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Regular Article

Short-term cortisol adaption to discrimination and Mexican-origin adolescents' mental and sleep health

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Abstract

Discrimination experiences are a salient contributor to the health disparities facing Latina/x/o youth. The biopsychosocial model of minority health posits that discrimination influences health through wear and tear on the biological stress responses, including the hypothalamic-pituitary-adrenal (HPA) axis, which is a primary stress response system in the body. Emerging evidence suggests that discrimination alters the secretion of cortisol, the end product of the HPA axis, yet, whether the daily processes between discrimination and diurnal cortisol response influence mental and sleep health remains unanswered. This study integrated daily diary and post-diary survey data to examine whether daily diurnal cortisol responses to discrimination influence adolescents' mental (depressive symptoms, anxiety) and sleep (sleep quality, duration) health in a sample of Mexican-origin youth ($N = 282$; $M_{age} = 17.10$; 55% female). Results showed that adolescents who experienced more discrimination across the four-day diary period exhibited steeper diurnal cortisol slopes and lower evening cortisol; however, such physiological responses tended to be associated with poorer adolescents' mental and sleep health. The current study underscores the potential adaptation cost associated with short-term cortisol adaptation in the face of discrimination.

Keywords: Discrimination; Mexican-American adolescents; mental and sleep health; diurnal cortisol response

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Introduction

The Latina/x/o population is the largest, fastest-growing, and youngest ethnic/racial minority group in the United States (U.S.; Funk & Lopez, 2022). They currently account for 19% of the total population in the U.S. (U.S. Census Bureau, 2019) and are projected to grow to 29% by 2060 (U.S. Census Bureau, 2017). It is also a population defined by its youth, with nearly half of U.S.-born Latina/x/o being younger than the age of 18 (Patten, 2016). However, Latina/x/o youth face salient disparities in mental and sleep health compared to their White counterparts. Specifically, Latina/x/o youth are at a greater risk for depressive symptoms and anxiety disorders (Isasi et al., 2016), and Latina/x/o youth experience shorter sleep duration, poor sleep quality, and higher rates of sleep disturbances than their White counterparts (Yip et al., 2020). Understanding and addressing such health disparities for Latina/x/o youth is paramount to the future health outlook of the Latina/x/o population, as research suggests that the health status of adolescents has significant implications for health during adulthood (Paula Braveman & Barclay, 2009). Therefore, it is critical to identify early risk factors that contribute to health disparities.

One salient contributor to health disparities for Latina/x/o youth is their experiences of discrimination (Stein et al., 2016). It is well established that Latina/x/o youth frequently experience discriminatory treatment in various social contexts, and discrimination is a pervasive source of stress in their daily lives (Delgado et al., 2019). Being exposed to discrimination is consistently found to be associated with poor mental and physical health such as depressive symptoms, anxiety, hypertension, and sleep dysregulation (Benner et al., 2018; Pascoe & Smart Richman, 2009; Yip, Cheon, et al., 2020). The biopsychosocial model of minority health (Myers, 2009) posits that discrimination influences health through wear and tear on the systems and tissues in the body, which is linked to the biological stress responses, including the hypothalamic-pituitary-adrenal (HPA) axis, which is a primary stress response system in the body (Clendinen & Kertes, 2022). Emerging evidence suggests that experiences of discrimination can alter the secretion of cortisol, the end product of the HPA axis, as well as diurnal cortisol rhythms (Huynh et al., 2016; Korous, 2017; Seaton & Zeiders, 2020), but whether the daily processes between discrimination and diurnal cortisol response influence overall health remains unanswered. To fill this gap in the literature, the current study integrates both daily diary and post-diary survey data to examine whether diurnal cortisol responses following discriminatory experiences influence Mexican-origin adolescents' mental health (i.e., depressive symptoms, anxiety) and sleep health (i.e., sleep quality, sleep duration). As Mexican heritage accounts for the majority (62%) of Latina/x/o in the U.S. (Funk & Lopez, 2022), the current study focuses on examining the development of Mexican-origin youth.

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Discrimination, diurnal cortisol rhythms, and health

Discrimination, a form of unfair and negative treatment based on an individual's real or perceived differences, has been consistently linked to a wide range of mental and physical health problems including depression, anxiety, cardiovascular disease, hypertension, and sleep dysregulation (Benner et al., 2018; Pascoe & Smart Richman, 2009; Slopen et al., 2016). Moreover, growing evidence has shown that discrimination likely explains health disparities not attributable to socioeconomic status (Williams, 1999). The biopsychosocial model of minority health (Myers, 2009) suggests that discrimination can get under the skin to influence health through elevating biological stress processes. One of the major stress response systems in the body is the HPA axis (Johnson et al., 1992). When an individual encounters a stressor, the HPA axis is activated to prepare the body for the "fight or flight" response by triggering a cascade of stress hormones, including corticotrophin-releasing hormone in the hypothalamus, adrenocorticotropic hormone in the pituitary gland, and glucocorticoid hormones (cortisol) from the adrenal cortex (Gunnar & Quevedo, 2007). Cortisol is the end product of the HPA axis, and it plays a key role in the metabolic system, the immune system, and the central nervous system in the body (Sapolsky et al., 2000). Although short-term activation of cortisol response is adaptive to cope with acute stress, frequent and chronic activation of cortisol responses can create wear and tear on the body, contributing to elevated allostatic load (McEwen, 2003).

Most of the early work on cortisol has focused on cortisol reactivity, which refers to the response process of the HPA axis to immediate stressors. For example, researchers have used the laboratory-based stress paradigm (e.g., Tier Social Stress Test) to elicit cortisol responses (Dickerson & Kemeny, 2004). More recent research has moved beyond the reactivity framework and focuses on the basal activity of the HPA axis in naturalistic settings (Adam et al., 2017; Seaton & Zeiders, 2020). Basal cortisol activity follows a strong diurnal rhythm, which is regulated by the body's internal circadian clock. The diurnal rhythm is characterized by high cortisol levels upon waking, a surge in the first 30–40 min after waking, and a decline throughout the day, reaching a nadir around bedtime (Pruessner et al., 1997). This diurnal rhythm of cortisol is important for regulating various physiological processes in the body, including metabolism, immune response, and cardiovascular activity (Chung et al., 2011). High levels of cortisol in the morning help to promote wakefulness and alertness, while lower levels in the evening help to prepare the body for sleep (Adam et al., 2017).

To quantify diurnal patterns, multiple parameters have been examined in prior research, including waking cortisol, bedtime cortisol, the size of the cortisol awakening response (CAR), and the degree of change in cortisol from morning to evening (diurnal slope). Specifically, waking cortisol refers to the cortisol level upon wakening and elevated waking cortisol levels have been associated with mental health problems (e.g., depression; Mannie et al., 2007). Bedtime cortisol refers to the cortisol level before bedtime and high levels of evening cortisol secretion has been linked to mental health disorders and sleep disturbances (Kamali et al., 2012; Kumari et al., 2009). The CAR refers to the rise in cortisol immediately post-awakening and prepares the body for the day's challenges (Pruessner et al., 1997), with the magnitude of CAR associated with psychosocial stress and health, although the direction of the effects remains inconclusive (Boggero et al., 2017). For example, research has shown that an elevated CAR is linked to chronic stress, general life stress, and depression (Chida & Steptoe, 2009; Wüst et al., 2000), while other studies have found that lower levels of CAR are associated with depression, fatigue, and burnout (Chida & Steptoe, 2009; O'Donnell et al., 2008). Diurnal cortisol slope is used to capture the rate of decline from waking levels of cortisol to levels assessed before bedtime. Flattening patterns of diurnal slopes with lower morning and higher evening cortisol levels are maladaptive and have been associated with poor overall mental and physical health such as loneliness, depression, fatigue, sleep disturbance, and cardiovascular disease (Adam et al., 2017; Doane & Adam, 2010; Kumari et al., 2009). The current study aims to comprehensively examine cortisol activity by including these four cortisol parameters (i.e., waking cortisol, bedtime cortisol, CAR, and cortisol slope).

