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Stress and diurnal cortisol among Latino/a college students: A multi-risk model approach

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Abstract

The transition to college is a time of increased opportunity and stress spanning multiple domains. Adolescents who encounter significant stress during this transition may be vulnerable to adverse outcomes due to a "wear and tear" of the hypothalamic pituitary adrenal (HPA) axis. Latino/a students may be particularly at-risk for heightened stress exposure due to experiences of both minority-specific and general life stress. Despite this, little is known regarding the cumulative impact of multiple stressors on Latino/a students' HPA axis functioning. The present study employed a "multi-risk model" approach to examine additive, common, and cumulative effects of multiple stress forms (general, academic, social, financial, bicultural, ethnic/racial discrimination) on diurnal cortisol in a sample of first-year Latino/a college students ($N = 196$; 64.4% female; $M_{age} = 18.95$). Results indicated that no stress forms were additively associated with the cortisol awakening response (CAR), but general stress was associated with a flatter diurnal cortisol slope (DCS) and bicultural stress was linked with a steeper DCS. A college stress latent factor was associated with a lower CAR, whereas a latent factor of discrimination was not associated with diurnal cortisol. Cumulative risk was linked with a lower CAR. Findings highlight the physiological correlates of various stressors experienced by Latino/a college students.

Keywords: college students; cortisol; HPA axis; Latino/a; stress

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The transition to college is a time of opportunity and stress, consisting of both developmental (e.g., into emerging adulthood) and ecological change (e.g., into new social contexts; Seidman & French, 2004). Adolescents who encounter significant stress during the transition to college may be particularly at-risk for adverse outcomes, due to repeated activation of stress-sensitive physiological systems. Evidence suggests that Latino/a[1] students may encounter greater stress during the transition to college, as minority youth often experience cumulative minority-specific and general life stress (Phinney & Haas, 2003; Wei et al., 2011). Importantly, Hispanic/Latino students represent the largest ethnic/racial minority group in higher education (McFarland et al., 2017), but are also the minority group least likely to graduate from a 4-year institution (Snyder et al., 2019). Alterations in typical stress responsive systems may serve as potential mechanisms underlying the development of mental and physical health problems, including anxiety disorders (Adam et al., 2014), major depressive disorder (Adam et al., 2010; Zajkowska et al., 2022), inflammation (Adam et al., 2017), and cardiovascular disease (Matthews et al., 2006). However, there is a lack of research disentangling the effects of different types of stress simultaneously (i.e., alongside each other) on physiological outcomes in Latino/a college students. Thus, the proposed study will investigate multiple forms of stress (e.g., general, college-related, minority-specific) as they relate to Latino/a college students' diurnal cortisol modeled via three-level growth curve models to best capture the diurnal pattern of cortisol across moments, days, and individuals. Further, in an effort to disentangle the complex associations between stress and cortisol, a multi-risk model approach will be implemented to best characterize perceptions of stress[2] during the first year of college.

Theories of stress, neurobiology, and health

Allostatic load theory

A prominent theory in the examination of stress exposure as it relates to biological functioning is allostatic load (McEwen, 1998). *Allostasis* refers to the body's adjustment of biological responses to meet the demands of acute stressors (e.g., psychosocial stress; McEwen, 1998). Whereas this process is adaptive under normal levels of stress exposure, individuals who undergo chronic and/or ongoing perceptions of stress often experience the cumulative "wear and tear" of the body's biological systems, wherein the overactivation of these systems results in diminished biological

[1]The word "Latino/a" is used here to refer to an individual who is of Latin American origin or ancestry. We use this term, rather than the nonbinary "Latinx," to honor the self-identification of the study participants who self-selected into the study based on Hispanic/Latino/a descent. Consistent with recommended best practices (Buchanan et al., 2021), when discussing other studies, we adhere to the label that was originally used to describe that study's sample (e.g., Hispanic, Latino, Latino/a, Latinx).

[2]For the purposes of this paper, perceptions of stress will be referred to broadly as "stressors." However, it should be noted that because we are using self-report data, it is likely that some of the constructs we are examining may better capture students' perceptions of stress (e.g., academic stress, social stress).

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functioning (McEwen, 1998). The hypothalamic pituitary adrenal (HPA) axis is a biological system that is particularly influenced by psychosocial stress and is hypothesized to be a key physiological mechanism in allostatic load (McEwen & Seeman, 1999). Similar to allostasis, immediate activation of the HPA axis in response to acute stress is adaptive in the short-term (i.e., release of cortisol helps the body manage stress), however, chronic activation of the HPA axis can cause a counterregulatory response in which chronically high cortisol levels (e.g., hypercortisolism) begin to drop below normal due to desensitization (e.g., hypocortisolism; Adam, 2012; Miller et al., 2007). Both hypercortisolism and hypocortisolism have been linked to numerous negative outcomes, including risk for mental and physical health problems (Adam et al., 2017). Thus, it is paramount that research examines predictors of HPA axis functioning among populations that are known to experience high levels of chronic and/or cumulative stress, such as minority students transitioning to college.

Cultural neurobiology framework

Emerging research has called for the need to examine how various aspects of culture, including culturally related stress, may affect biological systems (Causadias et al., 2017). The *cultural neurobiology* framework posits that cultural processes can influence ethnic/racial minority youths' neurobiological stress systems, including the HPA axis, across multiple time frames (e.g., moment, daily, yearly; Doane et al., 2018a). This framework also recognizes the discrete and often ongoing stressors that are experienced by minoritized groups in the United States (e.g., discrimination, acculturative stress), which may underlie ethnic/racial differences in stress biology and health status due to cumulative vulnerability (Myers, 2009). Chronic stress, including age and ethnicity-related stressors, have been linked to an increased risk for numerous adverse outcomes in ethnic/racial minority college student and adult samples, including depressive symptom severity (Arbona & Jiménez, 2014; Wei et al., 2010), poorer perceived physical health (Garcia et al., 2017), and risk for diabetes, hypertension, smoking, and coronary heart disease (Gallo et al., 2014). Importantly, individuals who experience the *cumulative* effects of multiple stressors may be particularly vulnerable to later negative health outcomes. Given that ethnic/racial minority adolescents often experience the chronic burden of minority-specific stressors *in addition* to the typical stressors associated with college (e.g., Arbona & Jiménez, 2014; Wei et al., 2010), it is plausible that Latino/a college students may experience diminished HPA axis activity as a result of cumulative stress.

Stress and the HPA axis

The HPA axis is one of the body's major stress response systems that, once activated, leads to the eventual release of cortisol, a hormone that helps the body manage stress and affects biological processes essential for daily functioning (e.g., heart rate, metabolism; Kirschbaum & Hellhammer, 2000). Whereas prior research has frequently focused on the immediate response to psychosocial stress (e.g., cortisol reactivity; Dickerson & Kemeny, 2004), the chronic effects of stress may be better understood by the diurnal activity of the HPA axis (Adam, 2006; Adam, 2012). Cortisol follows a typical diurnal rhythm, with high levels upon waking, a 50%–65% increase approximately 30 min after waking (cortisol awakening response (CAR); Stalder et al., 2016), and an overall decrease throughout the day with lowest levels at midnight (Adam & Kumari, 2009). Two parameters commonly used to characterize the diurnal pattern are the diurnal cortisol slope (DCS; decline in cortisol levels across the day) and the CAR.

There is robust evidence that chronic stress is associated with a flatter DCS (Miller et al., 2007), a pattern that results from deviations below or above the typical diurnal rhythm (e.g., low cortisol in the morning and/or high cortisol in the morning and evening) and that is linked with numerous adverse health outcomes in adolescents and adults (for review see, Adam et al., 2017). In contrast, findings regarding the CAR have been more inconsistent (Clow et al., 2004), with chronic stress linked to both an increase and decline in cortisol output (e.g., Chida & Steptoe, 2009). It has been hypothesized that a higher than normal CAR can be adaptive in the short-term by helping individuals prepare to meet the demands of the day (e.g., "boost hypothesis"; Adam et al., 2006); however, when these short-term elevations are chronically experienced, a heightened CAR can confer risk for negative outcomes (e.g., major depressive disorder; Adam et al., 2010). Conversely, a lower CAR may reflect HPA axis dysregulation resulting from prior overactivation (i.e., due to exhaustion of physiological systems) and has been associated with conditions such as fatigue and burnout (Chida & Steptoe, 2009; Pruessner et al., 1999).

Type of stressor

Specificity hypotheses suggest that different *types* of stress may play a large role in determining how HPA axis activity is impacted (Miller et al., 2007). Specifically, different forms of stress often require discrete adaptational demands that are differentially regulated via the HPA axis, pointing to a need to examine multiple types of stress. For example, general life stress has been frequently associated with a heightened CAR (Miller et al., 2017; Morin-Major et al., 2016), which may be indicative of metabolic support that prepares adolescents to cope with these daily stressors. In addition, a large body of evidence suggests that social stressors (i.e., that pose social threat to self) are particularly influential on HPA axis reactivity (Dickerson & Kemeny, 2004), and may also have implications for diurnal patterns. Indeed, prior work found that positive perceptions of family relationships in adolescence were associated with higher waking cortisol and a steeper DCS in young adulthood (Shirtcliff et al., 2017). Among early adolescents, greater average peer problems were linked to a flatter DCS, whereas day-to-day increases in peer or academic problems were linked with greater morning cortisol (Bai et al., 2017). Notably, one study observed that first-year graduate students' CAR was flatter in the Spring, as opposed to the beginning of classes in Fall, whereas CAR levels remained stable for community comparisons (McGregor et al., 2016). This may suggest that first-year graduate students faced stressors unique to that context that were linked with changes in diurnal cortisol patterns, which may also occur for undergraduate students.

