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Latino adolescents' cultural values associated with diurnal cortisol activity

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ABSTRACT

Hypothalamic-pituitary-adrenal (HPA) axis activity has been identified as a mechanism through which daily life stress contributes to health problems and racial/ethnic health disparities. Stress-related changes in neuroendocrine function are evident as early as adolescence, but the ways in which promotive cultural factors may also contribute to variation in diurnal HPA activity have received little empirical attention. Grounded in cultural models of resilience, dual dimensions of Latino adolescents' cultural values (ethnic heritage and U.S. mainstream) were examined as promotive and protective factors in relation to their diurnal salivary cortisol patterns using ecological momentary assessment ($N = 209$; $M_{age} = 18.10$; 64.4% female). Participants provided 5 daily saliva samples for 3 days while completing corresponding electronic diary reports and using time-sensitive compliance devices (track caps, actigraphs). Results from 3-level growth curve models indicated that higher U.S. mainstream cultural values (e.g., self-reliance, competition, material success) were associated with higher average waking cortisol levels and a more rapid rate of diurnal cortisol decline (i.e., "steeper" slope). Regarding situational deviations from the diurnal rhythm (within-person differences), cortisol levels were higher in relation to diary-reported ongoing stress (vs. completed). Accounting for these situational differences in stress timing, a cross-level interaction (i.e., between-person difference in within-person process) indicated that higher perceived stress than usual was associated with lower cortisol levels for adolescents with stronger alignment to Latino ethnic heritage values (e.g., familism, respect, religiosity), compared to relatively higher cortisol levels for those with less alignment to these values. Results were consistent adjusting for participants' sex, immigrant generation, parents' education level, depressive symptoms, medication use, sleep duration, and other self-reported health behaviors. These findings join the growing science of cultural neurobiology by demonstrating the promotive and potentially regulating influence of cultural values in the daily HPA functioning of Latino adolescents.

1. Introduction

Hypothalamic-pituitary-adrenal (HPA) axis activity has been identified as a mechanism through which life stress can lead to health problems and contribute to racial/ethnic health disparities (Levy et al., 2016). Cultural influences are considered organizing forces in health processes (Campos and Kim, 2017), yet the ways in which cultural factors relate to HPA activity specifically have received relatively little empirical attention. More often, efforts have focused on documenting racial/ethnic differences in physiological stress patterns as a proxy to measure cultural influences (see Doane et al., 2018a, for review), which has the potential to reify deficit interpretations for observed differences without accounting for within-group diversity and culturally-relevant stress adaptation (García Coll et al., 1996). As an alternative to these between-group comparisons, the current study examined differences in diurnal cortisol activity *within* a sample of U.S. Latino[1] adolescents – currently the largest and youngest racial/ethnic minority group that will comprise 30% of the U.S. population by 2060 (U.S. Census Bureau, 2015).

The HPA axis is one of the body's major stress response systems, recruiting the body's resources to react to stressors and stimulating cortisol release (de Kloet, 2004). Cortisol peaks in saliva approximately 20–25 min post-stressor and returns to baseline up to an hour later (Nicolson, 2008). In addition to stress response functions, cortisol is released throughout the day in a typical pattern characterized by relatively high waking levels, a dramatic increase (50–150%)

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[1] There are complex historical origins of the pan-ethnic labels "Latino(a)," "Latinx," and "Hispanic," as well as individual and regional preferences for identifying terms. "Latino" is used here to refer to an individual residing in the U.S. with family ancestry in a Spanish-speaking country in Latin America, the Caribbean, and parts of the U.S. that were formerly territories of Spain or México.

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approximately 30 min later (cortisol awakening response; CAR), and then a general decrease across the waking day (Adam and Kumari, 2009). Cortisol responses to real-world stressors have also been estimated as situation-specific, within-person deviations from an individual's average daily cortisol pattern (Schlotz, 2019). This method has linked adolescents' cortisol responses to daily experiences that are characterized by more stress than usual (compared to one's own average level), while also identifying substantial individual differences in real-world stress responsivity (Adam, 2006; Doane and Adam, 2010; Sladek et al., 2016). Alterations to the diurnal cortisol rhythm (e.g., less rapid rates of decline – "flatter" slopes) and exaggerated cortisol reactivity to daily experiences have been associated with adverse health consequences, including compromised immune function and major depression (Adam et al., 2017; Jacobs et al., 2007).

1.1. Stress, culture, and cortisol among Latino adolescents

Latino adolescents face a range of daily stressors, including normative developmental challenges (e.g., academic demands, interpersonal stress) and immigrant- and/or minority-related stress (e.g., translating for immigrant parents, discrimination; Kim et al., 2018). Latino adolescents also access supportive resources from *adaptive cultures*, which comprise sets of goals, values, and attitudes that influence developmental adaptation and stress regulation (García Coll et al., 1996; Gonzales and Kim, 1997). The dual dimension framework for cultural adaptation includes the process of *acculturation* – acquiring knowledge, behavioral expectations, and values associated with mainstream U.S. culture, and *enculturation* – acquiring these features associated with one's heritage culture (Gonzales et al., 2004). Latino youth with a greater orientation toward their heritage culture (e.g., valuing centrality of the family – familism) tend to have better mental and physical health (Katiria Perez and Cruess, 2014), theoretically by benefitting from strong family social support, higher quality family relationships, and less family conflict (Gonzales et al., 2015). Latino adolescents with higher familism values also report using more adaptive coping responses to stress on a daily basis (Santiago et al., 2016). Yet Latino youth also simultaneously adopt the dominant cultural values of mainstream U.S. society (e.g., importance of self-reliance, competition, material success), particularly as they transition to adulthood and spend less time with family (Updegraff et al., 2012). These dual dimensions need not represent a loss of orientation toward one culture at the expense of the other – greater acculturation to the U.S. and endorsing higher levels of mainstream values into young adulthood have been associated with stronger ethnic-racial identity commitment (Knight et al., 2014) and greater well-being (Schwartz et al., 2013). Aligning with and internalizing values along both of these cultural dimensions theoretically allow Latino youth to access diverse strategies to cope with daily stress by successfully navigating mainstream cultural expectations, while also retaining protective resources of their heritage culture (Gonzales et al., 2012, 2015).