The bourgeoning research examining the link between discrimination and the HPA axis is thus far inconclusive. Research emerging from animal models argues that chronic stressors that are social-evaluative and uncontrollable, such as discrimination, can *activate* diurnal cortisol secretion as a way to prepare individuals to mobilize resources and adjust to the situations in which their social standing is threatened (Dickerson & Kemeny, 2004; Selye, 1956). However, another group of researchers proposed an *attenuation hypothesis* (Susman, 2006; Trickett et al., 2010), which posits that the HPA axis adapts to chronic stress such as discrimination by downregulating cortisol secretion, which serves as a way to prepare the body for later stress. Empirical evidence linking discrimination and HPA axis functioning has yielded similarly conflicting results. Specifically, some studies have found that discrimination is associated with altered physiological functioning that may indicate poor cortisol functioning, such as lower waking cortisol (Huynh et al., 2016), more pronounced CAR (Doane & Zeiders, 2014; Zeiders et al., 2012), flatter diurnal slope (Huynh et al., 2016; Skinner et al., 2011; Zeiders et al., 2014), and greater overall diurnal output (Huynh et al., 2016; Seaton & Zeiders, 2020; Zeiders et al., 2012), whereas others have observed associations between discrimination and altered physiological functioning that may indicate adaptive cortisol functioning, including higher waking levels (Fuller-Rowell et al., 2012), less pronounced CAR (Seaton & Zeiders, 2020), steeper diurnal slope (Fuller-Rowell et al., 2012; Seaton & Zeiders, 2020), and lower overall diurnal output (Kaholokula et al., 2012; Lee et al., 2018). There are also studies that have yielded null findings between discrimination and diurnal slope (Doane & Zeiders, 2014; Martin et al., 2012), CAR (Zeiders et al., 2014), and overall secretion throughout the day (Brody et al., 2014; Lee et al., 2018).

A recent qualitative review (Busse et al., 2017) on discrimination and HPA axis functioning and a meta-analysis (Miller et al., 2007) on chronic stress and HPA axis functioning both suggest that, depending on the timing and onset of discrimination experiences, cortisol *activation* and *attenuation* might both come into play. As such, cortisol activity is activated at the onset of discrimination experience as indicated by steeper cortisol diurnal slopes, higher waking cortisol, less pronounced CAR, and lower bedtime cortisol. Such short-term activation of cortisol response is adaptive and beneficial for everyday function (Adam & Kumari, 2009). As time passes, however, chronic experiences of discrimination attenuate cortisol secretion to below normal levels as indicated by flatter diurnal cortisol slopes, lower waking cortisol, more pronounced awakening response, and higher bedtime cortisol. Chronic activation of cortisol response is associated with negative health outcomes (Adam & Kumari, 2009). Therefore, the

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mixed empirical findings may be due to the fact that most prior studies asked participants to report the incidence of discrimination within the past year or lifetime, leaving the time intervals between the onset of discrimination event and measures of HPA activity varying to a large extent. Given that timing and discrimination onset matter in the link between discrimination and the HPA axis, scholars have called for studies that use shorter intervals from stress onset to better disentangle the mixed findings (Korous, 2017; Miller et al., 2007). Another possible reason for the inconsistent empirical findings is that most prior research focuses on examining between-person (BP) associations (i.e., nomothetic approach) between discrimination and HPA activities. Given that individuals often respond to stress in an idiosyncratic way, it is important to examine the within-person (WP) associations (i.e., idiographic approach) between discrimination and HPA activity.

To address these limitations, the current study adopts a daily diary approach, which captures the snapshot of an individual's everyday life and permits the exploration of WP associations. A few empirical studies have utilized this approach to examine the association between discrimination and the HPA axis functioning, and these have generally involved adult populations (e.g., Seaton & Zeiders, 2020; Zeiders et al., 2018). For example, Seaton and Zeiders (2020) found that on days when Black college students experienced racial discrimination, they exhibited greater overall cortisol output the same day as well as less pronounced awakening response and steeper diurnal slope the next day. The daily processes of discrimination and HPA axis functioning remain relatively underexplored among adolescents, as only three studies have examined the link between discrimination and HPA activity during adolescence (Doane & Zeiders, 2014; Huynh et al., 2016; Zeiders et al., 2012; results of these studies are described above). Adolescence, however, is a salient developmental period marked by the onset of puberty, which triggers a series of biological processes including hormonal and neuroendocrine changes, and the HPA axis is particularly sensitive and responsive to stressors during puberty (Romeo, 2013). Simultaneously, adolescents undergo rapid cognitive, emotional, and social changes, which make them more sensitive to social-evaluative stressors such as discrimination (Dickerson & Kemeny, 2004; Romeo, 2013). Given that previous research has found spillover effects of daily experiences on cortisol responses (Adam et al., 2006; Doane & Adam, 2010; Seaton & Zeiders, 2020), the current study aims to comprehensively examine the concurrent (e.g., same-day) and lagged (e.g., next-day) associations between discrimination and four indicators of diurnal cortisol patterns (i.e., waking cortisol, bedtime cortisol, CAR, and cortisol diurnal slope) among Mexican-origin adolescents.

Linking the discrimination-cortisol response association to adolescents' mental and sleep health

Theorists posit that development results from a continuous accumulation of many daily experiences, and these daily experiences can accumulate and impact children's development (Barker, 1968; Gallimore et al., 1993). Research has also found that constant activation of the biological stress response can result in harmful wear and tear on the body and compromise health (McEwen, 2003). Building upon the developmental theories and research, it is possible that altered diurnal cortisol patterns in response to daily discrimination may influence mental (e.g., depressive symptoms, anxiety) and sleep health (e.g., sleep duration, sleep quality) of adolescents.

One approach to examining this postulation is to integrate daily diary and post-diary survey data. Daily diary data encompassing a series of data points of stress and cortisol responses over time can be combined to create an *association-between-two-variables* indicator that reflects the relation between daily discrimination and cortisol responses in a given individual using multilevel modeling, and this indicator can then be used to predict health (Charles et al., 2013; Cole et al., 2014; Mandel et al., 2015; Wichers et al., 2009). The advantage of this method is that it enables the association between discrimination and cortisol responses to vary across individuals, which captures the idiographic and dynamic nature of the physiological responses to stress (Abela & Hankin, 2009). Using this method, Charles et al. (2013) found that adults' daily affective reactivity to stress was associated with increased depressive and anxious symptoms 10 years later. Similarly, Wichers et al. (2009) found that that daily stress reactivity in adult populations prospectively predicted affective symptoms over time. These findings highlight the cumulative effects of daily stress responses on individuals' overall well-being. Thus, the current study adopts this strategy to explore how *the associations between daily discrimination and cortisol response patterns* influence overall well-being in Mexican-origin adolescents. The current study focused specifically on depressive symptoms, anxiety, sleep quality, and sleep duration as these developmental outcomes are sensitive to discrimination stress responses (Adam et al., 2017; Kumari et al., 2009), and they are also integral domains of adolescent well-being and development (DeHart et al., 2004; Short et al., 2020).

