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Predictors of High Allostatic Load in the Diverse, Urban Population of New York City

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PREDICTORS OF HIGH ALLOSTATIC LOAD IN THE DIVERSE, URBAN POPULATION OF NEW YORK CITY

by

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Abstract

The aims of this study are to evaluate allostatic load and explore factors that could be associated with high allostatic load in New York City (NYC) residents. This study may provide insight into the physiological impact of chronic stress in NYC residents by identifying risk factors related to high allostatic load, future morbidity and early mortality. Data for this project came from the NYC Health and Nutrition Examination Survey (HANES) 2013–2014, a population-based, cross sectional survey of NYC non-institutionalized adult residents. About half the population had high allostatic load. Predictors included gender, age, race/ethnicity, duration of US residence among immigrants, marital status, sexual orientation, education, employment status, household income, neighborhood income, health insurance, general physical health, physical activity, and sleep problems. This study could help the NYC Department of Health more precisely apply the City's resources to the health needs of the NYC population by designing interventions around these predictors.

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Background

Allostatic load assesses the effects of chronic stress on individuals by evaluating measurable physiological responses.[1] Allostatic load is measured by a score based on three types of biomarkers or indicators: primary neuroendocrine, secondary, and tertiary.[2] Primary neuroendocrine biomarkers, such as epinephrine, norepinephrine, cortisol, and dehydroepiandrosterone, serve as the first response mediators to acute stress.[2] Secondary indicators are the result of continuous neuroendocrine responses to acute stress and, therefore, represent the long-term stress response that activates changes in the immune, metabolic, and cardiovascular systems.[2] Therefore, secondary indicators include anthropometric measures (e.g., BMI and waist circumference), indicators of the immune system (e.g., C-reactive protein), metabolic measures (e.g., hemoglobin A1c and cholesterol), cardiovascular measures (e.g., blood pressure and pulse rate), and respiratory indicators (e.g., diagnosis of asthma).[2] Finally, responses to acute and chronic stress can manifest as tertiary indicators or outcomes, such as poor self-reported health, functional and cognitive decline, and cellular aging.[2]

Most often, researchers use a combination of primary stress mediators and secondary indicators of stress mediation to measure allostatic load; however, some researchers have used only measures of secondary indicators in their determination of allostatic load score to measure the effects of chronic stress. Developing an allostatic load score that is representative of the multisystem effect of chronic stress can be difficult due to the non-linearity of the effects of stress and the reciprocal relationship between stress and physical health.[2] With such a wide range of biomarkers associated with allostatic load, researchers often choose which biomarkers to include in their score calculations based on the ease and availability of obtaining these data.[2] Additionally, while a simple count score, where each high risk indicator is given one point and

the points from the indicators are summed to obtain the total score, is most often used, some researchers differ on how to score biomarkers.[2] This variability in calculating allostatic load scores makes it difficult to compare results between studies.[2]

Allostatic load is associated with demographic factors such as sex, age, race/ethnicity, nativity, educational attainment, and individual socioeconomic status. Males are more likely than females to have higher allostatic load,[3] and those of older age are more likely to have higher allostatic load than those of younger age.[3,4] While in general blacks and Hispanics are more likely than whites to have higher allostatic loads,[5] black females are more likely to have higher allostatic loads than all other racial and gender groups.[3,6] These associations with race/ethnicity are seen independent of other factors and persist after controlling for individual socioeconomic factors.[3,5] Compared to immigrants, especially recent immigrants who are less acculturated, U.S.-born men and women are more likely to have high allostatic loads; for example, U.S.-born blacks and U.S.-born Hispanics have higher allostatic load than their foreign-born counterparts.[3-5,7-11] Those with less educational attainment are more likely to have a higher allostatic load,[4] and higher levels of education may result in slower increases in allostatic load later in life.[12] Socioeconomic disadvantage throughout the lifetime is also associated with high allostatic load compared to those who have not experienced lifelong socioeconomic disadvantage.[13]

Sustained stress that begins with early adverse childhood experiences is associated with higher allostatic load later in life.[14,15] In fact, having lived in an impoverished neighborhood during childhood is associated with high levels of allostatic load compared to living in an impoverished neighborhood as an adult, and currently living in an impoverished neighborhood is associated with high allostatic load compared to those not currently living in impoverished neighborhoods.[3, 16-18] The associations of living conditions in childhood with adult allostatic load

persist even after controlling for individual socioeconomic status and current neighborhood characteristics,[16,17] and the associations of neighborhood poverty with high allostatic load become progressively stronger with increasing levels of neighborhood risk.[18]

With allostatic load being a method of quantifying the physiological effects of chronic stress, allostatic load is a useful tool for understanding how prolonged stress is associated with human behavior, physical health, and mental health. Individuals exposed to chronic stress, and who have high allostatic load, are more likely to engage in risky health behaviors, such as initiation and relapses of illicit drug use,[19] and are less likely to adopt healthy behaviors, such as engaging in physical activity.[4] Those with high allostatic load are more likely to additional chronic disease risks such as sleep problems,[4] higher caloric intake because of "self-medicating" with comfort foods,[20] and obesity.[21] Moreover, exposure to chronic stress is associated with the onset of chronic diseases, such as cardiovascular disease,[22] and worsened symptoms of chronic diseases, such as childhood asthma.[23] Finally, high allostatic load is even associated with structural and chemical changes to the brain that can lead to depression and other psychiatric conditions.[24,25]

Purpose of the Study

New York City has a large and diverse population with 41% of residents foreign- or US-territory-born and high variability in neighborhood income and living conditions.[26,27] Therefore, the city provides a unique opportunity to study and compare the influence of ethnicity/race, socioeconomics, health indicators, and risk behaviors on allostatic load. For this study, we use allostatic load to determine the physiological impact of chronic stress in the New York City population. The aims of this study are 1) to evaluate the allostatic load in the New York City population and 2) to explore factors that are associated with high allostatic load in New York

City residents. This study may provide insight into the physiological impact of chronic stress in New York City residents by identifying demographic, socioeconomic, immigration, and risk behaviors related to high allostatic load and, therefore, risk factors for future morbidity and early mortality. Use of the allostatic load model may provide insight into the biopsychosocial pathways of chronic stress.

