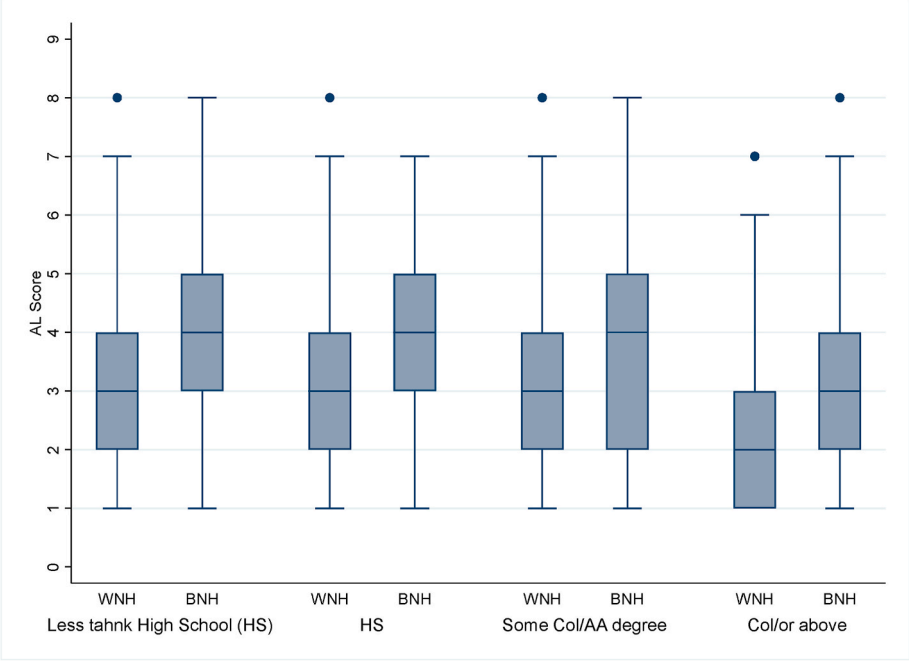

Fig. 1. Comparing AL scale among racial groups with different education attainment.
(Note: HS: High School; Col. College, AA, Associate in Arts).

0.001), we stratified the analyses by race. We found that high educational attainment was associated with lower allostatic load for white people (PR: 0.780, SE: 0.145) but not for black people. Similar to Model 4, we found age as a predictor for high ALS in black people and in white people. See Table 4.

3.5. Sensitivity analysis

Appendices 2 and 3 report the regression analysis results using the AL scale as a continuous variable. The findings support the results of the original analysis; for example, we found a negative association between the AL scale in respondents with 'some college or AA' and those with a 'college degree or higher' in all models. We found that race and age are two other predictors of the AL scale, and drinking alcohol (current drinker) and marital status were negative predictors of the AL scale. Similar to the original analysis, we found that black people with college degrees or higher had a higher coefficient of AL scale by 0.285 (SE: 0.125, $p < 0.05$). See Appendix 2 for more details. The stratified model by race results was in the same direction as the original analysis. See Appendix 3 for more details.

Table 4
Association between educational attainment and elevated allostatic load in black people and white people 25 years and above in the National Health and Nutrition Examination Survey (NHANES, 1999–2016).

	Black people (n = 2761)		White people (n = 7058)	
	PR[a]	SE[b]	PR	SE
Education (Ref. Less than high school)				
High school graduate/GED[c]	1.076	(0.073)	0.985	(0.057)
Some college or AA degree	0.932	(0.065)	0.877*	(0.056)
College graduate or above	0.800*	(0.076)	0.635***	(0.042)
Age categories (Ref. 25–34 year)				
35–49 year	1.534***	(0.125)	1.757***	(0.148)
50–64 year	1.925***	(0.150)	2.092***	(0.170)
65+ year	1.857***	(0.146)	1.807***	(0.148)
Male (*Ref.* Female)	0.776***	(0.038)	1.000	(0.041)
Smoking (Ref. Never)				
Former	0.922	(0.049)	1.02	(0.047)
Current	0.836**	(0.057)	0.965	(0.054)
Drinking (Ref. Never)				
Former	1.062	(0.077)	1.027	(0.080)
Current	0.971	(0.062)	0.795**	(0.055)
Married	1.012	(0.046)	0.919*	(0.038)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Notes: a) Prevalence Ratio after running a modified Poisson regression. b) SE: Weighted Standard Error. c) GED: high school equivalency diploma. d) NA; Not Applicable.