Cultural values are transmitted through more proximal experiences, communications, and relationships of daily life (Weisner et al., 2010). Latino adolescents' cultural orientations, including culturally-based values that guide behaviors and social interactions, figure prominently throughout the stress/coping process by mediating stress appraisal, coping strategy selection, and ultimately whether perceived stress leads to poor adjustment (Gonzales and Kim, 1997; Neblett et al., 2012). Risk and resilience theory and empirical evidence indicate that cultural values can be *promotive* (i.e., directly associated with positive outcomes, regardless of risk exposure; Causadias, 2013; Corona et al., 2017) and/or *protective* (i.e., associated with more positive than expected outcomes, specifically in the context of risk or adversity; Gonzales et al., 2015; Stein et al., 2014). Despite these proposed resilience pathways, the few studies that have examined Latino adolescents' diurnal cortisol patterns have mostly focused solely on risk (i.e., average differences in comparison to other racial/ethnic groups or exposure to adversity) rather than promotive or protective processes within this group. For example, experiencing more frequent discrimination has been associated with flatter diurnal slopes among racial/ethnic minority youth (Huynh et al., 2016). In studies of Mexican-origin adolescents and young adults, more frequent discrimination has been associated with greater total diurnal cortisol output (Zeiders et al., 2012), and greater chronic family stress and greater acculturation to the U.S. have been associated with reduced CARs characteristic of chronic fatigue (Kwak et al., 2017; Mangold et al., 2012). In a study of racially/ethnically diverse adolescents, moments of higher negative affect corresponded with higher cortisol levels for those who perceived more (compared to less) frequent discrimination (Doane and Zeiders, 2014).

1.2. Promotive role of cultural values — associations with average diurnal cortisol activity

Despite the risk factors that contribute to stress-related alterations in Latino adolescents' typical diurnal cortisol rhythms and cortisol reactivity, preliminary research also suggests that cultural promotive factors may correspond with more adaptive physiological patterns for Latino youth. In a recent study of Mexican-origin adolescents, those who felt more positively about their ethnic background exhibited steeper diurnal cortisol slopes (Zeiders et al., 2018), which represent adaptive daily stress regulation (i.e., less elevated cortisol levels later in the day) linked with positive health (Blair, 2010). In our own research of Latino adolescents, greater perceived parental support was associated with higher average CARs (Doane et al., 2018b), theorized to provide a physiological "boost" to prepare for anticipated demands of the day (Adam et al., 2006). Although no studies have considered individual differences in Latino adolescents' cultural values in relation to diurnal cortisol activity, research on theorized promotive factors in studies of European American youth has shown that attachment and positive parenting (Shirtcliff et al., 2017) and an active coping style (Sladek et al., 2017a) are associated with higher waking cortisol levels and steeper diurnal cortisol slopes – reflecting a more efficient daily regulatory pattern.

1.3. Protective role of cultural values – Moderators of cortisol responses to stress

Based on mixed findings in the growing number of stress physiology studies that include historically underrepresented groups without accounting for culturally-relevant adaptation measures, researchers have theorized that cultural values may attenuate stress-related alterations to HPA activity (Doane et al., 2018a; Gonzales et al., 2018; Korous et al., 2017). However, few studies have examined cultural protective factors that may differentiate acute cortisol reactivity to everyday stress. In laboratory studies, Latino adolescents with a greater orientation toward ethnic heritage and U.S. mainstream cultural customs exhibited more dramatic cortisol reactivity to and more efficient cortisol recovery from a psychosocial stressor (Gonzales et al., 2018), and Latino adults with higher familism values exhibited lower mean cortisol responses to stress (Campos et al., 2018). In a racially/ethnically diverse sample of adolescents, momentary mood and stress reports did not correspond with heightened levels of cortisol (i.e., reduced reactivity) for those who perceived greater social support from peers prior to college (Doane and Zeiders, 2014) and for those with greater confidence in their coping abilities once college began (Sladek et al., 2016), respectively. Some research has indicated that cultural relevance of theorized protective factors in the context of stress differs for minority and majority group members (Wang and Lau, 2018), highlighting the need for more studies that account for cultural diversity within racial/ethnic groups that remain understudied.

1.4. The present study

The present study exemplifies an expanding area of research termed *cultural neurobiology* (Doane et al., 2018a), comprising efforts to appropriately measure culturally salient adaptation processes in relation to the function of physiological stress systems. Following a strengths-based, culturally-informed framework for racial/ethnic minority youth development (García Coll et al., 1996), we examined whether cultural value differences were associated with average diurnal cortisol activity (e.g., waking levels, CAR, diurnal slope) among an ethnically homogenous sample of Latino adolescents anticipating college attendance during their final year of high school. Guided by the theorized promotive roles of heritage cultural value orientations for maintaining family support (Gonzales et al., 2015) and improving coping (Neblett et al., 2012), we expected that higher endorsement of ethnic heritage values (i.e., familism, respect, religiosity) would correspond with higher waking cortisol levels and steeper diurnal cortisol slopes. Due to mixed findings for psychosocial factors in relation to the CAR (Boggero et al., 2017) and its biological distinctiveness from the diurnal rhythm (Clow et al., 2010), these analyses were exploratory. We also estimated adolescents' cortisol responses to the type (e.g., ongoing vs. completed) and perceived severity of everyday stress using ecological momentary assessment (i.e., within-person changes in diary reports of stress in relation to deviations in cortisol from individual diurnal patterns), and whether cultural values were related to differences in these responses. Guided by the theorized role of cultural values as a protective factor (Gonzales et al., 2004; Neblett et al., 2012), we hypothesized that adolescents endorsing higher (compared to lower) ethnic heritage values would have relatively lower cortisol levels in the context of everyday stress. We conceptualized these expected between-person differences in a within-person process to reflect either attenuated reactivity and/or enhanced recovery in this naturalistic daily life study. Substantially less research has examined Latino adolescents' endorsement of U.S. mainstream values (i.e., self-reliance, competition, material success); thus, we considered these associations exploratory but essential to include in order to continue testing the dual adaptation framework in the study of cultural neurobiology.

