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Perceived Discrimination and Autonomic Reactivity
in the Midlife in the United States Study

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Master of Public Health

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An abstract of
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Abstract

Perceived Discrimination and Autonomic Reactivity
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By Sicha Chantaprasopsuk

Psychosocial stressors, particularly perceived discrimination, can have significant implications on cardiovascular disease (CVD) through complex stress mechanisms and may be further modified by race and depression. African Americans often report more discrimination than other races, which may lead to worse psychological and CVD outcomes. We aimed to investigate the associations of perceived discrimination, race, and autonomic stress reactivity in a cohort of 710 participants from Project 4 of the Midlife in the U.S. (MIDUS II), the biomarker project of a national longitudinal study of health and well-being. We measured autonomic stress reactivity during arithmetic and speech stressors with low and high frequency heart rate variability (LF-HRV, HF-HRV). We examined the association between perceived discrimination and autonomic stress reactivity with linear regression models while adjusting for traditional CVD risk factors. We evaluated race and depression as both potential confounders and moderators. The sample contained 14.1% African Americans, 46.1% females, and the mean age was 54.8 years. In African Americans only, decreased HF-HRV during stress and recovery was associated with increased perceived discrimination. In non-whites and depressed individuals, decreased LF-HRV during stress was associated with increased perceived discrimination. In depressed individuals, decreased LF-HRV during recovery was associated with increased perceived discrimination. Several interaction terms comparing race and depression status were statistically significant ($p < 0.05$). Adjustment for traditional risk factors did not attenuate the relationship. In conclusion, we observed increased autonomic dysfunction during stress and recovery in African Americans (vs. whites) and depressed (vs. non-depressed) individuals, supporting the potential role of autonomic dysfunction in mediating the relationship of discrimination and CVD outcomes.

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BACKGROUND

In 2017, cardiovascular disease (CVD) continued to be a major cause of morbidity and mortality in the United States with 90 million diagnosed and an estimated 800,000 deaths (1). Although there has been progress in the field, health disparities in CVD continue to exist among racial/ethnic minorities. Studies have shown that African-Americans are disproportionately affected by CVD risk factors such as hypertension, obesity, and heart failure when compared to other racial and ethnic groups (2, 3). Psychosocial stressors have been hypothesized to explain racial and ethnic disparities in mental and physical health. Numerous studies have shown that psychosocial stressors are associated with CVD events including traditional risk factors, atherosclerosis, endothelial function, myocardial ischemia, plaque rupture, thrombosis, and lethal arrhythmias (4). In 2016, 71% of African Americans report experiencing discrimination or being treated unfairly because of their race or ethnicity (5). Perceived discrimination can be categorized as a chronic stressor that causes increased short-term stress reactivity that may ultimately lead to the development of CVD risk factors and outcomes (6, 7).

Perceived discrimination research has been found to be associated with hypertension, coronary artery calcification, and incident myocardial infarction. In a study of 1005 US-born non-Hispanic black and white participants in Boston, MA, racial discrimination was associated with an excess risk of high systolic blood pressure (SBP) and hypertension (8). In addition, among 6,508 participants in the Multi-Ethnic Study of Atherosclerosis (MESA), everyday discrimination was associated with an increased risk of incident cardiovascular events among men (9). Despite these and other studies showing an association with increased risk of CVD outcomes (10, 11), multiple other

studies showed no effect or a null inverse association (12-15). Therefore, additional studies of discrimination as a CVD risk factor are needed.

The adoption of harmful health behaviors may help explain the association between perceived discrimination as a psychosocial stressor and the development of CVD (16). In the longitudinal Coronary Artery Risk Development in Young Adults (CARDIA) study of 2491 participants, those who perceived more discrimination were more likely to smoke, consume alcohol, and be physically active compared to those who do not perceive as much discrimination (17). Also, a study of 2129 African American college students in North Carolina found that students who reported being harassed were twice as likely to use tobacco daily (18). Many studies adjust for health behaviors, but still found a significant association between perceived discrimination and CVD outcomes. For example, the adjustment for health behaviors shifted their results closer to the null in a cohort of over 26,000 individuals from the National Epidemiologic Survey of Alcohol and Related Conditions (6).

The experience of chronic stress may lead to changes in specific biomarkers related to stress and CVD. Numerous studies have identified associations between perceived discrimination and stress inflammatory biomarkers that have an implication on CVD such as C-reactive protein and cortisol (19-21). For example, in 112 black and white adults from the Maryland Adolescent Development in Context Study, perceived racial discrimination measured across a 20-year period predicted a flatter diurnal cortisol slope and a lower cortisol awakening response among blacks (21). Inflammation and the lack of a normal cortisol response play a large role in the autonomic stress system and on CVD outcomes.

Autonomic stress reactivity can be examined in the lab with standardized psychological stressors while participants undergo continuous cardiovascular monitoring. Perceived discrimination has been demonstrated to lead to heightened stress reactivity and impaired stress recovery, and is therefore likely cardiotoxic. In a study of 80 women, black women had a greater mean DBP reactivity and lower heart rate during recovery during and after the racial stressor compared to white women (22). A similar study examining the cardiovascular response to a racial stimulus also found increased cardiovascular responses in blood pressure in a sample of black men (23). Perceived discrimination or racism may be a significant predictor of poor CVD outcomes through increased cardiovascular stress among blacks.

Chronic stress may have an important impact on stress reactivity and recovery. In particular, heart rate variability (HRV), an index of parasympathetic function in stress reactivity, has become an important component of cardiovascular health and has many implications in various fields including physiology and psychology (24). It has been hypothesized that HRV has diagnostic value that could be used as a measure of predicting cardiac health and as a marker of cardiopathology (25). In addition, HRV was found to be a moderate the relationship between race-related stress and psychological distress in 215 African Americans (26). Despite the attention given to incidence of CVD outcomes, adoption of health behaviors, and stress biomarkers, the relationship between perceived discrimination and cardiovascular stress reactivity as measured by HRV has been largely unexplored although it has been established as an important marker of cardiovascular health.

Perceived Discrimination and Heart Rate Variability

Previous literature suggests perceived discrimination has an association with CVD through stress pathways and behavioral factors. Therefore, it may be plausible that the mechanism in which perceived discrimination works could be through the autonomic dysfunction. However, few large epidemiologic studies have examined the association between perceived discrimination and HRV. To our knowledge, only one study in Brazil examined the association between perceived discrimination and HF-HRV (27). A cohort of about 15,000 civil servants in Brazil self-reported their race as one of three categories: 'black,' 'brown,' and 'white.' Researchers found an association between higher HRV with increasing everyday discrimination as measured by a modified version of the Everyday Discrimination Scale (EDS). Furthermore, blacks had higher HRV compared to browns and whites, and browns had higher HRV compared to whites.

On the other hand, there have been more small-scale studies that assess this relationship among diabetic women and college students. In a study of 16 black and 16 white diabetic women, higher lifetime discrimination, as measured by the Schedule of Racist Events scale, predicted lower high-frequency HRV even when controlling for other demographic characteristics and health conditions (28). Another study used the Perceived Ethnic Discrimination Questionnaire Community Version (PEDQ-CV) to assess the perceived discrimination and HRV of 103 self-identified African American college students in the Midwest (29). Their findings also suggested that a greater lifetime discrimination and discriminatory harassment and/or assault are associated with lower HRV. In the studies above, the level of heart rate variability was considered abnormal and suggests poor cardiovascular health. Of note, these results are opposite of the larger study of Brazilian civil servants, and underscore the need for more studies in this area.

Although it clear that perceived discrimination may play a role in the development of CVD or CVD risk factors and that HRV have strong diagnostic value, there have not been epidemiologic studies in the United States that have specifically examined the direct association between perceived discrimination and HRV. However, a recent study by Ong *et al.* assessed the relationship between everyday unfair treatment (considered as perceived discrimination in this current study) and allostatic load, as an index of various measurements, including HRV, related to biological dysregulation (30). Everyday unfair treatment was associated with higher allostatic load, suggesting that chronic stress from discrimination leads to the dysfunction of physiological systems.

Race and Perceived Discrimination

Many studies have mentioned the racial and ethnic differences in perceived discrimination. In particular, perceived discrimination was found to be highly prevalent among racial/ethnic minorities in the United States. Blacks reported the highest amount of discrimination while Hispanics and Asians reported less (31). Other studies have looked at prevalence within racial/ethnic groups. For example, in a nationally representative study of African American and Caribbean black adolescents, the majority perceived at least one discriminatory event in the past year (32). Racial/ethnic differences in perceived discrimination may persist due the adverse nature of racial discrimination compared to other types of discrimination.

A large number of studies on perceived discrimination and CVD outcomes tend to focus on African American cohorts. Although the psychosocial stress of perceived discrimination is not necessarily specific to particular race/ethnic groups, there are multiple downstream health effects that are expected to result from race-based

discrimination because of its greater prevalence among blacks (33). Collectively, the accumulation of chronic stress due to perceived discrimination among blacks increases the physiologic toll on the body through increased allostatic load (34). Therefore, the combined effect of race and perceived discrimination may differ across racial groups with a larger effect among blacks.

Depression and Perceived Discrimination

Previous literature suggests that perceived discrimination may have a direct link to mental health. In a meta-analysis of 110 studies, increases in perceived discrimination were significantly related to more negative mental health outcomes including mental illness scales, psychological distress, and general indicators of well-being (7). In addition, depressive symptoms have been shown to be associated with CVD risk factors not only among whites but among African Americans as well (35). Specifically, the effects of lifetime and day-to-day discrimination might be an important factor in mental health. In the MIDUS study, the high prevalence of perceived discrimination and its strong association with mental health may have a compounded effect on other health outcomes (36).

In addition, depression has been shown to be associated with decreased HRV in the Multi-Ethnic Study of Atherosclerosis (MESA) (37). In a study among 80 participants in China, those with major depressive disorder had reduced HRV during the Ewing test, an autonomic stimulation test, compared to those without depression (38). Also, melancholic features may be relevant for the association between major depressive disorder and HRV in Brazil (39). Because there are studies that have shown associations between perceived discrimination and depression and studies between depression and

HRV, the combined effect of depression and perceived discrimination may help explain the potential relationship between perceived discrimination and HRV in this study.

