Emotional Pathways to the Biological Embodiment of Racial Discrimination Experiences

Emily F. Hittner, MS and Emma K. Adam, PhD

ABSTRACT

Objective: Racial discrimination experiences are common among youth with an ethnic minority background, and such experiences affect health. Stress-sensitive systems like the hypothalamic-pituitary-adrenal (HPA) axis have been proposed as one mechanism. HPA-axis activity, measured through daily patterns of salivary cortisol, is altered among individuals who experience discrimination. We know little about the day-to-day processes by which discrimination experiences become embodied in stress biology. The HPA axis is responsive to negative social-evaluative (NSE) emotion. The present study investigated whether NSE emotions are a pathway by which discrimination dysregulates HPA-axis functioning as measured by cortisol levels.

Methods: Perceived discrimination, diurnal cortisol, and changes in NSE emotion were assessed in a sample of 102 young adults. Emotions and cortisol were measured across the day for seven consecutive days in naturalistic settings. Multilevel modeling and regression analyses were used to examine average and day-to-day associations between discrimination, NSE emotion, and cortisol. Mediation and specificity analyses were conducted.

Results: Discrimination was associated with NSE emotion ($\beta = 0.34$, $p = .001$). Day-to-day changes ($\beta = 0.10$, $p = .002$) and average levels ($\beta = 0.03$, $p = .013$) of NSE emotion were associated with dysregulated cortisol. NSE emotion mediated the association between discrimination and diurnal cortisol slopes ($\beta = 0.10$ [95% confidence interval = 0.01–0.21]). Findings were robust for covariates including stressful life events, more pronounced for NSE emotion compared with negative affect at the day level, similar for NSE emotion and general negative affect at the person level, and specific to cortisol slopes.

Conclusions: Findings suggest that daily NSE and average negative emotions are important pathways by which racial discrimination gets under the skin, or is embodied, in stress biology.

Key words: emotion, discrimination, diurnal cortisol slope, shame.

INTRODUCTION

Feelings of intense embarrassment or shame are often more than fleeting emotion states. These negative social-evaluative (NSE) emotions are linked to physiological changes in stress-responsive systems, including the hypothalamic-pituitary-adrenal (HPA) axis. The HPA axis, measured through daily patterns of salivary cortisol, has been shown to be affected by past experiences of discrimination (1). Discrimination may also be a powerful elicitor of NSE emotion. Bringing together several past lines of research, the current study tests whether average and day-to-day changes in NSE emotion, above and beyond general negative affect, are pathways by which experiences of perceived racial discrimination (PRD) get under the skin, or is embodied, to predict dysregulated diurnal cortisol.

Stress, Diurnal Cortisol, and Health

Perceptions of psychosocial stress, particularly those that involve uncontrollable or social-evaluative experiences, trigger changes in the HPA axis as evidenced by acute increases in cortisol, a key hormonal product of the HPA axis (2,3). Both acute and chronic stressors have also been related to changes in the diurnal cortisol rhythm (4–6). Cortisol follows a diurnal pattern, which is characterized by high cortisol levels at waking, a sharp increase in cortisol reaching its highest point approximately 30 minutes after waking, and a decline across the rest of the day (7–9). Research has shown changes in this diurnal cortisol rhythm in anticipation of and in response to acute stressors and acute increases in negative emotions (2,10), daily challenges (11–13), and chronic stressors (14). Although acute stressors and acute increases in negative emotions are associated with temporary surges in cortisol (15–19), more prolonged and repeated experiences of negative emotions are associated with changes in the diurnal cortisol rhythm. In particular, persistent negative emotions often elicit a flattening of the rhythm, emerging from a combination of lower morning and higher evening cortisol (4). A small and temporary flattening of the rhythm can be seen even in response to daily increases in negative emotions (11,20), with stronger and more lasting changes observed in response to accumulated stress, trauma, or more trait-like differences in emotion (21–25). Unlike average cortisol, which is harder to interpret given that either high levels or low levels can be interpreted as signs of "dysregulation," the literature is much more consistent in showing both stress-related flattenings of the diurnal cortisol rhythm (6), and associations between flatter diurnal

CAR = cortisol awakening response, **HPA axis** = hypothalamic-pituitary-adrenal axis, **NSE emotion** = negative social-evaluative emotion, **PRD** = perceived racial discrimination

SDC Supplemental Content

From the School of Education and Social Policy (Hittner, Adam) and Institute for Policy Research (Adam), Northwestern University, Evanston, Illinois. Address correspondence to Emily F. Hittner, MS, Northwestern University, 2120 Campus Drive, Evanston, IL 60208. E-mail: emilyhittner@u.northwestern.edu

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cortisol rhythms and negative health outcomes (for a meta-analysis supporting the latter point, see Ref. 26).

Racial Discrimination and Diurnal Cortisol Slopes

HPA-axis functioning has been shown to vary by race and ethnicity, with persons of color found to have flatter diurnal cortisol rhythms (27–30). One potentially relevant feature of the lives of individuals of color is exposure to PRD. Perceived discrimination can be defined as an individual feeling that one is being treated unfairly based on the affiliation they have with a particular group (e.g., race, sex, sexual orientation, religion, physical appearance, and age) (31); PRD occurs when an individual feels he/she are being treated unfairly because of race. PRD is experienced as a psychosocial stressor, and experiences of discrimination contribute to chronic stress (32–37). Indeed, previous research has shown that PRD is associated with dysregulated diurnal cortisol as evidenced by flatter diurnal cortisol slopes (1,38), with effects most pronounced in individuals of color.[1] Thus, PRD is one important contributor to racial and ethnic differences in diurnal cortisol rhythms.

NSE Emotions as a Mediator

One potential mechanism for how perceived discrimination may result in changes in diurnal cortisol rhythms is through the experience of negative emotions and more specifically, through NSE emotions. Past theoretical (41) and empirical research has posited that negative emotions may act as a mediator for the association between PRD and adjustment outcomes. For instance, indirect empirical evidence shows that affective responding (e.g., anger) mediated longitudinal associations between discrimination and health status and health behavior (42,43). In a similar vein, thoughts lingering on negative emotions (i.e., rumination) have been shown to mediate the association between PRD and health (e.g., depressive symptoms, hostility, and aggression (44)). PRD and threats to the social self (i.e., threats to one's self-esteem or feelings of acceptance) have been associated with NSE emotions like shame in laboratory-based settings (45,46). In naturalistic settings, same-day and prior-day negative emotions such as loneliness have be linked to changes in diurnal cortisol (11,20). To our knowledge, NSE emotion has not been assessed in relation to cortisol in naturalistic contexts. Further research is needed to address a) whether findings that past PRD is associated flatter diurnal cortisol (1,38) replicate for concurrent PRD-cortisol associations in this young adult community sample; b) whether, in naturalistic settings, PRD relates to NSE emotion; c) whether average and day-to-day changes in NSE emotion are associated with diurnal cortisol; and d) whether the association between PRD and diurnal cortisol is mediated by NSE emotion in particular. Moreover, further research should explore how proximity (i.e., day-to-day changes versus average emotion) and specificity (i.e., NSE emotion compared with general negative affect) of emotion relate to discrimination and cortisol parameters.