4. Discussion

The purpose of this study was to assess AL among black people and white people 25+ years old and how educational attainment moderates the allostatic load scale between them. Our results confirmed the trends in the literature which conclude that black people experienced a higher prevalence of AL than white people with the same level of education [33,42]. At the same time, our findings showed that in black people education was as protective as in white people, and among college graduates, black people had a higher AL than white people (PR: 1.322, SE: 0.134, $p < 0.01$). The literature has shown that access to education is a protective factor for health outcomes as individuals who have educational opportunities are more likely to have better options in life—better employment opportunities, better-paid jobs, access to health care services, and are less likely to have constant stressful events—that might lead to increased levels of allostatic load [1–10,17,23,24]. We explored racial/ethnic variations in the association between high educational attainment and low levels of allostatic load in US adults. In a national sample of black people and white people over 25 years old, race and educational attainment showed interdependent (interactive) rather than additive effects on the level of allostatic load.

The present study established the differential association between high educational attainment and low allostatic load among black people and white people. Studies have shown differences between white people and black people in risk and protective factors that correlate with health, depression [43], obesity [44], and stress [45]. In addition to educational attainment, income, and other SES indicators have also shown weaker effects for black people than for white people [43].

The protective effect of high educational attainment against high levels of allostatic load was found to be stronger for white people than

for black people in the US. The observation that educational attainment had a more salient protective and preventive role in reducing the allostatic load for white people than for black people was in line with the Marginalization-Related Diminished Returns or minorities' diminished returns (MDRs) framework [46], suggesting that individual-level protective social determinants, particularly educational attainment, have systematically weaker health effects for black people than for white people.

MDRs emerge because of racism, segregation, and social stratification: Health outcomes of black people deteriorate due to the influence of contextual factors that may reduce their healthy choices and individual-level SES variations. Under racism, black people continue to experience high stress levels, regardless of their education or income [17]. Extensive work on the MDRs phenomenon has shown worse-than-expected health of middle-class black people across studies, age groups, outcomes, and settings [47]. As a result of MDRs, the same change in SES results in smaller changes in health outcomes in black people than in white people communities. Racism, stratification, and segregation are all argued to limit the return of education for Black communities [48].

Research-based knowledge that informs us on how black people and white people differ in the risk and protective factors of allostatic load may have implications for the prevention, detection, diagnosis, and treatment of chronic diseases. The high allostatic load may have a role in the physiopathology of chronic diseases for racially diverse groups. Researchers, clinicians, and practitioners should be aware that one size does not fit all, and these heterogeneities require policies that address the needs of middle-class black people.

Structural racism [49] creates an environment that increases disparities. Structural racism can be highlighted through segregation and economic and employment gaps [50,51], income [52], and wage disparities [53]. Long-standing structural racism proliferates social and health inequities that are reflected in this black people-white people disparity [50]. Many other elements directly and indirectly influence racial differences and, consequently, illness. The political economy of mortgage markets and its impact on the socioeconomic status of a household, lobbying [54], rent-seeking [54], etc., are some examples of structural inequality. The Nobel Prize Economists believe that those at the very top level of income" are plundering the poor and the middle classes […] by lobbying, by rewriting the rules […], by rewarding, and being rewarded by their cronies in business and in government." [54,55].

As our findings suggested, educational attainment may be more relevant to white people' than black people' allostatic load. It is essential to tailor our diagnostic programs and health services for racial and ethnic groups simply because racial and ethnic differences exist in social and health correlates [56].

4.1. Strengths and limitations

The present study has a few strenghts that need to be noticed. Based on our knowledge, this is the first study with a wide range of data between 1999 and 2016 to examine the relationship between ALS and educational attainment, with a nationally representative data, with well-powered sample sizes for black people and white people. Additionally, we used the ALS as a composite measure of clinical strssors that has been used widely. Finally, by weighting the analyses, we made our findings nationally representative estimates. There are a few aspects of this study that need moee clarifications. First, this study was limited because of its cross-sectional design, which means we were unable to draw causal inferences. The second limiting factor was the lack of covariates at the neighborhood level and the lack of a measure of stress. Environmental factors such as neighborhood poverty and toxins may also correlate with both SES and allostatic load. However, we carefully limited our covariates to avoid over-adjustment [57]. Finally, there is no agreement on including patients' medication therapy on computing AL; thus, we have not considered using some specific medication that may affect biomarker values (such as using anti-hypertensives), and AL scale.