The goal of this study is to further explore whether perceived discrimination plays a role in stress reactivity as measured by high frequency and low frequency heart rate variability across demographic factors and whether depression plays an additional role in the association. This study draws from the population included in the MIDUS study. It is hypothesized that higher perceived discrimination will be associated with worse stress reactivity and worse recovery of autonomic function, measured by LF-HRV and HF-HRV. In addition, this study will examine whether race and/or depression modify this relationship. We hypothesize non-Hispanic blacks will have greater autonomic dysfunction compared to non-Hispanic whites and depressed individuals will also have greater autonomic dysfunction compared to non-depressed individuals. The results of this study can help to examine the potential cardiotoxic mechanisms of perceived discrimination that are mediated by the autonomic nervous system, and inform future interventions.

Perceived Discrimination and Autonomic Reactivity in the Midlife in the United States Study

Sicha Chantaprasopsuk, Amit Shah

ABSTRACT

Psychosocial stressors, particularly perceived discrimination, can have significant implications on cardiovascular disease (CVD) through complex stress mechanisms and may be further modified by race and depression. African Americans often report more discrimination than other races, which may lead to worse psychological and CVD outcomes. We aimed to investigate the associations of perceived discrimination, race, and autonomic stress reactivity in a cohort of 710 participants from Project 4 of the Midlife in the U.S. (MIDUS II), the biomarker project of a national longitudinal study of health and well-being. We measured autonomic stress reactivity during arithmetic and speech stressors with low and high frequency heart rate variability (LF-HRV, HF-HRV). We examined the association between perceived discrimination and autonomic stress reactivity with linear regression models while adjusting for traditional CVD risk factors. We evaluated race and depression as both potential confounders and moderators. The sample contained 14.1% African Americans, 46.1% females, and the mean age was 54.8 years. In African Americans only, decreased HF-HRV during stress and recovery was associated with increased perceived discrimination. In non-whites and depressed individuals, decreased LF-HRV during stress was associated with increased perceived discrimination. In depressed individuals, decreased LF-HRV during recovery was associated with increased perceived discrimination. Several interaction terms comparing race and depression status were statistically significant ($p < 0.05$). Adjustment for traditional risk factors did not attenuate the relationship. In conclusion, we observed increased autonomic dysfunction during stress and recovery in African Americans (vs. whites) and depressed (vs. non-depressed) individuals, supporting the potential role of autonomic dysfunction in mediating the relationship of discrimination and CVD outcomes.

Cardiovascular disease (CVD) continues to be a major cause of morbidity and mortality in the United States (1). Despite progress in the field, health disparities in CVD continue to exist among racial minorities (31). African Americans are disproportionately affected by CVD risk factors such as hypertension, obesity, and heart failure when compared to others (2, 3). Perceived discrimination is a chronic psychosocial stressor that may explain racial disparities in CVD risk factors and outcomes such as poor stress reactivity and recovery (4, 6, 7). In 2016, 71% of African Americans reported experiencing discrimination or unfair treatment because of their race or ethnicity (5).

Earlier studies with perceived discrimination largely focused on hypertension, coronary calcification, and incident cardiovascular events (8, 9). While some observational studies show positive associations (10, 11), results in other studies show no effect or a null inverse association (12-15). Various pathways that explain how perceived discrimination may lead to CVD outcomes have been suggested. The internalized experience of discrimination may lead to the adoption of risky health behaviors (16). Increased perceived discrimination was positively associated with tobacco use and alcohol consumption but not physical activity (17, 18). However, health behaviors do not fully explain the association between perceived discrimination and CVD outcomes (6).

New mechanistic hypotheses related to chronic stress have gained traction in current research of perceived discrimination and CVD outcomes. A number of observational studies found that African Americans had increases in inflammatory biomarkers such as C-reactive protein and a flattened diurnal cortisol slope (19-21). In addition, randomized controlled trials examining stress reactivity and recovery in

participants with and without an induced racial stressor found worse CVD responses such as blood pressure and heart rate (HR) among African Americans (22, 23).

High frequency heart rate variability (HF-HRV) is an index of parasympathetic function that has been hypothesized to have prognostic value (24, 25). HRV has been found to moderate the relationship between race-related and psychological stress notably in African Americans (7, 26). Few large epidemiologic studies have examined the association between perceived discrimination and HRV. Blacks with perceived discrimination have been found to have increased HRV compared to whites in Brazil, while smaller US studies found the opposite relationship (27-29). Perceived discrimination and the associate chronic stress can increase allostatic load, leading to biological dysregulation and, as a result, lower HRV (30). Race and depression may further modify this association; furthermore, race-based discrimination has greater prevalence among blacks (33, 34) and may lead to disparate CVD outcomes. Additionally, depression and discrimination both may lead to compounded adverse effects compared to either one alone (36, 38, 39).

The goal of this study is to determine whether discrimination is associated with worse autonomic reactivity, and if this relationship is modified by race or depression in middle and older aged Americans from the MIDUS II Biomarker Project. It is hypothesized that higher perceived discrimination among non-Hispanic blacks or those who are depressed will be associated with worse resting HR, SBP, DBP, and stress reactivity and worse recovery in LF-HRV and HF-HRV.

METHODS

Participants

The data were collected from 1255 participants during the 9-year follow-up of the Midlife Development in the U.S. (MIDUS II) cohort. The aim of the parent study was to examine the behavioral, psychological, and societal factors related to health and well-being in a national sample of middle-aged older Americans (40). All data in this current study comes from Project 1 and Project 4 of MIDUS II. Data for Project 1 was collected from January 2004 to September 2006 and consisted of a phone interview and self-administered survey of behavioral, social, and psychological factors. Biomarker and additional survey and biological data for Project 4 was collected from January 2005 to December 2008 during a visit to a clinical research center at three sites including the University of Wisconsin-Madison; University of California, Los Angeles; or Georgetown University (41). Out of 1255 participants, 427 were excluded because of physician-diagnosed chronic health conditions that may disproportionately affect HRV, including heart disease, stroke or MIA, COPD, diabetes, and thyroid disease. An additional 96 participants were missing exposure or outcome data and therefore excluded. Another 22 participants were also excluded for missing other covariate data. From the original sample, 710 participants remained for this study.

Measure of Perceived Discrimination

The Everyday Discrimination scale is a 9-item valid and reliable scale used to assess a person's perceived discrimination (42). This scale was assessed through a self-administered questionnaire during MIDUS II Project 1. Participants answered the following question based on how often on a day-to-day basis they experience each type

of discrimination. Discrimination experiences include being treated with less courtesy, with less respect, receiving poorer service at restaurants or stores, being called names or insulted, and being threatened or harassed. Other experiences include people acting afraid of the participant, like they are better than the participant, as if the participant is not smart, and as if the participant is dishonest. Participants responded with options indicating frequency of the previous situations including: 'often,' 'sometimes,' 'rarely,' and 'never.' The scale is constructed by calculating the sum of the values of the items, ranging from 1 to 4 for a minimum score of 9 and a maximum score of 36. The mean value of completed items is imputed for items with a missing value if there are data on at least five valid items on the scale. For ease of interpretation, perceived discrimination was categorized in tertiles, resulting in the groups: none, low, and high. The scores included in each group were 9, 10 to 14, and 14 to 36, respectively.

Covariates

Demographic characteristics. Self-reported race, age, gender, marital status, total household income, and education were used. Race was categorized as non-Hispanic white, non-Hispanic black, and other. Others encompass those who are not non-Hispanic White or non-Hispanic Black, reported having Hispanic origin, or those who reported being more than one race. Age in years at time of HRV data collection was analyzed as a continuous variable. Marital status was dichotomized as married or not married at time of HRV data collection. Participants' socioeconomic status was measured using total household income. Participants' educational attainment was the report of the highest level completed and categorized as less than high school, high school, some college but no degree, two to four year degree, and graduate degree or higher.

Biological characteristics. During Project 4, researchers measured height, weight, systolic and diastolic blood pressure (SBP, DBP), and resting heart rate of the participants. Medication use was self-reported. Use of at least one anti-depressant and/or beta-blocker medication was assessed as binary variables. Height and weight were used to calculate body mass index (BMI).

Behavioral characteristics. During Project 4, physical activity, smoking status, and alcohol use were self-reported. Physical activity was dichotomized as having regular exercise for at least 20 minutes three times per week or not. Smoking status was categorized as never smoker, past smoker, and current smoker. Alcohol use in the past month was categorized as none, less than one day per week, 1-2 days per week, and 3-7 days per week.

Psychological characteristics. Negative affect index was constructed using 6 items. Depression was measured using the Centers for Epidemiological Studies – Depression Scale (CES-D), a 20-item measure that rates how often over the past week the participant experienced symptoms associated with depression. The CES-D score ranges from 0 to 60 and a score of 16 or higher signifies high depressive symptoms with high internal consistency, sensitivity, and specificity for major depressive disorder (43).

Measurement of Resting Heart Rate and Heart Rate Variability

An electrocardiogram (ECG) was used to record a continuous measurement of cardiovascular reactivity. Detailed methods and descriptions for the psychophysiology protocol for the collection of resting heart rate, LF-HRV, and HF-HRV is described elsewhere (41). Resting heart rate was converted from the average of RR interval units (milliseconds) to beats per minute. HRV was measured in the low (0.04-0.15 Hz) and

high (0.15-0.50 Hz) frequency bands. LF-HRV and HF-HRV (in ms^2) were calculated using an interval method for computing Fourier transforms similarly described elsewhere (44). LF-HRV and HF-HRV was measured during baseline, psychological stressor tasks, and recovery periods. The psychological stress tasks include the Stroop Color-Word Task and a mental arithmetic task. Three months after Project 4 began, the mental arithmetic task was changed from the Paced Auditory Serial Addition Test (PASAT) to the Morgan And Turner Hewitt (MATH) task. The general order of the protocol was as follows: baseline, stressor 1, recovery 1, stressor 2, and recovery 2. The baseline values were subtracted from each stressor and recovery value to measure autonomic reactivity. The change in LF-HRV and HF-HRV from each stressor and recovery were then log transformed because the data were skewed.

Statistical Analysis

All data analyses were performed using SAS 9.4 (Cary, NC). Descriptive statistics were calculated to evaluate the differences between levels of perceived discrimination and between races. A one-way fixed effects analysis of variance was conducted on continuous variables and a Chi-square test of association on categorical variables. A bivariate analysis, interaction assessment, and confounding assessment were conducted in order to determine which covariates should be included in the model. Regression diagnostics were conducted to check for normality and multicollinearity.