[1] According to critical race perspectives, it is not possible for white individuals to experience racial discrimination because of their past and present position of privilege in US society. However, we note that our study measured perceived discrimination, which assessed whether individuals feel that they are being treated unfairly, regardless of whether that is truly the case. We also note that in the case of individuals of color, these perceptions correspond to an objective reality in which individuals of color are treated unfairly at both structural and interpersonal levels (39,40).

The Present Study

The current study used an analytic sample of 102 participants from the eighth wave of the Maryland Adolescent Development in Context Study (MADICS). It was hypothesized that the association between current levels of PRD and aspects of diurnal cortisol (particularly, the diurnal cortisol slope) would be explained by higher levels of NSE emotion. To test this hypothesis, analyses examined a) whether current PRD is associated with flatter diurnal cortisol slopes, b) whether PRD is associated with NSE emotion, c) how average levels of and daily changes in NSE emotion related to changes in diurnal cortisol slopes, and d) whether associations between PRD and diurnal cortisol slopes were mediated by levels of NSE emotion at the time of cortisol measurement. Secondary analyses further examined the specificity and generalizability of our findings through testing i) whether associations extend to general negative affect and whether NSE emotions are significant above and beyond general negative affect, ii) which specific emotions and emotion antecedents were driving the associations, and iii) whether findings extended to other cortisol parameters like morning, bedtime, and total cortisol levels.

METHODS

Study Overview

The present study focused on wave 8 of the MADICS (47). MADICS is a prospective longitudinal study of 1482 Black and white adolescents (n = 879 Black adolescents; 49% women) followed up for 20 years. Reflecting the demographics of the location at the time of recruitment, the sample consisted only of Black and white youth. Students were recruited at age 12 years in the fall of 1991 and were interviewed during eight waves: 7th grade (waves 1 and 2; 1991–1992), 8th grade (wave 3; 1993), 11th grade (wave 4; 1996), a year after high school (wave 5; 1997), 3 years after high school (wave 6; 1999), around age 30 years (wave 7; 2009), and around age 32 years (wave 8; 2010–2011). In wave 8, the study added physiological data and daily dairies that examined stress reactivity, regulation, and emotional functioning. These participants were sampled based on their levels of PRD in prior waves. Levels of PRD were calculated for Black and white participants for each wave and were then indexed as being above or below the median for each wave (with individuals above the median consider high discrimination for that wave). A count variable was then computed across waves to indicate the number of waves each individual encountered high discrimination. Equal numbers of participants were then selected from low, medium, and high discrimination within-race tertiles on this count variable and recruited into the present subsample. In wave 8, participants again were asked about their PRD, which was used for the present analyses. Prior articles assessed for systematic attrition of earlier waves (48,49), and showed that participants who remained in the study had higher income and were more likely to be women. Written consent was obtained from all participants. Procedures were approved by the institutional review boards of Northwestern University, the University of Michigan, Harvard University, and the University of California at San Francisco. Information on the full procedures for each wave is available from the Henry A. Murray Research Archive (https://murray.harvard.edu/dataverse).

Participants

From the initial sample, a wave 8 subsample was selected, as specified previously, to represent participants who had low, medium, and high levels of discrimination across prior waves and were willing to participate in additional measures that included a 7-day diurnal cortisol data collection period and a 7-day daily diary study (n = 124). The sample only included Black and white participants, which was representative of the county where the study was conducted at the time of recruitment. Participants were excluded

(n = 12) from analyses if they used corticosteroid-based medication, used illicit drugs, or had atypical sleep patterns (e.g., shift work), which have each been shown to have implications on diurnal cortisol rhythms. Participants were also excluded if they did not complete questionnaire data for PRD (n = 10) in the current wave. The remaining analytic sample included 102 participants, which comprised 45% African American and 61% female with an average (SD) family income of $75,905 ($45,645) and mean parent education of 12.82 years of school (some college).

Measures

Salivary Cortisol

Cortisol was measured from saliva samples provided by participants at waking, 30 minutes after waking, and at bedtime each day for 1 week. Participants were instructed to passively drool through a small straw into a 2-ml polypropylene vial, not to eat or drink 30 minutes before each sample, to record the time of each sample, and to refrigerate all samples after collection.

From these cortisol data, the diurnal cortisol slope, defined by the change of cortisol from waking to bedtime, was estimated as a latent variable[2] (11). A latent estimate of the postawakening cortisol surge (cortisol awakening response, or CAR) was also calculated and included in models to account for variance associated with this surge, but not used as an outcome of interest given that our approach to measuring the CAR does not meet current measurement standards (50). Total cortisol was measured by the area under the curve for the wake and bedtime samples averaged across the 7 days of testing. This was calculated separately for each day using the trapezoidal function (51), then averaged across the week (the CAR sample was not included, as the postawakening cortisol surge is influenced by different biological mechanisms than the underlying diurnal rhythm (52)). The present article examined diurnal cortisol slope and total cortisol as outcome variables in addition to morning and bedtime cortisol levels. As noted previously, we did not predict individual differences in the CAR because it did not meet current measurement standards (50).

Perceived Racial Discrimination

PRD was assessed during wave 8 and encompassed interpersonal experiences within work and school environments during young adulthood (16 items; e.g., "Overall, how much harder do you think your life has been because of unfair treatment based on your race/ethnicity?" "Do you think it will be harder or easier for you to get ahead in life because of your race/ethnicity?" 1 = *not at all* to 5 = *much harder*; α = .91) and were adapted from the Racism and Life Experiences Scale (53). Prior research on this sample used earlier waves of PRD measurement that were also adapted from the Racism and Life Experiences Scale (1,54). PRD was measured for all participants. PRD was significantly higher for Black (mean [SD] = 3.04 [0.93], min = 1.00, max = 5.13, skewness = 0.34 [SE = 0.37]) compared with white (mean [SD] = 1.81 [0.52], min = 1.00, max = 3.6, skewness = 1.1 [SE = 0.31]) participants (t = 8.52, p < .001). PRD distributions by race are plotted in Figure S1 (Supplemental Digital Content, http://links.lww.com/PSYMED/A612).

Daily Diary

Daily diaries were collected each day for 7 days including self-report levels of average emotion experience that day, rated at the end of each day. Daily emotions were assessed using an adapted version of the Positive and Negative Affect Schedule (55), in which additional items were added that were relevant to understanding HPA-axis activity, including depressed, anxious, rejected, judged, and embarrassed. Thus, each day, participants completed daily ratings for sad, anxious, alert, depressed, irritable, judged, excited, rejected, calm, nervous, angry, lonely, tired, embarrassed, happy, ashamed, and energetic (1 = *not at all*, 5 = *very much*). Factor analysis confirmed two subscales, negative (i.e., sad, anxious, depressed, irritable, nervous, lonely, tired, embarrassed, ashamed, and judged, rejected; α = .93) and positive affect (i.e., alert, excited, calm, happy, and energetic; α = .84). However, given our focus on social-evaluative experiences and emotions as a potential mediator (45), we also constructed a subscale of negative affect that isolates emotion antecedents and specific *NSE emotions* (i.e., embarrassed, ashamed, judged, and rejected; α = .94). Finally, we constructed a negative affect scale without NSE emotion (i.e., sad, anxious, depressed, irritable, nervous, angry, lonely, and tired; α = .92) to be used in secondary analyses testing the specificity of the average and day-level NSE emotion findings.