Importantly, a growing body of evidence suggests that minority-specific stressors, or additional forms of stress that are unique to members of marginalized communities, are associated with biological functioning (Doane et al., 2018a; Flentje et al., 2019; Myers, 2009). Currently, the most explored stressor to explain ethnic/racial disparities in physiological stress systems are experiences of discrimination or mistreatment (Huynh et al., 2016; Skinner et al., 2011; Zeiders et al., 2014; Zeiders et al., 2018). Indeed, numerous studies have examined the physiological correlates of discrimination experiences in adolescence and young adulthood,

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among them being greater overall cortisol output, lower waking cortisol, and a flatter DCS (Huynh et al., 2016; Skinner et al., 2011; Zeiders et al., 2012; Zeiders et al., 2014). In addition, more subtle forms of discrimination (e.g., microaggressions) have been linked with increased overall cortisol output (e.g., AUCg) among Latino and African American young adults (Zeiders et al., 2018).

Notably, less work has been done examining stressors that relate to cultural adaptation and diurnal cortisol among Latino/a adolescents. A recent study by Gonzales et al. (2018) found that youth who reported higher biculturalism (i.e., high on both Anglo and Mexican orientations) exhibited greater cortisol reactivity. Similarly, higher levels of acculturation (e.g., greater Anglo orientation) were linked with a smaller CAR in a sample of Mexican-American adults (Mangold et al., 2010). Further, in a sample of Latino late adolescents, Doane et al. (2018b) found that daily family assistance behaviors (e.g., helping sibling/family, translating for family member) were associated with lower waking cortisol and a flatter DCS the next day. Collectively, these studies suggest that there may be evidence for links between other culturally specific stressors (e.g., bicultural stress) and diurnal cortisol. However, to date, no known study has examined the impact of cultural stressors on diurnal cortisol patterns alongside general and college-specific stressors. This is an important gap in the literature, as emerging work suggests that a better understanding of youths' physiological stress processes may help address educational inequalities (Obradović & Armstrong-Carter, 2021), which are particularly evident in higher education (Snyder et al., 2019). For example, the *stress disparity model* contends that chronic stress can result in deviations in HPA axis activity, including a lower CAR and a flatter DCS, which in turn negatively affects students' ability to learn (e.g., trouble focusing, worse cognitive performance; Heissel et al., 2017). Thus, the present study also examined the *combined* impact of multiple stress types in an effort to better capture chronic stress experiences during this time.

Timing of stressor

The time frame, or recency, in which stress is measured (e.g., past year, past month, past week) is also critical to the examination of diurnal cortisol, given that a chronic activation of the HPA axis, often characterized by hypercortisolism, can eventually result in diminished HPA axis activity (i.e., hypocortisolism; Adam, 2012; Miller et al., 2007). In their seminal meta-analysis of chronic stress and the HPA axis, Miller et al. (2007) found that time was negatively associated with HPA axis activity (i.e., the longer it had been since the stressor emerged, the lower an individuals' morning and daily cortisol volume), whereas *current* experiences of stress were associated with greater morning and daily cortisol output. In the context of college life, it may be expected that recent, developmentally salient stressors (e.g., academic, financial stress) would be positively linked with HPA axis activity, whereas stressors that are often present in ethnic/racial minority youths' lives prior to college (e.g., discrimination) may be negatively associated with diurnal cortisol. Thus, future research is needed that examines multiple forms of stress that differ in both type (e.g., nature, controllability) and timing (e.g., past semester vs. past week).

A multi-risk model approach

There is prior evidence in adolescent and young adult populations supporting that general life stress (Miller et al., 2017; Morin-Major et al., 2016), academic-related stress (Bai et al., 2017; McGregor et al., 2016), and minority-specific stressors (Skinner et al., 2011; Zeiders et al., 2014) are each implicated in physiological stress activity. However, less is known about the additive influence of these stressors; that is, the impact of specific forms of stress when accounting for other forms. Previous work provides support for the unique effects of minority- and college-related stressors on Latino/a students' mental health. Specifically, studies found that minority-specific stressors (e.g., college climate, discrimination, intra-ethnic pressures) and general college stress were uniquely associated with depressive symptoms in minority (Wei et al., 2010) and Latino/a college students (Arbona & Jiménez, 2014; Arbona et al., 2018). Yet, no known study has examined the unique effects of minority-specific stressors alongside other forms of life stress (e.g., general, academic, social) on diurnal cortisol patterns. This is a critical gap in the literature, as these findings may help identify specific forms of stress that are particularly influential on Latino/a college students' physiological functioning, which may explain, or mediate, associations between stress and mental health.

In addition to the additive effects of stress, it is also meaningful to consider the potential common (i.e., shared) contributions of multiple stress forms. To date, no known studies have modeled different types of stress as an unobserved latent variable predicting physiological functioning. However, a recent study compared alternative methods to assess cumulative risk, among them being latent factor analysis, and found important similarities and differences in predicting outcomes (i.e., children's externalizing problems; Ettekal et al., 2019), highlighting the importance of testing competing models. Characterizing stress as a latent variable provides the utility of examining what is in common among discrete forms of stress, while also potentially providing an indirect measure of the individuals' *perceptions* of stress (i.e., individual differences in stress perceptions). Thus, comparing results of the common (latent) model to the additive effects may provide meaningful information regarding whether HPA axis functioning is a result of something potentially "trait-like" (i.e., how a person perceives stress in general), rather than stressor-specific effects.

Importantly, Latino/a college students may also endure the *cumulative* impact of multiple sources of stress. Consistent with allostatic load (McEwen, 1998), the accumulation of multiple stressors may be particularly deleterious for HPA axis functioning due to the "wear and tear" that results from chronic activation of biological systems. Although no studies have examined cumulative stress and physiological outcomes among Latino/a college students, existing research suggests that cumulative stress negatively impacts HPA axis functioning among minority groups (Kwak et al., 2017; Suglia et al., 2010). For example, Suglia et al. (2010) found that cumulative stress (e.g., discrimination, negative life events, community violence) was associated with lower morning cortisol and a flatter DCS among Black, but not Hispanic, pregnant women, and Kwak et al. (2017) found that Latino adolescents who reported greater cumulative family stress (e.g., financial, career, relationships, prejudice) had a lower CAR than those who endorsed low cumulative stress. Further, a longitudinal analysis of African American adolescents found that perceptions of discrimination that were high and stable across adolescence (e.g., ages 16 to 18) predicted higher levels of allostatic load (e.g., cortisol, blood pressure, BMI) in young adulthood (Brody et al., 2014). Although these studies do not generalize to the demographics of the current study, they provide general evidence for the link between cumulative stress and HPA axis functioning.

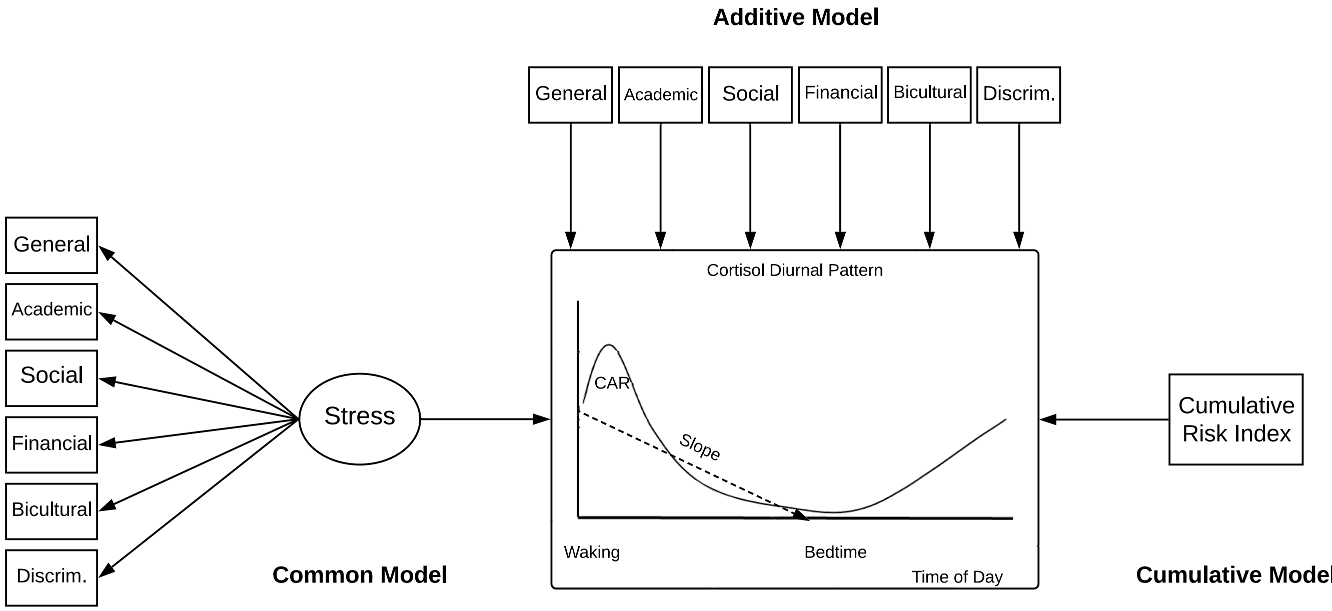

Figure 1. Conceptual representation of the "multi-risk model" approach.