Methods

Study Population

Data for this project came from the New York City Health and Nutrition Examination Survey (NYC HANES) 2013–2014. The NYC HANES is a population-based, cross-sectional survey of non-institutionalized adults aged 20 years or older residing in New York City, and it was modeled after the National Health and Nutrition Examination Survey (NHANES).[28] The NYC HANES was administered by the New York City Department of Health and Mental Hygiene (NYC DOHMH) and the City University of New York School of Public Health (CUNY SPH) in 2013–2014.[28] The NYC HANES used a three-stage cluster-sampling plan.[28] Survey data are weighted to adjust for the complex sampling design, non-response, and post-stratification (based on age, gender, race/ethnicity, New York City borough, education, and marital status, per the 2013 American Community Survey).[28] Selected households were mailed an introductory letter describing the study during the first few weeks of field data collection, and field interviews were then conducted.[28] Survey participants were eligible to receive up to $200 in cash upon completion of all three survey components (i.e., interview, physical exam, biospecimen collection).[28] Survey participants could complete the three survey components at home or at a designated survey clinic site in Manhattan.[28] The NYC DOHMH and CUNY SPH contracted with RTI International to develop the data collection applications and perform field data

collection. The study protocol was reviewed and approved by institutional review boards at the NYC DOHMH, CUNY SPH, and RTI International.[28] Written informed consent was obtained from all participants for each portion of the study.[28]

The interview portion of the study consisted of questions about health behaviors, medical history, health care access and utilization, nutrition, and demography, conducted through a face-to-face interview and an audio computer-assisted self-interview (ACASI).[28] The physical exam, adapted from the NHANES Medical Examination Component manuals, was conducted by field interviewers who were trained and certified in standardized protocols, and the portable equipment had been previously evaluated for validity and reliability.[28] For the biospecimen collection, trained field interviewers collected urine and oral rinse specimens, and phlebotomists collected blood samples.[28] All specimens were processed by the NYC DOHMH's Public Health Laboratory.[28] All measures from interviews, examinations, and biospecimen collections were evaluated for quality assurance.[28] The total sample size for the NYC HANES 2013–2014 was 1,527 participants, representing 6,285,749 New York City residents, and the analytic sample included 1231 participants.

Outcome

Indicators from laboratory, examination, and questionnaire data were assessed to develop the allostatic load score. Secondary indicators were chosen over primary neuroendocrine biomarkers for their stability and reliability in measuring chronic effects of stress rather than acute effects of stress, which are less stable and have large variability, and these indicators, available in NYC HANES 2013–2014, have previously been used in published literature.[3,5,6,8,10,12,18,21,24] Cardiovascular biomarkers included measurement of resting systolic blood pressure (BP), resting diastolic BP, and resting pulse rate. For these three cardiovascular

biomarkers, the average of the last two of three consecutive measurements was used. Metabolic biomarkers included total cholesterol, high-density lipoprotein cholesterol (HDL-C), hemoglobin A1c, and estimated age-, sex-, and race-specific glomerular filtration rate (eGFR), which was calculated from serum creatinine using the Chronic Kidney Disease Epidemiology Collaboration formula.[29]

Anthropometric indicators included body mass index (BMI), calculated as measured weight in kg divided by height in meters squared, and waist circumference. Immune system indicators included self-reported diagnoses of asthma and of rheumatoid or psoriatic arthritis.

Clinical ranges were used to score each biological indicator of allostatic load as "high risk" (given one point) or "low risk" (given no point), and these clinical ranges can be found in Appendix 1 Table 1. Systolic BP greater than or equal to 140 mmHg was considered to be high risk.[30] Diastolic BP greater than or equal to 90 mmHg was considered to be high risk.[30] A resting pulse rate of more than 100 beats per minute (bpm) was considered to be of high risk.[31] A total cholesterol of 240 mg/dL and above was considered to be high risk.[32] For men, an HDL-C of less than 40 mg/dL was considered to be high risk, whereas for women, an HDL-C of less than 50 mg/dL was considered to be high risk.[33] A hemoglobin A1c of 6.5 or above was considered to be high risk.[34] An eGFR below 60 was considered to be high risk.[35] A BMI of 30 kg/m^2 or above was considered to be high risk.[36] For men, a waist circumference of more than 102 cm was considered to be high risk, whereas a waist circumference of 88 cm was considered to be high risk for women.[33] Self-reported diagnosis of asthma has previously been used as a high risk immune system indicator.[18] Self-reported diagnoses of rheumatoid arthritis and psoriatic arthritis are associated with the immune system and inflammation and were considered to be high risk immune system indicators.[37,38]

Points from the indicators were then summed to create a total allostatic load score. The allostatic load scores were then dichotomized into low allostatic load (< 4) and high allostatic load (≥ 4) because past research found differences in morbidity and mortality once respondents had allostatic load scores of 3 or 4.[10,39,40] Respondents with data on all 11 indicators were included in the total sample size as well as those with combinations of total scores and numbers of missing indicators that made possible the individual's classification in one or the other of the dichotomous allostatic load categories. For example, those with a total allostatic load score of one and who were missing less than three of the 11 indicators were considered to have low allostatic load, whereas those with a total allostatic load score of one who were missing three or more of the eleven indicators were classified as missing because either high or low allostatic load score was possible. Similarly, those with a total allostatic load score of two and who were missing less than two of the 11 ndicators were considered to have low allostatic load, whereas those with a total allostatic load score of two who were missing two or more of the eleven indicators were classified as missing. Those with a total allostatic load score of three and who were missing no indicators were considered to have low allostatic load, whereas those with a total allostatic load score of 11 who were missing one or more indicators were classified as missing. Finally, those with a total allostatic load score of four or more were considered to have high allostatic load despite any missing indicators.