Covariates

Covariates include key demographic constructs known to be associated with diurnal cortisol rhythms, including race (i.e., indicator for Black race), sex (i.e., indicator for female), parental education (years of parental education), family income (measured in thousands of dollars), and stressful life events. Stressful life events were adapted from the Social Readjustment Rating Scale (56) and consisted of a sum of the occurrence of stressful events (16 items; i.e., death of a spouse, divorce, fired at work; 0 = did not occur; 1 = occurred; mean [SD] = 2.45 [2.55]). Race was also examined as a key moderator across analyses given that prior research has shown that the association between discrimination and diurnal cortisol is most pronounced for Black participants (1,38).

Data Analyses

Preliminary analyses first examined zero-order correlations between key study variables. To test our main hypotheses, primary analyses addressed the following: *Question 1*: Does current PRD relate to flatter diurnal cortisol slopes? *Question 2*: Do PRD experiences relate to NSE emotion? *Question 3*: Do average and day-to-day changes in NSE emotion relate to diurnal cortisol slopes? *Question 4*: Does NSE emotion mediate associations between PRD and diurnal cortisol slopes?

Question 1. We examined whether current PRD is associated with flatter diurnal cortisol slopes. A three-level hierarchical linear model used HLM 7.0 (57) with restricted maximum likelihood estimates to assess each person's diurnal cortisol rhythm by predicting momentary cortisol levels across the day from moment-level predictors entered at level 1 including the following: time since waking (with the coefficient reflecting the cortisol slope from waking to bedtime), time since waking squared (with the coefficient reflecting the acceleration or deceleration of the cortisol slope across the day), and an indicator used to estimate the size of the CAR (1 = sample taken 30 minutes after waking). Time was centered at the time of waking so that the intercept of the model reflected cortisol level at waking for each individual. Day-specific wake times were entered at level 2, and current PRD was entered at level 3. Random effects were included at level 2 predicting cortisol intercept and slope and at level 3 predicting average cortisol parameters. Day-level variables were group mean centered, and person-level continuous variables were grand mean centered. We first ran an unadjusted model, testing whether PRD was associated with flatter diurnal cortisol slopes. We then examined whether the association between PRD and diurnal cortisol differed by race using a race interaction with PRD, accounting for the main effects of PRD and race. In addition to race, we then adjusted for sex, parental education, family income, and stressful life events. Because PRD and race are likely largely overlapping in this sample, we also examined whether PRD is associated with diurnal cortisol adjusting for covariates without race in the model (i.e., sex, parental education, family income, and stressful life events).

Question 2. We examined whether PRD is associated with NSE emotion by calculating, for each person, the average of their NSE emotion for each day across the week. Multiple linear regressions were used to examine person-level associations between PRD and average NSE emotion. We first ran an unadjusted model. We then added a race interaction with PRD, accounting for the main effects of race and PRD. Next, we additionally adjusted for sex, parental education, family income, and stressful life events. As done previously, we also ran an adjusted model

[2]Using an uncontrolled three-level multilevel model that only included cortisol parameters (i.e., outcome: log-transformed cortisol; level 1: time since waking, time since waking squared, cortisol awakening response; level 2: day-level wake times), the ICC for each level was calculated (level 1: ICC = 0.34; level 2: ICC = 0.23; level 3: ICC = 0.43) to ensure the appropriate analytic strategy. The reliability estimates of random level 1 coefficients were 0.56 for the intercept and 0.66 for time since waking.

using all covariates except for race for the model that tests associations between NSE emotion and PRD.

Question 3. We tested whether daily changes in and average levels of NSE emotion related to changes in diurnal cortisol slopes. Day-to-day changes in emotion states and within-day clustering of cortisol variance, as well as day-specific wake times, were accounted for at level 2. Average NSE emotion was entered at level 3. Both same-day NSE emotion and prior-day NSE emotion (i.e., a 1-day prior lagged variable) were entered simultaneously to predict day-to-day changes in cortisol slope (Equation 1).[3]

Equation 1

Level 1 Model

$$\text{Log Cortisol}_{ijk} = \pi_{0jk} + \pi_{1jk}*\left(\text{Time Since Waking}_{ijk}\right) + \pi_{2jk}*\left(\text{Time Since Waking}^2{}_{ijk}\right) + \pi_{3jk}*\left(\text{CAR}_{ijk}\right) + e_{ijk}$$

Level 2 Model

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}*\left(\text{Wake Time}_{jk}\right) + \beta_{02k}*\left(\text{NSE Emotion}_{jk}\right) + \beta_{03k}*\left(\text{Prior}-\text{Day NSE Emotion}_{jk}\right) + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k} + \beta_{11k}*\left(\text{Wake Time}_{jk}\right) + \beta_{12k}*\left(\text{NSE Emotion}_{jk}\right) + \beta_{13k}*\left(\text{Prior}-\text{Day NSE Emotion}_{jk}\right) + r_{1jk}$$

$$\pi_{2jk} = \beta_{20k} + \beta_{21k}*\left(\text{Wake Time}_{jk}\right) + \beta_{22k}*\left(\text{NSE Emotion}_{jk}\right) + \beta_{23k}*\left(\text{Prior}-\text{Day NSE Emotion}_{jk}\right)$$

$$\pi_{3jk} = \beta_{30k} + \beta_{31k}*\left(\text{Wake Time}_{jk}\right) + \beta_{32k}*\left(\text{NSE Emotion}_{jk}\right) + \beta_{33k}*\left(\text{Prior}-\text{Day NSE Emotion}_{jk}\right)$$

Level 3 Model

$$\beta_{00k} = \gamma_{000} + \gamma_{001}(\text{Average NSE Emotion}) + u_{00k}$$

$$\beta_{01k} = \gamma_{010}$$

$$\beta_{02k} = \gamma_{020}$$

$$\beta_{03k} = \gamma_{030}$$

$$\beta_{10k} = \gamma_{100} + \gamma_{101}(\text{Average NSE Emotion}) + u_{10k}$$

$$\beta_{11k} = \gamma_{110}$$

$$\beta_{12k} = \gamma_{120}$$

$$\beta_{13k} = \gamma_{130}$$

$$\beta_{20k} = \gamma_{200} + \gamma_{201}(\text{Average NSE Emotion}) + u_{20k}$$

$$\beta_{21k} = \gamma_{210}$$

$$\beta_{22k} = \gamma_{220}$$

$$\beta_{23k} = \gamma_{230}$$

$$\beta_{30k} = \gamma_{300} + \gamma_{301}(\text{Average NSE Emotion}) + u_{30k}$$

$$\beta_{31k} = \gamma_{310}$$

Note *: i = person, j = day, k = moment*

We first ran an unadjusted model. Next, we added a race interaction with average NSE emotion, also accounting for the main effects of NSE emotion and race. Finally, we additionally adjusted for sex, parental education, family income, and stressful life events.

