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Chronic stress in the mother-infant dyad: Maternal hair cortisol, infant salivary cortisol and interactional synchrony

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ABSTRACT

Stress physiology is shaped by early experience, with enduring effects on health. The relation of chronic maternal physiological stress, as indexed by hair cortisol, to infants' stress systems and to mother-infant interaction quality has not been established. We examined maternal hair and salivary cortisol, six-month-old infants' salivary cortisol, and mother-infant interaction in 121 mother-infant dyads. High maternal hair cortisol was related to higher infant average salivary cortisol concentration. Maternal hair cortisol and bedtime salivary cortisol were both uniquely related to infant bedtime salivary cortisol. Mothers with higher hair cortisol were more intrusive and had lower positive engagement synchrony with their infants. Maternal intrusiveness moderated the association of maternal hair cortisol and infant salivary cortisol, such that maternal hair and infant average salivary cortisol were related only when mothers were more intrusive. Maternal chronic physiological stress may upregulate infants' developing stress systems, particularly in the context of lower mother-infant interaction quality.

1. Introduction

Chronic early life stress has enduring consequences, including risk for poorer physical and mental health in adulthood (Anda, Butchart, Felitti, & Brown, 2010). One of the most critical factors in infants' early experience is the dyadic mother-infant interaction. Early caregiving quality predicts language development and cognitive and social functioning (Gunnar and Stone, 1984; Saint-Georges et al., 2013). Caregiving quality also is related to infant cortisol function, including reactivity to stressors (Albers, Riksen-Walraven, Sweep, & Weerth, 2008; Jahromi, Putnum, & Stifter, 2004). Children who experience early life stress show concurrent and enduring abnormalities in cortisol function (Goldman-Mellor, Hamer, & Steptoe, 2012; Lupien, King, Meaney, & McEwen, 2000). Cortisol dysregulation is a key physiological mechanism through which early life stress leads to adverse long-term health outcomes (McEwen, 2006). The hypothalamic-pituitary-adrenal (HPA) axis, of which the end product is cortisol, is immature at birth. Infants and young children depend on sensitive, responsive caregiving; in the absence of sensitive care, their cortisol function may become dysregulated, exposing the developing brain to excessive cortisol (Gunnar & Talge, 2008).

Thus, it is critical to understand the proximal factors that shape early mother-infant interaction and infant cortisol function. The psychobiological theory of mothering (Barrett & Fleming, 2011) postulates that appropriate mothering requires

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coordination of multiple systems of perception, cognition, and action to read infant cues and respond sensitively. In mothers who are experiencing high levels of stress themselves due to psychosocial adversity, these systems may be compromised, and thus these mothers are less likely to be sensitive, responsive caregivers (Barrett & Fleming, 2011). Indeed, in a high poverty sample, mothers with higher salivary cortisol levels showed lower sensitivity to their infants (Finegood, Blair, Granger, Hibel, & Mills-Koonce, 2016). Because chronic stress in the early years of life has enduring consequences for infants' later health and well being (Anda et al., 2010), and because early caregiving is critical to buffering infants from stress, chronic *maternal* stress is particularly important to characterize. Yet the role of chronic maternal physiological stress in infant cortisol function and mother-infant interaction quality has not been determined, in part because widely used salivary cortisol measures index acute rather than chronic stress (Russell, Koren, Rieder, & Van Uum, 2012).