Current study

To address the limitations of prior research and promote a better understanding of the cumulative effects of discrimination experiences on mental and physical health, the current study integrated both daily diary and post-diary survey data from a community-based sample of 282 Mexican-origin adolescents (see Fig. 1 for the conceptual model). First, the current study examined the day-to-day association between experiences of discrimination and diurnal cortisol levels. Given the short interval since stress onset, we hypothesized that the cortisol response patterns to discrimination would be more in line with the *activation* hypothesis (Busse et al., 2017; Miller et al., 2007). That is, on days when adolescents reported discrimination experiences, they would have steeper cortisol diurnal slopes and lower bedtime cortisol the same day as well as higher waking cortisol and less pronounced CAR the next day.

Second, the current study examined whether the daily association between discrimination and diurnal cortisol response was linked with adolescents' mental health (i.e., depressive symptoms, anxiety) and sleep health (i.e., sleep quality, sleep duration). Based on deleterious effects of discrimination and altered diurnal cortisol response for health (Adam et al., 2017; Pascoe & Smart Richman, 2009), we hypothesized that adolescents who had a stronger association between discrimination and cortisol alteration would report more compromised health in the form of more depressive symptoms and anxiety as well as lower sleep quality and shorter sleep duration.

Method

Participants

Data for the present study were drawn from a three-wave longitudinal study of Mexican immigrant families living in and around a metropolitan area in central Texas (W1: $N = 604$, W2:

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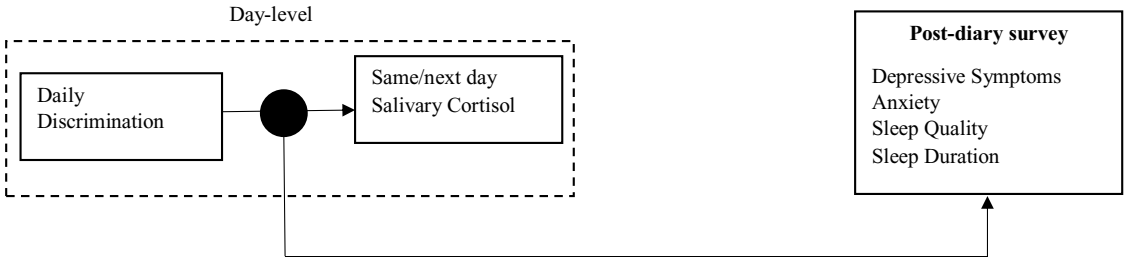

Figure 1. The conceptual figure for the proposed model. Post-diary survey was conducted around 1–2 weeks after the completion of the diary survey.

$N = 483$, W3: $N = 334$). At Wave 1, adolescents were in middle school (sixth through eighth grades), ranging from 11.08 to 15.29 years old ($M_{age} = 12.41$, $SD = .97$). Wave 2 data were collected 1 year later ($M_{age} = 13.22$, $SD = .95$) and Wave 3 data were collected about 3 years after Wave 2 ($M_{age} = 17.10$, $SD = 1.12$). Among the 344 families who consented to participate in the Wave 3 data collection, 290 adolescents participated in the 4-day daily diary study that included a salivary cortisol data collection. Post-diary survey was completed approximately 1–2 weeks after the daily diary data collection. Of the 290 daily diary participants, 8 were eliminated because of their use of steroid-based medication, leaving a final analytic sample size of 282 participants. For the analytic sample, approximately 55% were female ($n = 159$), and most adolescent participants were U.S.-born ($n = 217$, 75%). Adolescents came from families in which the median household income fell within the range of $20,001–$30,000 at Wave 1 (between years 2012 and 2015), and the median highest education level of adolescents' parents was some middle school/junior high school.

Procedures

At Wave 1, families were recruited through public records, school presentations, and community recruitment in and around a metropolitan area in central Texas from 2012 to 2015. To qualify for participation, parents were required to be of Mexican origin with a child in middle school who translated for at least one parent. A family visit was scheduled to obtain parents' consent and adolescent assent after families were screened as eligible. Bilingual and bicultural interviewers went on family visits, reading questions out loud to participants and entering participants' responses on a laptop computer. All questionnaires were prepared in both English and Spanish. Questionnaires were first translated to Spanish and then back-translated to English by bilingual and bicultural research assistants. The survey took approximately 2 hours to complete. About 1 year later, families were approached to participate in the Wave 2 study; about three years after Wave 2, families were approached to participate in the daily diary and Wave 3 study.

Adolescents who consented to participate in the daily diary study at Wave 3 were trained to use the Micro Motionlogger Watch (Ambulatory Monitoring, Ardsley, NY) to log their sleep data and the tablet to answer a short nightly survey before bedtime. In addition, adolescents were also trained to collect their own salivary samples immediately after waking, 30 minutes after waking, and at bedtime. Adolescents followed the same protocol for four consecutive school days from Monday to Thursday. On each of the sampling days, phone calls, text messages, or emails were made to remind adolescents to complete the survey on their assigned tablet, provide salivary samples, and wear the Micro Motionlogger Watch on their non-dominant wrist before going to bed. Another follow-up family visit was scheduled after each participant finished the daily diary study to collect all materials (including saliva samples) and equipment as well as family members' yearly health and demographic information. Most of the participants (77%) completed their follow-up yearly survey within a week after the completion of the diary survey, 9% completed within 2 weeks, 4% completed within 3 weeks, and 2% completed within 4 weeks. Families that participated were compensated $60 at Wave 1 and $90 at Wave 2 and Wave 3. Adolescents who participated in the daily diary component of Wave 3 were compensated up to an additional $40. The compliance rate for daily diary completion was high ($M = 3.79$, $SD = .57$), such that 85% of participants completed all four survey days, 11% of participants completed three survey days, 3% of participants competed 2 days and 2% of participants completed 1 day. The compliance rate for the saliva sample was also high ($M = 11.67$, $SD = 1.15$) such that 98% of participants provided at least 9 saliva samples and 86% of participants provided all 12 saliva samples.

Measures

Person-level outcome measures were assessed using Wave 3 surveys, and daily measures were assessed using daily diary surveys that occurred approximately 1–2 weeks prior to the Wave 3 survey.

Daily-level measures

Daily Discrimination. Discrimination was assessed daily by four items adapted from the daily discrimination scale (Kessler et al., 1999). A sample item is, "I was treated with less courtesy than other people today." Adolescents reported daily on a scale ranging from 1 to 5: "strongly disagree" (1), "disagree" (2), "neutral" (3), "agree" (4), and "strongly agree" (5). Each item was recoded as 0 if adolescents answered 1–3, indicating no such experience or 1 if adolescents answered 4–5, indicating they had such experiences. Scores were summed each day (range: 0–4). Consistent with other research employing daily diary methods, daily discrimination was a relatively low-frequency event ($M = .16$ $SD = .56$; Goosby et al., 2018; Torres & Ong, 2010; Yip et al., 2020). Therefore, discrimination was dichotomized to indicate whether adolescents experienced any of the four discriminatory experiences that day (0 = *no discrimination*, 1 = *discrimination*).

