

THE ASSOCIATION BETWEEN ETHNICITY AND ALLOSTATIC LOAD: FINDINGS
FROM THE 2017-2018 NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY

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Abstract

Background: The lived experience of ethnicity is a source of psychosocial stress.

Objectives: Estimate the association between ethnicity and allostatic load (AL) by measuring the physiological cost of prolonged stress response, reflected in measurable cardiovascular, metabolic, and immune system acclimating changes.

Methods: Adult participants were selected from the National Health and Nutrition Examination Survey (NHANES) 2017-2018 survey cycle and categorized into four ethnic groups: White, African-American (AA), Mexican-/Hispanic-American (MHA), and Asian-American (AsA). AL was calculated using 10 biomarkers representing the regulatory status of cardiovascular, metabolic, and immune systems. Poisson regression analyses produced age-education-adjusted prevalence ratios (PRs) of AL stratified by gender, and age-adjusted PRs stratified by both gender and education.

Results: Adjusting for age and education, AA women had the highest PRs (1.59) in the study, and AsA men had the highest PR (1.4) among men. Stratifying by both gender and education, highlighted the heterogeneity of effect that educational attainment has on the AL of each ethnicity by gender.

Conclusions: Complex relationships exist between gender, ethnicity, education, and allostatic load that underscore the extensive impact of social disparities on health and socioeconomic security, and highlight the need for disaggregation of ethnic subgroups to better understand these relationships.

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List of Abbreviations

A1C / HbA1c	Glycosylated hemoglobin
AA	Non-Hispanic Black
AL	Allostatic load
ALB	Albumin
AsA	Non-Hispanic Asian
BMI	Body mass index
CDC	Centers for Disease Control and Prevention
CI	Confidence interval
CRP	C-reactive protein
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
ER	Endoplasmic reticulum
FPL	Federal poverty level
HbA1c / A1C	Glycosylated hemoglobin
HDL	High-density lipoproteins
HPA	Hypothalamic-pituitary-adrenal
IR	Insulin resistance
MHA	Mexican-American/other Hispanic
NCD	Non-communicable disease
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
PLS	Pulse rate
PR	Prevalence ratio
SAM	Sympathetic-adrenal-medullary
SBP	Systolic blood pressure
SES	Socioeconomic status
TC	Total cholesterol
TG	Triglycerides
UPR	Unfolded protein response
White	Non-Hispanic White
WHR	Waist-to-hip ratio
YLD	Years lived with disability

Introduction

Chronic stress has been implicated in the development of several non-communicable diseases (NCDs)¹⁻³. In 2017, NCDs accounted for over 41 million deaths and 678 million years lived with disability (YLD) globally, of which, more than 2.5 million deaths and 41 million YLD occurred in the United States⁴. High body mass index (BMI), poor diet, high blood pressure, and high fasting plasma glucose level are risk factors associated with NCDs such as cardiovascular disease (CVD), chronic kidney disease, and diabetes. In 2017 these NCDs were collectively responsible for 37% of deaths and 5.4 million YLDs in the U.S.⁴. In the U.S., NCDs accounted for over \$1.2 trillion in treatment costs in 2013⁵.

The capacity to adapt to stressors through physiological and behavioral responses is key to survival⁶. These responses are indeed beneficial when activated for short durations. However, prolonged activation of the stress response comes at a cost and can result from psychosocial challenges over the life course^{6,7}. Extensive activation of the hypothalamic-pituitary-adrenal (HPA) and sympathetic-adrenal-medullary (SAM) axes are primary mediators between chronic social stress and pathological changes in physiology⁶⁻⁸. Allostatic load (AL) is the physiological cost of prolonged stress response and has been associated with mitochondrial dysfunction mediated by chronic activation of acclimating processes over time⁹. AL is reflected in acclimating changes of cardiovascular, metabolic, and immune systems¹⁰. Long-term activation of the HPA and SAM axes has been implicated in endoplasmic reticulum (ER) stress and impairment of the unfolded protein response (UPR)^{9,11-14}. The ER is the site of protein synthesis and folding¹². ER stress can occur when demands for protein synthesis result in protein mutations or exceed ER capacity to properly fold synthesized proteins¹². The UPR is a series of signaling pathways in response to ER stress to restore homeostasis¹². However, in the presence of chronic or severe ER stress, the UPR may result in inflammatory signaling and/or initiation of

cell death via apoptosis¹⁵. UPR and ER stress are associated with insulin resistance (IR), inflammation, and apoptotic cell death, all factors related to dysregulation in cardiovascular, metabolic, and immune systems^{11,12,16-18}. Dysregulation of these systems are reflected in several biomarkers.

Numerous studies have used biomarkers to measure the physiological effects of chronic stress in terms of allostatic load¹⁹. Blood pressure, cholesterol, and triglycerides are among cardiovascular measures. Glycosylated hemoglobin (HbA1c), BMI, waist-to-hip ratio, and albumin are among metabolic measures. C-reactive protein (CRP) and white blood cell count are among immune system measures¹⁹.

Several biomarkers used to measure AL are affected by age, gender, behavior, and psychosocial factors. Various sources of psychosocial stress, including socioeconomic status (SES) indicators of education and income as well as ethnicity and gender, have been the subject of previous studies on allostatic load^{9,20-22}. Research has found consistent inverse relationships between allostatic load and SES indicators such as income and education^{20,21,23,24}. Ethnicity is of particular interest in terms of allostatic load measures. Recent studies suggest that striving for educational attainment may contribute to dysregulation of the stress response among marginalized populations^{21,25}. Race and ethnicity have been argued as both biological and social constructs^{26,27}. These distinctions have implications regarding the use of biomarkers in quantifying allostatic load among various ethnic groups. For the purposes of this study, the concept of ethnicity is considered a social construct, in line with current research on race and genetics²⁸. As such, the aim of this study was to explore the influence that the lived experience of ethnicity may have on allostatic load by (i) providing a descriptive profile of participants by gender and self-reported ethnicity, known behavioral, socio-economic, and physiologic

covariates, (ii) estimating the association between self-reported ethnicity and allostatic load, adjusting for potential confounders.

Methods

Source data

This study used public domain data from the 2017-2018 survey cycle of the National Health and Nutrition Examination Survey (NHANES). NHANES is a continuous survey program administered by the National Center for Health Statistics (NCHS), a part of the Centers for Disease Control and Prevention (CDC), for the purpose of estimating the prevalence of conditions and diseases instrumental in health policy planning. NHANES conducts interviews and physical examinations of a nationally representative sample of approximately 5,000 of the noninstitutionalized civilian population. Cross-sectional demographic, nutritional, and health data are collected via a multi-year, stratified, clustered four-stage sampling method and released in 2-year cycles ²⁹. In-person interviews and physical examinations of selected participants are completed in accordance with appropriate NHANES procedure manuals ³⁰⁻³³.

For the 2017-2018 NHANES survey cycle, 16,211 persons were selected for the survey. Of those, 9,254 were interviewed and 8,704 were examined ²⁹. To increase the precision of estimates for underrepresented subgroups, oversampled populations were Hispanic, non-Hispanic black, non-Hispanic Asian, non-Hispanic white and other (non-Hispanic, non-Black, non-Asian, or non-White) at or below 185% federal poverty level (FPL), and non-Hispanic white and other persons aged 0-11 or 80 years and older ²⁹.

Study population

For this study, samples were selected from the 8,704 participants completing the physical examination. Inclusion criteria for this study are having completed both the interview and the physical exam. Exclusion criteria for this study are being less than 18 years of age, pregnant, or reported race as “Other Race - Including Multi-Racial”. Physical activity data adequate to determine individual activity levels were not part of the questionnaire for participants less than 18 years of age³³. Body measurements of pregnant participants are not comparable to non-pregnant participants for BMI and waist-to-hip ratio (WHR) calculations, and are missing for pregnant participants less than 20 years of age³⁰. The exposure variable category of “Other Race - Including Multi-Racial” fails to provide adequate information regarding the lived experience of ethnicity for this segment of the population. Participants lacking adequate biomarker data to determine reliable AL measures were deleted from analyses. Based on age, exam, pregnancy, ethnicity, and outcome data status, 4606 participants met criteria. Figure 1 provides a flow diagram of sample selection and determination of sample size.