4.2. Future directions

There is a need for future studies on other racial and ethnic minorities and within subgroups of black people, a large sample of black immigrants is needed to address the subgroup heterogeneity in health; it has been highlighted in the literature [58]. Future research should also consider within-race heterogeneity in Black Americans. Experiences and exposures of US-born and immigrant Black Americans are widely different. There is also a need to conduct studies with longitudinal design and change in allostatic load over time. Finally, by having access to restricted NHANES data, future studies may consider the influence of neighborhood characteristics and allostatic load.

5. Conclusion

While highly educated white people are protected against high allostatic load, highly educated black people remain at risk of high allostatic levels even after controlling for age, sex, smoking and drinking. This paradox—also known as black people' diminished returns—may reflect structural racism in the US.

Author contributions

Conceptualization, Shervin Assari; Data curation, Hossein Zare; Formal analysis, Hossein Zare; Funding acquisition, Hossein Zare; Methodology, Hossein Zare and Shervin Assari; Project administration, Babak Najand and Adriele Fugal; Resources, Babak Najand, Adriele Fugal and Shervin Assari; Software, Hossein Zare; Supervision, Hossein Zare and Shervin Assari; Validation, Shervin Assari; Writing – original draft, Shervin Assari, Hossein Zare, and Babak Najand; Writing – review & editing, Hossein Zare, Adriele Fugal and Shervin Assari.

Presence of declarations and ethics and consent statements

Our study did not require ethical board approval because no identifiable private information or identifiable biospecimens was accessed.

Funding

Author HZ is supported by the NIMHD U54MD000214.

Institutional review board statement

Not applicable.

Informed consent statement

Not applicable.

Data availability statement

Data available at: https://wwwn.cdc.gov/nchs/nhanes/

Declaration of competing interest

The Author(s) declare(s) that there is no conflict of interest.

Appendix 1. Descriptive statistics of the probability of having elevates AL (ALS ≥4) in Black and White adults 25 years and above in the National Health and Nutrition Examination Survey (NHANES, 1999–2016)

	All (n = 9820)		Black people (n = 2761)		White people (n = 7058)		Black pepople vs. white people
	%	SE[a]	%	SE	%	SE	*p*-value[b]
Sex							
Male	31.3	(0.8)	34.15	(1.4)	30.4	(0.9)	<0.001
Female	35.2	(0.9)	45.4	(1.3)	33	(1.0)	0.000
Age categories (%)							
25-34	18.9	(1.1)	27.2	(1.8)	17.2	(1.3)	<0.001
35-49	32.4	(1.2)	41.6	(2.0)	30.7	(1.3)	<0.001
50-65	39.2	(1.2)	53.2	(1.7)	37.2	(1.3)	<0.001
65+	36.6	(1.0)	53.2	(2.0)	35.1	(1.1)	<0.001
Marital status (%)							
Married	31.3	(0.8)	42.9	(1.7)	30.7	(0.8)	<0.001
Race/Ethnicity (%)							
% White people	31.7	(0.7)	–	–	31.7	(0.7)	–
% Black people	43.4	(1.1)	43.4	(1.1)	–	–	–
Education (%)							
Less than high school or 9–11th grade but not diploma	39.3	(1.4)	44.7	(2.4)	37.8	(1.7)	<0.05
High school graduate/GED[c]	38.5	(1.2)	47.2	(2.0)	37.2	(1.4)	<0.001
Some college or AA degree	34.2	(1.1)	42.6	(1.9)	28.2	(0.9)	<0.001
College graduate or above	24.6	(1.0)	37.6	(2.3)	37.8	(1.7)	<0.001
Smoking							
Never	33.2	(0.8)	45	(1.4)	31.1	(1.0)	<0.001
Former	34.1	(1.1)	46.3	(2.1)	33.1	(1.1)	<0.001
Current	32.1	(1.1)	37.8	(2.3)	31.1	(1.2)	<0.01
Drinking							
Never	39.7	(1.6)	46.8	(2.5)	37.9	(2.0)	<0.005
Former	43.7	(1.6)	51.2	(2.6)	42	(1.9)	<0.001
Current	30.6	(0.7)	40.3	(1.4)	29.4	(0.8)	<0.001

Notes: a) SE: weighted Standard Error. b) *P*-values report the results of chi-square tests for black people and white people. c) GED: high school equivalency diploma.