Salivary Cortisol. Participants were instructed to provide saliva samples via the passive drool method by spitting into a Sali Cap vial (IBL International GMBH, Hamburg, Germany). Participants provided saliva at three time points each day, resulting in a total of 12 samples: immediately upon waking up (sample 1), 30 minutes after waking up (sample 2), and at bedtime (sample 3). Participants were advised to not eat, drink, or brush their teeth 30 minutes before sampling. The 12 vials were stored in Medication Event

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Monitoring System (MEMS) caps, which contain an embedded computer chip that digitally records when the bottles are opened to dispense the saliva collection vial. In addition to using the MEMS caps, participants self-reported the timing of each sample using a tablet questionnaire. We prioritized using the sample timing recorded by the MEMS caps, but in cases where the timing was missing, we relied on self-reported sample timing. Participants' self-reported awakening times were validated by the Micro Motionlogger data. Participants were instructed to store their samples in the freezer section of their household refrigerators. At the conclusion of the saliva collection period, research assistants transported the samples to the research laboratory, where they were stored in a −32°C freezer before being sent to Biochemisches Labor in Trier, Germany, for cortisol assay. In total, 3,480 (4 days × 3 samples × 290 participants) saliva samples were collected during the 4-day diary period of 290 participants. However, eight participants reported taking steroid-based medication during the study period, and they were excluded, leaving the final analytic saliva samples to be 3,384. The compliance with the time interval for taking Sample 1 and 2 was high, as 94% of the second samples were taken within 45 minutes of Sample 1 (DeSantis et al., 2010). Cortisol concentration was determined using a time-resolved fluorescence immunoassay (see Dressendörfer et al., 1992, for a detailed description). Intra-assay coefficients of variation (CVs) were between 4.0% and 6.7%, and inter-assay CVs ranged from 7.1% to 9.0%. Consistent with prior cortisol studies (Kertes & van Dulmen, 2012), cortisol values were winsorized at 50 nmol/L to reduce the effect of outliers on the analyses. In total, there were 5 data points that were winsorized. We examined four different cortisol indicators: (1) waking cortisol, (2) bedtime cortisol, (3) CAR, and (4) diurnal slope. The CAR was calculated by subtracting the cortisol level of each day's Sample 2 (30 minutes post waking) from Sample 1 (waking). There were 62 cases in which sample 2 fell outside the 45-minute window after sample 1, and their CARs were coded as missing following the consensus guidelines (Stalder et al., 2022). The daily diurnal slope was computed by taking the difference between waking cortisol level and bedtime cortisol level and dividing by the time between samples. Among the four cortisol indicators, only bedtime cortisol was positively skewed (7.50), and thus it was transformed using the natural log transformation.

Person-level measures

Depressive Symptoms. Depressive symptoms were measured at Waves 2 and 3. It was assessed by the widely used 20-item Center for Epidemiologic Studies of Depression Scale (Chen et al., 2021; Radloff, 1977). Adolescents self-reported how often during the past week they had experienced depressive symptoms (a sample item: "Bothered by things usually not bothered by") on a scale of 1 (*rarely or none of the time*) to 4 (*most or all of the time*). Higher mean scores indicate more depressive symptoms ($\alpha_{wave.2} = .87$; $\alpha_{wave.3} = .88$).

Anxiety. Anxiety was measured at Waves 2 and 3 by four items adapted from prior studies (Chen et al., 2021; Reynolds & Richmond, 1978; Spitzer et al., 2006). On a scale of 1 (*not at all*) to 5 (*nearly every day*), adolescents self-reported how often they were bothered by the following problems over the last 2 weeks: (1) feeling nervous, (2) worrying about what is going to happen, (3) trouble relaxing, and (4) becoming easily annoyed or irritable. Higher mean scores suggest higher levels of anxiety ($\alpha_{wave.2} = .83$; $\alpha_{wave.3} = .82$).

Self-reported Sleep Quality. On a scale of 1 (*poor*) to 5 (*excellent*), adolescents self-reported their sleep quality with one item at Wave 2 and 3: "During the past month, how would you rate your sleep quality overall?" This was drawn from the Pittsburgh Sleep Quality Index (Buysse et al., 1989; Hou et al., 2018).

Sleep Duration. Sleep duration was recorded by the Micro Motionlogger Watch during the 4-day diary. It was averaged across the 4 days of the daily diary to represent participants' average sleep duration during the diary period.

Covariates

At the daily level, covariates included day of the study (i.e., 1–4) as well as a list of daily behaviors known to be associated with diurnal cortisol (Adam & Kumari, 2009): daily consumption of alcohol/nicotine/caffeine, daily exercise (1 = *yes*, 0 = *no*), waking time, oral disease or injury (1 = *yes*, 0 = *no*), and whether taken nonsteroid-based medication in the past 12 hours (1 = *yes*, 0 = *no*). For CAR, an additional daily-level covariate, time between cortisol sample 1 and 2, was added. At the person level, covariates included adolescent age, gender (0 = *male*, 1 = *female*), nativity (0 = *Mexico-born*, 1 = *US-born*), and family income, which were measured at Wave 1, to account for individual-level factors that have been found to relate to cortisol levels and discrimination experiences (Adam & Kumari, 2009; Chavous et al., 2008). Parents reported their highest education level on a scale of 1 (*no formal schooling*) to 11 (*finished graduate degree*).

Analysis plan

First, to examine the daily association between discrimination and cortisol activities, we conducted multilevel analyses in R using the *lme4* package (Bates et al., 2015). Daily cortisol parameters (i.e., waking cortisol, bedtime cortisol, CAR, and diurnal slope) were treated as dependent variables. At the WP level, we included daily discrimination as a predictor, and covariates were integrated at the between and within levels as appropriate. Daily discrimination was centered on each person's mean to represent the WP effect. Daily-level covariates were centered by each participant's personal mean, and person-level covariates were centered by the grand mean. Following the recommended statistical procedures for examining WP effects (Bolger & Laurenceau, 2013), we also included the BP centered discrimination variable to adjust for possible differences between participants. The equations were as follows:

$$\text{Level 1: Cortisol}_{ij} = \beta_{0i} + \beta_{1i}\,(\text{WP Daily Discrimination}) + (\beta_{2i,3i,\,4i}\ \ldots\ \text{Daily Covariates}) + e_{ij}$$

$$\text{Level 2: } \beta_{0i} = \gamma_{00} + \gamma_{01}\,(\text{BP Discrimination}) + (\gamma_{02,3,4}\ \ldots\ \text{Person-Level Covariates}) + u_{0i},$$

$$\beta_{1i} = \gamma_{10} + u_{1i}$$

At Level 1, the value β_{0i} was a regression intercept, reflecting the mean level of daily cortisol on days in which the predictor (i.e., WP daily discrimination) was at its mean and daily covariates were zero; β_{1i} was a regression slope (cortisol response to discrimination coefficient), representing the main effect of WP daily discrimination on diurnal cortisol patterns, holding all other variables constant; and the residual parameter (e_{ij}) indexed the day-to-day variability in cortisol values for each individual. At level 2, γ_{00} represented the sample average level of cortisol, holding the person-level covariates constant; γ_{10} represented the sample average effect of cortisol response to discrimination, holding the person-level covariates constant. In addition, u_{0i} and u_{1i} were

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variances reflecting individual differences from the sample average level of cortisol and cortisol response to discrimination estimates, respectively. Empirical Bayes (model-based) slopes were calculated for each individual by adding the sample average effect of daily discrimination on cortisol (γ_{10}) with individualized random slopes (u_{1i}, Singer & Willett, 2003). Therefore, each person had unique regression parameters, representing their own relation between discrimination and cortisol. The estimated Empirical Bayes slopes were outputted and used for subsequent analyses. Models were estimated by means of restricted maximum likelihood. The estimates of the association between discrimination and each cortisol indicator represented a slope for each participant and were saved and used for subsequent analyses. For the same-day effect, only bedtime levels and diurnal slope were included as dependent variables given that the waking cortisol and the CAR would have occurred before the reports of discrimination. For the next-day effect, the lagged analyses were examined where daily discrimination predicted next-day cortisol (i.e., waking, bedtime, CAR, diurnal slope).

