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The Effects of Trait and State Affect on Diurnal Cortisol Slope Among Children Affected by Parental HIV/AIDS in Rural China

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Abstract

Affect is believed to be one of the most prominent proximal psychological pathway through which more distal psychosocial factors influence physiology and ultimately health. The current study examines the relative contributions of trait affect and state affect to the hypothalamic-pituitary-adrenal axis activity, with particular focus on cortisol slope, in children affected by parental HIV/AIDS. A sample of 645 children (8-15 years old) affected by parental HIV/AIDS in rural China completed a multiple-day naturalistic salivary cortisol protocol. Trait and state affect, demographics, and psychosocial covariates were assessed via self-report. Hierarchical linear modeling was used for estimating the effects of trait affect and state affect on cortisol slope. Confidence intervals for indirect effects were estimated using the Monte Carlo method. Our results indicated that both trait and state negative affect predicted flatter (less “healthy”) diurnal cortisol slopes. Subsequent analyses revealed that children’s state negative affect mediated the effect of their trait negative affect on diurnal cortisol slope. The same relationships did not emerge for trait and state positive affect. These findings provide a rationale for future interventions that target negative affect as a modifiable antecedent of compromised health-related endocrine processes among children affected by parental HIV/AIDS.

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Keywords

Trait affect; State affect; Cortisol slope; Mediation analysis; Children affected by parental HIV/AIDS

Introduction

Accumulating evidence suggests that HIV infection has a profound impact not only on the infected individuals, but also on their families (Crampin et al., 2003; Lee, Li, Jiraphongsa, & Rotheram-Borus, 2010). Children of HIV-infected parents are particularly vulnerable to challenges in their schooling, economic stability, physical health, and psychosocial well-being (Bryant & Beard, 2016; Chi & Li, 2013; Xu, Wu, Duan, Han, & Rou, 2010). The stressors related to parental HIV/AIDS (e.g., poverty, stigmatization, and discrimination), can wear down children's psychological outcomes, including self-efficacy, self-esteem, and resilience (Chi & Li, 2013; Chi et al., 2016; Ji, Li, Lin, & Sun, 2007). These stressors could even get "under the skin" to impact children's biological function, such as the activity of the hypothalamic-pituitary-adrenal (HPA) axis (Chi et al., 2015), one of the key component of the stress systems that is thought to connect psychological experiences to health outcomes (Miller, Chen, & Zhou, 2007).

Affect is believed to be one of the most prominent proximal psychological pathways through which more distal psychosocial factors (e.g., chronic stress) influence physiology and ultimately health (Mikkelsen & Einarsen, 2002; Polk, Cohen, Doyle, Skoner, & Kirschbaum, 2005). Positive affect (PA) refers to pleasant moods, such as vigor, joy, excitement, happiness, and calm (Watson, Clark, & Tellegen, 1988). Negative affect (NA) refers to subjective feelings of distress that subsume anxiety, nervousness, hostility, and depression (Clark, Watson, & Mineka, 1994; Watson et al., 1988). Trait and state affect can be distinguished primarily by their duration, with trait affect representing more stable and typical affective disposition, and state affect representing transient fluctuations in mood over a short period of time (Polk et al., 2005; Pressman & Cohen, 2005; Rhoades, Arnold, & Jay, 2001). It is of considerable importance to identify the extent to which HPA axis function varies with trait and state differences in affect among children facing chronic stressors, such as parental HIV/AIDS. If affective factors predict HPA axis function, then interventions that target these affective processes directly, or teach children skills to increase their self-regulatory skills, may help to improve their health.

Cortisol, the end-product of the HPA axis, follows a strong circadian rhythm, peaking shortly after an individual awakens and then declining throughout the day. The HPA axis influences multiple biological processes throughout the body, including the metabolic, cardiovascular, and immune system (Charmandari, Kino, Souvatzoglou, & Chrousos, 2003; Miller et al., 2007; Sapolsky, Romero, & Munck, 2000). Diurnal cortisol slope – the rate of cortisol decline throughout waking hours – represents an important marker of HPA activity, with a flatter cortisol slope often used as an indicator of dysregulation of the HPA axis (Hoyt, Craske, Mineka, & Adam, 2015; Saxbe, 2008). There is convincing evidence that individuals with a more flattened diurnal cortisol slopes are at greater risk of adverse health

outcomes (e.g., coronary calcification, diabetes, and impaired glucose metabolism) (Hackett, Kivimäki, Kumari, & Steptoe, 2015; Matthews, Schwartz, Cohen, & Seeman, 2006) and earlier mortality (Kumari, Shipley, Stafford, & Kivimäki, 2011; Sephton, Sapolsky, Kraemer, & Spiegel, 2000).