Question 4. We tested whether associations between PRD and diurnal cortisol rhythms were mediated by levels of NSE emotion using PROCESS 3.0 (58) with 5000 bootstrapped samples and seed set to 17 (59). Given that PRD was captured at the person level, we computed person-level estimates of NSE emotion and diurnal cortisol slopes so that all measurements were at the same time scale of analysis. To do this, we exported the fitted diurnal cortisol slopes (β_{10k}) from the unconditional three-level multilevel model to be used as the outcome variable. For the mediator, we averaged the daily NSE emotion across the week. As done previously, we first ran an unadjusted model. Although we hypothesized that this mediation model was moderated by race, we were underpowered and did not execute this analysis. Next, in addition to race, we adjusted for sex, parental education, family income, and stressful life events. We also tested the mediating pathway adjusting for all covariates except for race. Coefficients and confident intervals reported for mediation analyses reflect bootstrapped estimates. Using MedPower (60), with a sample size of 102 and an α of .05, we had a power of 0.91 to detect a β indirect effect of 0.13. For ease of interpretation, all continuous variables in the model were in SD units.

Secondary analyses examined specificity and generalizability of the main findings. First, we tested whether NSE emotion was more predictive of PRD and dysregulated cortisol slopes than general negative affect. To do this, we repeated our analyses using general negative affect (i.e., sad, anxious, depressed, irritable, nervous, angry, lonely, and tired). We then tested, when in the same model, whether daily and average NSE emotion were related to diurnal cortisol slopes above and beyond daily and average negative affect and covariates.

Second, we examined whether daily and average changes in specific discrete emotions and emotion antecedents drove the relationship between emotion and diurnal cortisol. With this aim, we repeated analyses using specific NSE emotion items (i.e., embarrassed, shame, rejected, and judged) and specific negative affect items (i.e., sad, anxious, depressed, irritable, nervous, angry, lonely, and tired) at both the day and person levels. We also tested whether these findings were specific to negative emotion or whether they generalized to positive affect and specific positive emotion (i.e., excited, energetic, alert, happy, and calm). We probed whether specific emotions mediated the relationship between PRD and diurnal cortisol slopes at the person level.

Third, we examined whether the relationship between PRD, average and daily NSE emotion, and HPA-axis activity extended to other cortisol

[3]Random effects were included for the intercept (r_{0jk}) and slope (r_{1jk}) along with intercepts for level 2 variables (u_{00k}, u_{10k}, u_{20k}, u_{30k}). Model comparisons supported this analytic decision as deviance decreased when we added a random effect for the intercept (r_{0jk}) and slope (r_{1jk}) compared with the intercept (r_{0jk}) only ($\chi^2 = 158.95$, $df = 2$, $p < .001$). Similarly, deviance significantly decreased in the model with random intercepts for all level 2 parameters ($\chi^2 = 241.94$, $df = 2$, $p < .001$). Of note, our cortisol awakening response measurement does not abide by the current criterion standard of measurement (50); we therefore did not predict individual differences in the CAR in our results and did not assign random effects for this variable. Similarly, we did not believe we had sufficient rationale to expect random effects for the (de)acceleration of the cortisol slope, and given our relatively small sample size, we needed to be conservative with our use of random effects.

parameters such as waking cortisol level, bedtime cortisol level, and total cortisol. Waking cortisol levels were estimated from the intercept of the three-level HLM cortisol model (e.g., time was centered at waking). Next, we recentered time at bedtime so that the intercept of the model reflected cortisol level at bedtime for each individual. In these models, we examined whether PRD and NSE emotion were related to changes in the corresponding cortisol waking and bedtime levels and whether NSE emotion mediated the association between PRD and waking/bedtime cortisol levels. Next, we repeated analyses using total cortisol instead of diurnal cortisol slope. We used a two-level hierarchical linear model to predict a natural log-transformed total cortisol from day-level (i.e., wake time, same-day NSE emotion, and prior-day NSE emotion) and person-level (i.e., average NSE emotion) variables. As done with diurnal cortisol slope, we exported the fitted total cortisol coefficients from the unconditional two-level multilevel model to be used as the outcome variable. Specificity and generalizability analyses mirrored the structure of the main analyses. When appropriate, unadjusted analyses were presented first, then a race interaction (when the main analyses reported significant moderation) was presented followed by the fully adjusted models (i.e., including race, sex, parental education, family income, and stressful life events for all analyses except for the relationship between PRD and diurnal cortisol slope where PRD and race were largely overlapping).

RESULTS

Zero-order intercorrelations for key study variables are presented in Table 1 and showed that a) current discrimination was related to flatter diurnal cortisol slopes, extending prior research using earlier waves of discrimination data (1); b) NSE emotion was related to higher levels of discrimination; and c) NSE emotion was related to flatter diurnal cortisol slopes.

Is Current PRD Related to Flatter Diurnal Cortisol Slopes?

Using a three-level hierarchical linear model, current PRD was related to flatter diurnal cortisol slopes (β = 0.05, SE = 0.02, t = 2.33, p = .022). This effect did not differ by race (β = 0.01, SE = 0.05, t = 0.27, p = .80), accounting for the main effect of race and PRD. Adjusting for race, sex, parental education, family income, and stressful life events, PRD was not associated with flatter diurnal cortisol slopes (β = 0.02, SE = 0.02, t = 0.93, p = .36). Adjusting for sex, parental education, family income, and stressful life events (and not race given its large overlap with PRD), PRD was associated with flatter diurnal cortisol slopes (β = 0.05, SE = 0.02, t = 2.12, p = .037).

Is PRD Related to NSE Emotion?

Using regression-based approaches, analyses probed whether PRD was related to average levels of NSE across the week. As seen in Table 1, PRD was associated with average NSE emotion (β = 0.40, SE = 0.09, t = 4.31, p < .001). Accounting for the main effect of race and PRD, there was a significant interaction between race and PRD for NSE emotion (β = 0.43, SE = 0.19, t = 2.24, p = .027), with Black participants showing signs of stronger NSE emotion at higher levels of PRD. These results remained largely stable when adjusting for race, sex, parental education, family income, and stressful life events for both the main effect relationship between PRD and NSE emotion (β = 0.34 SE = 0.10, t = 3.32, p = .001) and interaction effect between race and PRD on NSE emotion (β = 0.29, SE = 0.20, t = 1.98, p = .050). Of note, while in the expected direction, the adjusted interaction was at the threshold for statistical significance. PRD also was related to NSE emotion when adjusting for all covariates (i.e., sex, parental education, family income, and stressful life events) except for race (β = 0.35 SE = 0.09, t = 3.67, p < .001).

Is Average and Day-to-Day Changes in NSE Emotion Related to Diurnal Cortisol Slopes?