Second, to examine whether daily cortisol response to discrimination would influence mental and sleep health, we included the estimated slopes of discrimination and each cortisol indicator as predictors of Wave 3 depressive symptoms, anxiety, sleep quality, and sleep duration in a structural equation model using Mplus 8.3 (Muthén & Muthén, 1998-2018). This model also integrated the person-level covariates. In order to avoid multicollinearity, each cortisol response to discrimination indicator was tested in a separate model due to high correlations among the estimated slopes. All health indicators (i.e., depressive symptoms, anxiety, and sleep quality) were included in the same model, thus adjusting for any covariance between the outcomes. Missing data were handled using full information maximum likelihood.

Alternative model

To provide more confidence in the proposed model for the present study, an alternative model was tested. As the biological reactivity to discriminatory treatment may be influenced by early experiences (Boyce & Ellis, 2005), it is possible that individuals who had poor sleep quality might be more reactive biologically when facing discrimination. Indeed, research has shown that individuals with depressive symptoms are at greater risk for being the target of discrimination (Hou et al., 2015) and that they tend to react more strongly to the negative treatment (Gotlib & Joormann, 2010). Therefore, the alternative model for research question 2 examined whether socioemotional and sleep health at an earlier wave (Wave 2) would influence adolescents' diurnal cortisol response (i.e., waking cortisol, bedtime cortisol, CAR, diurnal cortisol slope) to discrimination. To avoid multicollinearity, each health indicator was tested in a separate model due to high correlations among them. All cortisol response to discrimination indicators were included in the same model.

Results

Descriptive statistics and correlations of the primary study variables averaged within each person are reported in Table 1. In total, 21.7% of participants reported experiencing discrimination on at least one of the 4 days. Participants who experienced more frequent discrimination tended to have steeper diurnal cortisol slopes ($r = -.18$, $p < .01$), worse sleep quality ($r = -.13$, $p < .05$), more anxiety ($r = .35$, $p < .01$), and more depressive symptoms ($r = .36$, $p < .01$).

Association between daily discrimination and diurnal cortisol patterns

Unconditional means models were first conducted for each of the diurnal cortisol parameters to calculate the intraclass correlations. The results suggested that 25%–44% of the variance in cortisol parameters were attributable to BP variation, whereas 56%–75% was attributable to WP variation (Table 1), which supported the use of two-level models. In addition, inclusion of the random slope for daily discrimination resulted in lower AIC and BIC values and higher *R*-square value compared to the models without the random slope term, which suggests the importance of including random slope in modeling.

At the WP level, daily experiences of discrimination were not significantly associated with any of the diurnal cortisol indicators (Table 2). However, at the BP level, average discrimination across the study was significantly associated with same-day diurnal slope ($b = -.18$, $p = .02$) and next-day evening cortisol ($b = -.63$, $p < .001$) after accounting for all time invariant and time-varying covariates. That is, individuals who reported higher levels of discrimination across the study period had steeper diurnal slopes and lower evening cortisol.

Linking the discrimination-cortisol response association to adolescents' mental and sleep health

As shown in Table 3, the daily association between discrimination and the same-day diurnal slope was observed to be negatively related to sleep duration ($b = -1.70$, $p = .02$), indicating that stronger negative associations between discrimination and diurnal cortisol slope (i.e., steeper diurnal cortisol slope) were related to longer sleep duration. This effect was also significant for the relation between next-day diurnal slope response to daily discrimination and sleep duration ($b = -1.19$, $p = .01$). In addition, the daily association between discrimination and same-day bedtime cortisol was positively associated with sleep quality ($b = 1.44$, $p = .02$). That is, stronger negative associations between discrimination and bedtime cortisol were, in turn, related to lower levels of sleep quality. This effect was also significant for next-day bedtime cortisol response to daily discrimination ($b = .33$, $p = .01$). Finally, the daily association between discrimination and next-day diurnal slope was observed to be negatively related to both depressive symptoms ($b = -.39$, $p = .02$) and anxiety ($b = -.46$, $p = .02$). That is, stronger negative associations between discrimination and diurnal cortisol slope (i.e., steeper diurnal cortisol slope) were associated with higher levels of depressive symptoms and anxiety.

Alternative model

The alternative model for research question 2 examined whether socioemotional and sleep health at an earlier wave (Wave 2) influenced adolescents' diurnal cortisol response (i.e., waking cortisol, bedtime cortisol, CAR, diurnal cortisol slope) to discrimination. As shown in Table 4, depressive symptoms, anxiety, and sleep quality at Wave 2 were not significantly associated with any of the cortisol response to daily discrimination indicators, and, as such, the data supported the conclusion that diurnal cortisol response to discrimination precedes subsequent health-related problems.

Discussion

Discrimination is prevalent in the lives of Mexican-origin adolescents, one of the largest and fastest-growing ethnic minority groups in the U.S. (Noe-Bustamante et al., 2019). Discrimination

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Table 1. Bivariate correlations and descriptive statistics of study variables averaged within each person

	1	2	3	4	5	6	7	8	9
1. Daily discrimination (vs. no discrimination)	–								
2. Waking cortisol	0.10	–							
3. Bedtime cortisol	−0.04	.323**	–						
4. Cortisol awakening response	−0.07	−0.01	.131*	–					
5. Cortisol diurnal slope	−.175**	−.821**	.195**	.129*	–				
6. Depressive symptoms	.364**	0.11	0.00	−0.04	−.168**	–			
7. Anxiety	.352**	0.10	−0.02	0.04	−0.11	.700**	–		
8. Sleep quality	−.129*	−0.01	−0.11	0.01	−0.02	−.355**	−.261**	–	
9. Sleep duration	0.05	0.04	−0.07	−0.06	−.172**	0.06	−0.04	0.12	–
Mean	0.11	9.33	2.02	4.90	−0.48	1.54	1.84	2.53	7.59
SD	0.24	4.33	2.38	5.84	0.29	0.38	0.68	0.92	1.46
Min	0.00	0.77	0.09	−11.60	−1.61	1.00	1.00	1.00	3.60
Max	1.00	29.48	33.19	28.94	0.23	3.65	4.00	5.00	11.93
Intraclass correlation	0.44	0.33	0.42	0.32	0.25	n/a	n/a	n/a	n/a

All cortisol levels represent nmol/L. Total possible $N = 282$.
*$p < .05$.
**$p < .01$.
***$p < .001$.

Table 2. Multi-level models for associations between daily discrimination and adolescents' diurnal cortisol patterns