2. Method

2.1. Participants

Participants were Latino(a)/Hispanic high school seniors who gained acceptance to a public university in a large metropolitan area in the southwestern U.S. (N = 209; M_{age} = 18.10; 64.4% female; see Doane et al., 2018b). Participants were of Mexican (85.1%), South or Central American (10.1%), Cuban (5.3%), and other Latin American, Caribbean, or Hispanic heritage (4.3%). In addition to identifying as Latino/Hispanic, 15.5% of participants also identified as White/Caucasian-American, 1.5% as Native American, and 1.0% as Asian/Asian-American. Regarding immigrant generation, 10.6% of participants were 1st generation (born outside the U.S.), 62.0% 2nd generation (born in U.S., at least one parent born outside U.S.), and 27.4% 3rd generation or greater (both parents born in U.S.). Participants attended over 90 different high schools (ranging from 6% to 96% Latino enrollment; M = 53% Latino enrollment; SD = 26%) and lived in ethnically diverse neighborhoods (ranging from 4% to 96% Latino neighbors by census block group; M = 44% of neighbors were Latino; SD = 27%) within a 60 mile radius of the university.

2.2. Procedure

All procedures were approved by the university Institutional Review Board. For 3 typical weekdays, participants provided 5 saliva samples each day via passive drool: immediately upon waking (M_{time} = 7:17 AM; SD = 1.70 h), 30 min after waking (M_{time} = 7:50 AM; SD = 1.70 h), 2 other times during the day when they received automated text message reminders (approximately 3 and 8 h later, designed to avoid mealtimes; M_{time} = 12:21 PM; SD = 1.85 h; and 5:00 PM; SD = 1.68 h), and at bedtime (M_{time} = 11:26 PM; SD = 1.45 h). Participants were instructed not to eat, drink, or brush their teeth 30 min prior to providing a saliva sample. In addition to recording the date and time of each saliva sample, participants retrieved straws from a MEMS 6™(Aardex) track cap compliance device, which objectively recorded adherence to sample timing. Participants also wore an actigraph wrist-based accelerometer (Micro Motion Logger Watch; Ambulatory Monitoring, Inc. Ardsley, NY, USA) to objectively assess waking and bed times. These devices measure motion in one-minute epochs using a zero-crossing mode. Researchers scored sleep data using the Sadeh algorithm (Sadeh et al., 1995) in Action W-2 software version 2.7.1 (Ambulatory Monitoring)[2] . All sleep data were scored by pairs of trained research assistants, and scored a second time by graduate student researchers to address inconsistencies. Objective measurement of sleep periods was cross-referenced with diary self-reports of sleep and wake times for indications of outliers or equipment malfunction (see Doane et al., 2015a). Sleep duration values greater than three *SD*s above or below the mean were considered outliers (Bagley et al., 2016) and winsorized to avoid biasing results (0.3% of sleep duration data).

Following each saliva sample, participants completed brief diary entries using web-enabled smartphones to report on the presence, nature, and perceived severity of stress within the last hour ("situation"). Participants also reported recent eating, exercise, and caffeine, nicotine, and medication use. In total, 15 saliva samples (M = 14.56, SD = 1.61) and 15 corresponding diary reports (M = 13.97, SD = 2.24) were expected from each participant across the 3-day protocol. Across the full sample, 3018 saliva samples and 2877 diaries were completed. Participants also completed a one-time online questionnaire, including measures of cultural values and demographic and health information.

2.3. Measures

2.3.1. Salivary cortisol

Samples were stored at -80C upon return to the laboratory, and then sent by courier on dry ice over no more than 3 days to Biochemisches Labor at the University of Trier in Germany for assay. Samples were assayed for cortisol in duplicate using a competitive solid phase time-resolved fluorescence immunoassay with fluorometric endpoint detection (DELFIA; Dressendörfer et al., 1992). The inter-assay (7.1%–9.0%) and intra-assay (4.0%–6.7%) coefficients of variation were acceptable. Seven outlier samples were winsorized to 50 nmol/L, following standard practice (Nicolson, 2008).[3] Cortisol values were then transformed using the natural log function due to positive skew (2.08 before transforming, −0.70 after transforming). Two participants did not provide saliva samples and one used corticosteroid medication, resulting in an analytic sample of 206 individuals. Following recent expert consensus (Stalder et al., 2016), track cap, actigraph, and self-report data were carefully inspected to determine "compliant" vs. "non-compliant" saliva samples. Waking samples were considered compliant if track cap-detected times were within 15 min of participants' actigraph-detected wake times (79.5% of waking samples). Second samples were considered compliant if track cap-detected times were within 23 and 37 min after track cap-detected times for waking samples (67.4% of second samples). Cortisol values from non-compliant samples were treated as missing data in analyses. The intraclass correlation (ICC) was

[2] $A = E$ - 2(1/25) + E - 1(1/5) + E + E + 1(1/5) + E + 2(1/25), where A denotes activity counts and E denotes epoch. Within the Sadeh algorithm, activity counts (A) within each epoch (E) were calculated based on activity levels during the adjacent 2 min period. Sleep parameters were calculated based on 1-minute epochs and significant movement after at least 10 min of inactivity.

[3] Results were consistent with or without excluding these outlier samples.

.126, indicating 12.6% of the variance in cortisol was attributable to between-person differences, whereas 87.4% was attributable to within-person (i.e., sample-to-sample) differences.

2.3.2. Situational diary-reported perceived stress

In each diary report that followed saliva samples, participants were asked to briefly describe the most stressful event they encountered in the last hour (e.g., "Studying for my AP test," "deciding if I wanted to go to a party," "Being at the mall and feeling like the only Latino there, "Thinking about having to go to Mexico next week"), indicate whether this was ongoing (37.9% of situations) or completed, and rate how stressful that event was (0 = *no stress at all* to 10 = *extreme stress*; Adam, 2006; Sladek et al., 2016). The intraclass correlation (ICC) was .249, indicating 24.9% of variance in perceived stress level was attributable to between-person differences, whereas 75.1% was attributable to within-person (situational) differences. More information on diary reporting procedures is reported elsewhere (see Doane et al., 2018b).