1.1. Comparison of hair cortisol and salivary cortisol

Cortisol is deposited in the hair shaft as the hair grows, such that, taking into account the rate of hair growth, a hair sample provides a timeline of cumulative cortisol exposure over several months (Meyer & Novak, 2012). In contrast, salivary cortisol indexes cortisol concentration at a single point in time. Both these measures have their strengths and weaknesses. Due to diurnal variability in cortisol levels, approximately 70% of salivary cortisol variance is attributable to time-of-day effects (Adam, 2012). While repeated measures of salivary cortisol area under the curve from waking to bedtime (AUCg) have been used to estimate cumulative cortisol exposure, there are large fluctuations in salivary cortisol levels not only across the day but also from one day to the next (Ross, Murphy, Adam, Chen, & Miller, 2014). Salivary cortisol levels can be distorted by dairy or caffeine; illness; breastfeeding; and menstrual cycles (Kudielka, Hellhammer, & Wust, 2009) and are affected by time of waking and sleep duration (Edwards, Evans, Hucklebridge, & Clow, 2001; Kumari et al., 2009). Thus, there are substantial methodological hurdles to assessing cumulative cortisol exposure with salivary cortisol, even with multiple measures across several days. Compared to salivary cortisol, hair cortisol concentration (HCC) is less versatile: Salivary cortisol can provide information about diurnal rhythm and acute response to challenge, which HCC cannot. However, as an index of chronic stress, HCC solves most of the methodological challenges associated with salivary cortisol, because HCC reflects cumulative exposure over the past several months and is not unduly influenced by idiosyncrasies of the subject's experience or behavior on the day of sampling.

It is essential to resolve the pattern of association between HCC and well-established salivary measures, so as to integrate the emerging HCC literature with the vast existing salivary cortisol literature. While HCC has rapidly gained popularity in recent years, there is little data addressing the association of HCC with salivary cortisol. In a small sample, van Holland, Frings-Dresen, Sluiter (2012) reported a moderate correlation with mean salivary cortisol concentration (SCC) when saliva was intensively sampled, six samples per day across three days. In a recent study, HCC for 1 cm of hair, corresponding to a one-month period, was highly correlated with mean AUCg from saliva samples collected three times every day during that period, but was unrelated to mean slope or cortisol awakening response (CAR; Short et al., 2016). In a study of pregnant women, HCC for 3 cm of hair, corresponding to a three-month period, correlated with AUCg when the AUCg was calculated from saliva collected three times a day for two different three-day periods during the three-month span (D'Anna-Hernandez, Ross, Natvig, & Laudenslager, 2011). However, HCC and AUCg were unrelated when the AUCg was calculated from a single three-day sampling period. Based on these few studies, it appears that HCC may relate to average SCC and AUCg when these salivary measures are based on numerous samples or when the sampling days are spread out across time.

1.2. Interplay of maternal and infant cortisol and mother-infant interaction

Several studies report associations between mothers' and young children's SCC (Sethre-Hofstad, Stansbury, & Rice, 2002; Stenius et al., 2008). Maternal HCC and child HCC have been concurrently related in older children (Ouellette et al., 2015). In Antarctic seals, fur cortisol concentrations were correlated in mothers and their newborn pups, and were higher in mothers breeding in high density colonies, suggesting possible fetal programming (Meise, von Engelhardt, Forcada, & Hoffman, 2016). In light of the long-term health implications of infant HPA dysregulation, it is critical to examine the role of maternal chronic physiological stress in infants' cortisol exposure.

A key mechanism through which mothers may indirectly shape infant HPA function is caregiving quality. The infant HPA axis is immature at birth, and cortisol function in young children varies depending on the quality of caregiving they receive (Gunnar & Talge, 2008). Low maternal sensitivity is associated with higher infant basal SCC across the day and diurnal AUCg calculated from three samples from waking to bedtime (Letourneau, Watson, Duffett-Leger, Hegadoren, & Tryphonopoulos, 2011). Low maternal sensitivity has also been related to higher overnight AUCg based on three samples collected from late afternoon until the next morning (Philbrook et al., 2014). If mothers who are chronically physiologically stressed are less responsive to their infants, parenting quality may represent one pathway through which maternal chronic physiological stress could influence infant HPA function. However, the relation of maternal HCC to mother-infant interaction quality has not been established.

The degree of synchrony between maternal and child cortisol may vary depending on caregiving quality. In the salivary cortisol literature, it has been reported that the association of mother and child cortisol response to a stressor is moderated by quality of the mother-child interaction (Sethre-Hofstad et al., 2002; van Bakel & Riksen-Walraven, 2008). Affective involvement has also been shown to moderate the synchrony between mother and child diurnal salivary cortisol (Williams