The present study

The present study harnessed the strengths of an ethnically homogenous design to identify within-group differences (i.e., meaningful variability) in stress perceptions and physiological stress processes among Latino/a college students (García Coll et al., 1996). Specifically, to untangle the complex associations between stress and HPA axis functioning, we implemented a "multi-risk model" approach that characterized stress in three different ways. First, we examined the independent effects of stress by entering all stress forms into the model together (additive model), the common and/or "shared" influence of stress, measured by estimating underlying latent factor(s) of stress (common model), and the cumulative impact of experiencing multiple stressors to a high degree (cumulative model; see Figure 1). Given that ethnic/racial minorities are known to experience multiple sources of stress during college (e.g., Arbona et al., 2018; Wei et al., 2010), this multi-risk model approach sought to identify whether the common and/or cumulative effects of multiple forms of stress provide important information about physiological stress processes, separate from what can be observed by the additive effects of stress. We hypothesized that each form of stress would predict a flatter DCS (*Hypothesis 1a*). Further, based on previous findings (Bai et al., 2017; Miller et al., 2017; Skinner et al, 2011; Zeiders et al., 2014), we predicted that general, social, academic, financial, and bicultural stress would be associated with an increased CAR, while discrimination would be linked with a reduced CAR (*Hypothesis 1b*). Due to a lack of previous research examining stress as a latent variable, hypotheses regarding the common effects of stress on diurnal cortisol were exploratory (i.e., nondirectional). Lastly, in line with prior findings (Kwak et al., 2017; Suglia et al., 2010), we hypothesized that cumulative stress would be associated with a flatter DCS (*Hypothesis 2a*) and a reduced CAR (*Hypothesis 2b*).

Method

Participants

209 Hispanic/Latino/a adolescents ($M_{age} = 18.10$, $SD = 0.41$; 64.4% female) were recruited during the spring or summer of their senior year in high school (T1; Spring, 2017) prior to enrolling at a large, ethnically/racially diverse (49.6% White, 22.8% Hispanic or Latino/a, 6.9% Asian, 4.3% Black or African American) university in the southwestern United States, as part of a longitudinal, multi-method study of Latino/a adolescents transitioning to college (see Doane et al., 2018b). This study utilized data from Spring 2018 (T3; $N = 196$; $M_{age} = 18.95$, $SD = .40$), when the majority of participants were in their second semester of college ($n = 194$ enrolled in college). Participants were recruited through university orientation sessions, as well as via email, text messaging, and phone conversations in English or Spanish. Inclusion criteria required that participants: (1) had gained acceptance to the focal university and had paid an initial deposit or selected to defer payment; (2) were current seniors in high school; (3) identified as Hispanic/Latino/a; and (4) lived within 60 miles of the university when they were recruited. All participants identified broadly as Hispanic or Latino/a, with the majority of participants specifically identifying as being of Mexican descent (85.1%), followed by South or Central American (10.1%), Cuban (5.3%), and Other (4.3%) descent. Most participants (84.2%) identified as non-White Latino/a; 15.8% identified as White Latino/a. Eleven percent (10.6%) of participants were first-generation immigrants (born outside the United States), 62.0% were second generation (born in United States with at least one parent born outside the United States), and 27.4% were third generation or greater (both parents born in the United States). With regards to sexual orientation, most of our sample identified as straight (86.5%), followed by bisexual (7.2%), lesbian/gay (3.4%), unsure (1.4%), and other (1.4%). Thirty-four percent (33.7%) of the sample reported that their parents had attained less than a high school degree, 21.6% of parents earned a high school degree or GED, 22.8% of parents completed some college, 15.9% of parents had obtained a Bachelor's degree, and 3.8% reported that their parents had a graduate education. Participants' subjective social class was as follows: 12.6% working class, 28.2% lower-middle class, 48.5% middle class, 10.2% upper-middle class, and 0.5% upper class. More information on sample recruitment and demographics can be found in Doane et al. (2018b).

Procedure

The university's Institutional Review Board approved all procedures before data collection began. Informed consent and assent (i.e., for participants under the age of 18) were obtained from all participants prior to beginning study procedures. Study personnel traveled to participants' homes or hosted participants in a campus lab to deliver study materials, collect survey responses, and provide instructions for saliva sampling and daily diary procedures. Participants also completed an online battery of survey measures at a time of their convenience during the semester, which included measures of demographic information, cultural values, emotional health, and stress experiences.

During the week following the home and/or lab visit, participants wore wrist-based accelerometers (e.g., actigraphy watch) to assess objective sleep throughout the week ($M_{\text{nights}} = 6.49$, $SD = .91$) and completed 4–5 diary entries per day, across 7 days ($M = 26.20$, $SD = 3.98$). Participants also provided saliva samples via passive drool 5 times a day for 3 weekdays: immediately upon waking, 30 min after waking, twice during the day (approx. 2 hr and 8 hr from initial waking sample, to avoid mealtimes), and at bedtime. Thus, participants were asked to complete 15 saliva samples in total (i.e., 5 samples per day across 3-day cortisol protocol; $M = 14.88$, $SD = .95$). Within our analytic sample of 180 participants, there were a total of 2,667 cortisol samples. Participants were asked not to eat, drink, or brush their teeth an hour prior to saliva sampling. Participants recorded the date and time of each sample, but also used a track cap compliance device (MEMS 6$^{\text{TM}}$ (Aardex)) to objectively record the sample time upon track cap opening. Participants were instructed to press a button on the actigraphy watches each time they had completed a saliva sample or a daily diary entry (i.e., as secondary indicators). After providing each saliva sample, participants completed brief diary entries using web-based smartphones that assessed questions about stressors experienced in the last hour or across the day (e.g., bicultural stress). Further, participants reported whether they had recently eaten, exercised, used caffeine, nicotine, medication, slept, or experienced pain (i.e., as potential covariates in cortisol analysis).

Compliance with saliva sampling procedures for the waking and post-30 min waking sample was determined via participants recordings of time on vials, track cap device times, actigraphy-recorded times, and daily diary times. Because noncompliance with saliva sampling procedures can bias cortisol estimates (Kudielka et al., 2003; Stalder et al., 2016), each indicator of time was carefully inspected to determine "compliant" versus "noncompliant" saliva samples (Doane & Zeiders, 2014). Criteria for compliance are as follows: For the waking sample: track cap detected times were within 15 min of participants' actigraphy-recorded times (87.9% of samples with complete compliance data; 75% of all waking samples); for the second (post 30-min waking) sample: track cap detected times were within 25 to 45 min after track cap detected times of waking sample times (85.7% of samples with valid track cap data; 82.9% of valid samples of all second samples). Additionally, these rates required that actigraphy or track cap data were available for samples to be considered compliant, resulting in noncompliance if this data were missing. Lastly, to avoid biased estimates of DCS and CAR (see Stalder et al., 2016), cortisol values from noncompliant samples were treated as missing data in final analyses (4.9% of all samples).

Measures

Salivary cortisol

Salivary cortisol was assessed at T3. Participants were instructed to store their completed saliva samples in their refrigerator until study personnel retrieved the samples to return them to the lab (typically 4 days later). Samples were stored at -80 degrees Celsius, per existing recommendations (Nicolson, 2008). Once the study was completed and all saliva samples had been retrieved, they were placed on dry ice and transported via courier across 3 days to the Biochemisches Labor at the University of Trier in Germany for assay. This is the preferred method for handling and transporting salivary biomarkers (Granger et al., 2012). Samples were assayed in duplicate for salivary cortisol (Dressendörfer et al., 1992). Average concentration from both assays (excluding the samples for which only one assay was possible) was used to assess cortisol in nanomoles per liter. The intra-assay coefficient of variation ranged from 4.0% to 6.7%, and the inter-assay coefficient of variation ranged from 7.1% to 9.0%.

General stress

General stress was assessed using the 4-item Perceived Stress Scale (PSS-4; Cohen et al., 1983). Participants were asked to indicate their feelings and thoughts *during the last month* using a Likert-type scale ranging from 0 (*Never*) to 4 (*Very Often*). Sample items included "How often have you felt difficulties were piling up so high that you could not overcome them?" and "How often have you felt that you were unable to control the important things in your life?" The four items were summed to create a measure of general stress ($\alpha = .66$). Scores ranged from 0 to 16, with higher scores reflecting greater perceived stress. Previous studies have utilized the PSS-4 among Hispanic/Latino/a college student and emerging adult samples (Cano et al., 2021; Ibarra-Mejia et al., 2022).

College stress

Academic, Social, and Financial stress were each measured using the 18-item College Stress Scale (CSS; Rodriguez et al., 2000). Participants were asked to rate how stressful certain experiences were *since the beginning of the semester* using a 5-point scale that ranged from 1 (*does not apply*) to 5 (*extremely stressful*). This study examined three subscales: academic stress (7-items; e.g., "Handling your academic workload"), social stress (6-items; e.g., "Handling personal relationships"), and financial stress (5-items; e.g., "Paying for bills and living expenses"). Items within each subscale were averaged to create three college-related stress scales, with higher scores indicating greater stress in each domain. Internal consistencies were good for all three subscales: academic ($\alpha = .85$), social ($\alpha = .84$), and financial ($\alpha = .85$).

Bicultural stress

Bicultural stress was measured using participants' nighttime daily diary reports to five items adapted from the 20-item Bicultural Stress Scale (Romero & Roberts, 2003). Questions were framed in a daily format (e.g., "Today I did not feel comfortable with people whose culture is different from mine"). Participants responded "yes" or "no" to each item; a frequency count of "yes" items were summed at each day to represent daily bicultural stress. An aggregate measure of average bicultural stress was created using the mean of participants' daily scores *across the week*. The full week of diary data (i.e., measured across 7 days) was used to create this aggregate score, rather than limiting the measure to the 3-day cortisol protocol, as the current study aimed to assess bicultural stress across a *typical* week for students. This diary-based approach has been used successfully in previous waves of this sample (e.g., during high school) as a measure of adolescents' average daily bicultural stress (see Sladek et al., 2020a).