2.3.3. Cultural values

The 50-item Mexican American Cultural Values Scale (Knight et al., 2010) assessed the extent to which participants endorse Latino heritage cultural values (familism, respect, religiosity, traditional gender roles; e.g., "Parents should teach their children that the family always comes first"; $\alpha = .95$) and mainstream U.S. values (material success, independence and self-reliance, and competition and personal achievement; e.g., "Parents should encourage children to do everything better than others"; $\alpha = .81$; from 1 = *not at all*, to 5 = *completely*). Previous research with Mexican-origin adolescents has indicated the respective subscales load on two correlated higher-order latent factors reflecting endorsement of Latino cultural values (36 items) and mainstream U.S. values (14 items), respectively (Knight et al., 2010). In the present study, this same higher-order correlated two-factor CFA model fit the data well (and highly similar to the original measure development sample), $\chi^2(1160) = 1832.68$, $p < .01$; CFI = .87, RMSEA = .05, SRMR = .08, supporting the use of two related but distinct subscales in analyses. More specific subscales were used in follow-up sensitivity analyses, including familism (16 items; $\alpha = .91$), respect (8 items; $\alpha = .87$), religiosity (7 items; $\alpha = .97$), traditional gender roles (5 items; $\alpha = .79$), material success (5 items; $\alpha = .81$), independence and self-reliance (5 items; $\alpha = .65$), and competition and personal achievement (4 items; $\alpha = .64$). The measure was originally developed for Mexican Americans, but has since been used reliably with other Latino groups who share a cultural heritage (Corona et al., 2017). In the current study, endorsement of Latino values and U.S. mainstream values did not significantly differ for adolescents of Mexican origin compared to other Latino groups represented in the sample, $ps > .54$.

2.3.4. Covariates

Several factors known to influence cortisol activity (Adam and Kumari, 2009) and/or overlap with cultural values (Gonzales et al., 2012) were evaluated as potential covariates: participant's sex (1 = *male*, 0 = *female*), immigrant generation score (from 0 = *participant, both parents, and both sets of grandparents born outside U.S.* to 7 = *participant, parents, and both sets of grandparents born in U.S.*), average of mothers' and fathers' educational attainment (1 = *less than high school* to 10 = *doctorate or other advanced degree*), depressive symptoms (CES-D; Radloff, 1977), sleep duration assessed by actigraphy, oral contraceptive use ($n = 15$), corticosteroid or psychotropic medication use reported in the general health survey ($n = 36$), and other health behaviors reported in the hour prior to sampling (e.g., exercise, caffeine use, eating).

2.4. Analytic strategy

Three-level growth models were used to address situational (Level 1), daily (Level 2), and individual (Level 3) variation in cortisol and model multiple cortisol indices simultaneously (waking levels, CAR, diurnal slope, reactivity to daily experiences; e.g., Adam, 2006). These multilevel growth models were fit in *Mplus* version 8.1 (Muthén and Muthén, 1998–2017Muthén and Muthén, 1998Muthén and Muthén, 1998–2017) using maximum likelihood estimation with robust standard errors. Diurnal cortisol patterns were modeled at Level 1 by including a sample-, day-, and person-specific time variable indicating how long after waking each saliva sample was provided (*time since waking*; 0 = *wake time*), this variable squared to capture curvilinear trend (*time since waking*^{2}), and a dummy variable for the second saliva sample of the day representing the size of the CAR (1 = *second sample*, 0 = *not second sample*; Adam, 2006). The diary measures of situation-specific stress level and whether the situation was ongoing (dummy coded 1) or completed (dummy coded 0) were also included to predict situational deviations in cortisol from each individual's average pattern. Latino and mainstream cultural values were entered as Level 3 (between-person) predictors of waking levels (model intercept), the CAR, diurnal slope, and reactivity to perceived stress. Follow-up sensitivity analyses used more specific value subscales within the two main dimensions as predictors in separate models (e.g., valuing respect, material success, etc.).

Given significant associations with one or more average cortisol values (Table 1), participant's sex, immigrant generation score, average of mother's and father's education level, depressive symptoms, oral contraceptive use, and general corticosteroid medication use were included as Level 3 (between-person) covariates based on their associations with specific features of the diurnal cortisol pattern (e.g., waking levels, CAR, cortisol later in the day; see Adam and Kumari, 2009). Prior-night sleep duration (measured objectively via actigraphy) was included as a Level 2 (day-specific) covariate, and self-reported caffeine use in past hour was included as a Level 1 (situation-specific) covariate. Aside from the coding for time already described, continuous Level 1 and Level 2 predictors were centered within-person (i.e., an individual's average of available scores subtracted from each situational or daily score) and Level 3 predictors were grand-mean centered (i.e., the average for the full sample subtracted from each individual's score; Enders and Tofighi, 2007). Significant cross-level interactions (i.e., predictors accounting for significant between-person variance in within-person association) were probed using simple slopes techniques for multilevel modeling (Preacher et al., 2006).

3. Results

A linear growth model with a dummy code to represent the CAR fit significantly better than an unconditional model, $\chi^2(9) = 2428.77$, $p < .001$. Adding a quadratic term fit the data significantly better than the linear model, $\chi^2(6) = 86.12$, $p < .001$. Interpreting unadjusted estimates from Model 1 (Table 2) revealed the expected average diurnal cortisol pattern with relatively high cortisol levels at waking (5.99 nmol/L; intercept), an approximate 99.4% increase 30 min after waking (CAR),[4] and an approximate 6.7% linear decline in cortisol per hour estimated at waking, the rate of which significantly changed across the day, accounting for participants' protocol non-compliance.