Five linear regression models were used to determine the association between perceived discrimination and both HF-HRV and LF-HRV, three of which assess interaction by race and depression or separately. Model 1 is the unadjusted regression model between perceived discrimination and each outcome. Model 2 is fully adjusted for

all potential sociodemographic, biological, behavioral, and psychological covariates as previously described, except when SBP and DBP are evaluated as the outcome. The site of HRV data collection was included to account for data collection differences. This model will show the impact of potential confounders on the relationship between perceived discrimination and all outcomes compared to Model 1. Model 3 added the perceived discrimination × depression interaction term to Model 2 in order to assess effect modification by depression in a scenario where there is no interaction by race. Model 4 added the perceived discrimination × race interaction term to Model 2 in order to assess effect modification in a scenario where there is no interaction by depression. Model 5 adds both interaction terms to Model 2 in order to assess effect modification for both depression and race in a scenario where there is interaction by both variables. Although not all interaction terms were significant for each outcome, all five models were run for consistency. In the best model for each outcome, we removed non-significant interaction terms. The effect sizes from each outcome's best model are described in the results.

RESULTS

Subject Characteristics

Characteristics of the 710 participants are presented in Table 1. Perceived discrimination significantly differed across race, age, BMI, depression, and negative affect. Blacks or other race had a larger proportion of people who report high perceived discrimination among their respective racial group compared to whites ($p = 0.04$). Participants reporting high perceived discrimination were significantly younger (M:

52.03, SD: 9.75, $p < 0.0001$) compared to participants reporting no or low discrimination. Participants reporting high discrimination have a larger BMI (M: 30.25, SD: 6.51, $p = 0.02$) compared to participants reporting no or low discrimination. Twenty-five percent of participants reporting high discrimination were depressed compared to the 9% and 16% of participants with no or low discrimination ($p < 0.0001$). Negative affect differed across all levels of perceived discrimination. Negative affect increased as perceived discrimination increased ($p < 0.0001$).

Association between Perceived Discrimination and Low-Frequency HRV

Model 1 assessed the crude association between perceived discrimination and LF-HRV, while Model 2 adjusted for demographic, biological, behavioral, psychological, and health characteristics. There was no statistically significant crude association between perceived discrimination and baseline LF-HRV or LF-HRV reactivity during stressor 1 (Tables 2-3). The results did not change after adjusting for all covariates.

The LF-HRV reactivity during recovery 1 was significantly associated with high perceived discrimination ($B = -0.14$ ln ms^2, $p < 0.05$) compared with none (Table 4). The association between perceived discrimination and the LF-HRV reactivity during recovery 1 remained statistically significant after adjusting for all covariates ($B = -0.15$ ln ms^2, $p < 0.05$). Those who reported low discrimination did not significantly differ from those who reported none; those who reported high discrimination had significantly worse recovery compared to those who reported none.

The LF-HRV reactivity during stressor 2 and recovery 2 was not significantly associated with perceived discrimination (Tables 5-6). The results did not change after adjusting for all covariates.

Association between Perceived Discrimination and High-Frequency HRV

Model 1 assessed the crude association between perceived discrimination and LF-HRV, while Model 2 adjusted for demographic, biological, behavioral, psychological, and health characteristics. There was no crude association between perceived discrimination and baseline HF-HRV (Table 2). The results did not change after adjusting for all covariates. However, in fully adjusted models, non-Hispanic blacks had significantly higher baseline HF-HRV ($B = 0.43$ ln ms^2, $p < 0.01$) compared to non-Hispanic whites.

The HF-HRV reactivity in stressor 1, recovery 1, stressor 2, and recovery 2 was not statistically significantly associated with perceived discrimination (Tables 3-6). The results did not change after adjusting for all covariates.

Association between Perceived Discrimination and Other Outcomes

There was no crude association between perceived discrimination and resting HR, SBP, or DBP (Tables 7-8). The results did not change after adjusting for all covariates. However, when adjusting for all covariates, other races had significantly lower SBP ($B = -4.55$ ln ms^2, $p < 0.01$) and significantly higher DBP ($B = 3.01$ ln ms^2, $p < 0.01$) compared to non-Hispanic whites in Model 2.

Interaction between Perceived Discrimination and Race

There was statistically significant interaction between perceived discrimination and race in the LF-HRV reactivity during stressor 1 (Figure 1). Other races with high perceived discrimination had significantly worse LF-HRV reactivity during the first stressor ($B = -0.47$ ln ms^2, $p < 0.05$) compared to non-Hispanic whites with no perceived discrimination (Table 3). There was statistically significant interaction between perceived

discrimination and race in the LF-HRV reactivity during stressor 2 (Figure 1). Non-Hispanic blacks with low perceived discrimination had significantly worse stress during the second stressor (B = -0.78 ln ms^2, $p < 0.01$) compared to non-Hispanic whites with no perceived discrimination (Table 5). Interaction terms between perceived discrimination and race for baseline, recovery 1, and recovery 2 LF-HRV outcomes were not significant.

In Model 5, there was statistically significant interaction between perceived discrimination and race in the HF-HRV reactivity during stressor 1 (Figure 2). Only non-Hispanic blacks with high perceived discrimination had significantly worse stress during the first stress test (B = -0.34 ln ms^2, $p < 0.05$) compared to non-Hispanic whites with no perceived discrimination. However in Model 4, when removing the non-significant interaction term for depression, both non-Hispanic blacks with low and high perceived discrimination had significantly worse stress during the first stressor (B = -0.40 ln ms^2, $p < 0.05$; B = -0.36 ln ms^2, $p < 0.05$) compared to non-Hispanic whites with no perceived discrimination (Table 3).

There was statistically significant interaction between perceived discrimination and race in the HR-HRV reactivity during recovery 1 (Figure 2). Non-Hispanic blacks with low and high perceived discrimination had significantly worse stress during the first recovery period (B = -0.32 ln ms^2, $p < 0.05$; B = -0.28 ln ms^2, $p < 0.05$) compared to non-Hispanic whites with no perceived discrimination (Table 4).

In Model 5, there was statistically significant interaction between perceived discrimination and race in the HF-HRV reactivity during stressor 2 (Figure 2). Non-Hispanic blacks with low and high perceived discrimination had significantly worse stress during the second stress test (B = -0.52 ln ms^2, $p < 0.05$; B = -0.41 ln ms^2, $p < 0.05$)

compared to non-Hispanic whites with no perceived discrimination. When removing the non-significant interaction term for depression included in Model 5, this result became more significant for non-Hispanic blacks with low perceived discrimination (B = -0.57 ln ms^2, $p < 0.01$; B = -0.40 ln ms^2, $p < 0.05$) (Table 5).

There was no statistically significant interaction between perceived discrimination and race in baseline HF-HRV or HF-HRV reactivity during recovery 2. There was no statistically significant interaction between perceived discrimination and race for resting HR, SBP, and DBP.

Interaction between Perceived Discrimination and Depression

There were no statistically significant interactions between perceived discrimination and depression in baseline, stressor 1, and stressor 2 LF-HRV.

In Model 5, there was statistically significant interaction between perceived discrimination and depression in the LF-HRV reactivity during recovery 1 (Figure 3). Those with depression and low perceived discrimination had significantly worse recovery (B = -0.43 ln ms^2, $p < 0.05$) compared to those with depression and no perceived discrimination (Table 4). However, in Model 4, when removing the non-significant interaction term for race, this result stays the same (B = -0.48 ln ms^2, $p < 0.05$). Those with depression and high perceived discrimination also had worse recovery compared to those with depression and no perceived discrimination, but this result was not statistically significant.

In Model 5, there was statistically significant interaction between perceived discrimination and depression in the LF-HRV reactivity during recovery 2 (Figure 3). Those with depression and low perceived discrimination had significantly worse recovery

(B = -0.57 ln ms^2, $p < 0.05$) compared to those with depression and no perceived discrimination. When removing the non-significant interaction term between race and perceived discrimination from the model, those with depression and both low and high perceived discrimination had significantly worse recovery (B = -0.56 ln ms^2, $p < 0.05$; B = -0.41 ln ms^2, $p < 0.05$) compared to those with depression and no perceived discrimination (Table 6).

There were no statistically significant interaction between perceived discrimination and depression for baseline, stressor 1, recovery 1, stressor 2, and recovery 2 HF-HRV (Figure 4). Although there was significant interaction between low perceived discrimination and depression in Model 3 of the HF-HRV reactivity during stressor 1, the model including both interaction terms by race and depression showed no significant interaction by depression (Table 3). Therefore, Model 4 that does not include the interaction term for depression is the best model for the change in stressor 1 HF-HRV.

There was no statistically significant interaction between perceived discrimination and depression for resting HR and SBP (Tables 7-8). In Model 5, there was statistically significant interaction between perceived discrimination and depression in DBP (Table 8). Those with depression and high perceived discrimination had significantly lower DBP (B = -4.55 ln ms^2, $p < 0.05$) compared to those with depression and no perceived discrimination. When removing the non-significant interaction term for race included in Model 5, this result remained the same (B = -4.25 ln ms^2, $p < 0.05$).

DISCUSSION

Findings reveal poor stress reactivity and recovery in HF-HRV among blacks that experience increased perceived discrimination compared to whites with no perceived discrimination. In addition, blacks and other races that perceive discrimination have poor stress reactivity in LF-HRV while depressed individuals who perceive discrimination have worse LF-HRV recovery and lower DBP. These findings support the hypothesis that perceiving discrimination leads to increased psychosocial stress and dysfunction of the autonomic system. Poor stress reactivity and recovery in HRV may be one of the various mechanisms through which perceived discrimination becomes embodied in the individual and increases the risk of CVD.

The association between perceived discrimination and the various outcomes differed across the stressor and recovery periods. Individual stressor and recovery time points may represent a unique biological phase for particular groups (45). Due to the pervasive nature of racial discrimination, increased rumination among blacks may lead to chronic stress. Rumination or perseverative thinking is likely to occur during the recovery period after the removal of the stressor and could potentially explain the existing health disparity between blacks and whites (46, 47). Likewise, rumination or perseverative thinking is also observed in individuals who are depressed and may explain poor recovery in LF-HRV in this study (46, 48).