Discrimination stress

Ethnic/racial discrimination was assessed utilizing the Adult Discrimination and Peer Discrimination Scale (Greene et al., 2006; Way, 1997). Participants were asked to rate the frequency of the occurrence of racial or ethnic-based discrimination by adults and peers at their school. Although the original scale does not include timing, the current study asked participants to think about these experiences *during their second semester* at the focal institution (e.g., Spring, 2018). Participants responded on a 5-point Likert scale ranging from 1 (*never*) to 5 (*all the time*). Sample items include "How often do you feel that adults treat you unfairly because of your race or ethnicity?" and "How often do you feel that other students at your school insult you because of your race or ethnicity?" The current study examined perpetrator-specific experiences of discrimination (i.e., peer vs. adult-based), as is standard when using this measure (Greene et al., 2006) and due to research suggesting the need for closer attention to variation in outcomes by perpetrator (Benner et al., 2018). Peer and adult-based discrimination scores were computed by taking the average of 7 items on each scale, with higher scores indicating more experiences of peer and adult-based ethnic/racial discrimination. Internal consistencies were good for both peer ($\alpha = .93$) and adult discrimination ($\alpha = .95$).

Covariates

Several key demographic characteristics and health behaviors were examined as potential covariates, in an effort to isolate associations between stress and diurnal cortisol patterns (Adam & Kumari, 2009). Momentary covariates included whether participants ate, consumed caffeine, used nicotine, experienced pain, exercised, drank alcohol, slept, or used medication within the hour prior to sampling. Day-level covariates included actigraphy-measured sleep duration. Between-person covariates included sex designated at birth (herein referred to as sex; 0 = female, 1 = male), immigrant generation status (0 = participant, parents, and both sets of grandparents were born outside of the United States to 7 = all family members were born in the United States; Umaña-Taylor et al. 2009), whether participants completed the study during the summer (0 = school year participation, 1 = summer participation), living situation (0 = lived with parents or other family, 1 = lived away from the home in university dorms, with friends, or alone), parent education (1 = less than high school to 10 = doctorate or advanced degree), subjective social class (1 = upper class, 2 = upper-middle class, 3 = middle class, 4 = lower-middle class, 5 = working class; Rubin et al. 2014), topical medication use (i.e., corticosteroids), and oral contraceptive use.

Data analytic plan

The final analytic sample was limited to participants who had at least one valid day of cortisol data at T3 ($N = 180$). Independent *t*-test and Chi-square tests were conducted to investigate whether there were differences between participants who had valid cortisol data at T3 and those who did not. Independent *t*-tests revealed that there were no significant group differences on any of the continuous study variables ($p > .28$). Chi-square tests indicated that participants who did not provide cortisol samples ($n = 16$) were significantly more likely to participate [in other portions of the study] during the summer than during the school year ($\chi^2 = 52.45$ (1), $p < .001$). There were no significant group differences for any other categorical variables ($p > .09$). Within this analytic sample, data missingness ranged from 0% (e.g., general stress) to 1.7% (e.g., ethnic/racial discrimination).

Three separate models were created to characterize stress: (1) additive model; (2) common model; and (3) cumulative model. Additive effects were examined by inserting all stressors as predictors into the model simultaneously. Common effects were estimated by using exploratory factor analysis (EFA) to determine whether the seven stress variables exhibited optimal factor structure when modeled as indicators of one or more latent factors of stress, which were then included as predictor(s) of diurnal cortisol. To evaluate model fit, several fit indices were examined: chi-square test of model fit, comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square of approximation (RMSEA), and the standardized root mean square residual (SRMR). Based on published criteria (Hu & Bentler, 1999), good model fit was determined if CFI and TLI values were above .95, RMSEA values were below .06, and SRMR values were below .08. Lastly, cumulative effects were measured by calculating a cumulative risk index (CRI). A count variable was created indicating how many stressors the participant experienced to a high degree. Being in the highest quartile of any one form of stress added "1" to the count. Possible scores ranged from 0 to 7.

To assess momentary (Level 1), daily (Level 2), and between-person (Level 3) variation in cortisol, three-level growth curve models were fit using *Mplus* 8.0 (Muthén & Muthén, 1998–2017). The diurnal cortisol pattern (e.g., DCS and CAR) was modeled at Level 1 by including growth parameters based on participants' wake time (linear), the squared function of this variable (i.e., to assess curvilinear patterns; time since waking^2), and a dummy variable corresponding to the CAR sample (1 = second sample). At Level 3, additive, common, and cumulative stress were included as person-specific predictors of the cortisol diurnal pattern. Each model of stress was tested separately in the analyses. Presented below is an equation for the additive stress model. In this equation, $b_{0\text{di}}$ represents the intercept (average cortisol at waking), $b_{1\text{di}}$ represents the CAR, and $b_{2\text{di}}$ and $b_{3\text{di}}$, together, represent the cortisol slope across the day from waking to bedtime (excluding the CAR). Only the prediction of waking cortisol is presented here at Levels 2 and 3, as the other cortisol parameters were estimated equivalently at each level, with the exception of random effects at Level 2, which were only included for the intercept. In the additive model, all stress forms were allowed to covary with one another. Covariates that exhibited statistically significant associations with cortisol outcomes (DCS and CAR) at the bivariate level (i.e., tested in a multi-level framework) were retained in the final models. A full information maximum likelihood (FIML) method was utilized to account for missing data.

Level 1 (moment):

$$\begin{aligned} Cortisol_{\text{mdi}} &= b_{0\text{di}} + b_{1\text{di}}(CAR_{\text{mdi}}) + b_{2\text{di}}(Time\ Since\ Waking_{\text{mdi}}) \\ &+ b_{3\text{di}}(Time\ Since\ Waking^2_{\text{mdi}}) \\ &+ b_{\text{mdi}}(Momentary\ Covariates_{\text{mdi}}) + u_{\text{mdi}} \end{aligned}$$

Level 2 (day):

$$b_{0\text{di}} = \beta_{00i} + \beta_{01\text{i}}(Prior\ Night\ Sleep\ Duration_{0\text{di}}) + u_{0\text{di}}$$

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Level 3 (person):

$$\beta_{00i} = \gamma_{000} + \gamma_{001}(General\ Stress_i) + \gamma_{002}(Academic\ Stress_i) + \gamma_{003}(Social\ Stress_i) + \gamma_{004}(Financial\ Stress_i) + \gamma_{005}(Bicultural\ Stress_i) + \gamma_{006}(Peer\ Discrimination_i) + \gamma_{007}(Adult\ Discrimination_i) + \gamma_{008}(Person - Level\ Covariates_i) + u_{00i}$$

Results

Preliminary analyses

Descriptive statistics and bivariate correlations are presented in Table 1. First, the data were examined for normality and outliers. Bicultural stress levels were significantly skewed (2.45) due to relatively low endorsement of daily bicultural stress (e.g., 47.2% reported no instance of bicultural stress); however, a majority of the sample reported experiencing at least one bicultural stressor across the week. Thus, this variable was transformed using the natural log function prior to inclusion in main analyses. Raw cortisol values were also transformed to account for outliers and positive skew of the cortisol distribution. First, outlier cortisol values ($n = 14$) were winsorized at 50 nmol/L, following standard practice (Nicolson, 2008). Next, raw cortisol values were natural log-transformed (skew = 2.89 before transforming, −0.39 after transforming). Plots of cortisol values (prior to log transformation) are presented in Figure 2 for visualization purposes. Bivariate correlations shown in Table 1 depict the association between study variables and the average of participants' five cortisol samples across all three assessment days. Correlations between the different stress forms ranged from small ($r = .11$) to moderate ($r = .79$).

Factor analysis of stress

EFA was conducted to investigate the factor structure of each of the stress indicators. A scree plot, number of significant items per factor, and theoretical rationale were used to determine optimal factor structure. The scree plot identified two factors with an eigenvalue exceeding one (2.79 and 1.42). The 2-factor solution showed significantly better statistical fit than the 1-factor solution ($\Delta\chi^2$ (6) = 158.12, $p < .001$). Thus, the 2-factor solution was retained for subsequent analyses using confirmatory factor analysis (CFA). Model fit for this two-factor CFA was good (χ^2 (13) = 15.19, $p = .30$, RMSEA = .03, CFI = .99, TLI = .99, SRMR = .04). The first factor was composed of general stress, academic stress, social stress, financial stress, and bicultural stress, and the second factor consisted of both peer and adult ethnic/racial discrimination. Factor loadings for the first latent stress factor ranged from low to high: bicultural stress ($\lambda = .42$, $SE = .07$, $p < .001$), general stress ($\lambda = .47$, $SE = .07$, $p < .001$), financial stress ($\lambda = .57$, $SE = .06$, $p < .001$), academic stress ($\lambda = .69$, $SE = .06$, $p < .001$), social stress ($\lambda = .78$, $SE = .05$, $p < .001$). Because the three highest factor loadings were subscales of the CSS (Rodriguez et al., 2000), this latent factor was referred to as "college stress." In the second factor, peer ($\lambda = .88$, $SE = .08$, $p < .001$) and adult-based discrimination ($\lambda = .89$, $SE = .08$, $p < .001$) were both significant with high factor loadings. This factor was referred to as "discrimination stress." The two latent stress factors were significantly positively correlated ($r = .36$, $p < .001$).