Latino cultural values were not significantly associated with between-person differences in waking cortisol levels, $\gamma_{001} = -0.086$, $p = .098$, the CAR, $\gamma_{101} = -0.014$, $p = .784$, or the diurnal cortisol slope, $\gamma_{201} = 0.006$, $p = .308$, whereas mainstream cultural values were significantly associated with higher waking cortisol, $\gamma_{002} = 0.121$, $p = .022$ (adjusting for Latino values, immigrant generation, depressive symptoms, and oral contraceptive use), and steeper diurnal cortisol slopes (i.e., more dramatic rate of daily decline; $\gamma_{202} = -0.014$, $p =$

[4] Because cortisol values were log transformed, the effect sizes can be interpreted as a percent change per 1 unit change in the predictor after using the formula: β% change = [(e^β) – 1].

Table 1
Bivariate correlations and descriptive statistics.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Waking cortisol	–														
2. + 30 min cortisol	.66*	–													
3. + 3 hours cortisol	.32*	.30*	–												
4. + 8 hours cortisol	.40*	.34*	.55*	–											
5. Bedtime cortisol	.32*	.24*	.42*	.46*	–										
6. Latino cultural values	.05	−.01	−.11	.01	−.02	–									
7. Mainstream cultural values	.05	.05	.09	.05	−.05	.19*	–								
8. Average diary stress level	.02	−.07	−.17*	−.04	−.05	.10	−.02	–							
9. Sleep duration (hours)	.08	.04	−.18*	−.11	−.03	.11	−.12	−.10	–						
10. Sex (1 = male)	.01	−.06	.19*	.10	−.09	−.03	.20*	−.19*	−.16*	–					
11. Immigrant generation	−.17*	−.08	−.04	.03	−.003	−.07	.01	−.01	−.07	.05	–				
12. Parent education	−.02	.01	.15*	.10	.06	−.21*	.12	−.08	−.02	.10	.44*	–			
13. Depressive symptoms	−.15*	−.16	−.07	−.09	−.07	−.07	.03	.25*	−.01	−.21*	−.04	−.09	–		
14. Oral contraceptive use	−.21*	−.17*	−.05	−.13	.02	−.08	−.05	−.02	−.06	−.21*	.09	.12	.03	–	
15. General corticosteroid use	−.09	−.18*	.09	−.01	.004	−.13	.02	−.05	−.05	.11	.05	.10	.12	.12	–
M[a]	8.01	13.28	4.89	3.41	1.75	3.27	2.88	3.88	6.43	0.35	2.61	3.72	16.39	0.07	0.17
SD	3.97	6.05	2.85	2.06	1.54	0.70	0.58	1.73	1.23	–	2.32	2.36	10.29	–	–
Min	0.04	0.08	0.17	0.05	0.03	1.28	1.50	0.00	3.10	–	0.00	1.00	0.00	–	–
Max	25.41	47.05	21.56	15.72	12.88	4.94	4.71	8.69	9.92	–	7.00	10.00	50.00	–	–

Note. $N = 206$. Cortisol concentration (nmol/L) presented for descriptive purposes; natural log transformed for analyses. Immigrant generation: 0 = participant, both parents, and both sets of grandparents born outside U.S. to 7 = participant, parents, and both sets of grandparents born in U.S. Parent education level (average of mother's and father's if both reported): 1 = less than high school, 10 = doctorate or advanced degree; Oral contraceptive use (1 = yes, 0 = no and males); Corticosteroid use (1 = yes, 0 = no). *$p < .05$.

[a] Means presented for continuous variables; percentages presented for dichotomous variables.

.045 (adjusting for Latino values, sex, and parents' education level; Table 2, Model 3). For participants scoring 1 unit above the mean of mainstream cultural values (e.g., difference between endorsing values "somewhat" to "very much"), cortisol was estimated to be approximately 12.9% higher upon waking and decline at a rate of 1.4% more quickly per hour across the day estimated at waking (8.1% decline per hour). Sensitivity analyses for specific value subscales (adjusting for the same set of covariates) indicated higher material success values were significantly associated with higher waking cortisol, $\gamma_{002} = 0.104$, $p = .002$, but not the diurnal slope, $\gamma_{202} = -0.006$, $p = .252$, whereas

Table 2
Fixed Effects Estimates from 3-Level Growth Models of Diurnal Cortisol.

	Model 1		Model 2		Model 3	
	Est.	*SE*	Est.	*SE*	Est.	*SE*
Intercept (waking cortisol level), b_0	1.790*	0.046	1.763*	0.049	1.539*	0.110
Latino cultural values, γ_{001}			−0.082	0.055	−0.086	0.052
Mainstream cultural values, γ_{002}			0.152*	0.051	0.121*	0.053
Immigrant generation, γ_{003}					−0.018	0.014
Depressive symptoms, γ_{004}					−0.005	0.006
Oral contraceptive use, γ_{005}					−0.272	0.272
Night-before sleep duration, β_{01}					0.037*	0.015
Cortisol awakening response (1 = 2nd sample), b_1	0.690*	0.046	0.722*	0.039	0.772*	0.134
Latino cultural values, γ_{101}			0.016	0.048	−0.014	0.053
Mainstream cultural values, γ_{102}			−0.052	0.064	−0.037	0.066
Depressive symptoms, γ_{103}					−0.003	0.004
Oral contraceptive use, γ_{104}					−0.123	0.118
General corticosteroid use, γ_{105}					−0.192	0.153
Night-before sleep duration, β_{11}					−0.001	0.020
Diurnal cortisol slope (time since waking), b_2	−0.068*	0.010	−0.058*	0.011	0.007	0.008
Latino cultural values, γ_{201}			0.005	0.006	0.006	0.006
Mainstream cultural values, γ_{202}			−0.013†	0.007	−0.014*	0.007
Male, γ_{203}					0.050*	0.014
Parent education, γ_{204}					0.002	0.001
Night-before sleep duration, β_{21}					−0.013*	0.001
Quadratic function (time since waking^2), b_3	−0.002*	0.001	−0.003*	0.001	−0.004*	0.001
Male, γ_{301}					−0.347*	0.086
Night-before sleep duration, β_{31}					0.044*	0.015
Perceived stress level in last hour, b_4			−0.008	0.007	−0.009	0.007
Latino cultural values, γ_{401}			−0.024*	0.008	−0.023*	0.008
Mainstream cultural values, γ_{402}			0.011	0.012	0.010	0.012
Depressive symptoms, γ_{403}					0.001	0.001
Ongoing stress, b_5					0.018*	0.006
Caffeine in last hour, b_6					0.139*	0.061