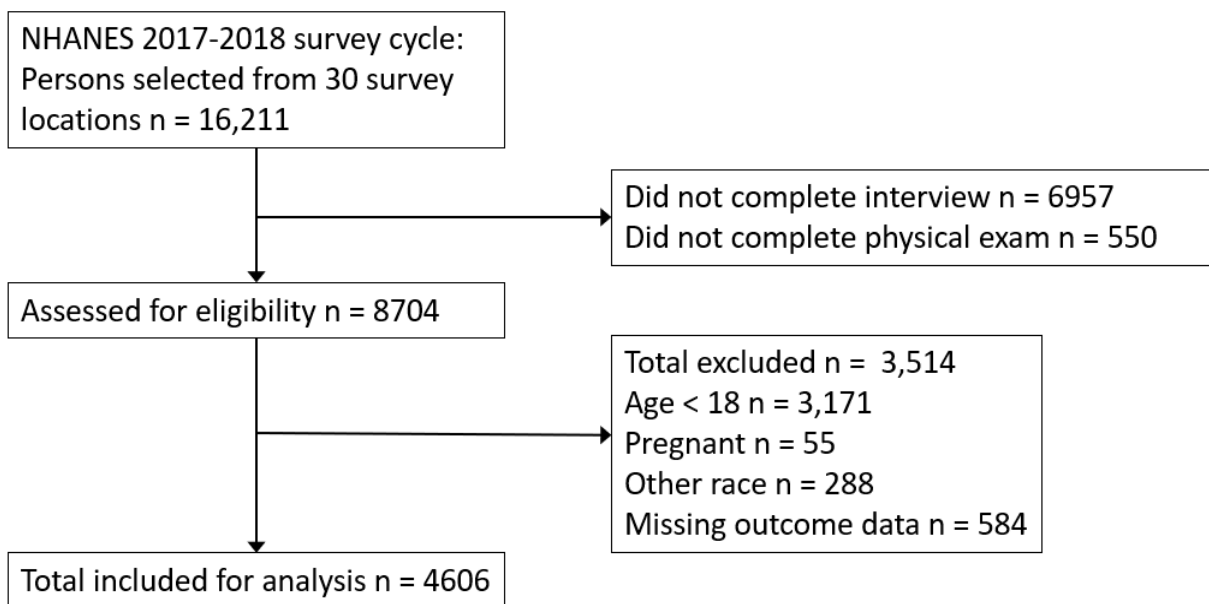


Figure 1. Flow diagram of sample selection

Allostatic load (Outcome variable)

Allostatic load index is based on measurements of 10 biomarkers representing the regulatory status of three systems: cardiovascular, metabolic, and immune. Allostatic load measures selected for this study include cardiovascular measures of systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse rate (PLS), total cholesterol (TC), triglycerides (TG), and high-density lipoproteins (HDL); metabolic measures include waist-to-hip ratio (WHR), glycosylated hemoglobin (A1C), and albumin (ALB); and immune system measure of C-reactive protein (CRP). Measures of allostatic load variables obtained during examination include SBP, DBP³⁴, and WHR³⁰. Measures obtained via laboratory testing include TC, TG, HDL, A1C, ALB, and CRP³¹.

SBP and DBP are calculated as the average of three seated blood pressure measurements taken one minute apart, using the Omron IntelliSense Blood Pressure Monitor (Model: HEM-907XL) and reported in mmHg³⁴. Measures for TC, TG, and HDL, are reported in mg/dL³¹. WHR is calculated using the waist circumference (taken at the uppermost lateral border of the iliac crest) divided by the hip circumference (taken at the maximum protuberance of the buttocks)³⁰. A1C is reported as a percentage³¹. ALB and CRP are reported in g/dL and mg/L respectively³¹.

Allostatic load score is calculated by the number of biomarkers within or exceeding the highest risk quartile of the normal range³⁵, where AL score is defined as the number of indicators measured as high risk. Cut points for AL measures with references are listed in Table 1. Based on previous studies, an AL score of 4 or greater will be used to define high AL^{23,36} with a total possible score of 10. For this study, valid ALI score requires at least one valid measure from each of four physiological system groupings: SBP, DBP, and PLS; TC, TG, and HDL; A1C, ALB, and WHR; and CRP.

Table 1. High risk scoring thresholds for allostatic load biomarkers

Biomarker	Below highest risk quartile of normal range score = 0	Within/exceeding highest risk quartile of normal range score = 1
SBP ³⁵	< 135 mmHg	≥ 135 mmHg
DBP ³⁵	< 87.5 mmHg	≥ 87.5 mmHg
PLS ³⁷	≤85	>85
TC ³⁸	< 206 mg/dL	≥ 206 mg/dL
TG ³⁵	< 139 mg/dL	≥ 139 mg/dL
HDL ³⁹	> 50 mg/dL	≤ 50 mg/dL
WHR (Male) ³⁵	< 0.83	≥ 0.83
WHR (Female) ³⁵	< 0.79	≥ 0.79
A1C ⁴⁰	< 5.4%	≥ 5.4%
ALB ⁴¹	≥3.9 or ≤ 4.6 g/dL	<3.9 or >4.6
CRP ⁴²	< 6.2 mg/L	≥ 6.2 mg/L

Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; PLS, pulse rate, TC, total cholesterol; TG, triglycerides; LDL, HDL, high-density lipoproteins; WHR, waist-to-hip ratio; A1C, glycosylated hemoglobin; ALB, albumin; CRP, C-reactive protein

Ethnicity (Exposure variable)

Data for the exposure variable were obtained during the NHANES doorstep interview in accordance with the Screener Module #1 questionnaire ⁴³. For this study, ethnicity was grouped into four categories, Mexican-American/Other Hispanic (MHA); non-Hispanic White (White); non-Hispanic Black (AA); and non-Hispanic Asian (AsA). Ethnicity has been associated with AL, physical activity, and BMI^{36,44,45}.

Covariates

Sociodemographic variables included in this study are gender, age, education level, ratio of income to federal poverty level (FPL), nativity (US-born), and duration in the US among the non-US-born participants ⁴⁶, as well as anthropometric variable of body mass index (BMI) (33), and behavioral variables of diet (44), physical activity (45), and sedentary lifestyle(45–48) as illustrated in the causal diagram, shown in Figure 2. Gender is categorized into two groups, male and female. Both AL biomarkers and physiological variations differ as a function of gender^{20,47,48}. The age variable is self-reported and categorized into 7 levels: 18 – 29, 30 – 39, 40

– 49, 50 – 59, 60 – 69, 70 – 79, and 80+ years of age. Previous studies have established positive associations between age and several AL biomarkers^{49–51}. Education is self-reported and grouped into four categories: no high school diploma, high school diploma, some college, and four-year or higher college education. Education has a positive association with physical activity, and a negative association with BMI as well as AL^{21,44,50}. However, research has found education to be an effect-measure modifier in the relationship between ethnicity and AL, with varying magnitude of association between ethnic groups^{25,52,53}. Nativity variable, having been born outside the US, was self-reported and grouped into three categories: US-Born, Non-US-Born with 10 or more years in the US, and Non-US-Born with less than 10 years in the US. Among the Non-US-Born, years in the US variable is self-reported and defined as having lived in the US for less than 10 years, and dichotomized as yes or no. Previous research has shown a protective effect of being foreign-born and in the US for 10 years or less^{54,55}. Age, gender^{20,47}, education^{56–58}, and nativity⁵⁴ are potential confounders. Income, physical activity, sedentary lifestyle, diet, and BMI are used for descriptive statistics only. Income is highly correlated with education²¹. Physical activity, sedentary lifestyle, and diet are known mediators between ethnicity and AL^{45,59–62}. BMI is highly correlated with AL and has been used as a biomarker for AL¹⁹.

Ethnicity and Allostatic Load – Covariate Diagram

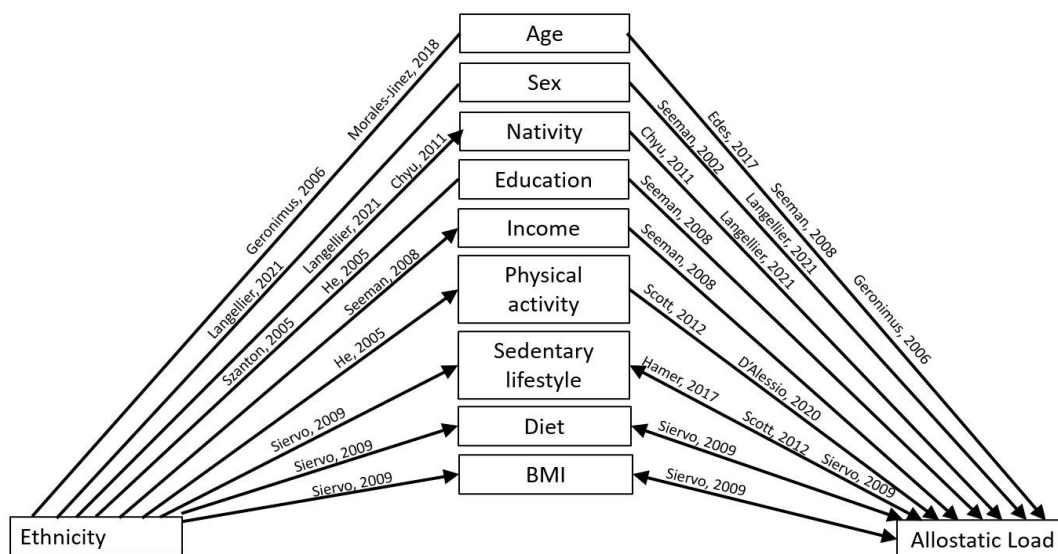


Figure 2. Causal diagram of association between ethnicity and allostatic load

Statistical analysis

Variables for analyses are contained in NHANES 2017-2018 demographics data, dietary data, examination data, laboratory data, and questionnaire data files. All relevant data files were sorted by sequence number and merged into one dataset, from which only variables relevant to this study were retained. Covariates were coded into categories as previously described.