Predictors

Demographics were obtained or derived from self-reported measures and included gender, age category, ethnicity/race, immigrant status, marital status, and sexual orientation. Gender was categorized as male or female, and age was categorized as 20 to 39 years of age, 40 to 59 years of age, or 60 years or older. Ethnicity and race were combined into one variable

categorized as non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic Asian, or non-Hispanic other race/ethnicity. Nativity was defined as native-born (born in the 50 states or DC) or foreign-born. Duration of residence was derived from self-reported nativity and year immigrated to the U.S. and was categorized as U.S. born, immigrant with less than or equal to 15 years in the U.S., or immigrant with greater than 15 years in the U.S. Age of arrival was derived from self-reported nativity, year immigrated to the U.S., and age at the time of interview and was categorized as U.S. born, immigrant who was younger than 25 years old at time of immigration, immigrant who was 25 years or older at time of immigration. Immigrant generation was derived from self-report of respondent's nativity and parents' nativity and was categorized as not of immigrant status (third generation immigrant or higher), first generation immigrant (respondent is foreign-born), or second generation immigrant (at least one of respondent's parents is foreign-born). Marital status was categorized as not currently with partner (single, never married, widowed, divorced, or separated) or currently living with partner (married or living with partner). Sexual orientation was categorized as heterosexual or straight ("that is, sexually attracted only to opposite gender") or not of heterosexual orientation.

Socioeconomic status indicators were obtained or derived from self-reported measures and included education, employment status, health insurance, outpatient care, and household income. Education was categorized as less than high school, high school graduate/GED, or more than high school. Employment status was categorized by the participants' employment status from the last week: employed, unemployed, or not seeking employment. Health insurance status was categorized as having health insurance coverage of any type. Outpatient care was measured as having had any form of care outside of an emergency room visit or hospitalization within the last twelve months. Annual household income was categorized as less than $20,000 or $20,000

or more. Neighborhood income was defined as the percentage of residents in the participant's census tract with an annual income below the federal poverty threshold (FPT) according to the American Community Survey 2008-2012, and was categorized as 0 to <10% (low poverty areas), 10 to <20%, 20 to <30%, or 30 to 100% (very high poverty areas).

Risky health behaviors included physical activity level, smoking, and drinking alcohol. The physical activity variable was derived from self-reported physical activity and the guidelines of Healthy People 2010 (HP2010), with physical activity categorized as moderate or vigorous activity that meets HP2010, some moderate or vigorous activity that does not meet HP2010, or no moderate or vigorous activity. Smoking status was measured by serum cotinine: greater than 10 ng/ml indicates active smoking, 0.05 ng/ml to 10 ng/ml indicates a non-smoker exposed to secondhand smoke, and less than 0.05 ng/ml indicates a non-smoker who was not exposed to secondhand smoke. Risky alcohol drinking status was assessed as the self-reported number of occasions during the past 30 days that a male participant drank five or more drinks or a female participant had four or more drinks.

Health indicators were obtained or derived from self-report measures and included general physical health, depression, and sleep quality. General physical health was assessed with the question "Would you say respondent's health in general is excellent, very good, good, fair, or poor," with participants' responses categorized as positive (responded either "excellent," "very good," or "good") or neutral/poor (responded either "fair" or "poor"). Depression was measured with the nine-item Patient Health Questionnaire (PHQ–9), that asks about the frequency of nine *Diagnostic and Statistical Manual of Mental Disorders (4th Edition)* signs and symptoms of depression over the past 2 weeks.[41] Responses of "0" (not at all), "1" (several days), "2" (more than half the days), and "3" (nearly every day) were summed for a total score ranging from 0 to

27. Scores of 10 or more indicate moderate to severe clinical depression, as validated in previous studies.[41,42] Sleep quality was measured by the question "Over the last 2 weeks, how often have you been bothered by the following problems: trouble falling or staying asleep, or sleeping too much?" Participants' responses on sleep quality were categorized as having no sleep problems (responded "not at all"), mild sleep problems (responded "several days") or moderate to severe sleep problems (responded either "more than half the days" or "nearly every day").

Data Analyses

All data were weighted to account for the complex survey design, non-response, and post stratification (based on age, sex, race/ethnicity, New York City borough, education, and marital status, per the 2013 American Community Survey), to represent the non-institutionalized adult NYC population aged 20 years or older of 6,285,749. Means and standard deviations for the nine continuous indicators and percentages and standard errors for the two categorical indicators were used to describe the clinical health of the males and the females in the population.

Descriptive statistics were computed using frequencies for categorical variables and means for risky alcohol drinking. Row percentagaes and weighted population estimates were determined to estimate the prevalence rates of low allostatic load and high allostatic load in the population for all categorical variables. Prevalence rates (row percentagaes) were flagged for unreliability or suppression. If the prevalence rate had a row percent standard error of zero and a confidence interval width of zero, then the estimate was suppressed. If the prevalence rate had a relative standard error of greater than or equal to 0.5 and a confidence interval width of six or more, then the estimate was suppressed; however, if the prevalence rate had a relative standard error greater than or equal to 0.5 but a confidence interval width of less than 6, then the estimate was flagged as unreliable. If the prevalence rate had a relative standard error of less than 0.3 and

a row sample size total of less than 50, then the estimate was flagged as unreliable. In addition, if the prevalence rate had a relative standard error of less than 0.3 and a row sample size total of 50 or more and a confidence interval half-width of more than 10, then the estimate was flagged as unreliable. Finally, if the prevalence rate had a relative standard error of greater than or equal to 0.3 but less than 0.5, then the estimate was flagged as unreliable. All prevalence rates that did not meet any of these criteria are considered reliable estimates.

Bivariate logistic regressions were used to identify differences among levels of the covariates compared to reference groups for each variable. Next, interactions between gender and race/ethnicity, race/ethnicity and nativity with duration of residence, and neighborhood income with race/ethnicity were assessed for significant effect modification (joint test p value $< .05$) by using logistic regression analyses with the full model, including all predictors and interaction terms. All variables and interactions were entered into the model, and backwards elimination was used to remove the least significant interaction term from the model until the final list of significant interaction terms was compiled. Once the interaction terms were tested in the full model, multiple models were tested to find the most concordance between the expected outcomes and the observed outcomes, and the predictors used within the models were chosen manually to reduce covariance and were chosen for their overall level of effect on the models. The c-statistic, Akaike information criterion (AIC), and Bayesian information criterion (BIC) from each model were compiled, and the best predictive model was chosen by looking for a model that maximized the c-statistic and, if possible, best minimized the AIC and BIC.