Cumulative risk index

Percentile/quartile scores were used to determine whether participants were experiencing "high" stress of any form. Scoring above the 75th percentile for any given stress form was considered high stress and given a "1" for this stressor ("0" was assigned to participants <75th percentile; Ettekal et al., 2019; Suglia et al., 2010). The cutoff criteria values were as follows: general stress (>9.00), academic stress (>4.00), social stress (>3.67), financial stress (>3.20), bicultural stress (>0.38), peer discrimination (>2.00), adult discrimination (>2.00). These dummy variables were then summed to create an overall CRI. The distribution of this CRI ($M = 1.52$, $SD = 1.65$) was as follows: 36.7% scored "0" (i.e., experienced no stressor to a high degree), 24.4% scored "1", 13.3% scored "2", 10.0% scored "3", 10.6% scored "4", 2.8% scored "5", 1.1% scored "6", and 1.1% scored "7" (i.e., experienced each form of stress to a high degree).

Diurnal pattern

A linear growth model with a dummy code to represent the CAR fit the data significantly better than an unconditional model with no predictors, χ^2 (9) = 2,386.442, $p < .001$. Adding a quadratic term fit the data significantly better than the linear model, χ^2 (6) = 64.513, $p < .001$. Growth modeling revealed the expected average diurnal cortisol pattern to have relatively high cortisol levels at waking (5.37 nmol/L), an approximate 84.04% increase 30 min after waking (CAR)[3], and an approximate 6.8% decline in cortisol per hour estimated at waking (DCS), accounting for participants' protocol noncompliance and adjusting for momentary, daily, and between-person covariates (Table 2, Diurnal Pattern Model). Notably, 86.7% of the variance in cortisol was attributable to within-person variance (i.e., sample-to-sample, day-to-day differences; intraclass correlation = .133).

Additive stress model

First, the additive (independent) contributions of all seven stress forms were examined as predictors of average diurnal cortisol (e.g., CAR and DCS), including covariates (Table 2, Additive Model). None of the stress forms were significantly associated with the CAR. Further, results indicated that higher general stress was associated with an approximate 0.8% flatter per hour at waking DCS ($\gamma_{201} = .008$, $p = .03$), whereas higher bicultural stress was associated with a 6.7% steeper per hour at waking DCS, on average ($\gamma_{205} = -.069$, $p = .047$). No other stress forms were significantly associated with the DCS, $ps > .59$. To aid in the interpretation of these results, we standardized the stressors, which revealed that a 1 SD increase in general stress was associated with a 2.3% flatter DCS per hour ($\gamma = .023$, $p = .03$), whereas a 1 SD increase in bicultural stress was linked with a 1.8% steeper DCS per hour ($\gamma = -.018$, $p = .047$).

Common stress model

Next, the two-factor latent stress variable (e.g., college stress, discrimination stress) was entered as the focal predictor of the diurnal pattern (Table 2, Common Model). This third model was composed solely of the two stress factors and previously included covariates. Results from this model indicated that greater college stress was significantly associated with an approximate 8.5% lower CAR

[3]Because cortisol values were log-transformed prior to analyses, effect sizes can be interpreted after using the following formula: β% change = ([e^β] − 1).

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Table 1. Bivariate correlations and descriptive statistics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Waking cortisol	–																					
2. 30-min postwaking cortisol	.62***	–																				
3. 3-hr postwaking cortisol	.25**	.43***	–																			
4. 8-hr postwaking cortisol	.32***	.45***	.53***	–																		
5. Bedtime cortisol	.19*	.30***	.45***	.55***	–																	
6. General stress	–.08	–.18*	.05	.02	.05	–																
7. Academic stress	–.02	–.14†	.04	.06	.11	.30***	–															
8. Social stress	.01	–.09	.01	.01	.02	.38***	.54***	–														
9. Financial stress	–.05	–.12	–.17*	.03	.03	.23**	.43***	.43***	–													
10. Bicultural stress	.06	–.03	–.06	–.09	–.01	.14†	.31**	.33***	.21**	–												
11. Peer discrimination	.05	–.03	.03	.05	–.002	.24**	.12	.25***	.19*	.23**	–											
12. Adult discrimination	.004	–.14†	–.03	.03	–.005	.28***	.11	.25***	.22**	.19*	.79***	–										
13. Cumulative risk index	.01	–.15*	.04	.01	.05	.49***	.54***	.64***	.52***	.53***	.61***	.61***	–									
14. Average sleep duration	.18*	–.05	.16*	–.10	–.08	–.07	–.05	.001	–.05	–.001	–.05	–.04	–.03	–								
15. Sex (1 = male)	–.07	–.09	.03	–.08	–.13†	–.18*	–.05	–.13†	–.17*	–.11	–.12	–.12	–.12	–.15*	–							
16. Immigrant generation	.02	.002	.01	–.06	.06	–.13†	–.07	–.06	–.01	–.14†	–.15*	–.15*	–.15†	.08	.03	–						
17. Summer participation	–.07	–.11	–.14†	–.10	–.02	.00	.04	–.05	.04	.00	–.02	–.02	–.02	.14†	–.01	.14†	–					
18. Living situation	.002	.05	.04	–.02	–.03	–.13†	–.05	–.12	.04	.04	–.002	–.04	–.02	.01	.03	.03	–.15*	–				
19. Parent education	.02	.08	–.06	.03	.08	–.21**	–.26***	–.14†	–.18*	–.13†	–.11	–.15†	–.25***	–.05	.09	.45***	.05	.03	–			
20. Subjective social class	.004	–.07	.02	–.05	–.01	.10	.17*	.001	.13†	.06	.09	.10	.12	–.02	.10	–.24**	–.004	.07	–.35***	–		
21. Topical medication use	.02	.17*	.15*	.25***	.15*	.09	.11	.13†	.04	.02	–.10	–.09	–.003	–.14†	.001	.03	–.01	–.02	.12	.02	–	
22. Oral contraceptive use	–.06	–.04	.17*	.11	.10	.15*	–.09	.10	–.02	–.10	–.07	–.01	–.02	.02	–.29***	.05	–.02	–.10	.01	–.10	.14†	–
M	6.71	7.26	6.32	5.89	5.03	7.44	3.46	3.13	2.69	0.20	1.52	1.54	1.52	6.52	0.33	2.56	0.09	0.61	3.75	3.45	0.07	0.14
SD	0.67	0.59	0.51	0.56	0.73	2.73	0.73	0.86	0.93	0.27	0.69	0.74	1.65	1.19	–	2.32	–	–	2.38	0.87	–	–
Minimum	4.04	4.23	4.30	4.51	2.81	0.00	1.57	1.33	1.00	0.00	1.00	1.00	0.00	4.11	–	0.00	–	–	1.00	1.00	–	–
Maximum	8.23	8.37	8.42	8.91	7.30	13.00	5.00	5.00	5.00	1.30	3.57	4.00	7.00	10.88	–	7.00	–	–	10.00	5.00	–	–

Note. $N = 180$. Averages of raw cortisol values (nmol/L) presented for descriptive purposes. Bicultural stress levels natural log-transformed for analyses due to positive skew, but descriptive statistics presented represent original scores. Average sleep duration = average total sleep time across days that cortisol samples were provided. Sex: 1 = male, 0 = female; Immigrant generation: 0 = participant, parents, and both sets of grandparents born outside the United States, 7 = all were born in the United States; Living situation: 1 = living away from home in university dorms or apartment, 0 = living at home with parents or other relatives; Parent education: 1 = less than high school, 10 = doctorate or advanced degree; Subjective social class: 1 = upper class, 2 = upper-middle class, 3 = middle class, 4 = lower-middle class, 5 = working class; Topical medication use: 0 = no, 1 = yes; Oral contraceptive use: 0 = no, 1 = yes.

†$p < .10$.

*$p < .05$,

**$p < .01$,

***$p < .001$.

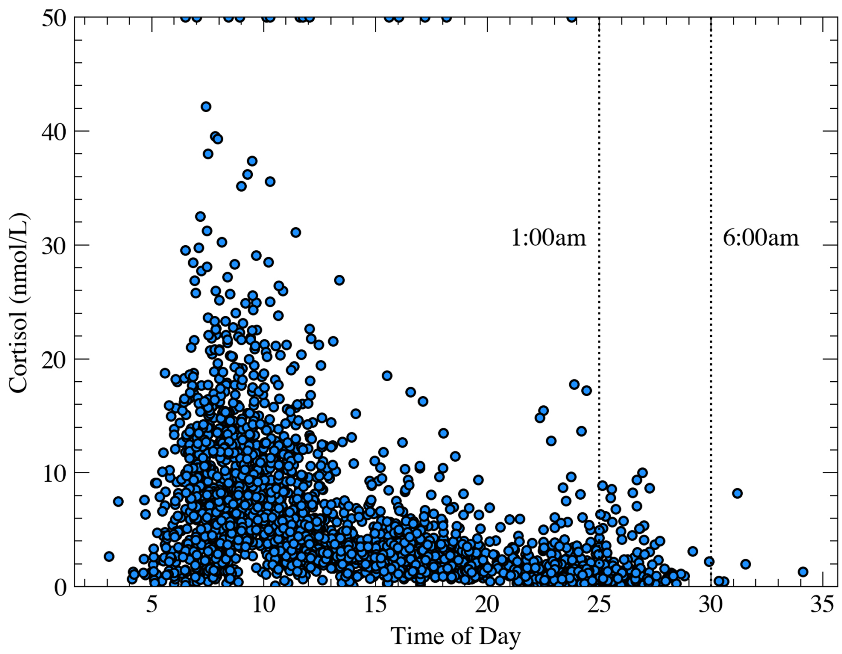

Figure 2. Cortisol values (nmol/L) across the waking day. *Note*. Time of day is presented on a 24-hr scale (e.g., 5 = 5 a.m.; 24 = 12 a.m.). Values above 24 correspond to the next waking day (25 = 1 a.m., 30 = 6 a.m.). Extreme values winsorized to = 50.