Descriptive statistics were computed using statistical software package SAS Version 9.4.

Descriptive statistics were calculated for categorical data using the surveyfreq procedure.

Unweighted frequencies and weighted percentages are reported by gender and ethnicity. Crude prevalence ratios (PRs) of high AL between genders by ethnicity were calculated using weighted percentages. To account for the complex NHANES survey design, variables for weighting, strata, and clusters provided by NHANES were used in all SAS statistical procedures. Missing data were negligible, well under 5%.

Statistical software package R version 4.1.0 with RStudio Version 1.4.1717 was used to produce Poisson regression models to estimate the PRs and 95% confidence intervals (95% CI) of exposure (ethnicity) and covariates on the outcome measure (AL). To account for the complex NHANES survey design, variables for weighting and strata provided by NHANES were used in all R statistical procedures. The cluster variable (two clusters as defined by survey design) was modified, manually assigned a value of one, due to limitations in fitting multiple categorical variables using the R svyglm procedure. Sensitivity analyses were performed, determining this modification to have inconsequential impact on statistical validity. The dataset was subset into male and female participants for analyses. Several models were used to estimate the association between ethnicity and AL by gender. All models were labeled using the following framework: Model 1 estimated the crude (unadjusted) effect of ethnicity on allostatic load, high AL (4+) with low AL (<4) as the referent. Model 2 estimated the effect of ethnicity adjusted for potential

confounder age determined *a priori*. Model 3 estimated the age-education-adjusted effect of ethnicity, and model 4 estimated the age-education-nativity-adjusted effect of ethnicity. Multiple comparisons were performed to examine the age-adjusted effect of ethnicity, stratified by education level.

Results

Characteristics of Study Population

Demographic, anthropometric, behavior, and AL characteristics of participants are provided by ethnicity and gender in Table 2. Age distribution varied between ethnicities. Whites had the most even distribution, with the highest percentage of adults aged 60 and older. MHAs had the lowest percentage of adults aged 60 and older, and the highest percentage of adults aged 18 to 29.

Women represented the highest percentages of adults aged 50 and older for all ethnicities, consistent with previous research⁶³. Educational attainment also varied. MHAs had the lowest percentage of adults with a four-year or higher college education and the highest percentage (31%) of adults not completing a high school education. AsAs hold the highest percentage (52%) of adults with a four-year or higher college education, and Whites had the lowest percentage of adults not completing a high school education. Whites and AsAs were most affluent with highest percentages within the 400+% FPL category and the lowest percentages below poverty level. AAs and MHAs were least affluent with the highest percentages below poverty level. Among both Whites and AAs, women have lower incomes. Conversely, women have higher incomes among both MHAs and AsAs. Within the AsA population, over 80% were non-US-Born, and over 20% having lived in the US for less than 10 years. Sedentary lifestyle was greatest among Whites and AsAs, and least among MHAs, consistent with previous research⁶⁴. AsA females had the lowest percentage of adults with a high allostatic load (36%). AsA males had the highest percentage of adults with high allostatic load (53%). With the exception of AAs, findings were consistent with previous literature where males were more likely to have high AL⁴⁸.

Crude Associations Between Gender, Ethnicity and Allostatic Load

Measures of association are reported as PRs. Stratified by ethnicity, crude PRs for the sample were highest among men, with the exception of AAs. Compared to White women, AA women were slightly more likely to have high AL than AA men compared to White men.

Results of gender-specific Poisson regression models are reported as PRs and provided in Tables 3 (female) and 4 (male).

Crude PRs for women by ethnicity are highest among AAs and lowest among AsAs. Crude PRs for men by ethnicity are highest among AsAs and lowest among Whites. The prevalence of high AL by ethnicity and gender, ranked highest to lowest: AsA men (53%), AA women (52%), AA men (49%), MHA men (48%), White men (47%), MHA women (42%), White women (39%), and AsA women (36%).

Adjusted Associations Between Ethnicity and Allostatic Load

Adjusting for age, non-White ethnicities had higher AL, with the exception of AsA women. By gender, AAs had the highest among women, and AsAs the highest among men. The lowest PR among men occurred in AAs.

Adjusting for both age and education, PRs decrease less than 10% among AAs and MHAs, and increased less than five percent among AsAs, consistent with previous research^{25,52}. Among women, AA women had the highest PR and AsA women had the lowest PR. Among men, AsA men had the highest PR and AA men the lowest PR. Lastly, adjusting for nativity with US-born as referent, no ethnicity had a PR change more than 10%. However, AsAs experienced an increased PR where AAs and MHAs decreased.

Age-adjusted Associations Between Ethnicity and Allostatic Load Stratified by Education – Multiple Comparisons

Due to evidence of effect-measure modification, where there was heterogeneity among and between ethnic groups when adjusting for education, further analyses were indicated. Results for multiple comparison analyses are provided in Tables 5 (female) and 6 (male). Except for AA women and MHA men, the lowest PR for all non-Whites were among those with no high school diploma.

All non-White women had a 40% increase in PR between the lowest and the highest education levels. However, the gradient patterns between education levels differed greatly for AA women. Where AsA women had the lowest PRs at all education levels with a generally linear increase, and MHA women followed the same linear pattern with PRs 10% higher than AsA women, the PRs of AA women sharply increasing by nearly 50% between those with a high school education and those with some college. Only at the lowest education level, did PRs of MHA and AsA women dip below that of White women, with AsA women having the lowest PR of the study. AA women with a greater than high school education hold the highest PRs of the study, and is consistent with previous research suggesting the unique stressors experienced, and subsequent coping strategies employed, by AA women ^{65,66}.

PR gradient patterns differed more among men than among women in the study as levels of education increased. AA men had the flattest and most linear, with a 15% increase in PRs from lowest to highest education levels. AsA men maintained the highest PRs for the lowest three education levels, peaked among those with some college, and dropped sharply by 20% among those with the highest education, with a PR nearly equal to AA men. For MHA men, the pattern was generally flat for the lowest three education levels, then sharply increased by 40% at the

highest education level, holding the highest PR among men with the highest education. For all but the highest education level, AsA men hold the highest PRs among men.

Comparing men and women within ethnic groups, MHA patterns were most closely aligned at each education level. AsAs had nearly identical gradient patterns for the first three education levels, with a 40% difference, except at the highest education level (10%). AA patterns were roughly opposite that of AsAs with a more than 40% divergence occurring at the highest two levels of education.

Table 2. Demographic, behavior, biomarker, and allostatic load characteristics by gender and ethnicity