The final logistic model was used to determine the odds ratios and 95% confidence intervals for the main effects of the significant predictors of high allostatic load. The odds ratios and 95% confidence intervals of the interaction effects were also found by stratifying the model

by gender to obtain stratum-specific odds ratios. The significance of the joint association for the final predictors with allostatic load was determined using the Type 3 Analysis of Effects. If the joint effect of the predictor is significant, individual levels of the predictors were also assessed for significance. All survey analyses were completed using the statistical software package SAS version 9.4 (Cary, NC), and an alpha level of .05 was used to assess significance.

Results

The distributions of the eleven allostatic load indicators, stratified by gender, can be found in Appendix 1, Table 2. Men, on average, were more likely than women to have clinical concerns about systolic blood pressure, diastolic blood pressure, waist circumference, HDL-C, and eGFR. Women, on average, were more likely than men to have clinical concerns about resting pulse rate, total cholesterol, and BMI. Women also had a higher prevalence of self-reported asthma and inflammatory arthritis than men.

About half (49.0%) of the overall population had high allostatic load (Appendix 1, Table 3). Men were less likely than women to have high allostatic load, with men having 0.63 times the odds (95% CI: 0.49, 0.80) of high allostatic load than men (Appendix 1, Table 3). Age was positively associated with high allostatic load, with those 40 to 59 years of age having 2.92 times the odds (95% CI: 2.18, 3.92) of high allostatic load and those 60 years of age or older having 6.12 times the odds (95% CI: 4.29, 8.71) of high allostatic load when compared to those 20 – 39 years of age (Appendix 1, Table 3). Non-Hispanic blacks and Hispanics had greater odds of high allostatic load than non-Hispanic whites, OR = 2.31 (95% CI: 1.61, 3.31) and OR = 1.83 (95% CI: 1.32, 2.55) respectively (Appendix 1, Table 3). Non-Hispanic other races/ethnicities also had greater odds of high allostatic load than non-Hispanic whites, but the values were unreliable. Nativity and immigrant generation were not found to be associated with high allostatic load.

Recent immigration with less than 15 years of residence in the U.S. was protective from high allostatic load, OR = 0.67 (95% CI: 0.46, 0.97). Immigrants who were more accultured and had been in the U.S. for 15 years or more had 1.95 times the odds (95% CI: 1.46, 2.61) of high allostatic load compared to those who were U.S. born (Appendix 1, Table 3). Age of arrival in the U.S. was not as associated with high allostatic load as duration of U.S. residence, with only immigrants who had arrived in the U.S. at age 25 or older having significantly greater odds than those who were US-born (OR: 1.80; 95% CI: 1.30, 2.47) (Appendix 1, Table 3). Marital status and sexual orientation were not significantly associated with high allostatic load, and the prevalence estimates for sexual orientation were unreliable.

Level of education also showed a dose-response association with high allostatic load with those having the lowest level of educational attainment (high school diploma or less education) having 2.77 times the odds (95% CI: 2.07, 3.71) of high allostatic load and those with some college or an associate's degree having 1.68 times the odds (95% CI: 1.21, 2.31) of high allostatic load when compared to college graduates or those with higher levels of education (Appendix 1, Table 3). Those who were unemployed were less likely to have high allostatic load, but the estimates were unreliable. However, those not seeking employment had 3.28 times the odds (95% CI: 2.47, 4.35) of high allostatic load than those who were employed (Appendix 1, Table 3). Those with an annual individual income of less than $20,000 had 1.81 times the odds (95% CI: 1.36, 2.42) of high allostatic load than those with an annual income of $20,000 or more (Appendix 1, Table 3). While those who lived in neighborhoods with 10 to < 20% of residents below the federal poverty threshold or 20 to < 30% of residents below the FPT were not significantly associated to high allostatic load, those living in the most impoverished neighborhoods (30 to 100% of residents below FPT) had 1.68 times the odds (95% CI: 1.12, 2.52)

of high allostatic load compared to those living in neighborhoods with 0 to < 10% of residents below FPT (Appendix 1, Table 3). Those with no health insurance were protected against high allostatic load, having 0.57 times the odds (95% CI: 0.40, 0.80) of high allostatic load compared to those with health insurance (Appendix 1, Table 3). Those who had not received outpatient care within the last 12 months were also protected against high allostatic load, having 0.57 times the odds (95% CI: 0.42, 0.76) of high allostatic load compared to those who had received outpatient care within the last twelve months (Appendix 1, Table 3).

Those who had fair or poor general physical health had 3.37 times the odds (95% CI: 2.44, 4.65) of high allostatic load compared to those who reported excellent, very good, or good general physical health (Appendix 1, Table 3). Moderate to severe depression was not significantly associated with high allostatic load, though the estimates were unreliable. Those with no moderate or vigorous physical activity had 2.68 times the odds (95% CI: 1.88, 3.82) of high allostatic load compared to those with moderate or vigorous activity (Appendix 1, Table 3). Smoking, risky alcohol drinking, and sleep problems were not found to be associated with to having high allostatic load.

The final logistic regression model found to be the best predictive model had a c-statistic of 0.805, meaning that the model had 80.5% concordant pairs of expected and observed outcomes generating a strong predictive model. While this model was found to be the best predictive model according to the c-statistic, this model did not minimize the AIC or BIC statistics compared to the other models tested. The model included the gender, age group, race/ethnicity, nativity with duration of stay, marital status, sexual orientation, education, employment status, annual household income, neighborhood income, any health insurance, self-reported general physical health, physical activity, and sleep problems. For the main effects of

