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Correlation between maternal and infant cortisol varies by breastfeeding status

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Abstract

Objective—The objective of this study was to examine associations of mother and infant salivary cortisol, measured three times over the course of a day, and assess whether these varied by breastfeeding status.

Methods—We conducted a cross-sectional study of 54 mothers and their infants aged 4–11 months. Mothers collected their own saliva and that of their infants upon awakening, 30 min after waking and at bedtime. Breastfeeding status was reported by mothers and cortisol level was measured in saliva in µg/dl using standard techniques. We used generalized linear models to evaluate relationships between maternal and infant cortisol levels, and assessed whether the relationship differed by breastfeeding status: formula only compared to partial and full breastfeeding, adjusting for infant sex, race, age, maternal education, and family income.

Results—Thirty-four infants received formula only and 20 were either partially or fully breastfed. Breastfeeding was associated with higher household income, higher maternal education, and white race. Cortisol levels were higher among breastfed infants at all three time points. After adjustment, maternal cortisol levels were related with infant cortisol at bedtime only (regression estimate 0.06; 95% CI: 0.10, 1.1; $p = 0.02$). The adjusted association between bedtime maternal and infant cortisol was stronger among breastfeeding dyads than among formula-feeding dyads (regression estimate 1.0; 95% CI: 0.1, 2.0; $p = 0.04$ vs. 0.6; CI: −0.1, 1.3; $p = 0.10$). In addition, we assessed the influence of maternal education and household income in our adjusted model; income strengthened the observed association, whereas maternal education did not change the estimate.

Conclusions—Breastfeeding mothers and infants had significant correlations for cortisol at bedtime, while formula-feeding dyads did not. These data suggest that several factors may contribute to cortisol synchrony observed in mother/infant dyads, including the transfer of cortisol in human milk, physical interaction such as skin-to-skin contact, and shared environment. In addition, our findings support household income as a possible contributor.

Keywords

Breastfeeding; Cortisol; Human milk; Stress

1. Introduction

Breastfeeding is an important predictor of long-term health (American Academy of Pediatrics, 2012; World Health Organization, 2002), but little is known about how it influences stress-related hormone levels in infants. One potential mechanism is the transfer of biologically active elements, such as cortisol, through human milk. Infants who are breastfed in their first year of life have higher cortisol levels than formula-fed infants (Cao et al., 2009) and studies suggest that cortisol present in human milk may be transmitted via breastfeeding from mother to baby (Bright, Granger, & Frick, 2011; Patacchioli et al, 1992; Stenius et al., 2008). In addition, breastfeeding may influence infant cortisol levels through the physical interactions that occur between mother and infant, leading to greater synchrony in cortisol levels. Breastfeeding dyads typically have more skin-to-skin contact, and mothers who engage in frequent skin-to-skin contact have cortisol levels that are more highly correlated with their infants than those who do not (Mörelus, Örténstrand, Theodorsson, & Frostell, 2015). Breastfeeding mothers also spend more time soothing, holding, and cuddling their infants, compared to mothers who formula feed their infants (Smith & Ellwood, 2011). Since shared environment is known to influence correlation of cortisol levels between individuals, more frequent interaction between breastfeeding mothers and their infants could influence synchrony. A study of infants and mothers in neonatal intensive care units found that mothers and infants who stayed together 24 h each day from admission to discharge had cortisol levels that were correlated at discharge whereas dyads who did not stay together were not correlated (Mörelus, Broström, Westrup, Sarman, & Örténstrand, 2012).

Several studies have assessed whether cortisol levels among mothers and their infants are linked, but none have examined differences by feeding method (Bright et al., 2011; Clearfield, Carter-Rodriguez, Merali, & Shober, 2014; Middlemiss, Granger, Goldberg, & Nathans, 2012; Spangler, 1991; Stenius et al., 2008). Stenius et al. (2008) compared salivary cortisol levels of 51 six-month-old infants to that of their parents, sampled in the morning, afternoon, and evening. They found a strong, positive association between mothers and infants at each time point, but a weak association between fathers and infants in the afternoon and evening only. The majority of infants in the study were breastfed; therefore, the authors were not able to compare breastfed to formula-fed infants. Spangler and colleagues (Spangler, 1991) found positive correlations in salivary cortisol levels between 14 mothers and their infants but were not able to assess differences by feeding status. Similarly, Bright et al. (2011) examined associations in salivary cortisol levels of 32 mothers and their infants or toddlers and found positive correlations at each of four assessments measured throughout the day. Clearfield et al. (2014) compared 16 high socio-economic status (SES) mothers and their infants to 16 low SES dyads to determine whether cortisol synchrony differed by SES. They sampled in the morning, afternoon, and evening and found that high SES dyads were significantly correlated in the evening only. Low SES dyads were not significantly correlated at any of the three time points assessed. Additionally,