Higher average NSE emotion across the week was associated with flatter cortisol slopes (β = 0.03, SE = 0.01, t = 2.31, p = .023) as reflected in a significant person-level effect of NSE emotion on the cortisol slope intercept in a three-level multilevel model (Figure 1). At level 2 (the day level) of the same model, same-day NSE emotion was not related to same-day diurnal cortisol slopes (β = −0.03, SE = 0.03, t = −1.20, p = .23), but higher prior-day NSE emotion was associated with a significant flattening of diurnal cortisol slopes the next day (β = 0.10, SE = 0.03, t = 3.31, p = .001; Table 2). There was not a significant moderation by race for the association between diurnal cortisol slopes and average NSE emotion (β = −0.03, SE = 0.02, t = −1.67, p = .098) or prior-day NSE emotion (β = −0.08, SE = 0.06, t = −1.23, p = .22),

TABLE 1. Zero-Order Correlations Between Key Variables (n = 102)

	2	3	4	5	6	7	8	9	10	11	12
1. Wake time cortisol, μg/dl	−0.41**	0.15	0.59**	−0.11	−0.14	−0.20*	−0.17	0.06	−0.05	0.16	0.02
2. Cortisol awakening response		−0.18	0.32**	−0.16	−0.07	−0.07	0.09	0.27**	−0.05	0.11	−0.22*
3. Wake to bed cortisol slope			0.14	0.33**	0.25**	0.29**	0.35**	0.03	−0.08	0.07	0.18
4. Average total cortisol				−0.18	−0.07	−0.20	−0.06	0.26**	−0.10	0.21*	−0.09
5. NSE emotion across week					0.87**	0.40**	0.14	0.00	0.07	−0.22*	0.25*
6. Negative affect						0.33**	0.05	0.09	0.03	−0.28**	0.19
7. Perceived racial discrimination							0.36**	−0.07	−0.10	−0.11	0.30**
8. Black race indicator								0.06	−0.30**	0.01	0.07
9. Female sex indicator									−0.02	0.02	−0.03
10. Parental education										−0.03	0.14
11. Family income											−0.11
12. Stressful life events											

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

NSE = negative-social evaluative.

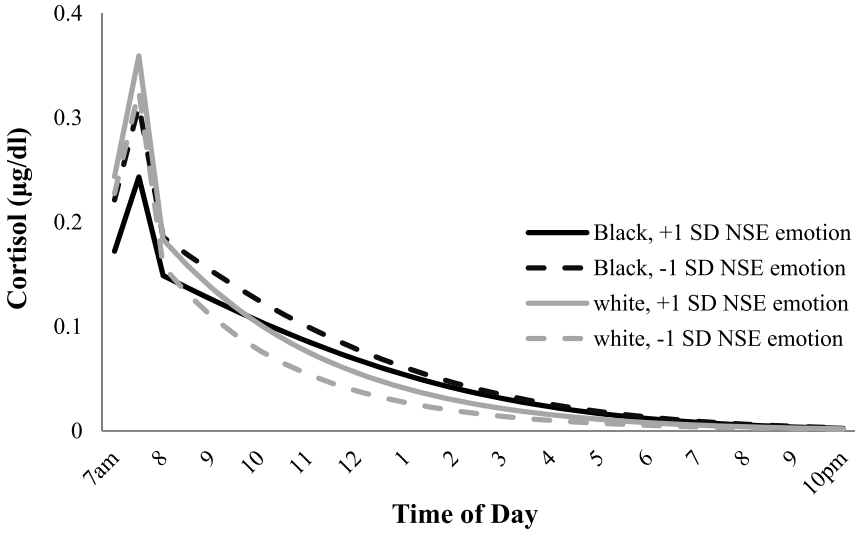

FIGURE 1. Diurnal cortisol rhythms were associated with average negative social-evaluative (NSE) emotion by race.

accounting for the main effect of race and NSE emotion. All results for NSE emotion and diurnal cortisol slope remained robust when adjusting for race, sex, parental education, family income, and stressful life events such that both person-level average NSE emotion and prior-day NSE emotion were related to flatter diurnal cortisol slopes (person-level: β = 0.03, SE = 0.01, t = 2.53, p = .013; prior-day: β = 0.10, SE = 0.03, t = 3.09, p = .002).

Does NSE Emotion Mediate Associations Between PRD and Diurnal Cortisol Slopes?

Formal partial mediation analyses revealed that NSE emotion significantly mediated the association between PRD experiences and diurnal cortisol slopes (β = 0.10 [95% confidence interval {CI} = 0.004–0.254]) at the person level (Figure 2).[4] The mediating association between PRD, NSE emotion, and diurnal cortisol slopes remained stable when adjusting for race, sex, parental education, family income, and stressful life events (β = 0.10 [95% CI = 0.01–0.21]). The mediating association remained stable when not including race as a covariate (β = 0.10 [95% CI = 0.01–0.23]).

Secondary Analyses

Additional analyses examined the specificity and generalizability of the main findings and tested whether results a) extended to general negative affect, b) were driven by discrete emotions, and c) extended to other cortisol parameters including waking cortisol, bedtime cortisol, and total cortisol levels.

Is NSE Emotion More Related to PRD and Dysregulated Cortisol Slopes Than Negative Affect?

NSE emotion and negative affect were highly correlated, particularly at the person level (person level: r = 0.88; day-level: r = 0.44). Adjusting for race, sex, parental education, family income, and stressful life events, PRD was also associated with negative affect (β = 0.32, SE = 0.10, t = 3.09, p = .003). The relationship between PRD and negative affect did not significantly differ by race (β = 0.22, SE = 0.20, t = 1.11, p = .27), accounting for the main effect of race and PRD. Adjusting for race, sex, parental education, family income, and stressful life events, average negative affect predicted diurnal cortisol slopes (β = 0.04, SE = 0.02, t = 2.18, p = .031), whereas the association between same-day (β = 0.02, SE = 0.04, t = 0.66, p = .511) and prior-day (β = 0.07, SE = 0.03, t = 1.91, p = .057) negative affect and diurnal cortisol slope did not reach the threshold of significance.

When daily and average NSE emotion and general negative affect were entered in the same model, adjusting for race, sex, parental education, family income, and stressful life events, neither average NSE emotion (β = 0.03, SE = 0.04, t = 0.69, p = .49) nor average negative affect (β = 0.00, SE = 0.04, t = 0.11, p = .91) was associated with diurnal cortisol slope. In contrast, when in the same model, prior-day NSE emotion (β = 0.09, SE = 0.04, t = 2.26, p = .025) was related to flatter diurnal cortisol slope, above and beyond prior-day negative affect (β = 0.01, SE = 0.03, t = 0.40, p = .69) and covariates.

Finally, adjusting for race, sex, parental education, family income, and stressful life events, general negative affect also mediated the association between racial discrimination and diurnal cortisol slopes (β = 0.08 [95% CI = 0.01–0.17]).

Do Average and Daily Changes in Emotion Antecedents and Specific Emotions Drive the Relationship Between Daily Emotion and Diurnal Cortisol Slopes?

The associations between daily and average specific emotions and emotion antecedents and diurnal cortisol slopes were explored. Adjusting for race, sex, parental education, family income, and stressful life events, the relationship between average negative emotion and diurnal cortisol slopes were driven by average feeling rejected (β = 0.06, p < .001), judged (β = 0.05, p = .009), irritable (β = 0.04, p = .024), and anxious (β = 0.06, p < .001), and, at the day level, by prior-day feeling embarrassed (β = 0.09, p < .001), shame (β = 0.08, p = .019), depressed (β = 0.11, p = .005), and tired (β = 0.06, p = .034). Of these emotions, NSE emotion items

[4]Mediation analyses were examined at the person-level because perceived racial discrimination was only available at the person-level. As such, multilevel mediation techniques were not conducted to ensure that measures were kept at the same time scale of analysis.