the final predictive model, only age-group, employment status, any health insurance, and self-reported general physical health had significant joint associations with high allostatic load (Appendix 1, Table 4). The positive association of age with high allostatic load remained with those aged 40 to 59 year of age having 2.28 times the odds (95% CI: 1.50, 3.46) of high allostatic load and those aged 60 years or more having 4.34 times the odds (95% CI: 2.50, 7.52) of high allostatic load compared to those aged 20 to 39 years of age (Appendix 1, Table 4). While those who were unemployed did not suffer a higher allostatic load than those who were employed, those who were not seeking employment had 2.05 times higher odds (95% CI: 1.28, 3.29) of high allostatic load than those who were employed (Appendix 1, Table 4). Those who reported not having health insurance were protected against high allostatic load, having lower odds (OR: 0.52; 95% CI: 0.32, 0.85) of high allostatic load than those who reported having health insurance (Appendix 1, Table 4). Those who reported having fair or poor general physical health had a 3.15 times the odds (95% CI: 1.74, 5.72) of higher allostatic load than those who reported having excellent, very good, or good general physical health (Appendix 1, Table 4). There was also one significant interaction term between gender and race/ethnicity that was kept in the predictive model, and these results can be found in Table 5. Stratum-specific odds ratios were obtained by stratifying the model by gender. While non-Hispanic black men were found to have a non-significant 2.07 times the odds (95% CI: 0.88, 4.85) 2.07 of high allostatic load compared to non-Hispanic white men, non-Hispanic black women had 4.70 times the odds (95% CI: 2.10, 10.49) of non-Hispanic white women (Appendix 1, Table 5). Hispanic men and women had similar odds of high allostatic load when compared to non-Hispanic white men and women, with no significant differences. While non-Hispanic Asian men had lower odds of high allostatic load than non-Hispanic white men and non-Hispanic Asian women had higher odds of high allostatic

load than non-Hispanic white women, the stratified associations were not significant. Non-Hispanic men of other races/ethnicities had non-significantly greater odds of high allostatic load than non-Hispanic white men; however, non-Hispanic women of other races/ethnicities had 3.32 times the odds (95% CI: 1.24, 8.92) of high allostatic load compared to non-Hispanic white women (Appendix 1, Table 5).

Discussion

Gender, age group, race/ethnicity, nativity with duration of stay, marital status, sexual orientation, education, employment status, annual household income, neighborhood income, any health insurance, self-reported general physical health, physical activity, and sleep problems were all found to be important in predicting high allostatic load in the NYC population. While both non-Hispanic black men and women were likely to have high allostatic load, non-Hispanic black women had the greatest risk, which is consistent with the literature.[3,6] Many demographic, socioeconomic, and health-related variables were found to predict high allostatic load, but only age, employment status, health insurance, and general physical health were significantly associated with high allostatic load. The odds of having high allostatic load increased with increasing age, with those who were not seeking employment, and with those reporting fair or poor physical health. Unexpectedly, those who reported having no health insurance were found to be protected against high allostatic load; that is, they were more likely to have low allostatic load. Only 6.8% of those who reported having no health insurance were 60 years or older, and the distribution of age significantly differed by health insurance group ($p < 0.0001$). Therefore, this association could be attributed to the distribution of age for those who reported no health insurance, as older age was found to be highly associated with high allostatic load.

Strengths

This study benefitted the large sample representing the New York City adult population. New York City has a large and diverse population, and demographics such as immigrant status and sexual orientation are more easily studied in large populations. In addition, NYC HANES provided data from the interview, exam, and laboratory components of the survey, which allowed for a diverse selection of covariates and an adequate selection of allostatic load indicators. Clinical ranges, rather than other sample-specific methods of scoring, were used to determine high risk biological indicators for the allostatic load score. Therefore, this study may have more clinical relevance and utility than studies that use other sample-specific methods of scoring, and using clinical ranges to define allostatic load indicators as high risk also allows for valid comparison across studies.

Limitations

While this study did look at a large and representative sample, it had several limitations. First, the study was cross sectional. With an observational, cross-sectional study, temporality between the health-related predictors and the allostatic load outcome cannot be assessed, meaning that there can be no discernment between whether certain covariates occurred before or after high allostatic load has occurred. Furthermore, there could also be reverse causality between the health-related variables and high allostatic load such that high allostatic load may have caused respondents to report poor or fair physical health, to be depressed, to avoid physical activity, to smoke, to drink in excess, or to have sleep problems. This study looked at the New York City adults and, therefore, can be generalized only to the New York City adult population. New Yorkers may have higher levels of chronic stress and allostatic load compared to other regions of the United States, or to the United States as a whole, due to living in a fast-paced city.

Conversely, New Yorkers may be healthier due to higher levels of daily physical activity, having a larger and more diverse selection of healthy foods, and having higher levels of education and income than residents of other U.S. regions.

Since this study was a secondary analysis of existing data, these data were not collected with this study in mind. Therefore, the biological indicators used in the calculation of allostatic load may not match those indicators used in previous studies, making it hard to compare measured allostatic load. Furthermore, there may have been misclassification of the indicators into high-risk and low-risk categories. Use of medications for blood pressure, cholesterol, and diabetes were not taken into account, and classification of the allostatic load indicators used older standards of care, which may not reflect newer methodologies, policies, and standards of care regarding hypertension, hypercholesterolemia, and diabetes.[44,45,46]

These data were not analyzed with specialized survey software such as SUDAAN that would have provided more appropriate confidence intervals, chi-square statistics, and p-values. While this study did have a large sample size, some stratified estimates were considered unreliable due to smaller sample sizes or high variability causing wider confidence intervals. This study was missing nearly 300 participants (19.4%) from the total sample size, with most of these participants missing indicators taken from the blood sample. Therefore, the data missingness may not be at random, which could have induced some selection bias. Most of the predictors for this study were self-reported in the interview component of the NYC HANES 2013–2014, thereby relying on the honesty, reliability, and understanding of the respondents, potentially causing response bias and misclassification. Lastly, for this study, the c-statistic was used as a measure of goodness of fit for the binary outcome of allostatic load in the final logistic regression model. The c-statistic, or the area under the receiver operating characteristic (ROC)

curve, summarizes the discrimination of the model but does not take into account the calibration of the model.[47] Therefore, the c-statistic as a single number does not provide information about the overall magnitude of accurate risk prediction.[47]

Conclusions

As a method for quantifying the effects of chronic stress on an individual, allostatic load holds implications for future research on the biopsychosocial correlates of prolonged stress. Future studies should assess the association of additional covariates with allostatic load. Factors at the macro-system level (e.g., socioeconomics, demographics, spirituality), exo-system level (e.g., neighborhood characteristics, social networks), micro-system level (e.g., family, work, or peer-group related), and individual level (e.g., genetics, personality) should be assessed over time to understand not only the association of these factors with allostatic load but also the causal pathways protecting against or fostering high allostatic load.[48] Finally, these predictors of allostatic load should be studied again to see if these results can be replicated and verified within the New York City population. Once these predictors have been verified, the New York City Department of Health could more precisely apply the City's resources to the health needs of the New York City population by designing interventions around these predictors.