Note. $N = 2638$ samples nested within 206 individuals. Cortisol values (nmol/L) transformed using the natural log function. Immigrant generation: 1 = participant, parents, and both sets of grandparents born outside U.S., 7 = all born in U.S.; Oral contraceptive use: 1 = using, 0 = not using, and all males; Parent education level: 1 = less than high school, 10 = doctorate or advanced degree; Ongoing stress: 1 = stress of last hour ongoing at time of saliva sample, 0 = stress completed. Est. = regression coefficient estimate. *SE* = robust standard error. †$p = .059$. *$p < .05$.

higher independence and self-reliance values were significantly associated with steeper slopes, $\gamma_{202} = -0.012$, $p = .022$, but not with waking levels, $\gamma_{002} = 0.051$, $p = .276$. Competition and personal achievement values were not significantly associated with waking levels, $\gamma_{002} = 0.046$, $p = .396$, or diurnal slopes, $\gamma_{202} = -0.007$, $p = .138$.

Regarding within-person differences, diary-reported stress characterized as ongoing (relative to completed) was significantly associated with situational elevations in cortisol from the typical pattern, $b_5 = 0.018$, $p < .01$ (Table 2, Model 3). This within-person association did not significantly vary across individuals, $\chi^2(6) = 3.628$, $p = .727$. Adjusting for situations of ongoing stress, diary-reported perceived stress level (i.e., 0 to 10 rating) did not significantly predict situational deviations in cortisol from the typical pattern, $b_4 = -0.009$, $p = .158$; however, there was significant between-person variance in this within-person association of perceived stress level with cortisol, $\chi^2(6) = 21.39$, $p < .01$ (i.e., random effect). Latino cultural values significantly predicted this between-person variance (i.e., cross-level interaction), $\gamma_{401} = -0.023$, $p < .01$ (adjusting for mainstream values and depressive symptoms; Table 2, Model 3).[5]

Probing simple slopes indicated that higher stress than usual (i.e., within-person increase, adjusting for ongoing stress) was significantly associated with lower cortisol for participants scoring 1 *SD* above the mean of Latino cultural values, $b = -0.025$, $p < .01$, but not at the mean, $b = -0.010$, $p = 0.153$, or 1 *SD* below the mean, $b = 0.005$, $p = .832$ (Fig. 1). The more detailed region of significance indicated that this within-person association of perceived stress with cortisol was significant specifically for participants scoring at least 0.033 points above the mean of Latino cultural values (52.0% of the sample). These significant individual differences in cortisol were estimated to emerge specifically when perceived stress was higher than 1.808 points above an individual's average stress level (24.0% of situations). Adjusting for stress that was ongoing at the time of the situation, cortisol levels were estimated to be approximately 11.5% lower for participants with above-average compared to below-average Latino cultural values. Sensitivity analyses for specific value subscales indicated this cross-level interaction was significant for familism, $\gamma_{401} = -0.027$, $p < .01$, but not for respect, $\gamma_{401} = -0.015$, $p = .057$, religiosity, $\gamma_{401} = -0.009$, $p = .080$, or traditional gender roles, $\gamma_{401} = -0.005$, $p = .523$. All findings were largely consistent with or without adjusting for covariates (Table 2; Model 2 vs. Model 3).

4. Discussion

Culture and its multi-layered influences make significant contributions to health (Campos and Kim, 2017) and development (García Coll et al., 1996), but the ways in which *promotive* cultural factors may correspond with variation in diurnal cortisol activity or *protective* cultural factors may relate to cortisol in the context of real-world stress have received less empirical attention (Doane et al., 2018a). The current study took important steps to better understanding connections between culture and stress biology by examining multiple aspects of the typical diurnal cortisol rhythm and stress-related situational deviations in diurnal cortisol in relation to U.S. mainstream and heritage cultural values among U.S. Latino adolescents, a rapidly growing yet underrepresented group in stress physiology research. Results from 3-level growth curve models indicated that adolescents endorsing higher U.S. mainstream cultural values (e.g., self-reliance, competition, material success) exhibited significantly higher waking cortisol levels and steeper diurnal cortisol slopes, on average, relative to those endorsing lower levels of these values. Regarding cortisol responsivity to daily stress experiences, operationalized as situational deviations in cortisol from the diurnal rhythm, within-person analyses revealed that ongoing perceived stress (compared to completed) corresponded with significantly higher situational cortisol levels. However, support for a cultural protective factor emerged – adjusting for the effect of stress timing, perceived stress was associated with lower cortisol levels for adolescents with greater alignment to Latino ethnic heritage values (e.g., familism, respect, religiosity), an association that was not significant for adolescents endorsing relatively lower levels of these values.

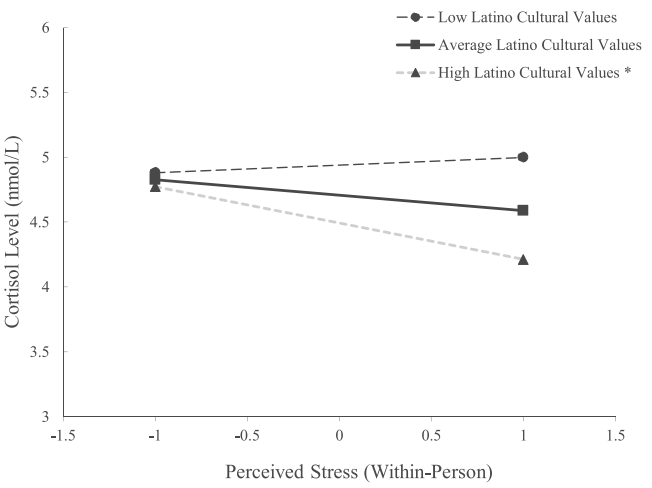

Fig. 1. *Note.* Simple slopes of perceived stress level (0 = within-person mean; +/-1 *SD*) with corresponding situational cortisol level (nmol/L) plotted at the grand mean and +/-1 *SD* from mean of Latino cultural values. *$p < 0.01$.