Variable	Categories	White						African-American						Mexican-/Hispanic-American						Asian-American					
		Male			Female			Male			Female			Male			Female			Male			Female		
		Unwtd Freq	Wtd %	Wtd	Unwtd Freq	Wtd %	Wtd	Unwtd Freq	Wtd %	Wtd	Unwtd Freq	Wtd %	Wtd	Unwtd Freq	Wtd %	Wtd	Unwtd Freq	Wtd %	Wtd	Unwtd Freq	Wtd %	Wtd	Unwtd Freq	Wtd %	Wtd
Sample size and represented % population		862	48.96	51.04	859	51.04	511	45.39	572	54.61	541	50.54	590	49.46	323	47.32	348	52.68							
Age																									
	18-29	131	19.15	16.77	145	16.77	86	25.13	99	22.42	131	28.60	120	27.39	66	25.88	48	16.72							
	30-39	114	15.72	14.30	126	14.30	61	18.61	85	17.52	83	20.11	83	20.11	45	18.97	61	20.87							
	40-49	98	14.29	106	14.12	106	14.12	74	17.62	83	15.82	65	16.87	90	17.11	57	16.59	58	15.80						
	50-59	118	18.76	118	18.56	118	18.56	75	17.10	96	19.03	88	17.03	116	18.30	66	16.57	75	20.98						
	60-69	140	17.30	136	18.22	145	14.03	145	14.03	137	14.60	127	8.81	123	9.79	62	12.78	59	13.99						
	70-79	146	10.17	114	11.61	146	10.17	47	4.94	42	6.21	38	3.98	48	6.25	18	6.39	38	9.08						
	80+	115	4.62	114	6.42	114	6.42	23	2.57	30	4.39	15	1.89	10	1.04	9	2.82	9	2.55						
Education																									
	< high school	143	9.67	117	8.33	90	14.56	90	14.56	92	14.26	263	31.59	253	30.60	50	12.96	61	15.31						
	High school	245	27.68	225	25.72	150	34.24	126	27.11	126	27.11	103	29.55	118	25.55	36	16.19	52	16.07						
	Some college/AA	291	29.23	320	32.56	174	32.42	242	35.93	242	35.93	121	25.34	147	26.81	54	19.02	56	16.98						
	College graduate+	183	33.41	196	33.38	97	18.78	97	18.78	111	22.70	51	13.52	71	17.03	183	51.83	178	51.65						
	Below FPL	102	7.25	122	10.10	89	18.85	89	18.85	116	23.37	113	20.09	118	21.93	32	11.77	30	10.51						
Ratio of Income to FPL																									
	100%-199% FPL	248	15.99	233	18.28	114	27.64	139	28.35	139	28.35	136	29.35	159	32.34	46	16.15	53	15.58						
	200%-300% FPL	223	29.25	220	29.33	130	30.54	131	27.48	123	29.06	123	29.06	110	22.39	73	28.76	91	29.55						
	400+% FPL	216	47.51	213	42.29	98	22.98	87	20.80	87	20.80	78	21.50	86	23.34	127	43.32	128	44.36						
Nativity																									
	US-Born	831	94.60	821	95.13	474	91.43	528	92.08	474	91.43	301	47.00	316	45.86	204	59.94	224	64.51						
	Non-US-Born #10+	23	3.70	30	3.60	29	6.05	29	6.05	32	5.67	43	9.71	50	9.77	66	20.84	79	22.13						
	Non-US-Born <10	8	1.71	8	1.26	8	2.52	8	2.52	12	2.25	83	14.04	128	25.42	125	37.40	188	52.70						
*BMI																									
	Normal weight	223	24.65	263	33.05	153	29.64	117	21.47	117	21.47	218	40.28	204	33.71	148	45.94	105	30.96						
	Overweight	266	30.87	230	26.44	153	30.67	124	21.23	124	21.23	218	40.28	204	33.71	148	45.94	105	30.96						
	Obese	373	44.49	366	40.51	205	39.69	331	57.30	331	57.30	240	45.68	258	40.87	50	16.66	55	16.34						
Meet dietary guidelines																									
	Yes	470	57.01	616	74.70	283	56.69	381	70.33	381	70.33	313	62.14	409	76.70	196	68.59	240	81.86						
	No	355	42.99	202	25.30	203	43.31	150	29.67	150	29.67	183	37.86	128	23.30	84	31.41	55	18.14						
@Meet physical Activity																									
	Yes	605	76.20	503	62.71	337	69.12	304	57.47	304	57.47	382	77.11	312	58.60	218	68.16	175	50.48						
	No	257	23.80	356	37.29	174	30.88	268	42.53	268	42.53	159	22.89	278	41.40	105	31.84	173	49.52						
Meet sedentary lifestyle																									
	Yes	430	54.93	412	54.71	288	63.52	312	63.25	312	63.25	385	75.26	435	76.90	159	53.00	210	65.93						
	No	308	45.07	324	45.29	171	36.48	191	36.75	191	36.75	107	24.74	107	23.10	135	47.00	108	34.07						
Allostatic load indicators																									
	SBP	286	26.16	254	25.51	210	34.08	235	37.21	235	37.21	159	24.26	173	21.03	90	25.80	101	26.21						
	DBP	128	16.41	77	9.29	132	25.99	93	15.98	93	15.98	91	19.59	58	8.89	61	18.80	36	9.18						
	PLS	112	11.85	128	13.92	54	11.65	64	10.66	64	10.66	57	11.67	73	11.77	33	11.99	42	12.74						
	TC	208	28.53	294	35.48	143	29.68	182	29.52	182	29.52	148	28.73	172	27.12	113	35.90	116	31.08						
	TG	123	30.03	90	21.09	29	13.55	24	6.75	24	6.75	88	33.57	77	22.43	51	36.33	33	20.67						
	HDL	587	65.77	290	30.09	253	52.24	189	33.94	189	33.94	395	73.06	258	40.78	223	71.43	100	28.07						
	WHR	806	97.40	772	92.72	466	89.61	496	91.34	496	91.34	508	96.48	525	93.24	307	96.40	309	92.37						
	A1C	571	60.30	536	61.16	391	73.26	435	72.17	435	72.17	365	59.69	404	62.07	250	74.19	241	66.33						
	ALB	194	18.54	261	27.18	133	21.57	261	43.83	261	43.83	122	20.44	191	32.86	60	16.81	73	22.19						
	CRP	124	12.02	160	17.02	75	13.09	151	25.72	151	25.72	52	8.18	127	22.29	10	3.23	30	9.14						
Allostatic Load Category																									
	High	455	47.02	368	38.90	274	50.84	307	51.65	307	51.65	279	47.82	273	47.82	171	53.23	133	36.17						
	Low	407	52.98	491	61.10	237	49.16	265	48.35	265	48.35	262	52.18	317	58.45	152	46.77	215	63.83						

Abbreviations: Unwtd, unweighted; Freq, frequency; Wtd, weighted; FPL, federal poverty level; SBP, systolic blood pressure; DBP, diastolic blood pressure; PLS, pulse rate; TC, total cholesterol; TG, triglycerides; HDL, high-density lipoproteins; WHR, waist-to-hip ratio; A1C, glycosylated hemoglobin; ALB, albumin; CRP, C-reactive protein; SII, systemic immune-inflammation index; #10+, 10 or more years in the US; <10, less than 10 years in the US; *Normal weight <24.9; Overweight ≥25 - <29.9; Obese ≥30; @cut-point= meeting WHO recommendations for weekly aerobic activity for adults; †cut-point=meeting WHO recommendations for moderate physical activity level by age, gender, and sedentary lifestyle

Table 3. Crude and adjusted estimated associations (Prevalence Ratios (PRs) and confidence intervals (CI)) of ethnicity and covariates with allostatic load (AL) among females: results from Poisson regression

Effect	Model 1, unadjusted				Model 2				Model 3				Model 4			
	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	
African-American vs White	1.328	1.157	1.524	0.0001	1.430	1.248	1.639	<0.0001	1.386	1.294	1.485	<0.0001	1.391	1.216	1.590	<0.0001
Mexican/Hispanic-American vs White	1.068	0.917	1.244	0.3960	1.234	1.059	1.437	0.0071	1.149	1.061	1.245	0.0829	1.183	0.974	1.437	0.0894
Asian-American vs White	0.930	0.776	1.114	0.4310	0.978	0.820	1.167	0.8070	1.004	0.915	1.102	0.9641	1.071	0.835	1.373	0.5909
Age Group: 30-39 vs 18-29					1.522	1.126	2.057	0.0063	1.621	1.391	1.889	0.0016	1.627	1.203	2.200	0.0016
Age Group: 40-49 vs 18-29					1.890	1.393	2.564	<0.0001	1.975	1.691	2.306	<0.0001	1.978	1.456	2.688	<0.0001
Age Group: 50-59 vs 18-29					2.438	1.842	3.228	<0.0001	2.491	2.159	2.873	<0.0001	2.476	1.865	3.289	<0.0001
Age Group: 60-69 vs 18-29					2.661	2.010	3.522	<0.0001	2.747	2.381	3.170	<0.0001	2.730	2.056	3.624	<0.0001
Age Group: 70-79 vs 18-29					2.642	1.982	3.522	<0.0001	2.671	2.305	3.095	<0.0001	2.657	1.986	3.556	<0.0001
Age Group: 80+ vs 18-29					2.946	2.213	3.922	<0.0001	2.885	2.496	3.334	<0.0001	2.861	2.149	3.810	<0.0001
Less than #HS vs HS									1.002	0.918	1.093	0.9837	1.006	0.846	1.196	0.9470
Some college/AA degree vs #HS									0.826	0.759	0.900	0.0257	0.824	0.698	0.974	0.0232
College graduate+ vs #HS									0.689	0.618	0.767	0.0005	0.689	0.558	0.851	0.0005
Non-US-Born ≥10 `years vs US-Born													0.982	0.792	1.217	0.8659
Non-US-Born <10 `years vs US-Born													0.732	0.524	1.024	0.0687

Footnotes: **High AL, ≥4; *CI, Confidence Interval; #HS, High school; `years, years in the US

Table 4. Crude and adjusted estimated associations (Prevalence Ratios (PRs) and confidence intervals (CI)) of ethnicity and covariates with allostatic load (AL) among males: results from Poisson regression