Although other studies have shown that controlling for demographic, biological, behavioral, and psychological factors attenuate the relationship between perceived discrimination and CVD outcomes, this was not observed in this study. When assessing interaction by both race and depression, significant effect modification for each outcome

in this study was exclusive either to race or to depression. This suggests that race and depression may have differing pathways to poor autonomic functioning. These results are consistent with a study of older blacks and whites where perceived discrimination subscales were positively related to depressive symptoms but did not differ by race (49).

Although previous studies have shown significant associations between perceived discrimination and traditional CVD risk factors and outcomes, our study supports other literature that determined that perceived discrimination is not associated with resting HR and SBP. These findings suggest that the mechanism in which perceived discrimination works may not be associated with an average value of HR or SBP at one time point. Perceived discrimination may become embodied through the dysregulation of autonomic activity. It is interesting to note that the other racial category had significantly lower SBP but higher DBP. The other racial category in this study was comprised of Hispanic, Asian, and multi-racial individuals. A protective effect may be seen in this group as seen in other literature.

Limitations, Strengths, and Future Directions

Some limitations may limit the interpretations of the results of this study. This study was cross-sectional and therefore cannot determine whether perceived discrimination causes poor stress reactivity and recovery in HRV. Because temporality cannot be established, the associations seen in this study may be due to an unmeasured confounder that is related to both perceived discrimination and the outcomes. However, this study controlled for many potential confounders assessed in previous studies. Although this study found an association between perceived discrimination and worse HRV outcomes mainly among blacks and among those who are depressed, these results

may not be generalizable to the population. The majority of blacks in this study were sampled from the Milwaukee, Wisconsin area. By looking at associations at the population level, individual perceived discrimination might not necessarily cause worse HRV in the individual. Third, only a subsample of the MIDUS II cohort was analyzed in this study. Potential selection bias could have occurred because participants had to travel to one of three clinical sites for the collection of HRV data. Participants who are healthier, have access to travel, and have time are most likely included in this study sample. Participants were excluded if they were missing any of the outcome data. However, only a small proportion of participants were unable to complete the stress tasks.

In addition, various studies have suggested taking caution in providing physiological significances to HRV measures. In the traditional stress tests, tests that require speech may significantly affect the level of HRV due to breathing changes (50). Also, instead of characterizing specific autonomic activity, LF-HRV may characterize a mixture of sympathetic and parasympathetic activity (51). In addition, HRV may exemplify various distinct factors of stress reactivity and recovery. For example, LF-HRV and HF-HRV is greatly influenced by mechanisms of blood control and respiratory activity, respectively (52). The measurement of HRV and its interpretation in relation to autonomic system functioning needs further clarification in future studies before strong conclusions can be made.

Although there are limitations, this is the first study to our knowledge that assesses the association of perceived discrimination in relation to changes in HRV during stressor tasks. HRV has potential prognostic value for CVD (53). Those with increased

perceived discrimination may be at greater risk for autonomic dysfunction. Understanding the mechanisms in which perceived discrimination leads to autonomic dysfunction may explain how increased perceived discrimination ultimately leads to poor CVD outcomes among blacks or those with depression. In the future, clinicians may be able to use perceived discrimination and HRV in order to identify those at risk for CVD in the population.

Future research should explore other potential stress mechanisms in which perceived discrimination may affect. Identifying how perceived discrimination is embodied would clarify how higher levels of perceived discrimination can lead to a higher risk for CVD risk factors and poor CVD outcomes among vulnerable populations. It would also inform a specific biological mechanism where people can intervene. Experiences and consequently the perception of discrimination may occur very early in age (21). Conducting similar research on younger cohorts may help identify when the manifestation of abnormal stress reactivity and recovery in HRV occurs. Although studying individual perceived discrimination is important, the effects of systemic racism may be more pervasive among blacks given the history of race relations in the United States (54). Additional research that looks at multi-level associations with a life course approach may advance the knowledge on the causal impacts of perceived discrimination on CVD outcomes.

REFERENCES

1. Benjamin EJ, Blaha MJ, Chiuve SE, et al. Heart disease and stroke statistics—2017 update: a report from the American Heart Association. *Circulation.* 2017.
2. Pool LR, Ning H, Lloyd‐Jones DM, et al. Trends in racial/ethnic disparities in cardiovascular health among US adults from 1999–2012. *Journal of the American Heart Association: Cardiovascular and Cerebrovascular Disease.* 2017;6(9):e006027.
3. Dunlay SM, Lippmann SJ, Greiner MA, et al. Perceived discrimination and cardiovascular outcomes in older african americans: insights from the Jackson Heart Study. *Mayo Clin Proc.* 2017;92(5):699-709.
4. Bairey Merz CN, Dwyer J, Nordstrom CK, et al. Psychosocial stress and cardiovascular disease: pathophysiological links. *Behavioral Medicine (Washington, DC).* 2002;27(4):141-7.
5. Pew Research Center. On views of race and inequality, blacks and whites are worlds apart. http://www.pewsocialtrends.org/2016/06/27/on-views-of-race-and-inequality-blacks-and-whites-are-worlds-apart/. Published June 27, 2016. Accessed February 2017.
6. Udo T, Grilo CM. Cardiovascular disease and perceived weight, racial, and gender discrimination in U.S. adults. *Journal of Psychosomatic Research.* 2017;100:83-8.
7. Pascoe EA, Richman LS. Perceived discrimination and health: a meta-analytic review. *Psychological Bulletin.* 2009;135(4):531-54.

8. Krieger N, Waterman PD, Kosheleva A, et al. Racial discrimination & cardiovascular disease risk: my body my story study of 1005 US-born black and white community health center participants (US). *PloS one.* 2013;8(10):e77174.

9. Everson-Rose SA, Lutsey PL, Roetker NS, et al. Perceived discrimination and incident cardiovascular events: the multi-ethnic study of atherosclerosis. *American Journal of Epidemiology.* 2015;182(3):225-34.

10. Thayer ZM, Blair IV, Buchwald DS, et al. Racial discrimination associated with higher diastolic blood pressure in a sample of American Indian adults. *American Journal of Physical Anthropology.* 2017;163(1):122-8.

11. Borrell LN, Kiefe CI, Williams DR, et al. Self-reported health, perceived racial discrimination, and skin color in African Americans in the CARDIA study. *Social Science & Medicine.* 2006;63(6):1415-27.

12. Roberts CB, Vines AI, Kaufman JS, et al. Cross-sectional association between perceived discrimination and hypertension in African-American men and women: the Pitt County Study. *American Journal of Epidemiology.* 2008;167(5):624-32.

13. Carlisle SK. Perceived discrimination and chronic health in adults from nine ethnic subgroups in the USA. *Ethnicity & Health.* 2015;20(3):309-26.

14. Everage NJ, Gjelsvik A, McGarvey ST, et al. Inverse associations between perceived racism and coronary artery calcification. *Annals of Epidemiology.* 2012;22(3):183-90.

15. Cozier Y, Palmer JR, Horton NJ, et al. Racial discrimination and the incidence of hypertension in US black women. *Annals of Epidemiology.* 2006;16(9):681-7.

16. Jones CP. Invited commentary: "race," racism, and the practice of epidemiology. *American Journal of Epidemiology.* 2001;154(4):299-304; discussion 5-6.

17. Borrell LN, Kiefe CI, Diez-Roux AV, et al. Racial discrimination, racial/ethnic segregation, and health behaviors in the CARDIA study. *Ethnicity & Health.* 2013;18(3):227-43.

18. Bennett GG, Wolin KY, Robinson EL, et al. Perceived racial/ethnic harassment and tobacco use among African American young adults. *American Journal of Public Health.* 2005;95(2):238-40.

19. Cunningham TJ, Seeman TE, Kawachi I, et al. Racial/ethnic and gender differences in the association between self-reported experiences of racial/ethnic discrimination and inflammation in the CARDIA cohort of 4 US communities. *Social Science & Medicine.* 2012;75(5):922-31.

20. Beatty DL, Matthews KA, Bromberger JT, et al. Everyday discrimination prospectively predicts inflammation across 7-years in racially diverse midlife women: study of women's health across the nation. *The Journal of Social Issues.* 2014;70(2):298-314.

21. Adam EK, Heissel JA, Zeiders KH, et al. Developmental histories of perceived racial discrimination and diurnal cortisol profiles in adulthood: A 20-year prospective study. *Psychoneuroendocrinology.* 2015;62:279-91.

22. Lepore SJ, Revenson TA, Weinberger SL, et al. Effects of social stressors on cardiovascular reactivity in black and white women. *Annals of Behavioral Medicine: a publication of the Society of Behavioral Medicine.* 2006;31(2):120-7.

23. Merritt MM, Bennett GG, Jr., Williams RB, et al. Perceived racism and cardiovascular reactivity and recovery to personally relevant stress. *Health psychology: official journal of the Division of Health Psychology, American Psychological Association.* 2006;25(3):364-9.

24. Moss D, Lagos L, Shaffer F. Don't add or miss a beat: A special issue on current evidence and current practice in heart rate variability biofeedback. *Biofeedback.* 2013;41(3):83-4.

25. Bigger JT, Jr., Fleiss JL, Steinman RC, et al. RR variability in healthy, middle-aged persons compared with patients with chronic coronary heart disease or recent acute myocardial infarction. *Circulation.* 1995;91(7):1936-43.

26. Utsey SO, Hook JN. Heart rate variability as a physiological moderator of the relationship between race-related stress and psychological distress in African Americans. *Cultural Diversity & Ethnic Minority Psychology.* 2007;13(3):250-3.

27. Kemp AH, Koenig J, Thayer JF, et al. Race and resting-state heart rate variability in brazilian civil servants and the mediating effects of discrimination: An ELSA-Brasil Cohort Study. *Psychosomatic Medicine.* 2016;78(8):950-8.

28. Wagner J, Lampert R, Tennen H, et al. Exposure to discrimination and heart rate variability reactivity to acute stress among women with diabetes. *Stress and Health: Journal of the International Society for the Investigation of Stress.* 2015;31(3):255-62.

29. Hill LK, Hoggard LS, Richmond AS, et al. Examining the association between perceived discrimination and heart rate variability in African Americans. *Cultural Diversity & Ethnic Minority Psychology*. 2017;23(1):5-14.