	Same-day diurnal slope		Same-day evening cortisol		Next-day waking cortisol		Next-day CAR		Next-day diurnal slope		Next-day evening cortisol	
Fixed effects	*b* (*SE*)	*p*	*b* (*SE*)	*p*	*b* (*SE*)	*p*	*b* (*SE*)	*p*	*b* (*SE*)	*p*	*b* (*SE*)	*p*
(Intercept)	**−0.84 (0.35)**	**0.02**	0.36 (0.84)	0.67	**20.73 (6.07)**	**0.00**	15.25 (7.6)	0.05	**−0.89 (0.4)**	**0.03**	0.28 (0.91)	0.76
WP Discrim	0.01 (0.07)	0.89	0.21 (0.13)	0.11	0.56 (1.31)	0.67	0.09 (1.47)	0.95	−0.02 (0.09)	0.86	−0.12 (0.15)	0.40
BP Discrim	**−0.18 (0.08)**	**0.02**	−0.27 (0.18)	0.14	1.02 (1.34)	0.44	−2.98 (1.68)	0.08	−0.17 (0.09)	0.06	**−0.6 (0.2)**	**<.001**
Covariates												
Exercise	0.05 (0.03)	0.10	−0.02 (0.06)	0.80	**−1.1 (0.49)**	**0.03**	−0.04 (0.71)	0.95	0.07 (0.03)	0.05	0.05 (0.07)	0.49
Caffeine	0.01 (0.03)	0.63	0.02 (0.06)	0.73	0.12 (0.49)	0.81	−1.22 (0.7)	0.08	0 (0.03)	0.92	−0.01 (0.07)	0.85
Alcohol	−0.17 (0.14)	0.23	0.4 (0.28)	0.16	2.59 (3.17)	0.41	8.2 (4.99)	0.10	−0.42 (0.25)	0.09	−0.44 (0.52)	0.40
Nicotine	0.03 (0.09)	0.73	**0.45 (0.2)**	**0.02**	1.84 (1.6)	0.25	0.27 (2.21)	0.90	−0.09 (0.12)	0.42	−0.02 (0.24)	0.93
Medication	0.01 (0.05)	0.82	0.09 (0.1)	0.36	0.5 (0.83)	0.55	0.44 (1.14)	0.70	−0.01 (0.06)	0.91	**0.25 (0.12)**	**0.04**
Waking time	**−0.02 (0.01)**	**0.03**	0.01 (0.02)	0.49	−0.26 (0.16)	0.12	−0.26 (0.23)	0.26	0.01 (0.01)	0.55	0.02 (0.02)	0.32
Day of study	**−0.05 (0.01)**	**0.00**	0.04 (0.02)	0.08	**0.68 (0.23)**	**0.00**	**−1 (0.35)**	**0.00**	**−.04 (0.02)**	**0.02**	0.05 (0.03)	0.15
Age	0.04 (0.02)	0.06	−0.03 (0.05)	0.50	−0.65 (0.34)	0.06	−0.43 (0.43)	0.32	0.03 (0.02)	0.20	−0.02 (0.05)	0.67
Nativity	−0.04 (0.04)	0.31	0.01 (0.1)	0.96	0.34 (0.74)	0.65	−0.32 (0.93)	0.73	−0.08 (0.05)	0.10	−0.09 (0.11)	0.41
Female	−0.05 (0.04)	0.19	**0.22 (0.09)**	**0.01**	**1.3 (0.63)**	**0.04**	**4.05 (0.79)**	**0.00**	−0.08 (0.04)	0.05	**0.28 (0.09)**	**0.00**
Parental education	0 (0.01)	0.98	0.01 (0.02)	0.73	0.06 (0.14)	0.67	−0.13 (0.17)	0.45	0 (0.01)	0.93	−0.01 (0.02)	0.49
Time between S1 and S2	–	–	–	–	–	–	−0.09 (0.82)	0.91	–	–	–	–
Random effect	Variance [95% CI]		Variance [95% CI]		Variance [95% CI]		Variance [95% CI]		Variance [95% CI]		Variance [95% CI]	
Intercept	0.05 [0.04, 0.06]		0.33 [0.25, 0.41]		16.51 [11.9, 20.52]		15.46 [8.55, 21.3]		0.06 [0.04, 0.08]		0.37 [0.26, 0.46]	
WP Discrim	0.08 [0, 0.19]		0.15 [0, 0.59]		36.15 [10.63, 75.69]		1.397 [0, 54.61]		0.15 [0.03, 0.32]		0.12 [0, 0.62]	

AUC = area under the curve; BP = between-person; CAR = cortisol awakening response; WP = within-person.
Significant results were in bold.
All cortisol levels represent nm/h.

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Table 3. Regression coefficients between cortisol response to discrimination and mental and sleep health outcomes

	Depressive symptoms		Anxiety		Sleep quality		Sleep duration	
	b (*SE*)	*p*	*b* (*SE*)	*p*	*b* (*SE*)	*p*	*b* (*SE*)	*p*
Same-day diurnal slope response to discrim	−0.49 (0.33)	0.13	−0.65 (0.46)	0.16	−0.55 (0.52)	0.29	**−1.7 (0.71)**	**0.02**
Nativity[a]	0.00 (0.05)	0.94	−0.07 (0.09)	0.43	0.12 (0.14)	0.38	0.15 (0.22)	0.48
Female	0.03 (0.04)	0.44	**0.26 (0.08)**	**0.00**	0.10 (0.11)	0.35	**0.46 (0.18)**	**0.01**
Age	0.01 (0.03)	0.78	0.06 (0.04)	0.17	−0.07 (0.07)	0.28	0.11 (0.08)	0.19
Parent education	0.01 (0.01)	0.40	0.03 (0.02)	0.13	−0.03 (0.03)	0.22	0.01 (0.04)	0.77
Same-day bedtime cortisol response to discrim	0.29 (0.3)	0.33	0.35 (0.48)	0.46	**1.44 (0.63)**	**0.02**	0.44 (0.92)	0.63
Nativity[a]	0.00 (0.05)	0.94	−0.06 (0.09)	0.49	0.13 (0.13)	0.32	0.18 (0.22)	0.41
Female	0.03 (0.04)	0.50	**0.25 (0.08)**	**0.00**	0.09 (0.11)	0.41	**0.45 (0.18)**	**0.01**
Age	0.00 (0.03)	0.88	0.05 (0.04)	0.20	−0.08 (0.06)	0.22	0.10 (0.08)	0.23
Parent education	0.01 (0.01)	0.47	0.03 (0.02)	0.16	−0.03 (0.03)	0.17	0.01 (0.04)	0.87
Next-day waking cortisol response to discrim	**0.02 (0.01)**	**0.06**	0.03 (0.02)	0.13	0.01 (0.02)	0.53	0.01 (0.04)	0.72
Nativity[a]	0.00 (0.05)	0.96	−0.07 (0.09)	0.48	0.13 (0.14)	0.35	0.18 (0.22)	0.42
Female	0.03 (0.04)	0.45	**0.26 (0.08)**	**0.00**	0.1 (0.11)	0.37	**0.45 (0.18)**	**0.01**
Age	0.00 (0.03)	0.95	0.05 (0.04)	0.23	−0.07 (0.07)	0.25	0.1 (0.08)	0.24
Parent education	0.01 (0.01)	0.53	0.02 (0.02)	0.19	−0.03 (0.03)	0.18	0.01 (0.04)	0.87
Next-day CAR response to discrim	−0.04 (0.08)	0.66	−0.11 (0.14)	0.45	0.03 (0.2)	0.89	0.21 (0.3)	0.47
Nativity[a]	0.00 (0.05)	0.98	−0.07 (0.1)	0.46	0.13 (0.14)	0.34	0.19 (0.22)	0.39
Female	0.03 (0.04)	0.49	**0.25 (0.08)**	**0.00**	0.1 (0.11)	0.37	**0.45 (0.18)**	**0.01**
Age	0.00 (0.03)	0.87	0.05 (0.04)	0.21	−0.07 (0.07)	0.27	0.11 (0.08)	0.21
Parent education	0.01 (0.01)	0.46	0.03 (0.02)	0.15	−0.03 (0.03)	0.19	0.01 (0.04)	0.86
Next-day diurnal slope response to discrim	**−0.39 (0.17)**	**0.02**	**−0.46 (0.2)**	**0.02**	−0.3 (0.28)	0.29	**−1.19 (0.48)**	**0.01**
Nativity[a]	0.00 (0.05)	0.97	−0.07 (0.09)	0.48	0.13 (0.14)	0.35	0.17 (0.22)	0.43
Female	0.04 (0.04)	0.39	**0.26 (0.08)**	**0.00**	0.1 (0.11)	0.35	**0.47 (0.18)**	**0.01**
Age	0.00 (0.03)	0.90	0.05 (0.04)	0.21	−0.07 (0.06)	0.25	0.09 (0.08)	0.27
Parent education	0.01 (0.01)	0.51	0.02 (0.02)	0.18	−0.03 (0.03)	0.18	0 (0.04)	0.94
Next-day bedtime cortisol response to discrim	0.04 (0.06)	0.54	0.03 (0.1)	0.79	**0.33 (0.13)**	**0.01**	0.24 (0.2)	0.22
Nativity[a]	0.00 (0.05)	0.93	−0.06 (0.09)	0.49	0.14 (0.13)	0.28	0.19 (0.22)	0.39
Female	0.03 (0.04)	0.49	**0.25 (0.08)**	**0.00**	0.09 (0.11)	0.38	**0.45 (0.18)**	**0.01**
Age	0.01 (0.03)	0.84	0.05 (0.04)	0.19	−0.07 (0.06)	0.25	0.1 (0.08)	0.22
Parent education	0.01 (0.01)	0.45	0.03 (0.02)	0.15	−0.03 (0.03)	0.20	0.01 (0.04)	0.85