Effect	Model 1, unadjusted				Model 2				Model 3				Model 4			
	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	**High AL Point Estimate	95% *CI	p-value	
African-American vs White	1.046	0.908	1.204	0.5370	1.117	0.977	1.277	0.1068	1.081	0.948	1.233	0.2450	1.082	0.948	1.234	0.2417
Mexican/Hispanic-American vs White	1.017	0.881	1.174	0.8190	1.144	0.997	1.314	0.0562	1.089	0.947	1.253	0.2328	1.101	0.919	1.320	0.2957
Asian-American vs White	1.132	0.974	1.316	0.1060	1.220	1.055	1.412	0.0074	1.269	1.088	1.479	0.0024	1.291	1.033	1.614	0.0251
Age Group: 30-39 vs 18-29					2.446	1.782	3.356	<0.0001	2.588	1.891	3.542	<0.0001	2.594	1.892	3.557	<0.0001
Age Group: 40-49 vs 18-29					3.411	2.528	4.603	<0.0001	3.569	2.649	4.809	<0.0001	3.574	2.646	4.827	<0.0001
Age Group: 50-59 vs 18-29					3.610	2.683	4.856	<0.0001	3.708	2.753	4.994	<0.0001	3.713	2.748	5.017	<0.0001
Age Group: 60-69 vs 18-29					3.575	2.654	4.816	<0.0001	3.667	2.732	4.923	<0.0001	3.669	2.722	4.944	<0.0001
Age Group: 70-79 vs 18-29					3.429	2.519	4.669	<0.0001	3.610	2.656	4.907	<0.0001	3.612	2.648	4.927	<0.0001
Age Group: 80+ vs 18-29					3.488	2.556	4.761	<0.0001	3.632	2.674	4.933	<0.0001	3.632	2.669	4.942	<0.0001
Less than #HS vs HS									0.936	0.805	1.088	0.3882	0.939	0.806	1.094	0.4179
Some college/AA degree vs #HS									0.847	0.725	0.989	0.0355	0.846	0.724	0.988	0.0346
College graduate+ vs #HS									0.752	0.624	0.906	0.0028	0.753	0.625	0.908	0.0029
Non-US-Born ≥10 `years vs US-Born													0.982	0.802	1.202	0.8585
Non-US-Born <10 `years vs US-Born													0.960	0.706	1.306	0.7961

Footnotes: **High AL, ≥4; *CI, Confidence Interval; #HS, High school; `years, years in the US

Table 5. Age-adjusted Estimated Associations (Prevalence Ratios (PRs) and confidence intervals (CI)) of ethnicity with allostatic load (AL) among females by educational attainment: results from Poisson regression

Effect	Model 5 NoHS				Model 6 HS				Model 7 SmClg				Model 8 4yrs			
	**High AL		95% *CI	p-value	**High AL		95% *CI	p-value	**High AL		95% *CI	p-value	**High AL		95% *CI	p-value
	Point Estimate	Point Estimate			Point Estimate	Point Estimate										
African-American vs White	1.154	0.861	1.546	0.3394	1.095	0.847	1.415	0.4896	1.589	1.278	1.975	<0.0001	1.588	1.136	2.219	0.0070
Mexican/Hispanic-American vs White	0.908	0.677	1.218	0.5188	1.124	0.856	1.476	0.4012	1.199	0.901	1.595	0.2135	1.251	0.798	1.961	0.3296
Asian-American vs White	0.788	0.551	1.127	0.1924	0.950	0.674	1.340	0.7718	1.040	0.697	1.554	0.8466	1.105	0.786	1.563	0.5667
Age Group: 30-39 vs 18-29	2.578	1.483	4.481	0.0008	1.536	0.877	2.692	0.1342	1.927	1.204	3.084	0.0064	0.942	0.429	2.067	0.8808
Age Group: 40-49 vs 18-29	2.764	1.539	4.963	0.0007	1.935	1.143	3.273	0.0142	1.930	1.176	3.167	0.0095	1.566	0.702	3.492	0.2741
Age Group: 50-59 vs 18-29	3.542	2.064	6.078	<0.0001	2.530	1.557	4.111	0.0002	2.009	1.246	3.241	0.0044	2.362	1.143	4.884	0.0207
Age Group: 60-69 vs 18-29	3.962	2.405	6.526	<0.0001	2.521	1.536	4.135	0.0003	2.534	1.591	4.036	<0.0001	2.552	1.244	5.237	0.0109
Age Group: 70-79 vs 18-29	3.424	1.951	6.007	<0.0001	2.129	1.250	3.627	0.0056	2.692	1.675	4.326	<0.0001	2.779	1.349	5.726	0.0058
Age Group: 80+ vs 18-29	3.509	2.050	6.007	<0.0001	2.496	1.513	4.118	0.0004	3.030	1.844	4.980	<0.0001	2.805	1.287	6.113	0.0097

Table 6. Age-adjusted Estimated Associations (Prevalence Ratios (PRs) and confidence intervals (CI)) of ethnicity with allostatic load (AL) among males by educational attainment: results from Poisson regression

Effect	Model 5 NoHS				Model 6 HS				Model 7 SmClg				Model 8 4yrs			
	**High AL		95% *CI	p-value	**High AL		95% *CI	p-value	**High AL		95% *CI	p-value	**High AL		95% *CI	p-value
	Point Estimate	Point Estimate			Point Estimate	Point Estimate										
African-American vs White	1.028	0.772	1.369	0.8485	1.028	0.818	1.291	0.8157	1.081	0.864	1.354	0.4949	1.184	0.854	1.641	0.3114
Mexican/Hispanic-American vs White	1.009	0.798	1.277	0.9389	1.072	0.832	1.380	0.5930	0.999	0.749	1.332	0.9943	1.375	0.994	1.902	0.0551
Asian-American vs White	1.199	0.905	1.589	0.2059	1.320	0.958	1.817	0.0900	1.452	1.107	1.905	0.0073	1.193	0.915	1.555	0.1928
Age Group: 30-39 vs 18-29	2.888	1.672	4.988	0.0002	2.476	1.519	4.038	0.0003	3.304	1.844	5.921	0.0001	1.963	0.836	4.706	0.1211
Age Group: 40-49 vs 18-29	4.288	2.609	7.046	<0.0001	3.077	1.884	5.026	<0.0001	3.508	1.947	6.321	<0.0001	3.773	1.685	8.449	0.0013
Age Group: 50-59 vs 18-29	4.845	3.013	7.790	<0.0001	2.837	1.705	4.718	0.0001	4.040	2.268	7.197	<0.0001	3.972	1.789	8.820	0.0008
Age Group: 60-69 vs 18-29	5.004	3.219	7.778	<0.0001	3.413	2.113	5.513	<0.0001	4.409	2.507	7.753	<0.0001	2.654	1.133	6.215	0.0250
Age Group: 70-79 vs 18-29	4.810	2.922	7.920	<0.0001	2.905	1.746	4.836	<0.0001	4.832	2.738	8.528	<0.0001	2.919	1.266	6.733	0.0123
Age Group: 80+ vs 18-29	4.194	2.587	6.798	<0.0001	4.010	2.502	6.427	<0.0001	4.836	2.696	8.677	<0.0001	2.420	1.006	5.822	0.0492

Footnotes: **High AL, ≥4; *CI, Confidence Interval; NoHS, No high school; HS, High School; SmClg, Some College; 4yrs, 4+ year College Degree

Discussion

The analyses of this nationally representative sample provide evidence of an association between ethnicity, gender, and allostatic load, and highlights the heterogeneity of effect that educational attainment has on the AL of each ethnicity by gender. These findings suggest the health benefits of higher educational attainment, and higher socioeconomic position, are not equally distributed.

Recent studies on AL among AA women suggest the pressures they experience are unique, resulting in equally unique coping strategies, labeled “strong Black woman” role, or “superwomen” schema^{65,67}. There is a large disparity (30%) between AA women and AA men. Given their similar education profiles, and AA men having the flattest gradient in the study, indicate considerable gender inequality unique to AAs.

This disparity holds true between AA women and other non-White women, most notably MHAs. Specifically, highly educated AA women have a higher PR of AL (1.588) than that of MHA women (1.251). Discrimination may be experienced more intensely among AA women, supporting previous research where striving for higher education may prove more stressful among marginalized populations²⁵. The nearly identical gradient pattern between MHA and AsA women, and their high proportions of non-US-born participants might indicate specific cultural influences are driving some of this disparity between AA and other non-White women. These findings also support evidence that the physiological response to stress is not uniform for all stressors. Specifically, circumstances in which one could be judged negatively by others (i.e. Racial discrimination, low SES) elicits a more pathophysiological response^{68(p),69}.

AsA men hold the highest adjusted AL among men, and for all but the highest education level in education-stratified analyses. Similar to AAs, AsAs also have nearly identical education profiles and large gender disparities (20%) in AL. However, it is the AsA men who carry the highest AL.

