Hormones and Behavior 98 (2018) 198–209

Contents lists available at ScienceDirect

Hormones and Behavior

journal homepage: www.elsevier.com/locate/yhbeh

A state-trait model of cortisol in early childhood: Contextual and parental predictors of stable and time-varying effects☆

Stephanie F. Thompson[a,*], Maureen Zalewski[b], Cara J. Kiff[c], Liliana J. Lengua[a]

[a] University of Washington, United States
[b] University of Oregon, United States
[c] UCLA Semel Institute for Neuroscience and Human Behavior, United States

ARTICLE INFO

Keywords:
Cortisol
Risk
Parenting

ABSTRACT

This study examined state-trait models of diurnal cortisol (morning level and diurnal slope), and whether income, cumulative risk and parenting behaviors predicted variance in trait and state levels of cortisol. The sample of 306 mothers and their preschool children included 29% families at or near poverty, 27% families below the median income, and the remaining families at middle and upper income. Diurnal cortisol, income, cumulative risk, and parenting were measured at 4 time points, once every 9 months, starting when children were 36–40 months. State-trait models fit the data, suggesting significant state but not trait variance in cortisol. Low income and cumulative risk were related to trait levels of diurnal cortisol with little evidence of time-varying or state effects. Stable levels of parenting predicted trait levels of diurnal cortisol and time-varying levels of parenting predicted time-varying state levels of diurnal cortisol. Findings highlight the allostatic process of adaptation to risk as well as time-specific reactivity to variability in experience.

The stress response system, including the hypothalamic-pituitary-adrenal (HPA) axis, has been described as an "environmentally sensitive" physiological system (Granger, 1998) and is associated with psychosocial adjustment outcomes across development (Granger et al., 1996; Gunnar et al., 2003; Yehuda et al., 1996). Evidence points to both stable aspects of HPA activity, attributed in part to genetic factors and individual differences (Schreiber et al., 2006), and a significant degree of change in the activity of the system over time, even within the same developmental period (Ross et al., 2014; Shirtcliff et al., 2012). The stability in individuals' HPA activity may be a function of stable environmental contexts known to relate to HPA activity, including poverty and contexts characterized by multiple or "cumulative" risk factors (Dowd et al., 2009; Miller et al., 2007). These associations are in line with the theory of allostasis, wherein exposure to chronic stress would lead to new "set points" or stable parameters of the stress system. While these distal and relatively stable factors relate to HPA activity, so too do contemporaneous person and situational factors, potentially predicting time-specific variations from stable levels of HPA activity. Few studies have examined whether more proximal and variable ecological factors influence individuals' HPA activity to the point of predicting changes in an individual's "set point" functioning (Berry et al., 2016). That is, few studies of HPA axis activity include repeated measures across time, and fewer still have explored how proximal and distal factors relate to stability and change in the system over time (Laurent et al., 2014). Understanding the predictors of early life alterations to the HPA axis is of particular salience when considering the *developmental origins of disease* (Gluckman and Hanson, 2006) and potential for *biological embedding* (Miller et al., 2011), which argue that childhood stress is programmed into stress-sensitive systems early in life.

The latent state-trait (LST) framework is a useful analytic approach to the identification of stable individual cortisol *traits* (the commonality of an individual's cortisol activity over time) as well as time-specific, or state, variations from trait levels (c.f. Steyer et al., 1999). The measurement approach may smooth the confluence of person and situational factors impacting cortisol levels sampled at any given moment on the trait level, allowing for a test of whether an accumulation of environmental or time-specific situational factors exert influence on an indvidual's set point, trait HPA axis activity (e.g. Hellhammer et al., 2007; Kirschbaum et al., 1990). The model further decomposes variance by identifying time (or epoch) specific variance in *states*. In a model with additional latent variables (e.g. income, cumulative risk, and parenting), it is possible to examine the association between stable aspects of cortisol activity and environmental factors (e.g. if characteristic levels of cumulative risk are associated with characteristic

☆ Author Note: This research was supported by a grant to the 4th author from the National Institute of Child Health and Human Development (R01HD054465). The authors wish to thank the families who participated in this research.

* Corresponding author at: University of Washington, Department of Psychology, Box 351525, Seattle, WA 98195, United States.
E-mail address: sfengler@u.washington.edu (S.F. Thompson).

https://doi.org/10.1016/j.yhbeh.2017.12.009
Received 9 August 2017; Received in revised form 6 December 2017; Accepted 23 December 2017
Available online 09 February 2018
0018-506X/

levels of diurnal cortisol), and also to examine if time-specific (state) variations in cortisol are associated with time-specific changes in the environment (e.g. if the experience of a change in parental negativity relative to what is typical for the individual is associated with a contemporaneous change in cortisol activity from what is typical for the individual).

The present study utilized cortisol samples from four time points, each separated by 9 months to characterize trait diurnal cortisol levels, with three consecutive morning and evening samples obtained at each time point to capture state values of cortisol morning level and diurnal slope to address the following questions: 1) Do contextual factors, such as income, cumulative risk and parenting, predict both trait and state variance in preschool-age children's diurnal cortisol (morning levels and diurnal slope)? 2) Do stable, distal factors, such as income and cumulative risk, predict trait variance in diurnal cortisol measures, whereas more time-varying and proximal factors, such as parenting, predict state variance? The current study models the stable and time-varying relations between cortisol patterns (measured as diurnal morning level and slope) with stable and time-varying contextual factors including income, cumulative risk and parenting.