Discrim = discrimination.
Significant findings are in bold.
[a]0 = Mexico–born, 1 = US – born.

also takes a toll on individuals' biological stress responses, including the HPA axis functioning (Doane & Zeiders, 2014; Huynh et al., 2016; Zeiders et al., 2012). Adolescents are particularly vulnerable to such harmful effects given that their HPA axis is reactive to stressors and that they are sensitive to social-evaluative stressors (Dickerson & Kemeny, 2004; Romeo, 2013). The current study integrated both daily diary and post-diary survey data to examine whether daily diurnal cortisol responses to discrimination influenced adolescents' mental and sleep health. The results indicated that daily experiences of discrimination were associated with steeper diurnal cortisol slope and lower evening cortisol; however, such physiological responses tended to come with a toll on mental and sleep health. Given the recent political attention on immigration in the U.S. and the associated backlash against immigrants, the findings of the current study appear to be especially pertinent at a time when Mexican Americans are facing increasing discriminatory and unfair treatment (Lopez et al., 2018).

The first goal of the study was to examine the association between the daily experience of discrimination and diurnal cortisol responses among Mexican-origin adolescents. Surprisingly, at the WP level, daily experience of discrimination did not predict any of the diurnal cortisol activity indicators after taking into account the control variables. That is, on days when adolescents reported greater discrimination compared to their average levels, their same-day and next-day diurnal cortisol patterns did not change significantly. It is possible that there may not be enough variability in the reported discrimination experiences to capture the significance of the WP effect, as only 21% of the study sample reported at least one incidence of discrimination across the 4-day study period. Future studies with longer study periods (e.g., 14-day

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Table 4. Regression coefficients predicting cortisol response to discrimination from w2 well–being

	Same-day diurnal slope response to discrim		Same-day bedtime cortisol response to discrim		Next-day waking cortisol response to discrim		Next-day CAR response to discrim		Next-day diurnal slope response to discrim		Next-day cortisol bedtime cortisol response to discrim	
	b (SE)	*p*	*b (SE)*	*p*	*b (SE)*	*p*	*b (SE)*	*p*	*b (SE)*	*p*	*b (SE)*	*p*
Depressive symptoms W2	−0.02 (0.02)	0.33	0.00 (0.02)	0.87	0.65 (0.51)	0.20	0.04 (0.05)	0.49	−0.05 (0.04)	0.18	−0.02 (0.09)	0.79
Nativity	−0.02 (0.01)	0.05	−0.01 (0.02)	0.58	0.03 (0.32)	0.93	−0.04 (0.04)	0.32	−0.01 (0.03)	0.81	−0.05 (0.08)	0.55
Age	0.01 (0.01)	0.47	0.01 (0.01)	0.61	−0.3 (0.30)	0.31	−0.01 (0.03)	0.75	0.02 (0.02)	0.33	0.02 (0.06)	0.79
Female	0.00 (0.01)	0.92	0.00 (0.01)	0.73	0.13 (0.14)	0.33	−0.01 (0.02)	0.46	−0.01 (0.01)	0.62	−0.01 (0.03)	0.81
Parental education	0.00 (0.00)	0.17	0.00 (0.00)	0.9	0.03 (0.05)	0.54	0.00 (0.01)	0.75	0.00 (0.01)	0.95	−0.01 (0.01)	0.61
Anxiety W2	−0.01 (0.01)	0.27	0.00 (0.01)	0.87	0.33 (0.24)	0.16	0.04 (0.03)	0.13	−0.02 (0.02)	0.22	−0.02 (0.05)	0.72
Nativity	−0.02 (0.01)	0.05	−0.01 (0.01)	0.58	0.02 (0.31)	0.95	−0.04 (0.04)	0.35	−0.01 (0.03)	0.83	−0.05 (0.08)	0.54
Age	0.01 (0.01)	0.51	0.01 (0.01)	0.6	−0.27 (0.27)	0.33	−0.01 (0.03)	0.68	0.02 (0.02)	0.38	0.02 (0.06)	0.78
Female	0.00 (0.01)	0.87	0.00 (0.01)	0.72	0.12 (0.13)	0.35	−0.01 (0.02)	0.47	−0.01 (0.01)	0.68	−0.01 (0.03)	0.81
Parental education	0.00 (0.00)	0.16	0.00 (0.00)	0.89	0.03 (0.05)	0.59	0.00 (0.01)	0.84	0.00 (0.01)	0.97	−0.01 (0.01)	0.64
Sleep quality W2	−0.01 (0.00)	0.11	0.00 (0.01)	0.85	−0.02 (0.15)	0.88	−0.02 (0.02)	0.34	−0.01 (0.01)	0.60	0.03 (0.03)	0.42
Nativity	−0.02 (0.01)	0.05	−0.01 (0.02)	0.59	−0.02 (0.30)	0.94	−0.04 (0.04)	0.31	0.00 (0.03)	0.92	−0.05 (0.08)	0.56
Age	0.00 (0.01)	0.64	0.01 (0.01)	0.63	−0.2 (0.27)	0.46	−0.01 (0.03)	0.87	0.02 (0.02)	0.50	0.01 (0.06)	0.81
Female	0.00 (0.01)	0.89	0.00 (0.01)	0.70	0.10 (0.13)	0.40	−0.02 (0.02)	0.39	0.00 (0.01)	0.72	0.00 (0.03)	0.88
Parental education	0.00 (0.00)	0.29	0.00 (0.00)	0.89	0.04 (0.05)	0.45	0.00 (0.01)	0.77	0.00 (0.01)	0.79	−0.01 (0.01)	0.66

CAR = cortisol awakening response; Discrim = discrimination.

diary) or weekly reports of discrimination could better capture the variation in discrimination experiences and provide further insights into the with-person relations. It is also possible that there may be potential moderators that are contributing to these null findings. For example, Seaton and Zeiders's recent work (2020) found that, for individuals with high levels of racial centrality, increased daily racial discrimination was associated with higher waking cortisol; however, this association was not significant for those with low racial centrality. Future studies should continue exploring culturally salient moderators such as acculturation (White et al., 2014), ethnic identity (Umaña-Taylor et al., 2009), and family racial socialization (Umaña-Taylor & Hill, 2020) in order to gain a more comprehensive understanding of the WP associations between daily discrimination and diurnal cortisol patterns among Mexican-origin adolescents.