4.1. Individual differences: Cultural values and average diurnal cortisol patterns

Results from this study highlight the importance of assessing the related but distinct dimensions of U.S. mainstream and ethnic heritage values among Latino youth. As prior work has shown (Corona et al., 2017; Knight et al., 2010), the two dimensions were slightly correlated in this sample, but only mainstream values were uniquely associated with higher average waking cortisol levels and steeper diurnal cortisol slopes. Latino adolescents who more strongly endorse holding these mainstream values may have been sensitized to the daily demands of the dominant mainstream U.S. culture that reinforce these very ideals, such as expectations set by school systems prioritizing individual achievement and success (Stephens et al., 2012). Given the characteristics of this sample of Latino high school students anticipating the transition to the notably mainstream context and expectations of college, the notion of cultural congruency (i.e., degree of fit between one's cultural orientation and context), and its relations with positive adjustment (Gloria and Robinson Kurpius, 1996), may help to explain this adaptive variation in the diurnal rhythm. Similar profiles of higher waking cortisol and steeper slopes have been observed in studies of European American youth for those who report greater parent bonding and more active coping styles (Shirtcliff et al., 2017; Sladek et al., 2017a). Prior research has also shown that more acculturated Latino adults (e.g., born in U.S. or living in U.S. for more than 30 years) exhibited higher waking cortisol compared to more recent immigrant arrivals (Novak et al., 2017). As our sample comprised a younger group of adolescents and we controlled for immigrant generation in these analyses, alignment with mainstream values may serve as a mechanism through which the behavioral acculturation process translates to biological adaptation to context over time.

Specifically, higher morning cortisol levels may provide a "boost" for adolescents to manage anticipated demands of the day, although this hypothesis is thought to apply to the CAR specifically (Adam et al.,

[5] Remained significant when adjusting for all covariates on all aspects of the diurnal cortisol pattern, $p = .03$.

2006). Indeed, previous research has linked various forms of adversity, including chronic family stress among U.S. Mexican-origin younger adolescents (Kwak et al., 2017) and acculturation and childhood trauma among Mexican American adults (Mangold et al., 2010), to reduced CARs. Differences in mainstream and Latino cultural values among the current sample were not associated with differences in the size of the CAR, suggesting that variation in the CAR may be influenced by more chronic forms of stress instead of general value orientations. At the biological level, waking levels of cortisol likely reflect pre-awakening processes that, in turn, regulate post-awakening HPA axis activation mediated by the suprachiasmatic nucleus (Clow et al., 2010). Thus, these results provide important specificity regarding links between cultural values and biologically distinctive mechanisms that regulate different aspects of diurnal cortisol activity. The present study of late adolescents in their final year of high school differed in age from previous studies and incorporated several indicators of compliance with the morning sampling protocol (e.g., objective sample timing, actigraph-recorded wake time), strengthening evidence for unique associations of mainstream cultural values with waking cortisol levels and the diurnal slope, which reflect more trait-like indices of regulation, rather than the size of the CAR, which reflects more state-like responsivity to contextual demands (Doane et al., 2015b).

Recent research on dual cultural adaptation processes has contrasted earlier assumptions that more mainstream or acculturated Latino youth must give up their culture of origin or experience stress/conflict in doing so (Gonzales et al., 2018; Knight et al., 2014). In the present study, Latino youth with stronger U.S. mainstream values who are preparing to attend university in the following year may be especially prepared to adapt to the multiple demands they face as racial/ethnic minorities living in the U.S. Indeed, higher cortisol upon waking may provide resources to prepare the body to respond to threat or opportunity cues in the environment by increasing alertness and energy (Hoyt et al., 2016a; Roozendaal, 2000). Increasing evidence indicates that discrimination experiences during adolescence contribute to flattening of the diurnal rhythm over time (Adam et al., 2015), and meta-analytic findings indicate that flatter diurnal cortisol slopes are most consistently linked with adverse health consequences, including compromised immune function and major depression (Adam et al., 2017). In previous studies of Mexican-origin adolescents, greater perceived ethnic-racial discrimination has been linked with heightened overall daily cortisol output (Zeiders et al., 2012), whereas stronger ethnic-racial affirmation (i.e., having positive feelings about one's group) has been linked with the opposite – *steeper* diurnal cortisol slopes (Zeiders et al., 2018). Results from the present study complement and extend this small but growing literature by identifying individual differences in mainstream cultural values as a promotive factor that accounts for additional variation in average diurnal cortisol patterns, specifically predicting higher waking cortisol levels and a stronger rate of cortisol decrease across the day (i.e., more efficient decline) in a sample of Latino adolescents prior to their college transition. Importantly, these results held accounting for objective indicators of protocol non-compliance (e.g., electronic track caps, actigraphs) and adjusting for potential confounds, including participants' sex, immigrant generation, parents' education level, depressive symptoms, medication use, sleep duration, and other health behaviors (e.g., caffeine use).

4.2. Situational differences: cortisol responses to everyday stress

Using an EMA approach that paired saliva samples with brief diary reports, the current study also provided novel contributions to the understanding of within-person (situational) deviations in cortisol from the diurnal pattern in relation to the type and perceived severity of Latino adolescents' everyday stress experiences. Consistent with prior research in adults (Jacobs et al., 2007), situations characterized by ongoing (rather than completed or past) stress in the last hour corresponded with significantly higher cortisol levels relative to individual diurnal patterns. The ongoing or chronic nature of these stressors (39.7% of all reports) likely activated Latino adolescents' HPA axis stress response more consistently or to a greater extent than stressors that were considered resolved at the time of sampling. This is the first study to identify this situational stress-cortisol association in the daily lives of Latino adolescents, consistent with previous EMA research in racially/ethnically heterogenous samples of adolescents that have identified momentary cortisol elevations in relation to diary-reported stress levels (Adam, 2006), negative affect ratings (Doane and Zeiders, 2014) and feelings of loneliness (Doane and Adam, 2010). Although the HPA stress response is adaptive to recruit cognitive and behavioral resources to cope with daily stress in the short term, consistently higher cortisol levels in response to stress over time may contribute to adverse health consequences via wear and tear on stress response systems (i.e., allostatic load; McEwen, 1998).