Evidence in favor of a link between affect and cortisol slope over the day remain limited and inconsistent. Findings from a study by Doane and colleagues (2013) showed that state NA was associated with flatter cortisol slopes in youths aged 16 to 18 years. However, the same association was not found in other studies (Doane & Adam, 2010; Moskowitz & Epel, 2006). Likewise, when considering trait NA, as in Adam's (2006) study, none of the trait NA (i.e., depression, anxiety, and anger) was associated with cortisol slope in adolescents. However, trait anxiety was associated with flatter diurnal cortisol profiles in post-puberty adolescents (Van den Bergh, Van Calster, Puissant, & Van Huffel, 2008). Although a large literature suggests that PA has a beneficial effect on physical health (for a review, see Pressman & Cohen, 2005), Polk et al. (2005) found that higher state PA among healthy adults was associated with a flatter diurnal cortisol slope. However, these findings are far from being conclusive, as others have failed to find any association between PA (both trait and state PA) and diurnal cortisol rhythm (Lai et al., 2005; Moskowitz & Epel, 2006).

Thus, in light of this inconsistent findings more research is needed to better understand the complex relationships between affect and activity of the HPA axis. Further, new hypotheses could be tested. One possibility, for example, is that state affect mediates the effect of individual difference in stable trait-like affect on cortisol secretion. This prediction stems from previous research showing that state-like individual differences in affect are important mechanisms through which trait-like individual differences in affect relate to psychosocial outcomes (Rhoades et al., 2001). To our knowledge, no study has tested this hypothesis with respect to health-related biological processes, such fluctuations in diurnal cortisol.

The purpose of the present investigation was to determine if the trait and state components of both PA and NA were related to diurnal cortisol slope among children affected by parental HIV/AIDS in China. We also explored whether state PA and state NA mediated the hypothesized effects of the corresponding trait affect on children's cortisol slope.

Method

Participants and procedure

Data were derived from the baseline survey of a psychological intervention project among children affected by parental HIV/AIDS in rural China. A total of 790 children aged 6-17 affected by parental HIV and their primary caregivers consented to participate in the survey. Participants were recruited through the village administration and school system. We first accessed village-level HIV surveillance data from the county's anti-epidemic station to identify villages with the highest numbers of HIV infected individuals in the area, then accessed the lists of family caring for children affected by parental HIV/AIDS. We randomly selected families on the lists and invited one child and his/her primary caregiver to participate in the study, till the target sample size was achieved. Based on the eligible criteria of the intervention study, children with known HIV infection were not included in the study.

For the current study, inclusion criteria required that children aged 8 through 15 ($n=746$), based on the age range for which some of the self-report measures used in the present analyses were normed. Further, 101 children who did not provide valid saliva samples for cortisol analyses were excluded, and a final sample of 645 children were therefore used in the analyses. The research protocol was approved by the Institutional Review Boards at Wayne State University in the United States and Henan University in China.

Each participating child completed confidential assessment inventories in Chinese, including measures of demographic information and a series of psychosocial scales. The majority of the child surveys was self-administered in a small group in which two interviewers were present. These interviewers assisted the children by providing them with necessary clarification or explanation of survey questions. For a small number of children with limited literacy, interviewers read each question to them and recorded their responses. Children were instructed to provide their saliva samples and daily diary data with the help of caregivers. Each child received an age appropriate gift (about five US dollars) at the completion of the assessment as a token of appreciation.

Measures

Salivary cortisol—Children provided four saliva samples daily (waking, 30 minutes after waking, late afternoon and bedtime) for three consecutive days (Thursday through Saturday). Prior to saliva collection, the investigators showed children and caregivers the correct procedure to collect saliva samples using Salivettes (Sarstedt, Rommelsdorf, Germany) and emphasized the importance of compliance with the time of collection. Cortisol levels were determined via chemiluminescent immunoassay (Access Cortisol kit YZB/USA 2802, Beckman Coulter, Inc, Fullerton, CA). To correct for positive cortisol skewness and kurtosis, cortisol values were natural logarithmically transformed before analysis. In order to ensure that all transformed scores were positive, a constant of 1 was added before the transformation.