30. Ong AD, Williams DR, Nwizu U, et al. Everyday unfair treatment and multisystem biological dysregulation in African American adults. *Cultural Diversity & Ethnic Minority Psychology.* 2017;23(1):27-35.

31. Fang G, Jun X, David TT. Racial and ethnic differences in perceptions of everyday discrimination. *Sociology of Race and Ethnicity.* 2016;3(4):506-21.

32. Seaton EK, Caldwell CH, Sellers RM, et al. The prevalence of perceived discrimination among African American and Caribbean black youth. *Developmental Psychology.* 2008;44(5):1288-97.

33. Mays VM, Cochran SD, Barnes NW. Race, race-based discrimination, and health outcomes among African Americans. *Annual Review of Psychology.* 2007;58:201-25.

34. Goosby BJ, Straley E, Cheadle JE. Discrimination, sleep, and stress reactivity: Pathways to African American-white cardiometabolic risk inequities. *Population Research and Policy Review.* 2017;36(5):699-716.

35. Weinstein AA, Abraham P, Diao G, et al. Relationship between depressive symptoms and cardiovascular disease risk factors in African American individuals. *Depression Research and Treatment.* 2011;2011:836542.

36. Kessler RC, Mickelson KD, Williams DR. The prevalence, distribution, and mental health correlates of perceived discrimination in the United States. *Journal of Health and Social Behavior.* 1999;40(3):208-30.

37. Ohira T, Diez Roux AV, Prineas RJ, et al. Associations of psychosocial factors with heart rate and its short-term variability: multi-ethnic study of atherosclerosis. *Psychosomatic Medicine.* 2008;70(2):141-6.

38. Chen X, Yang R, Kuang D, et al. Heart rate variability in patients with major depression disorder during a clinical autonomic test. *Psychiatry Research.* 2017;256:207-11.

39. Borrione L, Brunoni AR, Sampaio-Junior B, et al. Associations between symptoms of depression and heart rate variability: An exploratory study. *Psychiatry Research.* 2018;262:482-7.

40. Ryff C, Almeida DM, Ayanian J, et al. Midlife in the United States (MIDUS 2), 2004-2006. Inter-university Consortium for Political and Social Research [distributor], 2017.

41. Ryff CD, Seeman T, Weinstein M. Midlife in the United States (MIDUS 2): Biomarker Project, 2004-2009. Inter-university Consortium for Political and Social Research [distributor], 2017.

42. Williams DR, Yan Y, Jackson JS, et al. Racial differences in physical and mental health: Socio-economic status, stress and discrimination. *Journal of Health Psychology.* 1997;2(3):335-51.

43. Lewinsohn PM, Seeley JR, Roberts RE, et al. Center for Epidemiologic Studies Depression Scale (CES-D) as a screening instrument for depression among community-residing older adults. *Psychology and Aging.* 1997;12(2):277-87.

44. DeBoer RW, Karemaker JM, Strackee J. Comparing spectra of a series of point events particularly for heart rate variability data. *IEEE Transactions on Bio-medical Engineering.* 1984;31(4):384-7.

45. Lucas T, Wegner R, Pierce J, et al. Perceived discrimination, racial identity, and multisystem stress response to social evaluative threat among African American men and women. *Psychosomatic Medicine.* 2017;79(3):293-305.

46. Thayer JF, Friedman BH. A neurovisceral integration model of health disparities in aging. In: Anderson NB, Bulato RA, Cohen B, eds. *Critical Perspectives on Racial and Ethnic Diffrences in Health in Late Life*. The National Academies Press, Washington, 2004:47-69.

47. Williams DP, Pandya KD, Hill LK, et al. Rumination moderates the association between resting high-frequency heart rate variability and perceived ethnic discrimination. *Journal of Psychophysiology.* 2017:1-9.

48. Trick L, Watkins E, Windeatt S, et al. The association of perseverative negative thinking with depression, anxiety and emotional distress in people with long term conditions: A systematic review. *Journal of Psychosomatic Research.* 2016;91:89-101.

49. Barnes LL, Leon CFMD, Wilson RS, et al. Racial differences in perceived discrimination in a community population of older blacks and whites. *Journal of Aging and Health.* 2004;16(3):315-37.

50. Quintana DS, Heathers JAJ. Considerations in the assessment of heart rate variability in biobehavioral research. *Frontiers in Psychology.* 2014;5:805.

51. Bassett D. A literature review of heart rate variability in depressive and bipolar disorders. *The Australian and New Zealand Journal of Psychiatry.* 2016;50(6):511-9.

52. Reyes del Paso GA, Langewitz W, Mulder LJ, et al. The utility of low frequency heart rate variability as an index of sympathetic cardiac tone: a review with emphasis on a reanalysis of previous studies. *Psychophysiology.* 2013;50(5):477-87.

53. Grad C. Heart rate variability and heart rate recovery as prognostic factors. *Clujul Med.* 2015;88(3):304-9.

54. Ferdinand KC, Nasser SA. Disparate cardiovascular disease rates in African Americans: The role of stress related to self-reported racial discrimination. *Mayo Clin Proc.* 2017;92(5):689-92.

Table 1. Participant Characteristics by Perceived Discrimination (n=710)

	Perceived Discrimination			
Characteristics, M (SD) or *N* (%)	None (n = 297)	Low (n = 211)	High (n = 202)	p-value*
Race				0.04
White	229 (77.10)	163 (77.25)	137 (67.82)	
Black	43 (14.48)	22 (10.43)	35 (17.33)	
Other	25 (8.42)	26 (12.32)	30 (14.85)	
Age	56.42 (11.07)	55.33 (11.36)	52.03 (9.75)	<.0001
Gender				0.27
Female	156 (52.53)	123 (58.29)	119 (58.91)	
Male	141 (47.47)	88 (41.71)	83 (41.09)	
Education				0.23
Less than high school	16 (5.39)	13 (6.16)	14 (6.93)	
High school	56 (18.86)	48 (22.75)	42 (20.79)	
Some college/no degree	53 (17.85)	47 (22.27)	54 (26.73)	
2 or 4 year degree	98 (33.00)	63 (29.86)	51 (25.25)	
Graduate degree or higher	74 (24.92)	40 (18.96)	41 (20.30)	
Total household income	74,269 (66,852)	71,801 (57,610)	63,007 (53,036)	0.11
Marital status				0.11
Not married	105 (35.35)	79 (37.44)	90 (44.55)	
Married	192 (64.65)	132 (62.56)	112 (55.45)	
Site of HRV data collection				0.89
University of California, Los Angeles	105 (35.35)	68 (32.23)	70 (34.65)	
University of Wisconsin-Madison	130 (43.77)	92 (43.60)	90 (44.55)	
Georgetown University	62 (20.88)	51 (24.17)	42 (20.79)	
Systolic blood pressure	130.36 (16.94)	130.06 (17.01)	128.76 (17.47)	0.57
Diastolic blood pressure	75.86 (10.51)	75.85 (10.50)	76.76 (9.88)	0.58
Body mass index (kg/m^2)	28.80 (5.51)	28.89 (6.02)	30.25 (6.51)	0.02
Anti-depressant medication	33 (11.11)	26 (12.32)	23 (11.39)	0.91
Beta-blocker medication	26 (8.75)	17 (8.06)	15 (7.43)	0.87
Depression: CES-D	27 (9.09)	33 (15.64)	50 (24.75)	<.0001
Physical activity				0.31
No regular exercise	67 (22.56)	37 (17.54)	46 (22.77)	
Regular exercise	230 (77.44)	174 (82.46)	156 (77.23)	
Smoking status				0.06
Never smoker	174 (58.59)	127 (60.19)	97 (48.02)	
Past smoker	82 (27.61)	58 (27.49)	64 (31.68)	
Current smoker	41 (13.80)	26 (12.32)	41 (20.30)	
Alcohol use (in the past month)				0.77
None	85 (28.62)	71 (35.65)	58 (28.71)	
Less than 1 day/week	81 (27.27)	59 (27.96)	55 (27.23)	
1-2 days/week	55 (18.52)	35 (16.59)	43 (21.29)	
3-7 days/week	76 (25.59)	46 (21.80)	46 (22.77)	
Negative affect	1.40 (0.50)	1.51 (0.55)	1.71 (0.72)	<.0001

Note. HRV = heart rate variability; CES-D = Centers for Epidemiological Studies - Depression

*Comparisons between levels of perceived discrimination were made using a one-way analysis of variance and X^2 tests

Table 2. Results of Regression Analyses of Baseline HRV and Perceived Discrimination, Race, and Depression (n=710)

	LF-HRV (ln ms^2)					HF-HRV (ln ms^2)				
	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]
Perceived Discrimination										
No PD	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Low PD	-0.06 (0.10)	-0.05 (0.09)	-0.10 (0.10)	-0.06 (0.10)	-0.10 (0.11)	-0.05 (0.12)	-0.05 (0.11)	-0.12 (0.12)	-0.08 (0.12)	-0.13 (0.13)
High PD	0.02 (0.10)	-0.07 (0.09)	-0.08 (0.10)	-0.10 (0.11)	-0.11 (0.12)	0.14 (0.12)	-0.00 (0.11)	-0.02 (0.12)	-0.03 (0.13)	-0.04 (0.14)
Race										
White		ref	ref	ref	ref		ref	ref	ref	ref
Black		0.10 (0.13)	0.09 (0.13)	0.06 (0.18)	0.07 (0.19)		**0.43 (0.16)****	**0.42 (0.16)****	**0.38 (0.22)***	0.40 (0.22)
Other		-0.15 (0.12)	-0.16 (0.12)	-0.21 (0.22)	-0.22 (0.22)		-0.05 (0.15)	-0.06 (0.15)	-0.12 (0.26)	-0.13 (0.26)
Depression		-0.07 (0.12)	-0.28 (0.21)	-0.07 (0.12)	-0.28 (0.21)		0.16 (0.14)	-0.12 (0.26)	0.15 (0.14)	-0.12 (0.26)
PD × Depression										
No PD × Depression			ref		ref			ref		ref
Low PD × Depression			0.42 (0.28)		0.44 (0.29)			0.54 (0.34)		0.56 (0.35)
High PD × Depression			0.18 (0.26)		0.17 (0.27)			0.24 (0.32)		0.23 (0.32)
PD × Race										
No PD × White				ref	ref				ref	ref
Low PD × Black				0.04 (0.29)	-0.07 (0.29)				0.09 (0.35)	-0.05 (0.36)
Low PD × Other				0.09 (0.10)	0.07 (0.30)				0.14 (0.36)	0.11 (0.36)
High PD × Black				0.10 (0.26)	0.08 (0.26)				0.10 (0.31)	0.07 (0.31)
High PD × Other				0.10 (0.29)	0.11 (0.29)				0.08 (0.35)	0.09 (0.35)