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Appendix A. Tables

Table 1–Clinical Risk Criteria for Allostatic Load Indicators, NYC HANES 2013–2014

	High Risk Criteria	Low Risk Criteria
Systolic Blood Pressure, mmHg	≥ 140	< 140
Diastolic Blood Pressure, mmHg	≥ 90	< 90
Resting Pulse Rate, BPM	> 100	≤ 100
Total Cholesterol, mg/dL	≥ 240	< 240
High-Density Lipoprotein Cholesterol (HDL-C), mg/dL	Men: < 40 Women: < 50	Men: ≥ 40 Women: ≥ 50
Glomerular Filtration Rate (eGFR)	< 60	≥ 60
Glycohemoglobin % (Hemoglobin A1c)	≥ 6.5	< 6.5
BMI, kg/m^2	≥ 30	< 30
Waist Circumference, cm	Men: > 102 Women: > 88	Men: ≤ 102 Women: ≤ 88
Ever Diagnosed with Asthma	Yes	No
Ever Diagnosed with Rheumatoid or Psoriatic Arthritis	Yes	No

Table 2–Distribution for Allostatic Load Indicators, NYC HANES 2013–2014

	Male	Female
	(μ ± SE)	(μ ± SE)
Systolic Blood Pressure	127.5 ± 0.9	120.2 ± 0.9
Diastolic Blood Pressure	79.5 ± 0.6	76.7 ± 0.5
Resting Pulse Rate	71.4 ± 0.6	73.9 ± 0.5
Total Cholesterol, mg/dL	183.9 ± 2.0	188.0 ± 1.7
High-Density Lipoprotein Cholesterol (HDL-C), mg/dL	50.6 ± 0.7	61.2 ± 0.8
Glomerular Filtration Rate (eGFR)	98.5 ± 1.1	101.4 ± 1.0
Hemoglobin A1c	5.6 ± 0.05	5.6 ± 0.05
BMI	28.2 ± 0.3	28.7 ± 0.3
Waist Circumference, cm	97.3 ± 0.7	94.6 ± 0.7
	(Pop. % ± SE)	(Pop. % ± SE)
Ever Diagnosed with Asthma	15.5 ± 1.8	16.6 ± 1.5
Ever Diagnosed with Rheumatoid or Psoriatic Arthritis	2.0 ± 0.8	5.3 ± 0.9

Note. SE = standard error.

Table 3–Subject Characteristics by Allostatic Load Score from NYC HANES 2013–2014

		Low Allostatic Load		High Allostatic Load		
	Sample	% of NYC Pop. (95% CI)	Pop.^	% of NYC Pop. (95% CI)	Pop.^	Crude OR (95% CI)
Total	1231	51.0 (47.7, 54.2)	3203000	49.0 (45.8, 52.3)	3083000	
Gender						
Male	517	57.2 (52.4, 62.0)	1676000	42.8 (38.0, 47.6)	1256000	0.63 (0.49, 0.80)
Female (Ref)	714	45.5 (41.4, 49.6)	1527000	54.5 (50.4, 58.6)	1827000	1.00
Age Group						
20-39 (Ref)	543	69.8 (65.4, 74.2)	1817000	30.2 (25.8, 34.6)	786000	1.00
40-59	431	44.2 (38.9, 49.5)	991000	55.8 (50.5, 61.1)	1252000	2.92 (2.18, 3.92)
60+	257	27.4 (21.6, 33.3)	395000	72.6 (66.7, 78.4)	1045000	6.12 (4.29, 8.71)
Race/Ethnicity						
Non-Hispanic White (Ref)	433	59.4 (54.2, 64.6)	1308000	40.6 (35.4, 45.8)	894000	1.00
Non-Hispanic Black	264	38.8 (32.0, 45.7)	519000	61.2 (54.3, 68.0)	818000	2.31 (1.61, 3.31)
Hispanic	320	44.4 (38.2, 50.6)	757000	55.6 (49.4, 61.8)	947000	1.83 (1.32, 2.55)
Non-Hispanic Asian	155	62.4 (53.2, 71.5)	549000	37.6 (28.5, 46.8)	331000	0.88 (0.57, 1.38)
Non-Hispanic Other	59	43.1† (30.1, 56.0)	71000	56.9† (44.0, 69.9)	93000	1.94 (1.09, 3.45)
Nativity						
U.S. Born (Ref)	645	54.2 (49.8, 58.6)	1720000	45.8 (41.4, 50.2)	1454000	1.00
Foreign-Born	580	48.1 (43.3, 52.9)	1479000	51.9 (47.1, 56.7)	1597000	1.28 (0.99, 1.66)
Immigrant Generation						
Not of Immigrant Status (Ref)	397	52.0 (46.3, 57.7)	1006000	48.0 (42.3, 53.7)	928000	1.00
First Generation Immigrant	580	48.1 (43.3, 52.9)	1479000	51.9 (47.1, 56.7)	1597000	1.17 (0.87, 1.58)
Second Generation Immigrant	233	57.5 (50.3, 64.8)	672000	42.5 (35.2, 49.7)	496000	0.80 (0.55, 1.17)
Nativity + Duration						
U.S. Born (50 States & DC) (Ref)	645	54.2 (49.8, 58.6)	1720000	45.8 (41.4, 50.2)	1454000	1.00
Immigrant, < 15 Years in U.S.	213	63.9 (56.3, 71.6)	759000	36.1 (28.4, 43.7)	428000	0.67 (0.46, 0.97)
Immigrant, ≥ 15 Years in U.S.	353	37.7 (32.2, 43.2)	686000	62.3 (56.8, 67.8)	1132000	1.95 (1.46, 2.61)

Table 3 (Continued)