State affect—At the end of each day during which children provided saliva samples for cortisol, they were asked to rate, on a scale from 1 (not at all) to 3 (most of the day), how often they experienced each of the following 12 feelings during the day: 1) state PA: happy, excited, energetic, confident, curious, and calm; and, 2) state NA: lonely, sad, upset, fear, angry, and worried. Mean scores of all positive or negative affect items were calculated for each participant on each day ($\alpha = 0.72, 0.76$, respectively). Then we calculated state PA and state NA scores for each participant by averaging PA and NA scores across three days. This method of affect assessment is in line with that used in the existing literature (e.g., Piazza, Charles, Stawski, & Almeida, 2013).

Trait affect—The Positive and Negative Affect Schedule (Watson et al., 1988) was used to measure trait PA and trait NA. Each scale consists of 10 items. Sample items assessing trait PA included “enthusiastic, excited, and happy”, while sample items assessing trait NA included “scared, ashamed, and jittery”. Respondents indicated on a 5-point scale, from 1 (very slightly or not at all) to 5 (extremely), the extent to which they had experienced each feeling during the past six months. Mean scores across all trait PA or trait NA items were

calculated for each participant. Alpha coefficients were 0.69 and 0.76 for trait PA and trait NA, respectively.

Covariates

Family socioeconomic status (SES): A composite index was created by summing the standardized scores (i.e., *z* scores) of family income, maternal education, and paternal education with a higher composite score indicating a better family SES (Cohen, Doyle, & Baum, 2006).

Perceived health status: Children rated their overall health status on a 5-point scale, ranging from 1 (very poor) to 5 (very good).

Experience of stressful life events: Fifteen items from a stressful-life-events checklist used in our previous work (Li et al., 2009) were used to assess children's experience of stressful life events during the past six months. Sample items included being in a traffic accident, being a witness to violence, and being in a natural disaster.

Daily sleep quality and wake time: On each of the three mornings when children provided saliva samples, they rated the quality of their prior night's sleep on a 4-point scale, ranging from 1 (very bad) to 4 (very good), and reported the time when they woke up in the morning.

Statistical analyses—Hierarchical linear modeling (HLM) was used to account for the hierarchical nature of the data. Time since waking was modeled at Level-1 to provide an estimate of each child's cortisol slope, while the intercept provided an estimate of waking cortisol level. The cortisol awakening response (CAR) (dummy coded 0 or 1) and time since waking-squared were also modeled at Level 1. Cortisol intercept and slope were allowed to vary randomly at the day-level (Level-2) and the person-level (Level-3), whereas CAR and time since waking-squared were treated as fixed effects. All significance tests were two-tailed with robust standard errors.

A two-step approach was used to test the associations among trait affect, state affect, cortisol level at awakening, and cortisol slope. First, we estimated separately Level-3 effects of the individual differences in trait PA, trait NA, state PA, and state NA on waking cortisol level and cortisol slope. Second, state affect and trait affect were included simultaneously as predictors of wakeup cortisol and cortisol slope, while controlling for significant covariates. We considered day of the week (0 = weekday, 1 = weekend), daily wake up time, daily sleep quality, daily PA and NA (within person affect) at Level-2 as potential covariates. Age, gender (0 = male, 1 = female), SES, stressful life events, and perceived health status were considered as potential covariates at Level-3. Preliminary analyses suggested that day of the week, wake up time, and age significantly predicted wakeup cortisol, while day of the week and age significantly predicted cortisol slope. Thus, these covariates were included in the analysis. We also regressed state affect on trait affect while we controlled for significant person level covariates using multiple regression. Life event, age, and SES were included in the analysis as covariates because preliminary analyses suggested that life event significantly predicted state NA, while age and SES significantly predicted state PA. Next, confidence

intervals (CI) for indirect effects were estimated using the Monte Carlo method with 20,000 repetitions (Selig & Preacher, 2008). All continuous predictors of cortisol parameters were grand-mean centered. In order to curtail the bias associated with pairwise or listwise deletion of missing data (Collins, Schafer, & Kam, 2001), the expectation maximization (EM) algorithm was used to impute missing data at daily and person levels.