Interestingly, the only finding consistent with previous research showing an inverse AL relationship with education is the negative gradient among AsA men, occurring between those with some college and those with the highest education²¹. Among AsA men, AL is lowest for those most highly educated. However, there is little research to compare the positive gradient among AsA men that exists between no-high-school and some-college education levels. The inverse is true for MHA men, where the gradient pattern increases, from its lowest, among those having some college, and those most highly educated, at its peak. There are also very large differences between education and income profiles between MHA and AsA men. This might be explained by studies indicating strong values and feelings of obligation to support family exist among both MHA and AsA populations⁷⁰. Given the high proportions of non-US-born among both groups, and MHA men having the smallest proportion of those with the highest education compared to AsA men, a nearly four-fold difference, there may be a much larger burden on MHA men to meet these culturally driven obligations.

There are considerable differences in educational attainment and AL between Whites and AsAs, particularly at the highest and lowest education levels. However, there is little research on AL among ethnicities that specifically include AsA populations, much less inclusion of AsA ethnic subgroups, on which to compare these findings.

Strengths and Limitations

There are a number of strengths to this study. The recognized validity of data used in this study lies in the nationally representative characteristics of the sample, and the NHANES rigorous protocol²⁹. The over-sampling of underrepresented subgroups greatly improved the statistical precision of estimates for these groups. Notably, the over-sampling of AsAs allowed for analyses

that is rarely undertaken in studies of AL between ethnicities. In developing an index to quantify AL, this study used a composite of AL biomarkers and cut-points derived from previous studies, using variables available in the NHANES 2017 – 2018 dataset, and incorporates emerging philosophies^{19,35,38}. By including in analyses a comprehensive list of covariates available in the NHANES 2017 – 2018 dataset provided substantial adjustment for confounding and exploration of the effects of education and nativity on the relationship between ethnicity and AL. In recent years, the accuracy of BMI measurement protocol has come under scrutiny, therefore not included as a component of AL measurement^{71–73}. The cut-points for the AL index were set within the highest risk quartile of the normal range for each biomarker³⁵. These cut-points are chosen in order to capture risk scores that are indicative of developing pathological adaptive changes such that preventive, versus corrective, measures might be implemented³⁵.

There are several limitations in this study. The cross-sectional study design prevents assessment of temporal relationships between the lived experience of ethnicity, covariates, and allostatic load. Due to small sample sizes, Mexican-American and Other Hispanic-Americans were aggregated into Mexican-/Hispanic-American (MHA) for this study. The differences between these ethnic groups may well have been masked, accounting for the differences in direction and magnitude of effect across education levels. Regardless of oversampling in the NHANES survey design, AsA populations may not be accurately represented. Previous research has highlighted the need for disaggregation of AsA ethnic subgroups in future research^{74–76}. Very few studies examine associations between AsA ethnic subgroups and health outcomes^{75,76}. Of those, significant heterogeneity exists between these subgroups in terms of health, discriminatory experiences, educational attainment, income, and language barriers^{75,77}. Furthermore, access to data for detailed research on national health trends among these subgroups is limited due to disclosure concerns resulting from their small proportions in the US population⁷⁴. Publicly

available national level data used in current studies of health outcomes among AsA ethnic subgroups have been limited to self-rated health, lack objective measures, and are gleaned from surveys designed for purposes other than health⁷⁸. The lack of access to AsA ethnic subgroup data for this study precluded the ability to examine heterogeneity among these subgroups. Also, no subgroup for Native Hawaiian/Other Pacific Islanders was available in the publicly available NHANES dataset⁷⁴. Therefore, no Hawaii-specific generalizations could be made. Stratification by gender and education resulted in small subgroup sizes, reducing the statistical power of findings between education levels. Assessment of biomarkers are dependent upon self-reported fasting prior to specimen draw. Indicators of social connectedness are not available, which have been shown to be protective against the effects of stress and its presentation in AL measures^{20,47}. Biomarkers most associated with AL have been found to differ by gender, where the most common AL indicators for men are BP, cholesterol, and WHR⁴⁷. The most common AL indicators for women, urinary cortisol and catecholamines⁴⁷, are not available in the NHANES 2017 – 2018 dataset. Therefore, the effects of gender on AL may not be fully captured. Several allostatic load indices are being used to produce scores reflecting AL¹⁹. However, there has yet to be consensus on selection of biomarkers, biomarker cut-points, and methods to compose an AL index¹⁹.

Future Research

Future research based on this study should explore the strong positive relationship between education and AL among AA women. Efforts should also be made to use restricted-use data, such as available through NCHS Research Data Center (RDC) to disaggregate Asian ethnic subgroups. Exploring the effects of gender among AAs and AsAs on AL may well identify mutable factors that effectively address these significant disparities. Further investigation of nativity and years lived in the US could expand on cultural influences on AL and their

implications. Focused efforts must continue in the development of a gold standard measure of AL to improve the validity and comparability of findings based on biomarker data. More research on biomarkers that differ by gender is also an important consideration in that quest.

Conclusion

The current study illustrates the complex relationships between gender, ethnicity, education, and allostatic load that underscore the extensive impact of social disparities on health and socioeconomic security. It also highlights the need for disaggregation of Asian ethnic subgroups to better understand these relationships. Gender and ethnic disparities are not only associated with NCDs such as CVD, chronic kidney disease, diabetes, and their associated YLDs and treatment costs. They also influence perceptions of cohesiveness and power differentials in social and professional networks, key factors in socioeconomic security^{68,69,79}. The protective nature of cultural cohesiveness could be leveraged through policies and initiatives targeting discrimination and hostile environments not only in employment and educational environments, but in social media and public spaces as well⁸⁰⁻⁸².

References

1. Guidi J, Lucente M, Sonino N, Fava GA. Allostatic Load and Its Impact on Health: A Systematic Review. *Psychother Psychosom*. 2021;90(1):11-27. doi:10.1159/000510696
2. Bergmann N, Gyntelberg F, Faber J. The appraisal of chronic stress and the development of the metabolic syndrome: a systematic review of prospective cohort studies. *Endocr Connect*. 2014;3(2):R55-R80. doi:10.1530/EC-14-0031
3. Akinyemiju T, Wilson LE, Deveaux A, et al. Association of Allostatic Load with All-Cause and Cancer Mortality by Race and Body Mass Index in the REGARDS Cohort. *Cancers*. 2020;12(6):1695. doi:10.3390/cancers12061695
4. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet Lond Engl*. 2018;392(10159):1923-1994. doi:10.1016/S0140-6736(18)32225-6
5. Dieleman JL, Baral R, Birger M, et al. US Spending on Personal Health Care and Public Health, 1996-2013. *JAMA*. 2016;316(24):2627-2646. doi:10.1001/jama.2016.16885
6. Edes AN, Crews DE. Allostatic load and biological anthropology. *Am J Phys Anthropol*. 2017;162(S63):e23146. doi:https://doi.org/10.1002/ajpa.23146
7. McEWEN BS, Seeman T. Protective and Damaging Effects of Mediators of Stress: Elaborating and Testing the Concepts of Allostasis and Allostatic Load. *Ann N Y Acad Sci*. 1999;896(1):30-47. doi:https://doi.org/10.1111/j.1749-6632.1999.tb08103.x
8. Charmandari E, Tsigos C, Chrousos G. Endocrinology of the Stress Response. *Annu Rev Physiol*. 2005;67:259-284. doi:doi: 10.1146/annurev.physiol.67.040403.120816
9. Marón FJM, Ferder L, Saraví FD, Manucha W. Hypertension linked to allostatic load: from psychosocial stress to inflammation and mitochondrial dysfunction. *Stress*. 2019;22(2):169-181. doi:10.1080/10253890.2018.1542683
10. McEWEN BS. Stress, Adaptation, and Disease: Allostasis and Allostatic Load. *Ann N Y Acad Sci*. 1998;840(1):33-44. doi:https://doi.org/10.1111/j.1749-6632.1998.tb09546.x
11. Zhang XQ, Xu CF, Yu CH, Chen WX, Li YM. Role of endoplasmic reticulum stress in the pathogenesis of nonalcoholic fatty liver disease. *World J Gastroenterol WJG*. 2014;20(7):1768-1776. doi:10.3748/wjg.v20.i7.1768
12. Hasnain SZ, Lourie R, Das I, Chen ACH, McGuckin MA. The interplay between endoplasmic reticulum stress and inflammation. *Immunol Cell Biol*. 2012;90(3):260-270. doi:https://doi.org/10.1038/icb.2011.112
13. Song M, Wang C, Yang H, et al. P-STAT3 Inhibition Activates Endoplasmic Reticulum Stress-Induced Splenocyte Apoptosis in Chronic Stress. *Front Physiol*. 2020;11. doi:10.3389/fphys.2020.00680
14. Hotamisligil GS. Endoplasmic Reticulum Stress and the Inflammatory Basis of Metabolic Disease. *Cell*. 2010;140(6):900-917. doi:10.1016/j.cell.2010.02.034