Attention to situational differences also highlighted the diversity *among* Latino adolescents in reacting to everyday stress and identified a protective cultural factor (i.e., ethnic heritage values – specifically familism) as a moderator of the extent to which Latino adolescents' perceptions of stress relate to cortisol production in daily life. Consistent with the theorized protective role of Latino adolescents' heritage cultural values (Gonzales et al., 2004, 2012; Neblett et al., 2012), this value orientation may provide regulatory benefits to youth as they perceive, respond to, and cope with everyday stress. The ability to recover from physiological activation after perceived threats have ended (i.e., adjusting for stress timing) is an important component of regulation and is thought to protect against the potentially damaging effects of allostatic load (McEwen, 1998).

This potential evidence for Latino cultural values as a protective factor in daily life extends previous laboratory research demonstrating that affirming personal values reduced cortisol responses to a stress task (Creswell et al., 2005), higher familism values were related to lower mean cortisol increases in the context of stress (Campos et al., 2018), and associations between stress and subjectively reported health were attenuated for Latino college students with higher familism values (Corona et al., 2017). Establishing personally-relevant values are thought to enable individuals to appraise stressors in reference to a larger context by remembering what really matters to them, thereby protecting against social threats to identity that activate HPA activity (Cohen and Sherman, 2014). Latino cultural values have been associated with greater perceived availability of social support (Knight et al., 2010), and social support has been linked with lower cortisol levels in relation to situational reports of negative affect in adolescents' daily lives (Doane and Zeiders, 2014). Latino adolescents with a greater orientation toward their heritage culture also endorse more support-seeking coping (Brittian et al., 2013), a coping style that has been associated with lower HPA stress responses in laboratory studies (e.g., Sladek et al., 2017b). Thus, social resources and coping strategies (e.g., asking friends for help, receiving assistance from family) may help adolescents with higher Latino cultural values respond effectively when encountering more stress than usual in daily life.

Although it is possible that lower estimated cortisol in these situations could reflect HPA axis dysregulation (i.e., absence of an adaptive response, or hypocortisolism; Phillips et al., 2013), numerous other EMA studies have reported lower cortisol levels in relation to situational reports of positive affect (Matias et al., 2011; Nater et al., 2010) and use of active coping strategies (Sladek et al., 2016), all of which reported similar effect sizes (5–10% lower) as the present study. Further, up to 30% of participants do not show cortisol responses to stress in controlled laboratory studies (Dickerson and Kemeny, 2004), a proportion that is likely much higher in naturalistic field studies given the complexity of linking psychological and physiological responses to real-world stress. For adolescents with average or lower levels of Latino cultural values, there may have been greater variability in cortisol levels in response to stress (i.e., combination of increasing, remaining elevated, and returning to baseline following stress), potentially

masking the hypothesized positive within-person stress-cortisol relation.

4.3. Limitations and future directions

Although the present EMA study in daily life was supported by considerably strong external validity, estimates from situational analyses linking diary and salivary cortisol data likely underestimated true cortisol "reactivity" due to potential error in the precision of timing naturally occurring real-world cortisol responses to perceived stress (Schlotz, 2019). Despite the availability of up to 15 pairs of diary reports and saliva samples for each participant across 3 days, our approach only provided a window into the complex timing and type of perceived stress as they relate to physiological functioning in adolescents' daily lives, while balancing the participant burden of these procedures (Hoyt et al., 2016b). Future culturally-sensitive experimental research will prove useful to help better understand the contributions of cultural values to variation in Latino adolescents' HPA axis stress reactivity and recovery patterns under more controlled conditions. Latino adolescents in this study were preparing to attend a 4-year university within 60 miles of their home neighborhoods. As such, our findings may not generalize to other adolescents with different paths after high school (e.g., college further from home, community college, working full-time). However, our sample was quite heterogeneous in terms of socioeconomic status, and participants attended schools and lived in neighborhoods that varied considerably with respect to ethnic diversity. Participants were mostly, but not exclusively, Mexican descent; the smaller group sizes precluded consideration of specific subgroups (e.g., Mexican, Cuban, etc.) within this pan-ethnic group. Future research should aim to recruit Latino adolescents from groups with different levels of education, histories of immigration, and integration into mainstream U.S. culture. Future cortisol research should also consider the effects of daily stress unique to Latino adolescents' minority status or acculturation experiences, and whether these culturally-relevant stressors add to or modify associations between general everyday stress and daily stress physiology. Finally, longitudinal research is needed to test other physiological correlates and potential health implications of these identified differences in Latino adolescents' diurnal cortisol patterns.

5. Concluding comment

Latinos will account for almost 30% of the U.S. population by 2060 (U.S. Census Bureau, 2015). As HPA axis stress research moves forward, it is of paramount importance to adequately account for cultural strengths among Latinos and other historically minoritized groups. Novel findings from the present study highlight dual dimensions of cultural values among the existing strengths of Latino adolescents by identifying (1) mainstream U.S. cultural values as a predictor of higher waking cortisol levels and steeper diurnal cortisol slopes, and (2) Latino cultural values as a predictor of the stress-cortisol association in daily life. This study was strengthened by its ethnic-homogenous within-group design, an EMA approach to capture stress experiences and sample saliva in daily life, and objective indicators of sampling compliance in accordance with expert consensus recommendations. This research joins the growing science of cultural neurobiology by measuring key cultural processes in relation to the function of physiological stress systems, advancing understanding of culture-biology interplay and cultural models of resilience.

Author note

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Declaration of Competing Interest

The authors do not have any conflicts of interest to declare.

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