The average number of saliva samples provided by each participant in our study was 11.17 out of 12 possible samples. As for CAR compliance, in our sample of 645 individuals, of the available 1,810 CAR cortisol values, 453 (25%) had the collection time of the second saliva sample deviating by 15 min or more from the required 30-min interval. To control the potential effect of such non-compliance, we created a new “compliance with CAR timing” variable (0 = noncompliant, 1 = compliant) at the daily level, wherein participants were considered noncompliant if their reported collection time deviated by at least 15 minutes from the required 30-min interval on each day. This variable was included as a covariate for the CAR parameter at daily level.

Results

Means and standard deviations for the study predictors by gender are reported in Table 1, and correlations among the measures of trait and state affect are reported in Table 2.

In HLM analyses, we first entered trait PA, trait NA, state PA, and state NA separately as predictors of wakeup cortisol and cortisol slopes at level 3. Trait NA was associated with lower level of cortisol at awakening ($\beta = -0.0224$, $SE = 0.0086$, $p = 0.009$) and a flatter cortisol slope ($\beta = 0.0017$, $SE = 0.0008$, $p = 0.049$), indicating that those individuals who had higher levels of trait NA experienced a less steep cortisol decline throughout the day (Figure 1a). The same effect on cortisol slope was found for state NA, children reporting higher levels of state NA had a less steep diurnal decline in cortisol ($\beta = 0.0038$, $SE = 0.0018$, $p = 0.036$) (Figure 1b). State NA was not a significant predictor of wakeup cortisol ($\beta = -0.0363$, $SE = 0.0194$, $p = 0.063$). Neither trait PA nor state PA were related to wakeup cortisol ($\beta = 0.0056$, $SE = 0.0096$, $p = 0.557$; $\beta = -0.0198$, $SE = 0.0148$, $p = 0.180$, respectively) or cortisol slope ($\beta = -0.0001$, $SE = 0.0009$, $p = 0.891$; $\beta = 0.0008$, $SE = 0.0014$, $p = 0.583$, respectively).

We next tested whether the association between trait NA and cortisol slope was mediated by state NA. Multiple regression analyses controlling for significant covariates revealed that NA was significantly associated with trait NA ($B = 0.0778$, $SE = 0.0184$, $p < 0.001$). Next, we simultaneously entered trait NA and state NA into the HLM model to predict cortisol outcomes while controlling for the significant covariates and CAR compliance (Table 3). We found that the indirect effect linking trait NA to cortisol slope via state NA was significant (95% CI = 0.00001, 0.00062). Given the lack of any significant associations between trait PA or state PA and cortisol parameters, we did not run additional mediational analyses.

Discussion

Two main findings emerged from the current study among children affected by parental HIV/AIDS. First, both trait NA and state NA, but not trait PA and state PA, had a significant

impact on children's cortisol slope. Second, state NA mediated the association between trait NA and diurnal cortisol slope.

Adding to the literature on the relationships of affect with physical health outcomes and physiological processes, the current study indicates that negative affect might be a driver of HPA axis functioning among children. Although few studies have previously reported that negative affect modulates diurnal cortisol secretion in adolescents and adults (Doane et al., 2013; Piazza et al., 2013), the current study provides one of the first evidence that this link may also exist in younger children. Particularly, our findings suggest that higher levels of trait NA are ultimately associated with a flatter cortisol slope via increased levels of state NA. Children reporting higher levels of trait NA experienced higher negative affect in their daily life (i.e., state NA), which in turn was associated with dysregulation in the diurnal cortisol rhythm (i.e., flatter cortisol slope). Because flattened cortisol circadian profiles have been showed to have negative implications for physical health (Hackett et al., 2015; Kumari et al., 2011; Zilioli, Imami, & Slatcher, 2017), our findings echoed prior evidence emphasizing the importance of children's daily psychological experiences as important antecedents of physical health (Tobin et al., 2015). Trait NA was also found to be associated with lower wakeup cortisol. Although the link between lower wakeup cortisol and health is less clear, our findings align with previous work showing significant associations between low levels of morning cortisol in children who are exposed to chronic stressors, such as poverty (Zalewski, Lengua, Kiff, & Fisher, 2012) or relational difficulties with peers (Michels et al., 2012).