(γ_{109} = −.089, p = .045), but the discrimination-specific stress factor was not significantly associated with the CAR (γ_{108} = −.022, p = .71). Neither latent stress factor was significantly associated with the DCS ($ps > .82$).

Cumulative stress model

In the final model, the CRI was examined as a predictor of diurnal cortisol, accounting for covariates (Table 2, Cumulative Model). Results indicated that a one unit increase on the CRI (e.g., experiencing one more stressor to a high degree) was associated with an approximate 5.4% lower CAR (γ_{110} = −.055, p = .007), but was not significantly related to the DCS (γ_{210} = −.002, p = .74).

Sensitivity analyses

Although not a primary focus of this study, additional sensitivity analyses were conducted to examine whether stress predicted another common summary indicator of the diurnal cortisol pattern: area under the curve (AUCg; calculated following (Pruessner et al., 2003), averaged across the three study days. Results were as follows: in the additive model, no stress forms were significantly associated with the AUCg ($ps > .11$); in the common model, neither college stress (p = .57) nor discrimination stress (p = .89) were significantly related to the AUCg; in the cumulative model, the CRI was not significantly associated with the AUCg (p = .79).

Discussion

Latino/a adolescents transitioning to college are at increased risk for experiences of stress, including college demands, social stressors, and ethnic/racial stigma (Huynh & Fuligni, 2012; Rodriguez et al., 2000). The present study utilized a "multi-risk model" approach to investigate additive, common, and cumulative effects of stress on diurnal cortisol among first-year Latino/a college students. Results indicated that, in the additive model, no stress forms were associated with the CAR, however, general stress was associated with a flatter DCS and bicultural stress was linked with a steeper DCS. In the common model, the latent college stress factor was associated with a lower CAR, but was not related to the DCS. Further, greater cumulative stress was also linked with a reduced CAR, but not the DCS. These findings provide insight into the unique links between specific stress forms and HPA axis functioning during Latino/a students' transition to college, accounting for other relevant stressors experienced during this time. Differences and commonalities across the three models contribute to the complex literature surrounding stress and HPA axis linkages. Importantly, findings support theoretical frameworks positing that chronic and cumulative stress exposure can lead to alterations in physiological functioning that, accumulated over time, can result in maladaptive diurnal patterns (McEwen, 1998), which may underlie existing ethnic/racial disparities in HPA axis functioning (DeSantis et al., 2007), developmental psychopathology (e.g., Adam et al., 2010; Adam et al., 2014), and health and disease (Myers, 2009; Steptoe & Serwinski, 2016). These findings may be harnessed as evidence to promote services and mechanisms that support Latino/a students during this transition, including resources for coping and stress management (Bottaccioli et al., 2020; Sladek et al., 2016) and increased efforts to promote diversity and inclusion across campus (Sladek et al., 2020b).

Additive model findings

Findings indicated that general stress and bicultural stress were both significantly associated with the DCS, accounting for other stress forms. The relation between increased general stress and a flatter DCS is not surprising, as a flatter diurnal rhythm is a common indicator of altered HPA axis activity, and increased stress, in general, is related to this pattern (e.g., Miller et al., 2007). However, it was unexpected that general stress would be the *only* stress form related to a flatter rhythm. This is an interesting finding that prompts the examination of what differentiates this stressor from others. General stress was assessed using the PSS-4 (Cohen et al., 1983), a global measure of stress that assesses the degree to which individuals perceive nonspecific events in their

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Table 2. Fixed effects estimates from three-level growth models of diurnal cortisol

	Diurnal pattern model		Additive model		Common model		Cumulative model	
	Est.	*SE*	Est.	*SE*	Est.	*SE*	Est.	*SE*
Waking cortisol level, β_0								
Average waking cortisol level, β_{00}								
Intercept (waking cortisol level), γ_{000}	6.68**	0.04	6.68**	0.04	6.68**	0.04	6.68**	0.04
Night before sleep duration, β_{010}	0.10**	0.03	0.10**	0.03	0.10**	0.03	0.10**	0.03
General stress, γ_{001}	–	–	−0.03	0.02	–	–	–	–
Academic stress, γ_{002}	–	–	0.01	0.08	–	–	–	–
Social stress, γ_{003}	–	–	0.05	0.06	–	–	–	–
Financial stress, γ_{004}	–	–	−0.07	0.06	–	–	–	–
Bicultural stress, γ_{005}	–	–	0.12	0.16	–	–	–	–
Peer discrimination, γ_{006}	–	–	0.13	0.13	–	–	–	–
Adult discrimination, γ_{007}	–	–	−0.10	0.15	–	–	–	–
Discrimination stress factor, γ_{008}	–	–	–	–	0.004	0.08	–	–
College stress factor, γ_{009}	–	–	–	–	−0.02	0.06	–	–
Cumulative risk index, γ_{010}	–	–	–	–	–	–	0.01	0.04
Cortisol awakening response (1 = second sample), b_1								
Average size of cortisol awakening response (CAR), β_{10}								
Intercept (CAR), γ_{100}	0.61**	0.03	0.60**	0.03	0.60**	0.03	0.60**	0.03
Night before sleep duration, β_{110}	−0.07**	0.03	−0.06*	0.03	−0.07**	0.03	−0.07*	0.03
General stress, γ_{101}	–	–	−0.01	0.01	–	–	–	–
Academic stress, γ_{102}	–	–	−0.10†	0.05	–	–	–	–
Social stress, γ_{103}	–	–	−0.03	0.05	–	–	–	–
Financial stress, γ_{104}	–	–	0.04	0.04	–	–	–	–
Bicultural stress, γ_{105}	–	–	−0.09	0.12	–	–	–	–
Peer discrimination, γ_{106}	–	–	0.10	0.08	–	–	–	–
Adult discrimination, γ_{107}	–	–	−0.13†	0.07	–	–	–	–
Discrimination stress factor, γ_{108}	–	–	–	–	−0.02	0.06	–	–
College stress factor, γ_{109}	–	–	–	–	**−0.09***	**0.04**	–	–
Cumulative risk index, γ_{110}	–	–	–	–	–	–	**−0.06****	**0.02**
Topical medication use, γ_{111}	0.20†	0.10	0.23*	0.10	0.23*	0.11	0.20†	0.10
Diurnal cortisol slope (time since waking), β_2								
Average diurnal cortisol slope (DCS), β_{20}								
Intercept (DCS), γ_{200}	−0.07**	0.01	−0.07**	0.01	−0.07**	0.01	−0.07**	0.01
Night before sleep duration, β_{210}	−0.03**	0.01	−0.03**	0.01	−0.03**	0.01	−0.03**	0.01
General stress, γ_{201}	–	–	**0.01***	**0.004**	–	–	–	–
Academic stress, γ_{202}	–	–	0.001	0.02	–	–	–	–
Social stress, γ_{203}	–	–	0.001	0.01	–	–	–	–
Financial stress, γ_{204}	–	–	−0.01	0.01	–	–	–	–
Bicultural stress, γ_{205}	–	–	**−0.07***	**0.04**	–	–	–	–
Peer discrimination, γ_{206}	–	–	−0.01	0.02	–	–	–	–
Adult discrimination, γ_{207}	–	–	0.01	0.02	–	–	–	–
Discrimination stress factor, γ_{208}	–	–	–	–	−0.001	0.01	–	–
College stress factor, γ_{209}	–	–	–	–	0.003	0.01	–	–
Cumulative risk index, γ_{210}	–	–	–	–	–	–	−0.002	0.01
Quadratic function (time since waking^2), β_3								

(*Continued*)

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Table 2. (*Continued*)

	Diurnal pattern model		Additive model		Common model		Cumulative model	
	Est.	*SE*	Est.	*SE*	Est.	*SE*	Est.	*SE*
Average quadratic function, β_{30}								
Level 1 intercept (quadratic function), γ_{300}	−0.17**	0.02	−0.17**	0.02	−0.17**	0.02	−0.17**	0.02
Night before sleep duration, β_{310}	0.14**	0.04	0.14**	0.04	0.14**	0.04	0.14**	0.04
General stress, γ_{301}	–	–	−0.03	0.02	–	–	–	–
Academic stress, γ_{302}	–	–	0.06	0.09	–	–	–	–
Social stress, γ_{303}	–	–	−0.06	0.08	–	–	–	–
Financial stress, γ_{304}	–	–	0.06	0.06	–	–	–	–
Bicultural stress, γ_{305}	–	–	0.32†	0.19	–	–	–	–
Peer discrimination, γ_{306}	–	–	−0.002	0.11	–	–	–	–
Adult discrimination, γ_{307}	–	–	−0.02	0.12	–	–	–	–
Discrimination stress factor, γ_{308}	–	–	–	–	−0.02	0.07	–	–
College stress factor, γ_{309}	–	–	–	–	0.02	0.06	–	–
Cumulative risk index, γ_{310}	–	–	–	–	–	–	0.02	0.03
Eating in last hour, γ_{400}	0.06*	0.03	0.07*	0.03	0.06*	0.03	0.06*	0.03
Caffeine in last hour, γ_{500}	−0.14†	0.08	−0.14†	0.08	−0.13†	0.08	−0.13†	0.08
Pain in last hour, γ_{600}	0.07	0.06	0.07	0.06	0.07	0.06	0.08	0.06
Medication in last hour, γ_{700}	−0.16†	0.08	−0.15†	0.08	−0.14†	0.08	−0.15†	0.08

Note. $N = 2,667$ samples nested within 180 individuals. Cortisol values (nmol/L) transformed using the natural log function. Besides growth parameters, continuous Level 1 and Level 2 predictors centered within-person; continuous level 3 predictors grand-mean-centered.
†$p < .10$.
*$p < .05$.
**$p < .01$.

lives to be stressful (e.g., unpredictable, uncontrollable, overloading). Thus, it is possible that this measurement was tapping into something unique to participants' stress perceptions (i.e., their appraisal of stress, rather than frequency/type of stress). Further, perhaps the most compelling rationale for the distinct effect of general stress is the PSS-4's assessment of stress as *uncontrollable*. In their meta-analysis, Miller et al. (2007) identified the "controllability of stress" as a major characteristic influencing how chronic stress relates to HPA axis activity, with greater uncontrollability linked with alterations in HPA axis functioning, including flatter rhythms.