Middlemiss and colleagues (Middlemiss et al., 2012) examined maternal-infant interactions and cortisol levels in 25 dyads throughout a 5-day sleep training program, meant to induce stress, to determine if synchronicity in hypothalamic-pituitary-adrenal (HPA) axis activity was established and maintained. They found a positive association between maternal and infant cortisol levels throughout the day, at the initiation of a bedtime sleep routine, and after transition to sleep during the first few days of the program.

Since the majority of these studies included only breast- or mixed-feeding mothers and infants, it is still unclear whether correlations in cortisol levels are present in exclusively formula-feeding dyads. The purpose of this study was to evaluate associations of salivary cortisol between mothers and their infants, and assess the extent to which these associations differed by breastfeeding status. Based on findings from previous studies, we hypothesized that cortisol levels would be correlated among breastfeeding but not formula-feeding dyads.

2. Materials and methods

2.1. Study population

Participants were part of the Newborn Epigenetic Study (NEST), an observational cohort designed to examine epigenetic influences on the development of child adiposity. Information about the NEST study and its protocols are available elsewhere (Hoyo et al, 2011). Briefly, between 2009 and 2012, 1700 pregnant women were enrolled from one of five prenatal clinics in Durham, NC, USA. Infants were excluded from the NEST study if they were born <28 weeks gestation, were not feeding by mouth at hospital discharge, were in the hospital for more than 21 days post birth, or had health conditions that would interfere with normal feeding. From this cohort we enrolled a sub-sample of 54 mother/infant dyads in the spring of 2011 to evaluate factors affecting maternal and infant stress. This sample size was dictated by available funding.

To participate in the sub-study, infants had to be between 0 and 12 months of age and mothers had to agree to a home visit and had to be willing to collect saliva samples from themselves and their infants the following day. We mailed a letter of invitation to a random sample of 200 NEST women whose infants met the age criterion for inclusion. We enrolled the first 54 women who called the study coordinator in response to the letter and were willing to participate in the sub-study. We conducted home visits with each mother/infant dyad to implement the assessments; visits lasted approximately 1.25 h. Mothers provided written informed consent for their participation and that of their infants. This research was conducted in accord with prevailing ethical principles; the institutional review board of Duke University Medical Center approved this study and its protocol.

2.2. Exposure – breastfeeding status

Mothers reported their breastfeeding status through a questionnaire completed at the home visit. We categorized dyads as full breastfeeding (breastfeeding only, no formula, $n = 13$), any breastfeeding (a combination of some human milk and some formula, $n = 7$), or formula feeding (no human milk, $n = 34$) at the time of assessment. We did not distinguish between feeding human milk via bottle or breast; both were considered breastfeeding. To differentiate infants who were receiving any human milk and those who received formula

exclusively, we compared full or any breastfeeding ($n = 20$) to formula-feeding ($n = 34$) dyads.

2.3. Outcome – salivary cortisol

We provided both verbal and written instructions and supplies for mothers to guide the salivary cortisol collection. We asked mothers to collect three saliva samples from themselves and three from the infant over the course of a single day, documenting the time of day each sample was collected, and any potential problems with the collection. Mothers collected samples upon waking, 30 min after waking, and at bedtime. Infant sample collection involved absorbing a small amount of saliva from the back of the mouth with a sorbette (Salimetrics, State College, PA, USA), placing it in a sterile plastic tube, and then immediately in the refrigerator. Mothers were instructed to wait until after the first morning saliva collection to feed infants, and to rinse and wipe their infants' mouths prior to the second morning collection. Mothers collected their own samples via a 2-min passive drool method deposited directly into a sterile plastic tube. We requested that mothers avoid lotions, makeup, toothpaste and brushing their teeth, food, and beverages prior to the collection and to refrain from cigarette smoking on the day of the collection. They were also instructed to wait at least 60 min after eating dinner or consuming caffeine before collecting the bedtime sample. This protocol is consistent with other studies examining changes in cortisol throughout the day in adults and children (Geoffroy, Côté, Parent, & Séguin, 2006; Vermeer & van Ijzendoorn, 2006). Mothers stored saliva samples in their home refrigerators until a study team member returned to retrieve the samples (median time to pick up was 36.2 h), after which they were taken to the Biobehavioral Laboratory at the University of North Carolina at Chapel Hill and stored at -80 until analysis.