15. Kimata Y, Kohno K. Endoplasmic reticulum stress-sensing mechanisms in yeast and mammalian cells. *Curr Opin Cell Biol.* 2011;23(2):135-142. doi:10.1016/j.ceb.2010.10.008
16. Ilich JZ, Gilman JC, Cvijetic S, Boschiero D. Chronic Stress Contributes to Osteosarcopenic Adiposity via Inflammation and Immune Modulation: The Case for More Precise Nutritional Investigation. *Nutrients.* 2020;12(4):989. doi:10.3390/nu12040989
17. Boden G, Cheung P, Kresge K, Homko C, Powers B, Ferrer L. Insulin Resistance Is Associated With Diminished Endoplasmic Reticulum Stress Responses in Adipose Tissue of Healthy and Diabetic Subjects. *Diabetes.* 2014;63(9):2977-2983. doi:10.2337/db14-0055
18. Shimobayashi M, Albert V, Woelnerhanssen B, et al. Insulin resistance causes inflammation in adipose tissue. *J Clin Invest.* 2018;128(4):1538-1550. doi:10.1172/JCI96139
19. Duong MT, Bingham BA, Aldana PC, Chung ST, Sumner AE. Variation in the Calculation of Allostatic Load Score: Twenty-One Examples from NHANES. *J Racial Ethn Health Disparities.* 2017;4(3):455-461. doi:10.1007/s40615-016-0246-8
20. Seeman TE, Singer BH, Ryff CD, Dienberg Love G, Levy-Storms L. Social relationships, gender, and allostatic load across two age cohorts. *Psychosom Med.* 2002;64(3):395-406. doi:10.1097/00006842-200205000-00004
21. Seeman T, Merkin SS, Crimmins E, Koretz B, Charette S, Karlamangla A. Education, income and ethnic differences in cumulative biological risk profiles in a national sample of US adults: NHANES III (1988–1994). *Soc Sci Med.* 2008;66(1):72-87. doi:10.1016/j.socscimed.2007.08.027
22. Morales-Jinez A, Gallegos Cabrales EC, D’Alonzo KT, Ugarte-Esquivel A, López-Rincón FJ, Salazar-González BC. Social Factors Contributing to the Development of Allostatic Load in Older Adults: A Correlational-Predictive Study. *Factores Soc Que Contrib Al Desarro Carga Alostática En Adultos Mayores Un Estud Correlacional-Predict.* 2018;18(3):298-310. doi:10.5294/aqui.2018.18.3.5
23. Geronimus AT, Hicken M, Keene D, Bound J. “Weathering” and Age Patterns of Allostatic Load Scores Among Blacks and Whites in the United States. *Am J Public Health.* 2006;96(5):826-833. doi:10.2105/AJPH.2004.060749
24. Langellier BA, Fleming PJ, Kemmick Pintor JB, Stimpson JP. Allostatic Load Among U.S.- and Foreign-Born Whites, Blacks, and Latinx. *Am J Prev Med.* 2021;60(2):159-168. doi:10.1016/j.amepre.2020.08.022
25. Sims J, Coley RL. Variations in links between educational success and health: Implications for enduring health disparities. *Cultur Divers Ethnic Minor Psychol.* 2019;25(1):32-43. doi:10.1037/cdp0000239
26. Krieger N. Refiguring “Race”: Epidemiology, Racialized Biology, and Biological Expressions of Race Relations. *Int J Health Serv.* 2000;30(1):211-216. doi:10.2190/672J-1PPF-K6QT-9N7U
27. Best LE, Chenault J. Racial Classifications, Biomarkers, and the Challenges of Health Disparities Research in the African Diaspora. *J Pan Afr Stud.* 2014;7(1):74-98. Accessed June 18, 2021. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6162056/>
28. Vyas DA, Eisenstein LG, Jones DS. Hidden in Plain Sight — Reconsidering the Use of Race Correction in Clinical Algorithms. *N Engl J Med.* Published online 2020:9.

29. Chen T, Riddles M, Mohadjer L, Fakhouri T. National Health and Nutrition Examination Survey, 2015–2018: Sample design and estimation procedures. *Natl Cent Health Stat Vital Health Stat.* 2020;2(184):35.
30. Anthropometry Procedures Manual. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Published 2017. Accessed November 19, 2020. <https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/manuals.aspx?cycle=2017-2020>
31. MEC Laboratory Procedures Manual. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Published 2017. Accessed November 19, 2020. <https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/manuals.aspx?cycle=2017-2020>
32. MEC In-Person Dietary Interviewers Procedures Manual. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Published 2017. Accessed November 20, 2020. <https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/manuals.aspx?cycle=2017-2020>
33. MEC Interviewers Procedures Manual. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Published 2017. Accessed November 20, 2020. <https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/manuals.aspx?cycle=2017-2020>
34. Physician Examination Manual. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Published 2018. Accessed November 20, 2020. <https://wwwn.cdc.gov/nchs/data/nhanes/2017-2018/manuals/2018-Physician-Examination-Manual-508.pdf>
35. Sabry SM, Hend G, Nadia B, Sanaa R, Ola A. Prediction of Health Risk and Estimation of Associated Variables with Work Stress using Allostatic Load Index. *Biomed Pharmacol J.* 2020;13(2):979-987. Accessed January 19, 2021. <https://biomedpharmajournal.org/vol13no2/prediction-of-health-risk-and-estimation-of-associated-variables-with-work-stress-using-allostatic-load-index/>
36. Nelson KM, Reiber G, Kohler T, Boyko EJ. Peripheral arterial disease in a multiethnic national sample: the role of conventional risk factors and allostatic load. Accessed February 28, 2021. <https://www-ethndis-org.eres.library.manoa.hawaii.edu/priorarchives/ethn-17-04-669.pdf>
37. Ostchega Y. Resting Pulse Rate Reference Data for Children, Adolescents, and Adults: United States, 1999–2008. *Natl Health Stat Rep.* 2011;(41):17.
38. Bandyopadhyay D, Qureshi A, Ghosh S, et al. Safety and Efficacy of Extremely Low LDL-Cholesterol Levels and Its Prospects in Hyperlipidemia Management. *J Lipids.* 2018;2018. doi:10.1155/2018/8598054
39. Lee Y, Siddiqui WJ. Cholesterol Levels. In: *StatPearls.* StatPearls Publishing; 2020. Accessed January 28, 2021. <http://www.ncbi.nlm.nih.gov/books/NBK542294/>
40. Eyth E, Naik R. Hemoglobin A1C. In: *StatPearls.* StatPearls Publishing; 2020. Accessed January 27, 2021. <http://www.ncbi.nlm.nih.gov/books/NBK549816/>
41. Moman RN, Gupta N, Varacallo M. Physiology, Albumin. In: *StatPearls.* StatPearls Publishing; 2020. Accessed January 28, 2021. <http://www.ncbi.nlm.nih.gov/books/NBK459198/>

42. Nehring SM, Goyal A, Bansal P, Patel BC. C Reactive Protein. In: *StatPearls*. StatPearls Publishing; 2020. Accessed January 27, 2021. <http://www.ncbi.nlm.nih.gov/books/NBK441843/>
43. Screener Module #1 (SCQ). Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Published 2017. Accessed June 18, 2021. <https://www.cdc.gov/nchs/nhanes/continuousnhanes/manuals.aspx?cycle=2017-2020>
44. Finger JD, Tylleskär T, Lampert T, Mensink GB. Physical activity patterns and socioeconomic position: the German National Health Interview and Examination Survey 1998 (GNHIES98). *BMC Public Health*. 2012;12:1079. doi:10.1186/1471-2458-12-1079
45. He XZ, Baker DW. Differences in Leisure-time, Household, and Work-related Physical Activity by Race, Ethnicity, and Education. *J Gen Intern Med*. 2005;20(3):259-266. doi:<https://doi.org/10.1111/j.1525-1497.2005.40198.x>
46. Demographics Information DMQ SP. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Published 2017. Accessed August 23, 2021. <https://www.cdc.gov/nchs/nhanes/continuousnhanes/questionnaires.aspx?Cycle=2017-2020>
47. Larrabee Sonderlund A, Thilsing T, Sondergaard J. Should social disconnectedness be included in primary-care screening for cardiometabolic disease? A systematic review of the relationship between everyday stress, social connectedness, and allostatic load. *PLoS One*. 2019;14(12):e0226717. doi:10.1371/journal.pone.0226717
48. Kerr P, Kheloui S, Rossi M, Désilets M, Juster RP. Allostatic load and women's brain health: A systematic review. *Front Neuroendocrinol*. 2020;59:100858. doi:10.1016/j.yfrne.2020.100858
49. Crimmins EM, Johnston M, Hayward M, Seeman T. Age differences in allostatic load: an index of physiological dysregulation. *Exp Gerontol*. 2003;38(7):731-734. doi:10.1016/S0531-5565(03)00099-8
50. Seeman TE, McEwen BS, Rowe JW, Singer BH. Allostatic load as a marker of cumulative biological risk: MacArthur studies of successful aging. *Proc Natl Acad Sci U S A*. 2001;98(8):4770-4775. doi:10.1073/pnas.081072698
51. Cornman JC, Gleib DA, Goldman N, Weinstein M. Physiological Dysregulation, Frailty, and Risk of Mortality Among Older Adults. *Res Aging*. 2017;39(8):911-933. doi:10.1177/0164027516630794
52. Howard JT, Sparks PJ. The Role of Education in Explaining Racial/Ethnic Allostatic Load Differentials in the United States. *Biodemography Soc Biol*. 2015;61(1):18-39. doi:10.1080/19485565.2014.937000
53. Szanton SL, Gill JM, Allen JK. Allostatic Load: A Mechanism of Socioeconomic Health Disparities? *Biol Res Nurs*. 2005;7(1):7-15. doi:10.1177/1099800405278216
54. Peek MK, Cutchin MP, Salinas JJ, et al. Allostatic Load Among Non-Hispanic Whites, Non-Hispanic Blacks, and People of Mexican Origin: Effects of Ethnicity, Nativity, and Acculturation. *Am J Public Health*. 2010;100(5):940-946. doi:10.2105/AJPH.2007.129312
55. Chyu L, Upchurch DM. Racial and Ethnic Patterns of Allostatic Load Among Adult Women in the United States: Findings from the National Health and Nutrition Examination Survey 1999–2004. *J Womens Health*. 2011;20(4):575-583. doi:10.1089/jwh.2010.2170