Note. Results are reported as B (SE); B = beta estimate; SE = standard error; PD = perceived discrimination

[a] Model 1 is unadjusted

[b] Model 2 includes all covariates

[c] Model 3 includes Model 2 variables plus the interaction term, PD × depression

[d] Model 4 includes Model 2 variables plus the interaction term, PD × race

[e] Model 5 includes Model 2 variables plus the interaction terms, PD × depression and PD × race

**p<.01, *p<.05

Table 3. Results of Regression Analyses of Stressor 1 - Baseline HRV and Perceived Discrimination (n=710)

	LF-HRV (ln ms^2)					HF-HRV (ln ms^2)				
	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]
Perceived Discrimination										
No PD	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Low PD	0.01 (0.07)	0.00 (0.07)	0.03 (0.07)	0.05 (0.08)	0.07 (0.08)	0.01 (0.06)	0.01 (0.06)	0.06 (0.06)	0.04 (0.07)	0.08 (0.07)
High PD	0.02 (0.07)	0.04 (0.07)	0.03 (0.08)	0.12 (0.09)	0.11 (0.09)	0.01 (0.06)	0.03 (0.06)	0.05 (0.07)	0.11 (0.07)	0.12 (0.08)
Race										
White		ref	ref	ref	ref		ref	ref	ref	ref
Black		-0.08 (0.10)	-0.07 (0.10)	0.04 (0.14)	0.04 (0.14)		0.02 (0.09)	0.03 (0.09)	0.23 (0.12)	0.22 (0.12)
Other		-0.01 (0.10)	-0.01 (0.10)	0.18 (0.16)	0.19 (0.16)		0.03 (0.08)	0.04 (0.08)	0.04 (0.14)	0.05 (0.14)
Depression		0.07 (0.09)	0.16 (0.16)	0.10 (0.09)	0.14 (0.16)		0.01 (0.08)	0.22 (0.14)	0.03 (0.08)	0.19 (0.14)
PD × Depression										
No PD × Depression			ref		ref			ref		ref
Low PD × Depression			-0.24 (0.21)		-0.18 (0.22)			**-0.42 (0.18)***		-0.36 (0.19)
High PD × Depression			-0.01 (0.20)		0.02 (0.20)			-0.18 (0.17)		-0.12 (0.17)
PD × Race										
No PD × White				ref	ref				ref	ref
Low PD × Black				-0.35 (0.22)	-0.29 (0.23)				**-0.40 (0.19)***	-0.31 (0.19)
Low PD × Other				-0.10 (0.23)	-0.09 (0.23)				0.10 (0.20)	0.12 (0.20)
High PD × Black				-0.13 (0.20)	-0.14 (0.20)				**-0.36 (0.17)***	**-0.34 (0.17)***
High PD × Other				**-0.47 (0.22)***	**-0.48 (0.22)***				-0.15 (0.19)	-0.16 (0.19)

Note. Results are reported as B (SE); B = beta estimate; SE = standard error; PD = perceived discrimination

[a] Model 1 is unadjusted

[b] Model 2 includes all covariates

[c] Model 3 includes Model 2 variables plus the interaction term, PD × depression

[d] Model 4 includes Model 2 variables plus the interaction term, PD × race

[e] Model 5 includes Model 2 variables plus the interaction terms, PD × depression and PD × race

**p<.01, *p<.05

Table 4. Results of Regression Analyses of Recovery 1 - Baseline HRV and Perceived Discrimination, Race, and Depression (n=710)

			LF-HRV ($\ln ms^2$)					HF-HRV ($\ln ms^2$)		
	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]
Perceived Discrimination										
No PD	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Low PD	-0.07 (0.06)	-0.09 (0.06)	-0.03 (0.07)	-0.04 (0.07)	-0.01 (0.08)	0.00 (0.05)	0.00 (0.05)	0.04 (0.05)	0.03 (0.06)	0.06 (0.06)
High PD	**-0.14 (0.06)***	**-0.15 (0.07)***	-0.12 (0.07)	-0.11 (0.08)	-0.08 (0.08)	-0.03 (0.05)	-0.02 (0.05)	-0.01 (0.06)	0.03 (0.06)	0.03 (0.06)
Race										
White		ref	ref	ref	ref		ref	ref	ref	ref
Black		-0.14 (0.09)	-0.13 (0.09)	-0.01 (0.13)	-0.04 (0.13)		0.05 (0.07)	0.06 (0.07)	**0.22 (0.10)***	**0.21 (0.10)***
Other		-0.02 (0.09)	-0.01 (0.09)	0.03 (0.15)	0.03 (0.15)		-0.03 (0.07)	-0.03 (0.07)	-0.05 (0.12)	-0.05 (0.12)
Depression		0.06 (0.08)	**0.34 (0.15)***	0.08 (0.08)	**0.32 (0.15)***		-0.02 (0.07)	0.12 (0.12)	-0.01 (0.07)	0.09 (0.12)
PD × Depression										
No PD × Depression			ref		ref			ref		ref
Low PD × Depression			**-0.48 (0.20)***		**-0.43 (0.20)***			-0.30 (0.16)		-0.24 (0.16)
High PD × Depression			-0.29 (0.18)		-0.26 (0.19)			-0.11 (0.15)		-0.06 (0.15)
PD × Race										
No PD × White				ref	ref				ref	ref
Low PD × Black				-0.35 (0.20)	-0.25 (0.20)				**-0.32 (0.16)***	-0.26 (0.16)
Low PD × Other				-0.01 (0.21)	0.01 (0.21)				0.08 (0.17)	0.09 (0.17)
High PD × Black				-0.15 (0.18)	-0.12 (0.18)				**-0.28 (0.14)***	-0.28 (0.14)
High PD × Other				-0.15 (0.21)	-0.15 (0.21)				-0.03 (0.16)	-0.04 (0.16)

Note. Results are reported as B (SE); B = beta estimate; SE = standard error; PD = perceived discrimination

[a] Model 1 is unadjusted

[b] Model 2 includes all covariates

[c] Model 3 includes Model 2 variables plus the interaction term, PD × depression

[d] Model 4 includes Model 2 variables plus the interaction term, PD × race

[e] Model 5 includes Model 2 variables plus the interaction terms, PD × depression and PD × race

**p<.01, *p<.05

Table 5. Results of Regression Analyses of Stressor 2 - Baseline HRV and Perceived Discrimination, Race, and Depression (n=710)

	LF-HRV ($ln\ ms^2$)					HF-HRV ($ln\ ms^2$)				
	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]
Perceived Discrimination										
No PD	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Low PD	0.04 (0.07)	0.03 (0.08)	0.08 (0.08)	0.13 (0.09)	0.16 (0.09)	-0.02 (0.06)	-0.02 (0.06)	0.02 (0.07)	0.06 (0.07)	0.07 (0.07)
High PD	-0.04 (0.08)	-0.02 (0.08)	-0.06 (0.09)	0.08 (0.09)	0.04 (0.10)	-0.04 (0.06)	0.01 (0.07)	0.00 (0.07)	0.07 (0.08)	0.06 (0.08)
Race										
White		ref	ref	ref	ref		ref	ref	ref	ref
Black		-0.09 (0.11)	-0.08 (0.11)	0.20 (0.15)	0.21 (0.16)		0.10 (0.09)	0.12 (0.09)	**0.37 (0.15)****	**0.37 (0.13)****
Other		-0.17 (0.11)	-0.17 (0.10)	0.00 (0.18)	0.01 (0.18)		-0.05 (0.09)	-0.04 (0.09)	-0.04 (0.15)	-0.04 (0.15)
Depression		0.12 (0.10)	0.15 (0.18)	0.16 (0.10)	0.10 (0.18)		0.01 (0.05)	0.08 (0.15)	0.01 (0.08)	0.03 (0.15)
PD × Depression										
No PD × Depression			ref		ref			ref		ref
Low PD × Depression			-0.31 (0.23)		-0.16 (0.24)			-0.26 (0.20)		-0.14 (0.20)
High PD × Depression			0.18 (0.22)		0.26 (0.22)			-0.03 (0.18)		0.04 (0.19)
PD × Race										
No PD × White				ref	ref				ref	ref
Low PD × Black				**-0.78 (0.24)****	**-0.71 (0.25)****				**-0.57 (0.20)****	**-0.52 (0.21)***
Low PD × Other				-0.13 (0.25)	-0.12 (0.25)				-0.01 (0.21)	-0.00 (0.21)
High PD × Black				-0.34 (0.21)	-0.39 (0.22)				**-0.40 (0.18)***	**-0.41 (0.18)***
High PD × Other				-0.39 (0.24)	-0.42 (0.24)				-0.04 (0.20)	-0.05 (0.21)

Note. Results are reported as B (SE); B = beta estimate; SE = standard error; PD = perceived discrimination

[a] Model 1 is unadjusted

[b] Model 2 includes all covariates

[c] Model 3 includes Model 2 variables plus the interaction term, PD × depression

[d] Model 4 includes Model 2 variables plus the interaction term, PD × race

[e] Model 5 includes Model 2 variables plus the interaction terms, PD × depression and PD × race

**p<.01, *p<.05

Table 6. Results of Regression Analyses of Recovery 2 - Baseline HRV and Perceived Discrimination, Race, and Depression (n=710)