TABLE 2. NSE Emotion and Diurnal Cortisol (n = 102)

Fixed Effect	Coefficient	SE	t	p	Interpretation
Model for waking cortisol level, π_0					
Average waking cortisol level, β_{00}					
Intercept, γ_{000}	−1.52	0.04	−36.23	<.001	Waking level = 0.22 μg/dl[a]
Average NSE Emotion, γ_{001}	−0.08	0.04	−2.23	.028	8% less for every +1 SD NSE emotion[b]
Wakeup time, β_{01}					
Intercept, γ_{010}	0.01	0.03	0.21	.834	n.s.
Current-day NSE emotion, β_{02}					
Intercept, γ_{020}	−0.01	0.03	−0.41	.682	n.s.
Prior-day NSE emotion, β_{03}					
Intercept, γ_{030}	−0.04	0.03	−1.18	.240	n.s.
Model for time since waking, π_1					
Average effect of time since waking, β_{10}					
Intercept, γ_{100}	−0.25	0.03	−9.11	<.001	−22% per hour at waking
Average NSE emotion, γ_{101}	0.03	0.01	2.31	.023	+3% flatter for +1 SD NSE emotion
Wakeup time, β_{11}					
Intercept, γ_{110}	−0.01	0.01	−1.26	.208	n.s.
Current-day NSE emotion, β_{12}					
Intercept, γ_{120}	−0.03	0.03	−1.20	.230	n.s.
Prior-day NSE emotion, β_{13}					
Intercept, γ_{130}	0.10	0.03	3.31	.001	+11% increase for +1 SD prior-day NSE emotion
Model for time since waking squared, π_2					
Intercept, β_{20}					
Intercept, γ_{200}	0.01	0.00	5.39	<.001	1% deceleration in slope per hour after waking
Average NSE emotion, γ_{300}	0.00	0.00	−2.19	.031	−0.2% deceleration in slope for +1 SD NSE emotion
Wakeup time, β_{21}					
Intercept, γ_{210}	0.00	0.00	1.13	.261	n.s.
Current-day NSE emotion, γ_{22}					
Intercept, γ_{220}	0.00	0.00	1.39	.169	n.s.
Prior-day NSE emotion, γ_{23}					
Intercept, γ_{230}	−0.01	0.00	−3.12	.002	−0.6% deceleration in slope for +1 SD NSE emotion
Model for cortisol awakening response, π_3					
Average cortisol awakening response, β_{30}					
Intercept, γ_{300}	0.53	0.04	13.63	<.001	+70% CAR
Average NSE emotion, γ_{301}	−0.07	0.06	−1.16	.249	n.s.
Wakeup time, β_{31}					
Intercept, γ_{310}	−0.10	0.02	−4.70	<.001	−9% for every hour later waking
Current-day NSE emotion, β_{32}					
Intercept, γ_{320}	0.01	0.03	0.14	.886	n.s.
Prior-day NSE emotion, β_{33}					
Intercept, γ_{330}	−0.01	0.03	−0.36	.722	n.s.

All level 1 predictors are uncentered; level 2 variables were group mean centered; level 3 continuous variables were grand mean centered.

[a] Because the outcome was log transformed, the inverse of that transformation (exponential function) was applied to the coefficient to transform the units back to the original scale of measure.

[b] Using log-transformed outcomes allows coefficients to be interpreted as percent change in the outcome per unit change in the independent variable. As such, the following transformation was applied: $B_{\%change} = [\exp(B_{raw})] - 1$.

NSE = negative social-evaluative; n.s., not significant; CAR = cortisol awakening response.

such as rejected (β = 0.14 [95% CI = 0.01–0.28]), and judged (β = 0.09 [95% CI = 0.01–0.21]), and other negative emotion items such as feeling anxious (β = 0.05 [95% CI = 0.01–0.13]) mediated the association between PRD and diurnal cortisol slope, adjusting for covariates.

Next, we tested whether the relationship between average and daily negative emotions extended to positive affect and specific positive emotions. Average positive affect (β = −0.03, p = .25), prior-day positive affect (β = 0.00, p = .98), and same-day positive affect (β = −0.05, p = .084) were not associated with diurnal

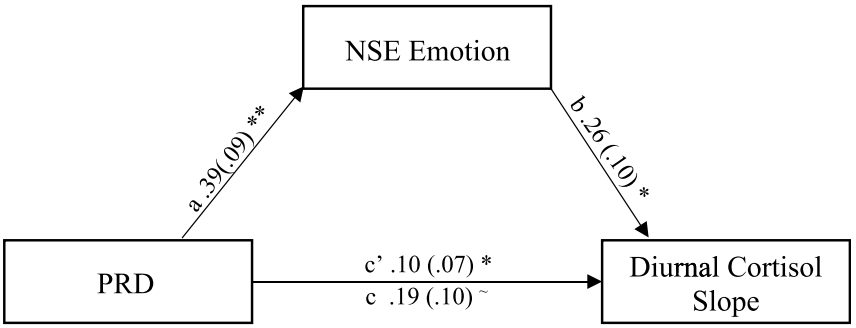

FIGURE 2. Negative social-evaluative (NSE) emotion partially mediates the association between perceived racial discrimination (PRD) and diurnal cortisol slope. $^{**}p < .01$. $^{*}p < .05$. $\sim p < .10$.

cortisol slopes. There were no significant associations for specific positive emotions (i.e., energetic, alert, happy, and calm) and diurnal cortisol slopes, with one exception. Current-day feelings of excitement ($\beta = -0.07$, $p = .029$), was associated with steeper diurnal cortisol slopes, with findings robust when accounting for race, sex, parental education, family income, and stressful life events ($\beta = -0.07$, $p = .018$). Feeling excited did not mediate the relationship between PRD and diurnal cortisol slopes, adjusting for race, sex, parental education, family income, and stressful life events.

Does the Relationship Between PRD, Average and Daily NSE Emotion, and Diurnal Cortisol Slopes Extend to Other Cortisol Parameters?

When examining waking cortisol levels using a three-level multilevel model, higher levels of PRD were associated with lower waking cortisol ($\beta = -0.10$, SE = 0.04, $t = -2.58$, $p = .011$), with results remaining stable when adjusting for sex, parental education, family income, and stressful life events ($\beta = -0.10$, SE = 0.04, $t = -2.62$, $p = .010$). Average NSE emotion ($\beta = -0.08$, SE = 0.04, $t = -2.23$, $p = .028$), but not prior-day NSE emotion ($\beta = -0.04$, SE = 0.03, $t = -1.18$, $p = .24$), was associated with lower waking cortisol levels. Adjusting for race, sex, parental education, family income, and stressful life events, the relationship between average NSE emotion and waking cortisol level did not reach the threshold of significance ($\beta = -0.05$, SE = 0.04, $t = -1.39$, $p = .17$). Person-level NSE emotion did not mediate the association between PRD and waking cortisol level ($\beta = -0.00$ [95% CI = −0.01 to 0.01]).