56. Suvarna B, Suvarna A, Phillips R, Juster RP, McDermott B, Sarnyai Z. Health risk behaviours and allostatic load: A systematic review. *Neurosci Biobehav Rev.* 2020;108:694-711. doi:10.1016/j.neubiorev.2019.12.020
57. Popa AR, Fratila O, Rus M, et al. Risk factors for adiposity in the urban population and influence on the prevalence of overweight and obesity. *Exp Ther Med.* 2020;20(1):129-133. doi:10.3892/etm.2020.8662
58. Gallo LC, Jiménez JA, Shivpuri S, Espinosa de los Monteros K, Mills PJ. Domains of Chronic Stress, Lifestyle Factors, and Allostatic Load in Middle-Aged Mexican-American Women. *Ann Behav Med.* 2011;41(1):21-31. doi:10.1007/s12160-010-9233-1
59. Siervo M, Wells JCK, Cizza G. The Contribution of Psychosocial Stress to the Obesity Epidemic. *Horm Metab Res Horm Stoffwechselforschung Horm Metab.* 2009;41(4):261-270. doi:10.1055/s-0028-1119377
60. D'Alessio L, Korman GP, Sarudiansky M, et al. Reducing Allostatic Load in Depression and Anxiety Disorders: Physical Activity and Yoga Practice as Add-On Therapies. *Front Psychiatry.* 2020;11. doi:10.3389/fpsy.2020.00501
61. Scott KA, Melhorn SJ, Sakai RR. Effects of Chronic Social Stress on Obesity. *Curr Obes Rep.* 2012;1(1):16-25. doi:10.1007/s13679-011-0006-3
62. Hamer M, Yates T, Demakakos P. Television viewing and risk of mortality: Exploring the biological plausibility. *Atherosclerosis.* 2017;263:151-155. doi:10.1016/j.atherosclerosis.2017.06.024
63. Baum F, Musolino C, Gesesew HA, Popay J. New Perspective on Why Women Live Longer Than Men: An Exploration of Power, Gender, Social Determinants, and Capitals. *Int J Environ Res Public Health.* 2021;18(2):661. doi:10.3390/ijerph18020661
64. Bauman AE, Petersen CB, Blond K, Rangul V, Hardy LL. The Descriptive Epidemiology of Sedentary Behaviour. In: Leitzmann MF, Jochem C, Schmid D, eds. *Sedentary Behaviour Epidemiology.* Springer Series on Epidemiology and Public Health. Springer International Publishing; 2018:73-106. doi:10.1007/978-3-319-61552-3_4
65. Allen AM, Wang Y, Chae DH, et al. Racial discrimination, the superwoman schema, and allostatic load: exploring an integrative stress-coping model among African American women. *Ann N Y Acad Sci.* 2019;1457(1):104-127. doi:10.1111/nyas.14188
66. Salomon K, Jaguszyn NE. Resting cardiovascular levels and reactivity to interpersonal incivility among Black, Latina/o, and White individuals: The moderating role of ethnic discrimination. *Health Psychol.* 2008;27(4):473. doi:10.1037/0278-6133.27.4.473
67. Allen AM, Thomas MD, Michaels EK, et al. Racial discrimination, Educational Attainment, and Biological Dysregulation Among Midlife African American Women. *Psychoneuroendocrinology.* 2019;99:225-235. doi:10.1016/j.psyneuen.2018.09.001
68. John-Henderson NA, Rheinschmidt ML, Mendoza-Denton R, Francis DD. Performance and Inflammation Outcomes are Predicted by Different Facets of SES Under Stereotype Threat. *Soc Psychol Personal Sci.* 2014;5(3):301-309. doi:10.1177/1948550613494226
69. Brondolo E, Libby DJ, Denton E ge, et al. Racism and Ambulatory Blood Pressure in a Community Sample. *Psychosom Med.* 2008;70(1):49-56. doi:10.1097/PSY.0b013e31815ff3bd

70. Fuligni AJ, Tseng V, Lam M. Attitudes toward Family Obligations among American Adolescents with Asian, Latin American, and European Backgrounds. *Child Dev.* 1999;70(4):1030-1044. Accessed October 6, 2021. <https://www.jstor.org/stable/1132260>
71. Ode J, Knous J, Schlaff R, Hemenway J, Peterson J, Lowry J. Accuracy of body mass index in volunteer firefighters. *Occup Med Oxf Engl.* 2014;64(3):193-197. doi:10.1093/occmed/kqt143
72. Jackson AS, Stanforth PR, Gagnon J, et al. The effect of sex, age and race on estimating percentage body fat from body mass index: The Heritage Family Study. *Int J Obes.* 2002;26(6):789-796. doi:10.1038/sj.ijo.0802006
73. Romero-Corral A, Somers VK, Sierra-Johnson J, et al. Accuracy of body mass index in diagnosing obesity in the adult general population. *Int J Obes.* 2008;32(6):959-966. doi:10.1038/ijo.2008.11
74. Paulose-Ram R, Burt V, Broitman L, Ahluwalia N. Overview of Asian American Data Collection, Release, and Analysis: National Health and Nutrition Examination Survey 2011–2018. *Am J Public Health.* 2017;107(6):916-921. doi:10.2105/AJPH.2017.303815
75. Nicholson HL, Ahmmad Z. Associations between everyday and major discrimination and health status among a diverse national sample of ten Asian ethnic subgroups. *Ann Epidemiol.* 2021;59:5-9. doi:10.1016/j.annepidem.2021.03.011
76. Ahmmad Z, Wen M, Li K. Self-rated Health Disparities Among Asian Americans: Mediating Roles of Education Level and Household Income. *J Immigr Minor Health.* 2021;23(3):583-590. doi:10.1007/s10903-020-01051-0
77. Oh H. The Association Between Discriminatory Experiences and Self-Reported Health Status among Asian Americans and Its Subethnic Group Variations. *J Racial Ethn Health Disparities.* Published online July 23, 2021. doi:10.1007/s40615-021-01108-2
78. AAPI Data Repository. AAPI Data Repository. Accessed September 30, 2021. <http://aapidata.com/repository/>
79. Upchurch DM, Stein J, Greendale GA, et al. A Longitudinal Investigation of Race, Socioeconomic Status, and Psychosocial Mediators of Allostatic Load in Midlife Women: Findings from the Study of Women’s Health Across the Nation. *Psychosom Med.* 2015;77(4):402-412. doi:10.1097/PSY.000000000000175
80. Francisco SC, Felmlee DH. What Did You Call Me? An Analysis of Online Harassment Towards Black and Latinx Women. *Race Soc Probl.* Published online May 14, 2021. doi:10.1007/s12552-021-09330-7
81. Vaahensalo E. Creating the Other in Online Interaction: Othering Online Discourse Theory. In: Bailey J, Flynn A, Henry N, eds. *The Emerald International Handbook of Technology Facilitated Violence and Abuse.* Emerald Studies In Digital Crime, Technology and Social Harms. Emerald Publishing Limited; 2021:227-246. doi:10.1108/978-1-83982-848-520211016
82. Umaña-Taylor AJ, Tynes BM, Toomey RB, Williams DR, Mitchell KJ. Latino adolescents’ perceived discrimination in online and offline settings: An examination of cultural risk and protective factors. *Dev Psychol.* 2015;51(1):87-100. doi:10.1037/a0038432