	LF-HRV (ln ms^2)					HF-HRV (ln ms^2)				
	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]
Perceived Discrimination										
No PD	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Low PD	-0.03 (0.07)	-0.03 (0.07)	0.04 (0.07)	-0.01 (0.08)	0.04 (0.08)	0.02 (0.05)	0.03 (0.05)	0.06 (0.05)	0.06 (0.06)	0.08 (0.06)
High PD	-0.02 (0.07)	0.01 (0.07)	0.06 (0.08)	0.09 (0.08)	0.13 (0.09)	0.01 (0.05)	0.03 (0.05)	-0.00 (0.06)	0.05 (0.06)	0.02 (0.07)
Race										
White		ref	ref	ref	ref		ref	ref	ref	ref
Black		-0.04 (0.10)	-0.03 (0.10)	0.08 (0.14)	0.05 (0.14)		0.11 (0.07)	0.12 (0.07)	**0.23 (0.11)***	**0.24 (0.11)***
Other		-0.05 (0.09)	-0.04 (0.09)	0.03 (0.16)	0.04 (0.16)		-0.06 (0.07)	-0.06 (0.07)	-0.08 (0.12)	-0.08 (0.12)
Depression		-0.01 (0.09)	0.35 (0.16)	0.00 (0.09)	**0.34 (0.16)***		-0.09 (0.07)	-0.08 (0.12)	-0.09 (0.07)	-0.10 (0.12)
PD × Depression										
No PD × Depression			ref		ref			ref		ref
Low PD × Depression			**-0.56 (0.19)***		**-0.57 (0.21)***			-0.20 (0.16)		-0.17 (0.16)
High PD × Depression			**-0.41 (0.18)***		-0.37 (0.20)			0.12 (0.15)		0.16 (0.15)
PD × Race										
No PD × White				ref	ref				ref	ref
Low PD × Black				-0.11 (0.21)	0.03 (0.22)				-0.20 (0.16)	-0.14 (0.17)
Low PD × Other				0.01 (0.22)	0.03 (0.22)				0.00 (0.17)	0.01 (0.17)
High PD × Black				-0.28 (0.19)	-0.23 (0.19)				-0.20 (0.15)	-0.23 (0.15)
High PD × Other				-0.25 (0.22)	-0.24 (0.21)				0.05 (0.17)	0.03 (0.17)

Note. Results are reported as B (SE); B = beta estimate; SE = standard error; PD = perceived discrimination

[a] Model 1 is unadjusted

[b] Model 2 includes all covariates

[c] Model 3 includes Model 2 variables plus the interaction term, PD × depression

[d] Model 4 includes Model 2 variables plus the interaction term, PD × race

[e] Model 5 includes Model 2 variables plus the interaction terms, PD × depression and PD × race

**p<.01, *p<.05

Table 7. Results of Regression Analyses of Resting Heart Rate (beats/min) and Perceived Discrimination, Race, and Depression (n=710)

	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]
Perceived Discrimination					
No PD	ref	ref	ref	ref	ref
Low PD	0.28 (0.95)	-0.29 (0.90)	0.10 (0.97)	-0.50 (1.03)	-0.22 (1.06)
High PD	0.86 (0.96)	-0.29 (0.94)	0.02 (1.03)	-0.53 (1.11)	-0.24 (1.16)
Race					
White		ref	ref	ref	ref
Black		-0.93 (1.31)	-0.85 (1.31)	-1.31 (1.85)	-1.54 (1.86)
Other		1.77 (1.24)	1.85 (1.24)	0.81 (2.15)	0.84 (2.15)
Depression		0.61 (1.19)	2.74 (2.13)	0.64 (1.19)	2.84 (2.15)
PD × Depression					
No PD × Depression			ref		ref
Low PD × Depression			-3.34 (2.78)		-3.32 (2.87)
High PD × Depression			-2.46 (2.61)		-2.72 (2.65)
PD × Race					
No PD × White				ref	ref
Low PD × Black				-0.85 (2.85)	-0.12 (2.95)
Low PD × Other				2.62 (3.00)	2.74 (3.00)
High PD × Black				1.52 (2.55)	1.91 (2.59)
High PD × Other				0.32 (2.91)	0.38 (2.92)

Note. Results are reported as B (SE); B = beta estimate; SE = standard error; PD = perceived discrimination

[a] Model 1 is unadjusted and does not include other covariates

[b] Model 2 includes all covariates

[c] Model 3 includes Model 2 variables plus the interaction term, PD × depression

[d] Model 4 includes Model 2 variables plus the interaction term, PD × race

[e] Model 5 includes Model 2 variables plus the interaction terms, PD × depression and PD × race

**p<.01, *p<.05

Table 8. Results of Regression Analyses of Blood Pressure and Perceived Discrimination, Race, and Depression (n=710)

	SBP (mmHg)					DBP (mmHg)				
	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]
Perceived Discrimination										
No PD	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Low PD	-0.30 (1.54)	0.28 (1.08)	0.06 (1.16)	-0.40 (1.23)	-0.51 (1.27)	-0.01 (0.93)	0.04 (0.68)	0.37 (0.73)	0.33 (0.78)	0.54 (0.80)
High PD	-1.60 (1.56)	-0.44 (1.13)	-0.70 (1.23)	-0.46 (1.33)	-0.65 (1.39)	0.90 (0.94)	0.74 (0.71)	1.36 (0.77)	0.62 (0.84)	1.17 (0.87)
Race										
White		ref	ref	ref	ref		ref	ref	ref	ref
Black		0.11 (1.57)	0.07 (1.57)	-1.09 (2.21)	-0.96 (2.023)		0.50 (0.98)	0.56 (0.99)	0.12 (1.39)	-0.21 (1.39)
Other		**-4.55 (1.47)****	**-4.60 (1.48)****	**-5.12 (2.56)***	**-5.12 (2.57)***		**3.01 (0.93)****	**3.08 (0.93)****	**4.17 (1.61)****	**4.13 (1.61)****
Depression		-1.76 (1.42)	-3.21 (2.55)	-1.81 (1.43)	-2.99 (2.57)		0.32 (0.89)	**3.17 (1.60)***	0.40 (0.90)	**3.27 (1.61)***
PD × Depression										
No PD × Depression			ref		ref			ref		ref
Low PD × Depression			2.01 (3.33)		1.49 (3.44)			-3.29 (2.08)		-3.03 (2.15)
High PD × Depression			1.91 (3.13)		1.69 (3.18)			**-4.25 (1.96)***		**-4.55 (1.98)***
PD × Race										
No PD × White				ref	ref				ref	ref
Low PD × Black				2.16 (3.42)	1.87 (3.53)				-1.36 (2.15)	-0.85 (2.21)
Low PD × Other				3.49 (3.59)	3.44 (3.60)				-1.65 (2.26)	-1.56 (2.25)
High PD × Black				1.89 (3.06)	1.63 (3.10)				1.81 (1.92)	2.50 (1.94)
High PD × Other				-1.44 (3.49)	-1.50 (3.50)				-1.77 (2.19)	-1.55 (2.19)

Note. Results are reported as B (SE); B = beta estimate; SE = standard error; PD = perceived discrimination

[a] Model 1 is unadjusted

[b] Model 2 includes all covariates

[c] Model 3 includes Model 2 variables plus the interaction term, PD × depression

[d] Model 4 includes Model 2 variables plus the interaction term, PD × race

[e] Model 5 includes Model 2 variables plus the interaction terms, PD × depression and PD × race

**p<.01, *p<.05

SUMMARY, PUBLIC HEALTH IMPLICATIONS, AND FUTURE DIRECTIONS

This study was conducted in order to examine the association between perceived discrimination and the stress reactivity in HRV, a measure of autonomic functioning. We also explored whether perceived discrimination would be associated with traditional CVD risk factors (resting HR, SBP, DBP) like in previous studies. Based on previous literature, we hypothesized that race or depression may modify this relationship. Perceived discrimination was not a significant predictor of resting HR or SBP but was a significant predictor of lower DBP among depressed participants with high perceived discrimination. In LF-HRV, the interaction between perceived discrimination and race was significantly associated with worse stress reactivity while perceived discrimination and depression was significantly associated with worse recovery. In HF-HRV, blacks with increased perceived discrimination had significantly worse stress reactivity and recovery compared to whites with no perceived discrimination.

Although there are limitations, this is the first study to our knowledge that assesses the association of perceived discrimination in relation to changes in HRV during stressor tasks. Those with increased perceived discrimination may be at greater risk for poor stress reactivity and recovery. Due to the pervasive nature of racial discrimination, increased rumination among blacks may lead to chronic stress, CVD, and the health disparities still seen in the United States (46, 47). Rumination or perseverative thinking is also observed in individuals who are depressed and may explain poor recovery in LF-HRV in this study (46, 48). Understanding the mechanisms in which perceived discrimination leads to dysfunction of stress reactivity may explain how increased perceived discrimination ultimately leads to poor CVD outcomes among blacks or those

with depression. In the future, perceived discrimination and HRV could possibly be used in order to identify those at high risk for CVD and other stress-related illnesses in the population.

Researchers should consider how perceived discrimination and HRV are measured in future studies. Many validated instruments that have been used or modified to assess perceived discrimination leading to difficult comparisons across studies. The scoring of these instruments can lead to varying cutpoint categorizations. Also, the measurement of HRV and its interpretation in relation to autonomic system functioning needs further clarification. HRV is multifaceted and may be incorporating other causes of HRV rather than perceived discrimination itself (50-52). But based on this study, dysfunction in stress reactivity as measured by HRV may explain how perceive discrimination becomes embodied and leads to poor health.

Future research should explore other potential stress mechanisms in which perceived discrimination may have an affect. Identifying how perceived discrimination is embodied would clarify how higher levels of perceived discrimination can lead to a higher risk for CVD risk factors and poor CVD outcomes among vulnerable populations. It would also inform a specific biological mechanism where people can intervene. Experiences and consequently the perception of discrimination may occur very early in age (21). Conducting similar research on younger cohorts may help identify when the manifestation of abnormal stress reactivity and recovery in HRV occurs. Although studying individual perceived discrimination is important, the effects of systemic racism may be more pervasive among blacks given the history of race relations in the United States (54). Additional research that looks at multi-level associations with a life course

approach may advance the knowledge on the causal impacts of perceived discrimination on CVD outcomes.

According to this study, the autonomic dysfunction during stress and recovery may explain how increased perceived discrimination may lead to poor CVD outcomes among blacks or those with depression. Additional research in this area could inform possible interventions that aim to improve autonomic function or manage perceived discrimination. Future directions of this issue should focus on improving the measurement of both perceived discrimination and HRV among racial/ethnic minorities and those with mental illness across the United States.