	Sample	Low Allostatic Load		High Allostatic Load		
		% of NYC Pop. (95% CI)	Pop.^	% of NYC Pop. (95% CI)	Pop.^	Crude OR (95% CI)
Nativity + Arrival						
U.S. Born (Ref)	645	54.2 (49.8, 58.6)	1720000	45.8 (41.4, 50.2)	1454000	1.00
Immigrant, Younger than 25 Years Old	272	58.0 (51.4, 64.6)	797000	42.0 (35.4, 48.6)	578000	0.86 (0.62, 1.19)
Immigrant, 25 Years or Older	294	39.7 (33.3, 46.1)	647000	60.3 (53.9, 66.7)	982000	1.80 (1.30, 2.47)
Marital Status						
Never Married, Single, Widowed, Divorced, or Separated	648	51.8 (47.5, 56.0)	1611000	48.2 (44.0, 52.5)	1502000	0.94 (0.73, 1.20)
Married, Living With Partner (Ref)	583	50.2 (45.5, 54.8)	1591000	49.8 (45.2, 54.5)	1581000	1.00
Sexual Orientation						
Heterosexual (Ref)	900	53.5 (49.8, 57.3)	2439000	46.5 (42.7, 50.2)	2117000	1.00
Not of Heterosexual Orientation	94	60.7† (49.7, 71.6)	286000	39.3† (28.4, 50.3)	185000	0.75 (0.46, 1.22)
Education						
High School Diploma or Less	439	39.2 (34.1, 44.4)	1018000	60.8 (55.6, 65.9)	1577000	2.77 (2.07, 3.71)
Some College or Associate's Degree	282	51.6 (45.2, 58)	765000	48.4 (42.0, 54.8)	717000	1.68 (1.21, 2.31)
College Graduate or More (Ref)	508	64.1 (59.5, 68.8)	1410000	35.9 (31.2, 40.5)	789000	1.00
Employment Status						
Employed (Ref)	760	59.5 (55.6, 63.4)	2239000	40.5 (36.6, 44.4)	1524000	1.00
Unemployed	103	64.3† (53.2, 75.4)	347000	35.7† (24.6, 46.8)	193000	0.82 (0.49, 1.35)
Not Seeking Employment	367	30.9 (25.8, 36.1)	612000	69.1 (63.9, 74.2)	1367000	3.28 (2.47, 4.35)
Annual Income						
Less than $20,000	331	41.0 (35.2, 46.9)	692000	59.0 (53.1, 64.8)	995000	1.81 (1.36, 2.42)
$20,000 or More (Ref)	829	55.8 (51.8, 59.7)	2347000	44.2 (40.3, 48.2)	1862000	1.00

Table 3 (Continued)

		Low Allostatic Load		High Allostatic Load		
	Sample	% of NYC Pop. (95% CI)	Pop.^	% of NYC Pop. (95% CI)	Pop.^	Crude OR
Neighborhood[a] Income						
30 to 100% Below Federal Poverty Threshhold	218	39.3 (31.7, 46.9)	473000	60.7 (53.1, 68.3)	730000	1.68 (1.12, 2.52)
20 to <30% Below FPT	261	56.2 (49.2, 63.2)	729000	43.8 (36.8, 50.8)	568000	0.85 (0.58, 1.24)
10 to <20% Below FPT	418	53.5 (47.9, 59.1)	1104000	46.5 (40.9, 52.1)	960000	0.95 (0.68, 1.33)
0 to <10% Below FPT (Ref)	334	52.1 (45.9, 58.3)	897000	47.9 (41.7, 54.1)	825000	1.00
Any Health Insurance						
Yes (Ref)	1024	48.5 (45.0, 51.9)	2507000	51.5 (48.1, 55.0)	2666000	1.00
No	204	62.5 (54.8, 70.2)	684000	37.5 (29.8, 45.2)	411000	0.57 (0.40, 0.80)
Any Outpatient Care in Last 12 Months						
In Care (Ref)	912	47.4 (43.6, 51.1)	2213000	52.6 (48.9, 56.4)	2457000	1.00
Not in Care	316	61.4 (55.4, 67.5)	986000	38.6 (32.5, 44.6)	619000	0.57 (0.42, 0.76)
Self-Reported General Physical Health						
Fair/Poor	256	28.4 (22.4, 34.3)	383000	71.6 (65.7, 77.6)	969000	3.37 (2.44, 4.65)
Excellent/Very Good/Good (Ref)	975	57.1 (53.6, 60.7)	2819000	42.9 (39.3, 46.4)	2114000	1.00
Depression						
Moderate to Severe	101	42.1† (31.3, 53.0)	211000	57.9† (47.0, 68.7)	290000	1.57 (0.99, 2.48)
No Moderate or Severe Depression (Ref)	1075	53.3 (49.9, 56.7)	2920000	46.7 (43.3, 50.1)	2559000	1.00

Table 3 (Continued)

		Low Allostatic Load		High Allostatic Load		
	Sample	% of NYC Pop. (95% CI)	Pop.^	% of NYC Pop. (95% CI)	Pop.^	Crude OR
Physical Activity - Healthy People 2010						
Moderate HP2010 or Vigorous Activity (Ref)	361	60.3 (54.7, 66.0)	1132000	39.7 (34.0, 45.3)	745000	1.00
Some Moderate or Vigorous but not HP 2010	456	55.8 (50.7, 60.9)	1247000	44.2 (39.1, 49.3)	988000	1.20 (0.90, 1.63)
No Moderate or Vigorous Activity	348	36.2 (30.2, 42.2)	664000	63.8 (57.8, 69.8)	1170000	2.68 (1.88, 3.82)
Smoking (serum cotinine)						
Smoker	235	58.2 (51.2, 65.3)	738000	41.8 (34.7, 48.8)	529000	0.83 (0.58, 1.17)
Non-smoker, exposed to SHS	323	56.7 (50.8, 62.7)	941000	43.3 (37.3, 49.2)	718000	0.88 (0.65, 1.19)
Non-smoker, non-exposed (Ref)	570	53.5 (48.8, 58.2)	1506000	46.5 (41.8, 51.2)	1308000	1.00
Risky Alcohol Drinking Status ($\mu \pm SE$)[b]	921	1.3 ± 0.1	3545000	1.0 ± 0.2	1930000	0.96 (0.89, 1.02)
Sleep Problems During the Last Two Weeks						
None (Ref)	665	51.1 (46.7, 55.5)	1743000	48.9 (44.5, 53.3)	1669000	1.00
Mild	317	56.3 (50.1, 62.4)	882000	43.7 (37.6, 49.9)	685000	0.81 (0.60, 1.10)
Moderate to Severe	195	50.8 (43.0, 58.5)	511000	49.2 (41.5, 57.0)	495000	1.01 (0.71, 1.44)

Note. CI = confidence interval; OR = odds ratio, SE = standard error.