The finding that increased bicultural stress was associated with a *steeper* DCS is an unexpected result of the current study. Whereas no previous research has directly examined the relation between bicultural stress and diurnal cortisol, other studies examining related cultural stressors (e.g., microaggressions, acculturative stress) among Latino/a adolescents and adults led us to expect that greater bicultural stress would be linked with maladaptive patterns of HPA axis activity (Garcia et al., 2017; Torres et al., 2018; Zeiders et al., 2018). One important consideration that may help explain this finding is the *timing* in which bicultural stress was measured. Compared to the other stress forms, which asked over the past month or semester, bicultural stress was an average of the daily count of stress experiences that occurred over 1 week, alongside the measurement of cortisol. Thus, it is possible that average daily bicultural stress was associated with what appeared to be an "adaptive" diurnal pattern due to the body adapting to the stressor in the short-term (i.e., steeper slopes resulting from adaptive cortisol activity across days/week). Indeed, a previous study found that Mexican American adolescents who reported higher biculturalism exhibited greater cortisol reactivity in the face of a stressor (i.e., adaptive short-term response; Gonzales et al., 2018). Given that more bicultural youth likely encounter a greater frequency of bicultural stressors (e.g., Love & Buriel, 2007), it could be that these individuals were responding to these stressors in an adaptive manner. Future studies may choose to examine stress–HPA axis linkages over a longer period of time to better elucidate the short-term versus chronic effects of bicultural stress (i.e., whether "adaptive" diurnal patterns persist in future months/years).

Contrary to our expectations, the additive model did not yield support for independent contributions of academic, social, financial, or discrimination stress on diurnal cortisol. These results contrast previous work linking similar stressors with HPA axis activity. For example, previous studies have linked social stress (e.g., peer problems) with a flatter DCS and greater waking cortisol (Bai et al., 2017) and academic stress (e.g., academic problems, student status) with greater morning cortisol and a smaller CAR (Bai et al., 2017; McGregor et al., 2016). However, it is worth noting that these studies were conducted in younger (Bai et al., 2017) and older (McGregor et al., 2016) student samples and were not framed within the undergraduate college context, as they were in the present study. Importantly, the current study focused on Latino/a college students, a population for whom these questions had not yet been studied to the authors' knowledge. Furthermore, the present study estimated these stress–diurnal cortisol associations while accounting for various other forms of stress, which is not as commonly practiced in the literature and may underlie these observed differences.

The nonsignificant findings for ethnic/racial discrimination were particularly unexpected, given the accumulation of evidence

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linking discrimination with HPA axis functioning in adolescence and young adulthood for Latino/a and ethnically/racially diverse youth (Huynh et al., 2016; Skinner et al., 2011; Zeiders et al., 2012; Zeiders et al., 2014). One potential explanation is that the timing of ethnic/racial discrimination was more recent than the timing of discrimination scales used in previous studies (e.g., lifetime, past year; Huynh et al., 2016; Skinner et al., 2011; Zeiders et al., 2014). In addition, there is evidence that experiences of discrimination may *decrease* across the transition to college for Latino students (Castro et al., 2022; Huynh & Fuligni, 2012). Given that previous research found associations between *high and stable* trajectories of discrimination on African American young adults' physiological functioning (Brody et al., 2014), it could be that, in our sample, recent experiences of discrimination in college were not related to cortisol the same way observed in previous studies that were longitudinal (Brody et al., 2014) or asked about discrimination across a longer time frame (Skinner et al., 2011; Zeiders et al., 2014).

Lastly, it is important to consider the college context that the majority of adolescents in our sample were attending when interpreting these findings. The university that participants attended had considerable Hispanic/Latino/a student representation (22.8%), which was the second most represented ethnic/racial group following White students (49.6% White; ASU Institutional Analysis, 2017). As such, these students' experiences may not reflect those of Latino/a students attending universities with less co-ethnic representation. Future studies may choose to examine these associations in contexts where Latino/a students are less represented and, in turn, may experience more frequent experiences of discrimination (e.g., Bellmore et al., 2012). In sum, findings of the additive model provide additional evidence for links between higher stress perceptions and flatter DCSs, and offer new findings linking bicultural stress with steeper slopes in the short-term. These results may suggest that students' appraisals of stress are particularly linked with maladaptive patterns of diurnal cortisol, whereas the frequency of stressors may have more complex relationships with HPA axis activity.

Common model findings

The present study's examination of stress as a latent variable uncovered two distinct stress factors: (1) college stress, which consisted of social, academic, financial, general, and bicultural stress; and (2) discrimination stress, which consisted of peer and adult ethnic/racial discrimination. To the authors' knowledge, this was the first study to conduct a factor analysis using multiple stress indicators during the college years. These results highlight distinct differences between stress experiences relating to ethnic/racial discrimination, as opposed to normative college stress, general stress, and daily bicultural stress. Notably, the EFA suggested that college-specific stressors (e.g., social, academic, financial) loaded highest onto the first latent factor, demonstrating that context-specific stressors seemed to be carrying the weight of these stress perceptions. These findings support theoretical and empirical research suggesting that ethnic/racial minority students encounter minority-specific stress that is distinct from general college stress, with the latter thought of as experienced by all students (Arbona et al., 2018; Wei et al., 2010). However, in this study, bicultural stress contributed to the college stress, rather than the discrimination stress latent factor, which may point to important differences between experiences of discrimination/prejudice, as compared to other manifestations of bicultural stress (e.g., dual language demands, inter/intra-group pressures). Indeed, whereas discrimination is often an interaction between ethnic groups resulting from ethnocentrism (e.g., White youth as majority group), bicultural stress represents dual processes stemming from both pressures to maintain adolescents' native culture (e.g., within-ethnic group stress), as well as pressures to adapt mainstream behaviors (Romero & Van Campen, 2018). Further, this finding may be due, in part, to bicultural stress being assessed daily, as these experiences are likely nested within college contexts (e.g., interactions with classmates). In sum, these results underscore the importance of examining interrelations between stressors, rather than assuming that all forms of stress are capturing the same underlying construct.

When examining associations between the two latent factors and diurnal cortisol, findings revealed that greater college stress was associated with a lower CAR, but not the DCS, whereas discrimination stress was not significantly related to the CAR or DCS. The null findings for discrimination are surprising from a theoretical perspective, and inconsistent with previous work linking discrimination and diurnal cortisol. However, these results are similar to what was observed in the additive model, and may point to important commonalities among nondiscrimination stress forms as they relate to the CAR. Although no specific hypotheses were made for the common model, we expected that the stress forms that contributed to the college stress factor would be *additively* related to a larger CAR, due to the recency and predictability of these stressors (Miller et al., 2007), which may elicit an "adaptive" boost of cortisol upon waking (Adam et al., 2006). In contrast, we found that the *common* contributions of these stressors were associated with a lower CAR, a pattern linked with fatigue and burnout (Chida & Steptoe, 2009). This finding suggests that these developmentally salient stressors may correlate with maladaptive neuroendocrine processes (e.g., blunted CAR), even within the first year of college. However, none of these stressors were individually related to the CAR, suggesting that this association was driven primarily by something all stress forms had in common (i.e., underlying unobserved latent construct), and thus moves beyond additive expectations for stress–HPA axis linkages. Given that this latent construct was comprised of college, general, *and* minority-specific stressors, it could be that these findings capture the chronic, multiple stress experiences that Latino/a students experience during the transition to college, which would be expected to result in disruptions in diurnal cortisol activity.

In sum, findings from the common model further highlight ethnic/racial discrimination stress as distinct from general and college-specific stress, and link developmentally salient stressors (i.e., relating to or nested in college contexts) with diminished biological functioning. These results may be particularly important for intervention and prevention programs aiming to reduce student stress and burnout, particularly among Latino/a students, which may seek to target stress immediately upon entry into college settings.