Appendix 2. Association between educational attainment and allostatic load scale in black people and white people 25 years and above in the National Health and Nutrition Examination Survey (NHANES, 1999–2016)

	Model 1 Basic Model (n = 9820)		Model 2 Basic Model (n = 9820)		Model 3 (n = 9820)		Model 4 (n = 9820)	
	Coeff.[a]	SE[b]	Coeff.	SE	Coeff.	SE	Coeff.	SE
Education (Ref. Less than high school)								
High school graduate/GED[c]	−0.094	(0.058)	−0.06	(0.058)	−0.039	(0.056)	−0.064	(0.064)
Some college or AA degree	−0.208**	(0.064)	−0.174**	(0.063)	−0.132*	(0.062)	−0.151*	(0.071)
College graduate or above	−0.584***	(0.059)	−0.530***	(0.058)	−0.464***	(0.058)	−0.503***	(0.065)
Black NH (Ref. White NH)	NA[d]		0.387***	(0.040)	0.403***	(0.041)	0.295***	(0.084)
Age categories (Ref. 25–34 year)								
35–49 year	NA		NA		0.507***	(0.054)	0.507***	(0.054)
50–64 year	NA		NA		0.782***	(0.050)	0.783***	(0.050)
65+ year	NA		NA		0.675***	(0.052)	0.675***	(0.051)
Male (Ref. Female)					−0.01	(0.038)	−0.008	(0.038)
Smoking (Ref. Never)								
Former	NA		NA		0.033	(0.041)	0.033	(0.041)
Current	NA		NA		−0.042	(0.053)	−0.042	(0.053)
Drinking (Ref. Never)								
Former	NA		NA		0.053	(0.082)	0.053	(0.083)
Current	NA		NA		−0.244***	(0.071)	−0.241***	(0.072)
Married	NA		NA		−0.093*	(0.039)	−0.093*	(0.039)
Interaction Race and Education								
Black people with high school graduate/GED	NA		NA		NA		0.119	(0.108)
Black people with Some college or AA degree	NA		NA		NA		0.068	(0.112)
Black people with College graduate or above	NA		NA		NA		0.285*	(0.125)
N	**9820**		**9820**		**9820**		**9820**	

*p < 0.05, **p < 0.01, ***p < 0.001.

Notes: a) Coeff. Report coefficient after weighted regression model b) SE: Weighted Robust Standard Error. c) GED: high school equivalency diploma. d) NA: Not Applicable.

Appendix 3. Association between educational attainment and allostatic load in black people and white people 25 years and above in the National Health and Nutrition Examination Survey (NHANES, 1999–2016)

	Black people (n = 2761)		White people (n = 7058)	
	Coeff.	SE	Coeff.	SE
Education (Ref. Less than high school)				
High school graduate/GED	0.035	(0.031)	−0.06	(0.065)
Some college or AA degree	−0.03	(0.031)	−0.144*	(0.071)
College graduate or above	−0.095*	(0.040)	−0.492***	(0.066)
Age categories (Ref. 25–34 year)				
35–49 year	0.146***	(0.027)	0.491***	(0.063)
50–64 year	0.256***	(0.026)	0.760***	(0.058)
65+ year	0.240***	(0.028)	0.653***	(0.059)
Male (*Ref.* Female)	−0.108***	(0.020)	0.025	(0.044)
Smoking (Ref. Never)				
Former	−0.039	(0.025)	0.051	(0.044)
Current	−0.076**	(0.028)	−0.017	(0.061)
Drinking (Ref. Never)				
Former	0.03	(0.035)	0.029	(0.099)
Current	−0.015	(0.029)	−0.280**	(0.085)
Married	0.004	(0.020)	−0.104*	(0.045)

*p < 0.05, **p < 0.01, ***p < 0.001.

Notes: a) Coeff. Report coefficient after weighted regression model b) SE: Weighted Robust Standard Error. c) GED: high school equivalency diploma.

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