^Rounded to the nearest 1000 population.

[a] Neighborhoods defined by census tract. Percentage below FPT from American Community Survey 2008-2012.

[b] Risk Alcohol Drinking Status defined as number of times during past 30 days did male respondent have 5 or more drinks or one occasion or did female respondent have 4 or more drinks on one occasion.

†Value is unreliable.

Table 4–Predictors of High Allostatic Load from NYC HANES 2013–2014

	AOR (95% CI)	P
Gender		0.377
Male	0.73 [0.50, 1.05][b]	
Female (Ref)	1.00	
Age Group		< .001
20-39 (Ref)	1.00	
40-59	2.28 [1.50, 3.46]	
60+	4.34 [2.50, 7.52]	
Race/Ethnicity		< .001
Non-Hispanic White (Ref)	1.00	
Non-Hispanic Black	2.88 [1.69, 4.91][b]	
Hispanic	1.69 [0.99, 2.86][b]	
Non-Hispanic Asian	0.88 [0.46, 1.72][b]	
Non-Hispanic Other	2.41 [1.18, 4.90][b]	
Nativity + Duration		0.098
U.S. Born (50 States & DC) (Ref)	1.00	
Immigrant, < 15 Years in U.S.	0.86 [0.48, 1.55]	
Immigrant, ≥ 15 Years in U.S.	1.52 [0.97, 2.40]	
Marital Status		0.344
Never Married, Single, Widowed, Divorced, or Separated	0.84 [0.58, 1.21]	
Married, Living With Partner (Ref)	1.00	
Sexual Orientation		0.553
Heterosexual (Ref)	1.00	
Not of Heterosexual Orientation	0.84 [0.48, 1.48]	
Education		0.179
High School Diploma or Less	1.61 [0.97, 2.68]	
Some College or Associate's Degree	1.17 [0.75, 1.83]	
College Graduate or More (Ref)	1.00	
Employment Status		0.012
Employed (Ref)	1.00	
Unemployed	1.08 [0.59, 1.97]	
Not Seeking Employment	2.05 [1.28, 3.29]	
Annual Income		0.177
Less than $20,000	0.71 [0.44, 1.17]	
$20,000 or More (Ref)	1.00	
Neighborhood[a] Income		0.395
30 to 100% Below Federal Poverty Threshold	1.12[0.58, 2.16]	
20 to <30% Below FPT	0.74 [0.43, 1.25]	
10 to <20% Below FPT	1.08 [0.67, 1.73]	
0 to <10% Below FPT (Ref)	1.00	

Table 4 (Continued)

	AOR (95% CI)	P
Any Health Insurance		0.010
Yes (Ref)	1.00	
No	0.52 [0.32, 0.85]	
General Physical Health		< 0.001
Fair/Poor	3.15 [1.74, 5.72]	
Excellent/Very Good/Good (Ref)	1.00	
Physical Activity - Healthy People 2010		0.231
Moderate HP2010 or Vigorous Activity (Ref)	1.00	
Some Moderate or Vigorous but not HP 2010	1.19 [0.80, 1.79]	
No Moderate or Vigorous Activity	1.56 [0.94, 2.58]	
Sleep Problems During the Last Two Weeks		0.068
None (Ref)	1.00	
Mild	0.72 [0.48, 1.08]	
Moderate to Severe	0.56 [0.31, 0.99]	

Note. AOR = adjusted odds ratio; CI = confidence interval. Model Statistics and Fit: c-statistic = 0.805, $p < .0001$.

[a] Neighborhoods defined by census tract. Percentage below FPT from American Community Survey 2008-2012.

[b] Reported as main effect odds ratios due to significant interaction term.

Table 5–Association between High Allostatic Load and Race/Ethnicity Stratified by Gender, NYC HANES 2013–2014

	Male	Female
	AOR (95% CI)	AOR (95% CI)
Race/Ethnicity		
Non-Hispanic White (Ref)	1.00	1.00
Non-Hispanic Black	2.07 (0.88, 4.85)	4.70 (2.10, 10.49)*
Hispanic	1.79 (0.74, 4.32)	1.76 (0.88, 3.52)
Non-Hispanic Asian	0.50 (0.17, 1.47)	1.37 (0.63, 2.97)
Non-Hispanic Other	1.88 (0.60, 5.88)	3.32 (1.24, 8.92)*

Note. AOR = adjusted odds ratio; CI = confidence interval. Model adjusted for main effects of age, nativity with duration of U.S. residence, marital status, sexual orientation, education, employment status, health insurance, household income, neighborhood income, physical activity, general health, and sleep problems.

*P < .05.

Appendix B. IRB Approval

Institutional Review Board
Office of Sponsored Programs
University of Memphis
315 Admin Bldg
Memphis, TN 38152-3370

Jan 20, 2017

PI Name: Lisa Wang
Co-Investigators: George Relyea, Fawaz Mzayek
Advisor: Vikki Nolan
Submission Type: Modification
Title: Predictors of High Allostatic Load in the Diverse, Urban Population of New York City

Approval: Jan 20, 2017
Expiration: *

*Modifications do not extend the expiration of the original approval

Approval of this project is given with the following obligations:

1. This IRB approval for modification has an expiration date, an approved renewal must be in effect to continue the project prior to that date. If approval is not obtained, the human consent form(s) and recruiting material(s) are no longer valid and any research activities involving human subjects must stop.

2. When the project is finished or terminated, a completion form must be submitted.

3. No change may be made in the approved protocol without prior board approval.

Thank you,
James P. Whelan, Ph.D.
Institutional Review Board Chair
The University of Memphis.