1. Low income, cumulative risk and HPA axis function

Studies of rodents and non-human primates indicate that early exposure a range of adverse environments result in immediate and long-term changes to the HPA axis activity and reactivity, as well as animal behavior (c.f. Sanchez, 2006). In humans, aberrant profiles may take the form of hypocortisolism, or low cortisol levels or responses, and hypercortisolism, in which an individual's cortisol levels start elevated and remain elevated across the day. Both profiles are observed among individuals experiencing chronically stressful environments (c.f. Davies et al., 2007) and types and nature of environmental stressors that predict elevated versus blunted cortisol are not clearly understood.

One measure of environmental stress is a *cumulative risk* index, which captures the number of risk factors that an individual experiences across demographic, psychosocial, and environmental domains. Although there are studies that show high levels of economic or cumulative risk are associated with higher levels of cortisol in children (Blair et al., 2005; Evans and English, 2002; Evans and Kim, 2007), both a review and a meta-analysis of the relation of risk to cortisol show that low income and high cumulative risk are associated with lower or blunted cortisol levels, whereas acute stress is associated with elevated diurnal levels (Dowd et al., 2009; Miller et al., 2007). This finding is consistent with the allostatic load theory; after prolonged exposure to stress common to low-income, high-cumulative risk contexts, an individual, unable to generate the energy required to regulate and maintain an acute stress response, may shift from hyper-responding to a downregulated response. Of note, these reviews were comprised of studies from early childhood through adulthood. Therefore, while there is some evidence of these observed patterns in children (e.g. Evans and Kim, 2007; Badanes et al., 2011), the review findings are driven by adult studies (e.g. M_{age} = 38.39 in Miller et al., 2007) and it is less clear, developmentally, when these patterns may emerge in children.

The literature does not clearly address the extent to which risk exerts a stable influence over HPA axis functioning versus a more transient disruption the stress response system. There is some evidence that socioeconomic risk is exceedingly taxing to the HPA axis over time and related to its long-term stability (Evans and Kim, 2007), evidence that risk relates to the dynamic change of the stress response system, rather than its stability (Fernald and Gunnar, 2009) and research to suggest that stable, distal risk factors relate to stable, characteristics of HPA activity while more time-specific, proximal risk factors relate to contemporaneous states of HPA activity (Laurent et al., 2014). Further study on the contributions of environmental risk to the stability, as well as the variability, of cortisol over time, are needed. The current study seeks to address this gap in the literature, using four time points of cortisol data to examine whether income and cumulative risk predict stable, trait aspects of HPA axis functioning.

2. Parenting and HPA axis function

Parenting reflects a proximal environmental influence upon stress hormone functioning. Studies have suggested that maternal withdrawal and insensitivity relates to elevated baseline cortisol among infants (Bugental et al., 2003; Haley and Stansbury, 2003), maternal negative affect relates to blunted diurnal slope among preschoolers (Zalewski et al., 2012), and decreased parenting quality, as indexed by lower involvement and lower warmth, relates to flatter diurnal slope in children in kindergarten and adolescence (Pendry and Adam, 2007). Early parenting appears to be a long-term predictor of HPA axis functioning, with studies finding, for example, that higher levels of maternal engagement during infancy predicted lower basal cortisol in toddlerhood (Blair et al., 2008) and higher levels of maternal insensitivity in the first 3 years of life predicted lower awakening cortisol at age 15 (Roisman et al., 2009).

While parenting behaviors have long-term predictive value, they are also thought to be variable over time (Dallaire and Weinraub, 2005). Providing some support to the notion that state parenting contributes to children's contemporaneous or state cortisol, one study found that inconsistency in parenting, not parenting behavior itself, interacted with genetic and prenatal risk factors to predict cortisol variability across the first 4.5 years of life (Marceau et al., 2013). The current study examined whether parenting behaviors relate to stable, trait HPA axis functioning in preschool age children and/or explain time-varying variance in HPA axis functioning—that is, whether variations from one's “typical” parenting experiences can account for deviation from one's own “typical” HPA axis functioning.

3. State-trait models of cortisol

Few studies of children's cortisol function have utilized state-trait models, which may have limited the field's ability to evaluate predictors of diurnal cortisol. As highlighted by Kirschbaum et al. (1990), there are three sources of variance in cortisol: (1) trait factors related to internal personal factors, and we note, that these might also reflect stable aspects of an individual's environment or context, (2) state factors related to time varying situational and/or person-situational interactions, and (3) error variance, which includes measurement error introduced by assay unreliability and unmeasured sources of variance. Collapsing across these sources of variance may not only obscure relations by reducing the power to detect meaningful differences, but also ignores potential specificity between the predictor and the portion of cortisol variance explained.

When it comes to prior LST studies, the time between assessments vary significantly, with some studies considering traits over days and weeks (Kirschbaum et al., 1990), as well over years (Wang et al., 2014). Therefore, estimates of trait variance may be accentuated by time frame, such that estimates have captured epoch speciifc rather than true trait variance in cortisol. On balance, as is characteristic of a variable's diminishing correlation over time, the longer the time between time points of assessment, the lower the trait-effect estimates. Further, stability estimates vary depending on the aspect of cortisol (e.g., morning v. evening level) being examined (Doane et al., 2015; Stroud et al., 2016; Wang et al., 2014).

Notably, few studies have examined stability and change in the HPA among children. On balance, in mid-childhood and adolescence, models suggest the majority of morning cortisol is attributed to state factors, with estimates including 50% of variance to 70% of variance, and a significant but smaller percent of variance (e.g. 41% and 28%, respectively) attributed to trait factors (Kertes and van Dulmen, 2012; Shirtcliff et al., 2005). In terms of diurnal slope, state variance estimates have ranged widely, with estimates ranging from 35% to 76% of