In contrast, at the BP level, discrimination was associated with steeper diurnal slopes and lower evening cortisol. This suggests that individuals who reported experiencing more discrimination tended to have steeper diurnal slopes, which is possibly driven by lower evening cortisol levels. Together, these findings lend support to the *activation hypothesis* (Dickerson & Kemeny, 2004; Selye, 1956), suggesting that when Mexican-origin adolescents encounter the stressful experience of discrimination in the short term, they tend to activate their cortisol response to prepare to mobilize physiological resources and adjust to the threatening situation by demonstrating activated physiological functioning. Our results shed light on the mixed findings of the effects of discrimination on diurnal cortisol responses by highlighting the importance of taking into account the timing between discrimination and diurnal cortisol responses (Busse et al., 2017). Specifically, unlike most of the prior studies that measured discrimination over the past 12 months or lifetime, our study asked participants to report discrimination experiences on a daily basis, and thus our findings are more in line with the cortisol release patterns that are due to acute stress (Miller et al., 2007). Indeed, a recent study that examined daily experiences of racial discrimination also found that increased racial discrimination experiences on a day-to-day basis were associated with steeper diurnal cortisol slopes and less pronounced CAR for Black adults who endorsed high levels of racial centrality (Seaton & Zeiders, 2020). It is possible that when Mexican-origin adolescents experience discrimination as an acute event, they might be well-equipped to deal with the discriminatory experience by relying on positive aspects of their racial/ethnic identity or by mobilizing their cognitive resources and attributing the cause of negative treatment to external factors rather than to themselves (Graham & Chen, 2020). Thus, they respond to discrimination incidents with activated physiological responses. The significant finding of discrimination and activated physiological responses profiles at the BP level also implies that when discrimination occurs in a broader environment that permits such mistreatment, it might be linked with short-term activated physiological reactions, which is consistent with theoretical perspectives suggesting that daily awareness of racism can act as a protective mechanism for negatively stigmatized minority groups (Fuller-Rowell et al., 2012; Helms, 1995; Sellers et al., 1998). Future studies should further consider the timing between discrimination exposure and cortisol response to examine the potential cognitive and psychological mechanisms through which daily experiences of discrimination influence diurnal cortisol responses.

When linking the discrimination-cortisol association to adolescent mental and sleep health, the results showed that next-day steeper diurnal slopes following discrimination were associated with higher levels of both depressive symptoms and anxiety at Wave 3. In terms of sleep health, our results showed that the same/next-day lower bedtime cortisol following discrimination was significantly associated with lower levels of sleep quality and

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the same/next-day steeper diurnal slopes following discrimination were associated with longer sleep duration. Together, these findings suggest that the short-term *activation* of cortisol responses in the face of discrimination may take a toll on Mexican-origin adolescents' mental and sleep health. It is possible that, even though the marginalized groups are well-equipped to deal with discrimination by showing resilience in adapting their physiological responses, their cognitive resources might be depleted, and the cognitive strain might pile up to undermine their mental health and sleep quality. Our findings echoed the literature on the under-the-skin wear and tear of stressors (McEwen, 2003), which argues that there is an *adaptation cost* associated with the activation of physiological systems. This can lead to wear and tear in the body, contributing to allostatic load. These findings further added to the Latina/x/o health disparities literature by demonstrating that the short-term altered physiological response might be one potential pathway through which discrimination undermines mental and sleep health among Mexican-origin youth. Future studies examining potential moderators in these processes are needed to identify potential avenues for interventions. For example, as family connectedness is highly valued in Mexican culture (Stein et al., 2014), future studies could explore whether Mexican-origin adolescents with supportive parents could be shielded from the adaption cost in the face of discrimination.

As a final note, the findings of the short-term activation of cortisol responses following discrimination linked to longer sleep duration were somewhat surprising. This finding suggests that sleep might serve as a restorative process, and engaging in longer sleep could potentially assist individuals in recovering from the physiological adaptations in response to stress (e.g., discrimination). This is consistent with research on the *escape-to-sleep* coping strategy, which has found that individuals tend to use sleep as a coping mechanism to counter adverse social conditions (Goosby et al., 2018; Yip, 2015). Given that sleep and cortisol often work together in response to stress (e.g., discrimination; Goosby et al., 2017) and the fact that both sleep duration and cortisol responses were measured daily in the current study, it is also possible that longer sleep duration following a daily discrimination incident could potentially result in improved memory encoding, and consequently leading to greater cortisol responses. Future studies with longer intervals between cortisol responses to stress and sleep measurements are encouraged to delve deeper into the stress response pathways following discrimination experiences.

Strengths, limitations, and future directions

The current study contributed to the extant discrimination literature in several key ways. First, using daily diary data, the current study was able to capture adolescents' experiences of discrimination closer in time to the event occurring and identified BP effects of daily discrimination on diurnal cortisol. The results suggested a different short-term diurnal cortisol pattern in response to discrimination (i.e., steeper diurnal slope, less pronounced CAR, and lower bedtime cortisol) as compared to prior studies that primarily measure chronic discrimination experienced over longer time spans documenting flatter slopes, higher bedtime cortisol, and more pronounced CAR (Doane & Zeiders, 2014; Huynh et al., 2016; Zeiders et al., 2012). Our findings highlight the benefits of investigating day-to-day experiences of discrimination using the daily diary approach. Second, by integrating daily diary and Wave 3 post-diary survey data, the current study linked the day-to-day cortisol responses to discrimination to overall mental and sleep health. Findings of the current study highlight that daily experiences in adolescents' lives can accumulate to influence their developmental outcomes. Recognizing the bidirectional associations between stress responses and well-being (Boyce & Ellis, 2005), we also tested alternative models using health indicators at Wave 2 to predict diurnal cortisol responses to discrimination. The alternative models were not supported, providing additional evidence that stress response to discrimination is more likely to precede health-related problems.

Although the contributions of this study are clear, limitations must be acknowledged. First, the daily diary component of the study was restricted to four consecutive school days. Although daily dairy designs provide a snapshot of individuals' day-to-day lives, the four-day design may not be sufficient for capturing incidents of discrimination given how infrequent reports of everyday discrimination are (Goosby et al., 2018; Huynh & Fuligni, 2010). Future studies with longer diary periods (e.g., 14-day or 21-day diary) or weekly reports of discrimination over a month are strongly encouraged to examine whether the study findings could be replicated over longer time periods. In a similar vein, the four-day design also may not be sufficient to capture the complexities of the physiological processes underlying adolescents' daily experiences given that diurnal cortisol activity is not highly stable across days (Ross et al., 2014). Future studies with a greater number of days and across a greater span of developmental periods are needed to gain a more comprehensive understanding of the physiological underpinnings of discriminatory experiences. Second, although the current study integrated the daily diary data with post-diary survey data, the design is a short-term longitudinal design with the mental and sleep health indicators collected shortly after the daily surveys were concluded. Future studies with longer-term longitudinal designs are needed to better capture the accumulative effects of daily experiences on long-term health (Barker, 1968; Gallimore et al., 1993). Thirdly, the generalizability of the findings is limited given that the sample of the current study was collected in the southern U.S. in areas with a large Mexican American population. Research has shown that ethnic enclaves tend to protect ethnic minorities from discrimination (White et al., 2014). Therefore, future studies with samples from settings that vary in diversity and same-ethnic representation are needed to replicate the findings of the current study. Lastly, current CAR guidelines recommend accessing CAR using at least three samples in the morning (Stalder et al., 2022). Here, only two saliva samples were collected to calculate CAR. Therefore, future studies should replicate the analyses in the current study using cortisol data adhere to these new cortisol data collection guidelines (Stalder et al., 2022).

Conclusions

The current study took a novel approach in integrating daily diary and post-diary survey data to delve into the physiological mechanisms underlying perceptions of discrimination and larger health disparities. The current study provided important insights into adolescents' daily experiences and physiological responses to discrimination as well as the implications of these associations for adolescents' mental and sleep health. Our findings suggest that there might be adaptation costs associated with the short-term cortisol activation in the face of discrimination. The current study makes an important contribution to understanding the biological process underlying Mexican-origin adolescents' experiences of

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discrimination and points to the importance of considering discrimination experiences for Mexican-origin youth's stress biology in unpacking health disparities among this population.

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