When examining bedtime cortisol levels using a three-level multilevel model, PRD was not associated with bedtime cortisol levels ($\beta = 0.01$, SE = 0.02, $t = 0.79$, $p = .43$). Although average NSE emotion was not associated with bedtime cortisol levels ($\beta = -0.00$, SE = 0.04, $t = -.12$, $p = .91$), prior-day NSE emotion was associated with higher bedtime cortisol levels ($\beta = 0.10$, SE = 0.04, $t = 2.10$, $p = .028$). Adjusting for race, sex, parental education, family income, and stressful life events, the relationship between prior-day NSE emotion and bedtime cortisol levels remained significant ($\beta = 0.09$, SE = 0.04, $t = 2.19$, $p = .029$). Finally, person-level NSE emotion did not mediate the association between PRD and bedtime cortisol ($\beta = -0.00$ [95% CI = −0.00 to 0.01]).

When examining total cortisol across the day using a two-level multilevel model, PRD was not related to total cortisol ($\beta = 0.23$, SE = 0.89, $t = 0.26$, $p = .80$). There was also no significant race interaction for this association ($\beta = -0.46$, SE = 1.85, $t = -.25$, $p = .80$). Same-day ($\beta = 0.16$, SE = 0.43, $t = 0.38$, $p = .70$), prior-day ($\beta = -0.07$, SE = 0.28, $t = 0.24$, $p = .81$), and average NSE emotion ($\beta = -0.91$, SE = 0.65, $t = -1.41$, $p = .16$) were not associated with total cortisol. However, a significant race by average NSE emotion interaction for total cortisol emerged ($\beta = -2.63$, SE = 1.25, $t = -2.11$, $p = .038$), such that the link between higher levels of NSE emotion related to lower levels of total cortisol was present for only Black participants (Table S1, Supplemental Digital Content, http://links.lww.com/PSYMED/A612). Findings did not reach the threshold for significance when adjusting for race, sex, parental education, family income, and stressful life events ($\beta = -2.41$, SE = 1.24, $t = -1.95$, $p = .054$).

In contrast to the significant mediating role of NSE emotion for the association between PRD and diurnal cortisol slope, we did not find a significant mediation of NSE emotion for the association between PRD and total cortisol level across the day ($\beta = -0.04$ [95% CI = −0.19 to 0.03]). We also did not find a significant mediation of NSE emotion for the association between PRD and total cortisol when looking only at Black participants ($\beta = -0.20$ [95% CI = −0.48 to 0.03]). Thus, for each of the research questions examined, results were more robust in predicting diurnal cortisol slopes than they were for other diurnal cortisol measures.

DISCUSSION

The present study provided evidence that NSE emotion is one pathway through which stressful experiences like discrimination can become embodied in stress biology. These findings were robust when adjusting for race, sex, parental education, family income, and stressful life events and were typically stronger for Black participants compared with white participants. Secondary analyses showed that findings were more pronounced for NSE emotion compared with negative affect at the day level and were similar for NSE emotion and general negative affect at the person level, did not generalize to positive affect (although links between positive affect and diurnal cortisol slopes were in the expected direction; 61), were driven by a combination of higher bedtime and lower waking cortisol levels, and were more robust for diurnal cortisol slopes as compared with other cortisol parameters.

There has been a wealth of research that reveals how stressful experiences get under the skin to influence biology (57–59). Consistent with prior theory and research that highlight emotions as a mechanism connecting stressors to biology, we find that a particular

type of emotion (NSE emotion) arising from experiences of PRD may facilitate both acute and more chronic biological changes in the HPA axis (2,43,60–62). This is consistent with prior laboratory-based research that has shown that NSE emotion such as shame is associated with cortisol reactivity (2,63,64). Importantly, however, we are observing shame-cortisol links in response to real-life stressors in everyday settings, as participants go about the course of their daily lives.

One of our most interesting findings is that NSE emotion reported at the end of one day was associated with flatter diurnal cortisol slopes the next day. These findings suggest that the accumulation of negative moments across a day seems to have a spillover biological signature in next-day diurnal cortisol slopes. When interpreting diurnal cortisol slopes, flatter patterns can arise from lower morning levels and/or higher bedtime cortisol levels (e.g., Ref. (29)). Our findings show that the association between prior-day NSE emotion and flatter diurnal cortisol slopes was driven by higher bedtime cortisol levels. There are multiple pathways by which NSE emotion can influence cortisol levels the next day. For instance, higher bedtime cortisol levels could reflect higher levels of rumination, or repetitive negative thinking, across the day. Prior research indeed shows that rumination over social-evaluative threats can persist across the week and is driven by NSE emotion like shame (65). It is possible that, in the short-term, individuals may have trouble "letting go" of the memories of their bad day as they try to wind down and prepare for bed. Across days, higher levels of rumination in the evenings may disrupt sleep patterns (66) cascading into further dysregulation of diurnal cortisol rhythms (67). We find that across the week, person-level PRD and average NSE emotion were related to lower waking cortisol, which may reflect more chronic alterations in sleep during the week of data collection (68). Further research is needed to test these hypotheses. For example, further research can examine whether daily rumination and sleep troubles mediate the relationships between NSE emotion and basal cortisol levels.

Indeed, although differences existed for the relationships between waking and bedtime cortisol, day-level emotion and person-level emotion, and experiences of racial discrimination, there were no significant mediations when waking or bedtime cortisol levels were the outcomes of interest. Instead, we found that NSE emotion significantly mediated the association between PRD and diurnal cortisol slope. These apparent differences between mediation for diurnal cortisol slope but not components of the diurnal cortisol slope (i.e., waking and bedtime levels) were likely due to the fact that wake time and bedtime cortisol levels jointly contribute to the strength of the diurnal cortisol slope. Zero-order correlations and multilevel models provided some evidence that PRD and average NSE emotion were weakly related to bedtime cortisol in the expected direction (i.e., higher bedtime cortisol levels) in addition to being more strongly associated with lower waking cortisol. Daily NSE emotion was also weakly related to waking cortisol in the expected direction (i.e., lower waking cortisol levels), in addition to being more strongly associated with higher bedtime cortisol. What seems to be nonsignificant movements toward lower waking levels and higher bedtime levels, neither of which are robust on their own, may together signify a meaningful change in diurnal cortisol slope. In this case, the variance associated with mediational variance of NSE emotion for the association between PRD and cortisol slope could be a combination of nonsignificant variance associated with the morning and evening cortisol levels. However, further research is needed to continue to differentiate between instances when flatter diurnal cortisol slopes are driven by lower waking cortisol, higher bedtime cortisol, or both.

We also find that average NSE emotion and negative affect behaved similarly; both were significantly associated with PRD, related to diurnal cortisol slopes, and mediated the association between PRD and diurnal cortisol slopes. This is not surprising because average NSE emotion and negative affect were highly correlated (r = 0.88). NSE emotion and negative affect were less correlated at the day level (r = 0.44). Differences between NSE emotion and negative affect in relation to cortisol seemed to emerge at the day level. For example, we showed that prior-day NSE emotion was associated with flatter diurnal cortisol slopes at the day level, over and above negative affect and covariates. NSE emotion may be particularly distinct from general negative affect at the day level because daily emotions are more proximal to the context of the experienced stressors and therefore may be experienced as more specific affect, more closely related to the psychological content of the daily experience, as opposed to a more diffuse negativity that may emerge as memories and interpretations of events become layered over time. In other words, compared with more trait-like emotional experiences with greater overlap between NSE emotion and negative affect, the emotional experiences reported more proximal to an event may be more specific, less altered by reflection over time, and less influenced by general personality characteristics (69,70). Further research is needed to test these hypotheses.