Interestingly, we found that neither trait PA nor state PA were associated with cortisol outcomes, suggesting that negative affect might be the only dimension of affect that predicts diurnal cortisol slope among children affected by parental HIV/AIDS. The extant literature on the role played by positive affect in modulating the activity of the HPA axis is inconsistent. For example, some studies failed to find an association between PA and cortisol slope (Lai et al., 2005; Moskowitz & Epel, 2006). One study found that state PA was associated with a flatter diurnal slope (Polk et al., 2005), while Hoyt and colleagues (2015) found that only high arousal state PA, but not low arousal state PA, predicted a steeper cortisol slope among adolescents. These mixed findings may be attributable to differences in the samples (e.g., adults vs. adolescents vs. children) or in the methods employed to measure affect. Moreover, future work would benefit from considering some of the factors mentioned above, such as affective arousal (Hoyt et al., 2015) as possible ways to explore nuances in the relationship between affect and HPA functioning among children.

Our study has some limitations. First, the cross-sectional nature of our data limits our ability to draw conclusions regarding the directionality of the relationships among the study variables. Second, paper-and-pencil reports of timing of saliva sample collection were used (rather than electronic devices). Lastly, even though we claimed that flatter diurnal cortisol slope is predictive of negative health consequences, measures of physical health were not employed in the present study. Future studies with this population would benefit from including indices of somatic symptoms as well as other measures of physical health, similar to previous studies (Zilioli et al., 2017).

Despite these limitations, the current study is among the first ones showing a significant relationship between negative affect (both trait and state) and dysregulation of daily cortisol rhythm among children. From a prevention/intervention perspective, our findings provide preliminary data to inform future behavioral interventions that target negative affect as a modifiable antecedent of compromised health-related endocrine processes among children affected by parental HIV/AIDS.

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Figure 1.

Effects of trait NA and state NA on diurnal cortisol levels.

Note: Log-transformed cortisol level is graphed as a function of time since waking for (a) participants who reported high and low levels of trait NA (i.e., 1 *SD* above and below the mean) and (b) participants rated high and low on state NA (i.e., 1 *SD* above and below the mean).

Table 1

Means (standard deviations) for the person level predictors by gender group

	Overall (N=645)	Girl (N=310)	Boy (N=335)	<i>t</i>
Age in years	10.67(1.79)	10.51(1.78)	10.82(1.78)	2.22 *
Socioeconomic status	0.00(2.19)	-0.04(2.02)	0.04(2.34)	0.44
Perceived health status	4.25(1.05)	4.30(1.03)	4.20(1.07)	-1.20
Life event	2.47(2.11)	2.39(2.03)	2.55(2.19)	0.96
Trait PA	2.92(0.65)	2.89(0.63)	2.95(0.68)	1.23
Trait NA	2.06(0.66)	1.99(0.64)	2.13(0.68)	2.65 **
State PA	2.19(0.39)	2.19(0.39)	2.19(0.40)	0.16
State NA	1.34(0.30)	1.33(0.30)	1.36(0.31)	1.01

Note:

**
 $p < 0.01$,*
 $p < 0.05$.

Table 2

Correlations between measures of trait and state affect

Measure	1	2	3	4
1. Trait PA	1.00			
2. Trait NA	0.04	1.00		
3. State PA	0.22***	0.03	1.00	
4. State NA	-0.03	0.20***	-0.06	1.00

Note:

p< 0.001.

Table 3

Time of day, negative affect, and covariates predicting cortisol

Fixed effect	Coefficient (SE)	<i>t</i>	<i>p</i>
Average Cortisol at Awakening	0.6987 (0.0073)	95.79	<0.001
Trait NA	−0.0167 (0.0086)	−1.93	0.054
State NA	−0.0340 (0.0196)	−1.73	0.084
Age	0.0092 (0.0033)	2.77	0.006
Weekend	−0.1103 (0.0083)	−13.21	<0.001
Daily wakeup time	−0.0221 (0.0041)	−5.43	<0.001
Average CAR	−0.0369 (0.0105)	−3.51	<0.001
CAR compliance	0.0346 (0.0115)	3.02	0.003
Average Diurnal Cortisol Slope	−0.0388 (0.0020)	−19.28	<0.001
Trait NA	0.0011 (0.0009)	1.25	0.213
State NA	0.0036 (0.0018)	1.97	0.049
Age	−0.0007 (0.0003)	−2.30	0.022
Weekend	0.0080 (0.0008)	9.51	<0.001
Average Slope of Time Since Waking Squared	0.0008 (0.0001)	5.75	<0.001

Note: Average diurnal cortisol slope indicates change in cortisol per 1-hr change in time; average slope of time since waking squared indicates change in cortisol per 1-hour change in time squared; CAR = cortisol awakening response, indicating amount of change in cortisol during the 30 min after waking.