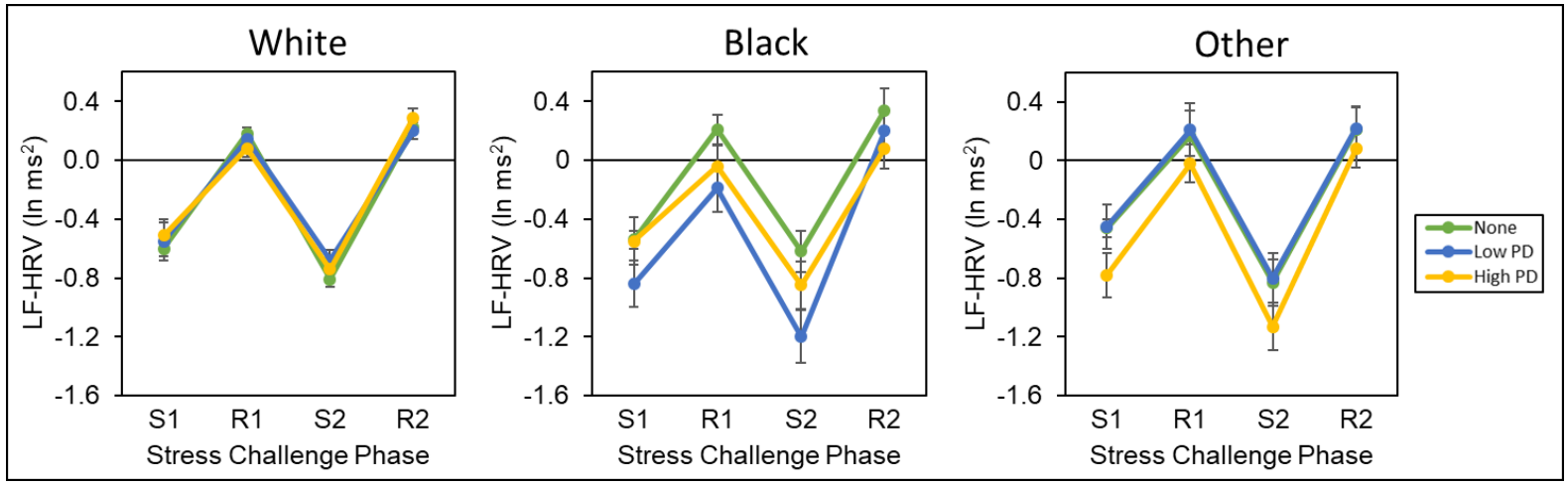

Figure 1. Effect modification of race on perceived discrimination and LF-HRV at each stress challenge phase. The mean change in LF-HRV (ln ms^2) in non-Hispanic whites, non-Hispanic blacks, and other race. Error bar magnitude is SEM.

Abbreviations: S1 = stressor 1 – baseline; R2 = recovery 1 – baseline; S2 = stressor 2 – baseline; R2 = recovery 2 – baseline; PD = perceived discrimination; LF-HRV = low frequency heart rate variability; SEM = standard error of the mean

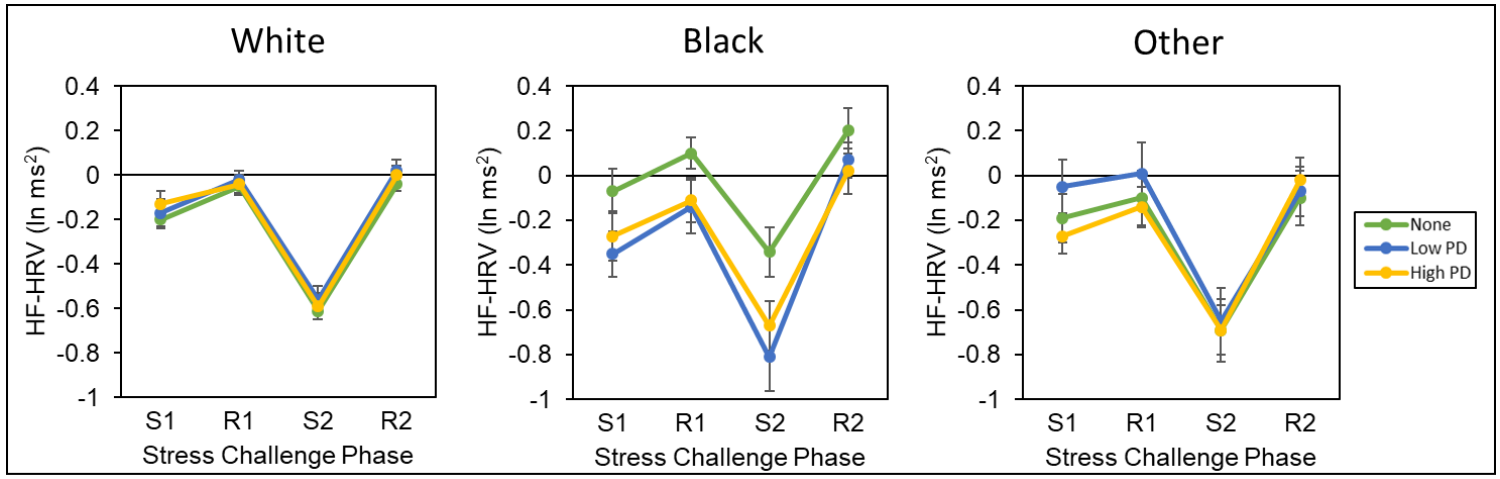

Figure 2. Effect modification of race on perceived discrimination and HF-HRV at each stress challenge phase. The mean change in HF-HRV (ln ms^2) in non-Hispanic whites, non-Hispanic blacks, and other race.

Abbreviations: S1 = stressor 1 – baseline; R2 = recovery 1 – baseline; S2 = stressor 2 – baseline; R2 = recovery 2 – baseline; PD = perceived discrimination; HF-HRV = high frequency heart rate variability; SEM = standard error of the mean

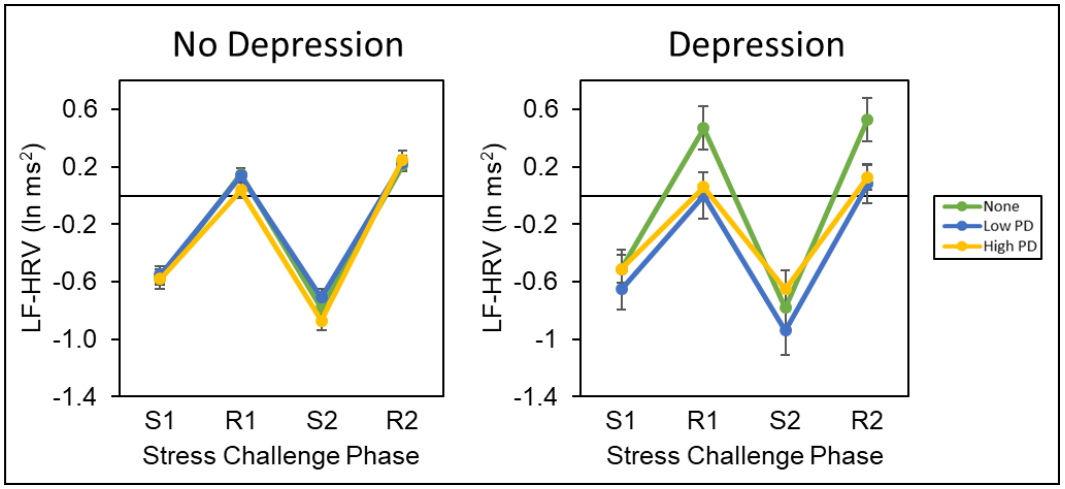

Figure 3. Effect modification of depression on perceived discrimination and LF-HRV at each stress challenge phase. The mean change in LF-HRV (ln ms^2) in participants with no depression and depression based on the CES-D.

Abbreviations: S1 = stressor 1 – baseline; R2 = recovery 1 – baseline; S2 = stressor 2 – baseline; R2 = recovery 2 – baseline; PD = perceived discrimination; LF-HRV = low frequency heart rate variability; SEM = standard error of the mean

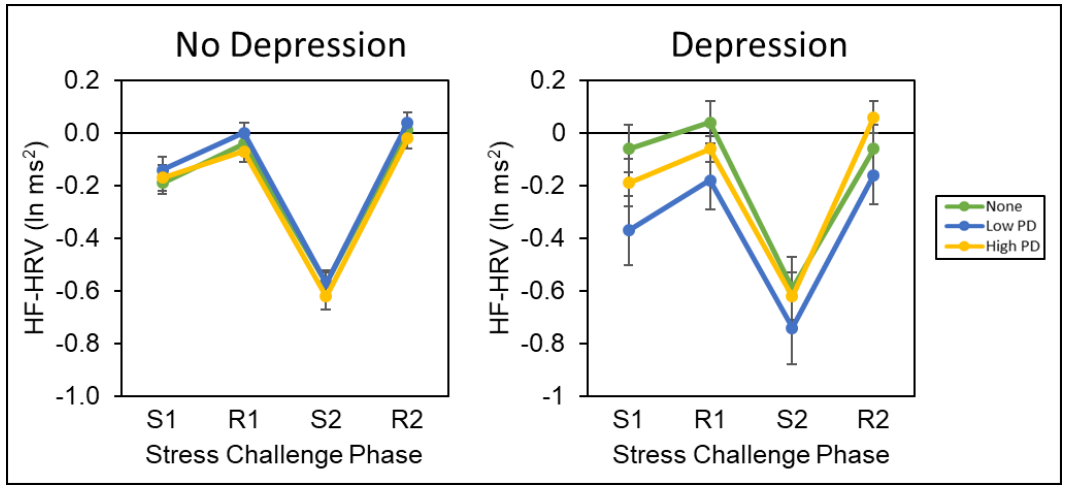

Figure 4. Effect modification of depression on perceived discrimination and HF-HRV at each stress challenge phase. The mean change in HF-HRV (ln ms^2) in participants with no depression and depression based on the CES-D.

Abbreviations: S1 = stressor 1 – baseline; R2 = recovery 1 – baseline; S2 = stressor 2 – baseline; R2 = recovery 2 – baseline; PD = perceived discrimination; HF-HRV = high frequency heart rate variability; SEM = standard error of the mean