Daily NSE emotion may be particularly relevant for cortisol because the HPA axis has evolved to be sensitive to threat (71). Social threat is thought to be particularly potent because humans evolved as a social species. Negative social judgment devalues an individual's social status and increases the risk of ejection from the social group (72). In our evolutionary and our current contexts, group membership is necessary for survival and thriving. Interestingly, we find that at the day level, discrete NSE emotions such as shame and embarrassment drive flatter diurnal cortisol slopes, whereas at the person level, NSE emotion antecedents such as feeling rejected and judged drive flatter diurnal slopes. At the person level, feeling rejected and judged also mediate the association between PRD and diurnal cortisol slopes. Dating back to Darwin and Prodger (73), discrete emotions are thought to derive from evolutionary adaptiveness (i.e., blushing when embarrassed signals genuine remorse; shame motivate us to maintain and improve social relationships (74,75)). Compared with emotion antecedents (e.g., rejected and judged) that reflect contexts that elicit discrete emotions and may operate on a longer time scale, discrete emotions likely are more acutely elicited by daily stressors.

In a similar vein, our results also highlight that features of stressors matter when considering the corresponding emotional experience and diurnal cortisol. For instance, we see that PRD, above and beyond stressful life events, drives associations for NSE emotion and diurnal cortisol. PRD experiences may evoke NSE emotion because of the implied status differentials, social rejection, and negative social judgment associated with PRD experiences. Of note, we ideally would have been able to control for perceived life stress, instead of a count of stressful life events, to be more parallel to the measure of PRD. It is possible, and perhaps likely, that perceived life stress and PRD are more correlated than

stressful life events and PRD. Indeed, further research can examine differences between perceived life stress and PRD. In a similar vein, future research can explore frequency of racial discrimination events above and beyond other stressful life events, along with other types of stressors that evoke threats to the social self (i.e., other types of discrimination, financial stress).

The present findings contribute to and extend prior research that has shown that negative emotions can mediate the relationship between stress and health (42) by highlighting the importance of emotion (e.g., captured by day-level NSE emotion or an overlap between person-level NSE emotion and negative affect) in predicting a proximal biological outcome (i.e., diurnal cortisol slope). For instance, we find that NSE emotion and general negative affect mediate the associations between discrimination and flatter diurnal cortisol slope as compared with total cortisol. Our results suggest that in response to more acute stressors, the HPA-axis alterations include lower waking and higher bedtime cortisol levels, which result in a flattening of the diurnal cortisol slope, but not necessarily changes in total or average cortisol levels across the waking day. Only with more chronic stressors, or repeated acute stressors accumulated over years, is there evidence for changes in total cortisol level, such as the overall lowering of cortisol levels found in individuals with high cumulative exposure to discrimination over the course of adolescence and young adulthood (1). As such, the diurnal cortisol slopes may provide a stronger signal for daily changes in emotion and current experiences of discrimination. Moreover, the diurnal cortisol slope is one of the most widely examined aspects of diurnal cortisol rhythms because of its well-documented links to physical and psychological health outcomes (e.g., Refs. (24,26,76–79)). Further research can examine whether NSE emotion elicited by racial discrimination is related to long-term health outcomes by way of alterations in HPA-axis activity. This line of research would advance our understanding of racial-ethnic disparities in health by further elucidating some of the contributing mechanisms at play.

Taken together, these findings highlight that daily emotions may be one pathway by which experiences of discrimination can become embodied to shape biology, which may in turn bear consequences for health.

Directions for Future Research

There are several promising directions for future research that would extend the present findings. For example, the present study examined whether NSE emotion across the week mediates the associations between person-level PRD and diurnal cortisol slopes. However, cortisol diurnal rhythms reflect both trait and state variations that each provides unique information. Although the present study design and sample constrained our ability to examine multilevel mediation, further research should examine whether day-level experiences of NSE emotion mediate the association between day-level experiences of discrimination and diurnal cortisol slopes. Further examination of the dynamic interactions between emotion and cortisol across other time scales would extend the present study to better understand within-person and between-person contributors to HPA-axis activity. Moreover, the present study focuses on concurrent associations. We extend prior research that has shown that past experiences of discrimination during developmentally sensitive periods are associated with adult stress biology (1) to further show that current discrimination is similarly related to flatter diurnal cortisol slopes. We additionally show that current NSE emotion mediates the association between current PRD and current diurnal cortisol slopes at the person level. However, an unanswered question is whether past discrimination predicts changes in current stress biology by way of past emotional and biological states. Further research that includes longitudinal measurement of diurnal cortisol and daily emotions across developmental periods is needed to begin to answer this question.

Limitations and Strengths

The present study has some important limitations. First, the subsample of participants who had physiological data was relatively small (n = 102), and a larger sample would have provided greater statistical power that could allow for tests such as moderated mediation analyses. For instance, one might expect that the mediation of NSE emotion on the association between discrimination and diurnal cortisol slopes might be different across race and ethnicity. Second, although the present sample captured many diverse aspects of sociodemographic characteristics, the study only includes white and Black participants. The ethnic-racial composition was representative of the county where the study was conducted at the time of recruitment. However, the results have limited generalizability across other demographic groups. Moreover, white and Black participants were selected from the bottom, middle, and top thirds of their respective distributions of PRD from prior waves of data collection to be recruited into the present subsample. As such, white participants who report PRD were likely oversampled compared with the generalized population. It is important that future research with a larger sample tests the generalizability of our findings within different ethnic-racial samples across varying levels of PRD. Third, although there was a relatively diverse socioeconomic sample, the mean for education and income for Black participants is higher than the national average. This was an intentional component of the study, as it allowed for disentangling the influences of race and income to focus on the race-related stressors independent of income-related stressors, which are often confounded. However, it is unknown whether the present findings would extend to samples of other economic contexts. Fourth, analyses presented are concurrent (although longitudinal in nature at the day-level using lag-dependent modeling) and correlational at the person level. Precautions should be taken around the interpretation regarding directionality of results.

The present study has several methodological strengths. First, MADICS is, to our knowledge, the most expansive data set that includes discrimination, daily emotion, and stress biology measurement in naturalistic settings. Second, multiple time scales were used to assess NSE emotion including day-to-day changes and average levels of NSE emotion. Third, there was strong measurement of diurnal cortisol with cortisol sampled multiple times across the day for seven consecutive days. This allowed for a more reliable estimation of average levels of and daily changes in diurnal cortisol slopes in naturalistic settings.

CONCLUSIONS

The present study provides empirical evidence for the emotion pathways by which experiences of PRD can become embodied in stress biology. Findings revealed that PRD experiences were

linked with flatter diurnal cortisol slopes and higher levels of NSE emotions. Higher levels of day-to-day and average NSE emotion were related to flatter diurnal cortisol slopes, and NSE emotion in part mediated the association between PRD and diurnal cortisol slopes. Broadly, the present study highlights the importance of considering the role of emotion processes as a mechanism for the impact of stressful events on stress biology. More specifically, it highlights the unfortunate and unjust emotional and biological costs of discrimination, particularly for persons of color.

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