Cumulative model findings

A primary objective of this study was to examine whether the cumulative impact of multiple stress forms was associated with diurnal cortisol in ways that were distinct from the additive or common impact of these stressors. The present study observed that cumulative stress was associated with a blunted CAR for first-year Latino/a students. This finding is consistent with the study hypothesis, as well as previous literature examining cumulative risk and altered HPA axis functioning (Kwak et al., 2017; Suglia et al., 2010). Specifically, our findings closely relate to those of Kwak et al. (2017), in which higher cumulative family stress was linked with a lower CAR among Latino adolescents. In addition, these results are consistent with allostatic load (McEwen, 1998) and models of cumulative vulnerability and minority health (Myers, 2009), such that the cumulative effects of various stressors, including general, college, and minority-specific stress, were related to a diurnal pattern indicative of overactivation of the stress response systems (e.g., lower CAR). Despite our predictions, we did not find evidence for an association between cumulative stress and a flatter DCS – a pattern often considered the "hallmark" of stress and strain (Adam et al., 2017). Though surprising, this finding may help bolster support for the responsivity of the CAR in the context of cumulative stress. Importantly, these findings may help inform future research on the determinants of fatigue and burnout among first-year Latino/a college students. Specifically, they corroborate the notion that students who are subjected to *cumulative* experiences of multiple forms of stress, which are often initiated and perpetuated by broader systemic and societal racism and marginalization, are at-risk for alterations in stress responsive systems that have been linked with disease onset and mental health problems (Mangold et al., 2011; Steptoe & Serwinski, 2016).

Multi-risk model approach: differences and takeaways

The primary goal of the multi-risk model approach was to elucidate the complex links between experiences of stress and HPA axis functioning by testing the effects of stress in three different ways (e.g., additive, common, cumulative). Though we cannot make direct comparisons across these models, it is worthwhile to examine clear commonalities and differences observed. Perhaps the most striking difference was the aspect of diurnal cortisol that was associated with stress across the models. Specifically, in the additive model, general and bicultural stress were significantly associated with the DCS, whereas common and cumulative stress were not. This difference was unexpected, as previous work has consistently linked chronic stress with a flatter DCS (e.g., Miller et al., 2007), which led us to expect significant links between common and cumulative stress and the DCS. However, given that time since stress onset is associated with more altered HPA axis functioning (Miller et al., 2007), it is possible that the proximity of stress forms in the current study (e.g., daily, monthly, semesterly) may explain these null findings.

Importantly, findings from the additive model may also provide insight into nonsignificant findings across models. For example, in the common model, general and bicultural stress had the lowest factor loadings on the college stress factor (below .50), indicating that there was more variance *not* attributed to these stressors, which may explain why this latent factor was not associated with the DCS. Further, in the additive model, general and bicultural stress were differentially linked with the DCS (i.e., higher stress linked with flatter and steeper slopes, respectively). Thus, it is possible that the combination of these two stressors into one construct contributed to the nonsignificant DCS findings in the common and cumulative models. This discrepancy across models points to a potential strength of the multi-risk model approach, as the removal of the additive model may have led to substantially different conclusions (e.g., DCS not impacted by stress, general and bicultural stress not as influential on HPA axis activity).

In addition, there were also important similarities across models, with the most notable being that college stress and cumulative stress were both significantly associated with a lower CAR. This similarity is consistent with previous work demonstrating that both observed-score (e.g., CRI) and variable-centered (e.g., latent factor analysis) methods can be used to assess cumulative risk with multiple indicators (Ettekal et al., 2019), and that these two techniques hold unique advantages and disadvantages. For example, the current study found that the common model was less robust with regards to the statistical significance of this effect ($p = .045$ as compared to $p = .007$). This highlights a potential strength of the CRI, as it allows for the inclusion of distinct risk processes (e.g., discrimination), as compared to latent factor analysis, which imposes that all stressors are interrelated. On the other hand, the common model provides more specificity regarding which stressors are tapping into the same underlying stress construct, which can aid in interpretation when pinpointing the combined impact of a specific set of stress forms. Indeed, findings from the common model point to college-specific stress forms (e.g., social, academic, financial) as potential drivers of the negative association between cumulative stress and the CAR, a specificity not provided by the cumulative model alone.

Taken together, findings from this multi-risk model approach provide evidence that general, college-related, and cumulative stress experiences (which may disproportionally affect ethnic/racial minority students; Phinney & Haas, 2003; Wei et al., 2011) were linked with alterations in HPA axis activity, which has been hypothesized to underlie subsequent health disparities (Myers, 2009). Future studies may seek to extend these findings by investigating HPA axis functioning as a mechanism underlying longitudinal links between stress and maladaptive mental and physical health outcomes. Importantly, compared to the robust evidence linking the DCS with mental and physical health (Adam et al., 2017), the literature is more mixed regarding the CAR (e.g., both heightened and blunted CAR linked with illness; Adam et al., 2010; Mangold et al., 2011; Steptoe & Serwinski, 2016). Therefore, it will be important for future research to disentangle how this pattern of diurnal cortisol is longitudinally related to maladaptive developmental outcomes such as anxiety and depression, and whether cortisol serves as a mechanism through which additive, common, and cumulative stress experiences are linked with developmental psychopathology.

Limitations and strengths

The findings of the present study should be interpreted alongside its limitations. First, participants in the present study attended a large, 4-year public university in the Southwestern United States and had lived near it at the time of study recruitment. Thus, findings may not generalize well to students attending colleges that differ in geographic location, size, or who choose to attend community or 2-year college contexts. Next, there were more females than males in the current study, which could have impacted study findings, as previous research has found sex differences in average levels of the CAR, as well as stress–CAR linkages (Miller et al., 2017). Further, because our sample was limited to students who provided valid cortisol data, our final sample size was 180, which could have resulted in a reduction of statistical power for models with multiple predictors (e.g., additive model). Additionally, this study was conducted within one college semester (Spring, 2018); therefore, we were unable to capture the stability or enduring effects of first-year stress on subsequent HPA axis functioning across months or years later. Similarly, although the incorporation of stress forms that were specific and varied with regards to *timing*

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was a strength of the additive model (e.g., helped clarify potential time-related effects of stress on diurnal cortisol), the presence of different time scales could have influenced results of the common and cumulative models, as stress forms were essentially treated the same in these approaches. Thus, future studies examining common or cumulative stress may seek to measure multiple stressors on the same time scale, to avoid unequal weight of more proximal and/or distant stress forms. Further, the current study utilized the PSS-4 to examine general stress. Although the PSS-4 has been validated for use in adolescent populations, the abbreviated nature of the scale may have resulted in lower reliability of this measure, as was shown in the current study ($\alpha = .66$). Thus, future studies may seek to incorporate longer versions of the PSS (e.g., PSS-10, PSS-14) or other comprehensive stress assessments that have been validated for use among Latino/a adolescents. Lastly, whereas the current study focused on minority-specific stress forms that were specific to participants' ethnic/racial background and Latino/a heritage, future studies would be strengthened by examining how minority stressors due to other identities (e.g., gender, sexual orientation) may influence these relationships.

Despite these limitations, the current study harnessed the strengths of an ethnically homogenous, multi-method study design to examine seven distinct forms of stress and their additive, common, and cumulative relation to HPA axis functioning using gold standard salivary cortisol collection procedures (Stalder et al., 2016) and advanced statistical procedures (e.g., three-level growth curve models). Further, this study design helped provide an important snapshot into proximal stress–HPA axis linkages within the first year of college, a time when students are at increased risk for stress experiences (Kerr et al., 2004). This was the first known study to examine links between general *and* minority-specific stressors and diurnal cortisol among Latino/a college students, and importantly, the first to utilize a "multi-risk model" to investigate stress–HPA axis linkages, which represents a major contribution to the literature on physiological stress processes among Latino/a adolescents and young adults.

Conclusions & implications

Chronic or repeated stress exposure, which may be especially common during a major sociocultural shift such as the transition to college (Kerr et al., 2004), can alter typical HPA axis functioning, which has lasting consequences on health and well-being (Adam et al., 2017). The present study provided evidence for additive, common, and cumulative effects of stress on diurnal cortisol in a sample of first-year Latino/a college students. Specifically, there were unique effects of certain stressors on students' DCS, whereas common and cumulative stress were related to a blunted CAR, providing preliminary evidence that college stress, which is often viewed as "normative," may have short-term negative effects on students' stress responsive systems. Furthermore, the finding that common and cumulative stress were linked with a lower CAR, a pattern closely tied to fatigue, exhaustion, and burnout (Chida & Steptoe, 2009), suggests that Latino/a students may be experiencing burnout *within their first year of college*, which may have lasting consequences for mental and physical health.

The implications of the present study findings span multiple levels of influence (e.g., individual, educational, systemic). From an intervention standpoint, these findings point to stress management/reduction techniques as especially promising for first-year college students. Evidence from randomized controlled trials indicate that stress management programs can result in reductions in basal morning cortisol and cortisol reactivity among undergraduate students (Bottaccioli et al., 2020; Hammerfald et al., 2006), which may protect against maladaptive alterations in diurnal patterns. From a prevention standpoint, educational institutions may seek to reduce the burden of stress on ethnic/racial minority students by promoting a culture that values diversity, as evidence among Latino students suggests that an institution's commitment to diversity and inclusion can reduce physiological responses to psychosocial stress, specifically for students with greater Latino values (Sladek et al., 2020b). Lastly, broader implications of these findings include nationwide efforts to reduce systemic racism and inequalities in the United States by targeting mechanisms of social disadvantage (e.g., access to healthcare, educational resources; Caldwell et al., 2017; Hanushek & Rivkin, 2006), which may alleviate the cumulative burden of general, college, and minority-specific stressors for Latino/a students' transitioning to college.

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Author contributions. Jeri Sasser conceived of the study, participated in its design, performed statistical analysis, and drafted the manuscript; Leah D. Doane obtained funding for the broader project, designed and coordinated all parts of the study, supervised statistical analysis, and reviewed and edited writing. Jinni Su participated in the framing of the study and reviewed and edited writing; Kevin J. Grimm supervised statistical analysis and reviewed and edited writing. All authors read and approved the final manuscript.

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