For analysis, samples were thawed and assayed for salivary cortisol using a high sensitivity salivary cortisol enzyme immunoassay kit (Salimetrics, State College, PA, USA). The samples were assayed in duplicate. The criteria for repeated testing were variation between duplicates of greater than 15%, and the average of the duplicates was used in all analysis. Intra-assay and inter-assay coefficients of variations were 2.5% and 5.7%, respectively.

2.4. Other measures

During the home visit, trained data collectors measured maternal weight and infant length and weight. We measured maternal weight to the nearest hundredth of a kilogram via an electronic portable scale (Tanita BWB-800, Arlington Heights, IL, USA) using standard protocol (Shorr, 1986). Mothers reported their height and pre-pregnancy weight. We calculated body mass index by dividing weight in kilograms by height in meters squared. For infants, we measured recumbent length to the nearest hundredth of a centimeter with a Shorr infant measuring board (Shorr Productions, Olney, MD, USA). We measured weight to the nearest hundredth of a kilogram with a Seca model 874 portable electronic scale (Seca Corporation, Columbia, MD, USA). We converted weight-for-length values to sex-specific z-scores based on the 2000 Centers for Disease Control and Prevention growth chart reference, used as a continuous variable (Kuczmarski et al., 2000; Shorr, 1986).

Mothers also completed questionnaires at the time of enrollment in NEST and during the home visit to assess infant age, race (white, black, other), and ethnicity (Hispanic/Latino(a) or not), maternal pre-pregnancy body mass index (weight in kilograms divided by height in meters squared), race (white, black, other), ethnicity (Hispanic/Latina or not), education (high school degree, some college or technical degree, college or graduate degree), and relationship status (single, married/partner); and family income (<\$25,000, \$25,000–49,999, \$50,000/year).

2.5. Analysis

We examined Spearman correlations between maternal and infant cortisol levels at three time points across the day to assess whether the relationship differed by breastfeeding status. We then used linear regression models to examine maternal cortisol levels in relation to overall mean infant cortisol, and at each time point, for the entire sample. Finally, we repeated the linear regression models, stratified by breastfeeding status, to assess associations between maternal and infant cortisol among breastfeeding and formula-feeding dyads. We included infant sex, infant race, maternal education, and household income as covariates in all regression models. Because salivary cortisol levels showed a skewed distribution, we log transformed cortisol for all regression analyses. We report unadjusted estimates of Spearman's rho, regression coefficients representing adjusted associations between maternal and infant cortisol, corresponding 95% confidence intervals (CI), and *p* values. We conducted all analyses using SAS version 9.2 (SAS Institute, Cary, NC, USA) with a 0.05 significance level.

3. Results

We found that 37% ($n = 20$) of infants in the study were partially (some human milk, $n = 7$) or fully (human milk only, $n = 13$) breastfed (Table 1). Household income and maternal education were both higher among breastfed infants (63.2% vs. 43.8% with household income >\$50,000/year and 80.0% vs. 58.8% of mothers had a college or graduate degree). More breastfed than formula-fed infants were white (70.0% vs. 47.1%). The mean (standard deviation) age was 8.1 (2.2) months for formula-feeding infants and 8.2 (2.1) months for breastfeeding infants. Breastfed infants had 0.5 lower weight-for-length *z*-scores than formula-fed infants (−0.2 vs. 0.3).

Fifty-one of the mothers and 52 of the infants had usable cortisol data for at least one time point. Awakening samples were collected, on average, at 7:27 a.m. (range 4:50 a.m.–11:28 a.m.) for infants and at 7:15 a.m. (range 4:40 a.m.–11:28 a.m.) for mothers. Samples collected 30 min after waking were collected, on average, at 8:04 a.m. (range 5:30 a.m.–11:58 a.m.) for infants and at 7:51 a.m. (range 5:10 a.m.–11:40 a.m.) for mothers. Bedtime samples were collected, on average, at 9:05 p.m. (range 6:20 p.m.–11:30 p.m.) for infants and at 9:52 p.m. (range 6:00 p.m.–12:30 a.m.) for mothers. Mother and infant sampling times were highly correlated for the waking and 30 min after waking times, but not for the bedtime sample times. We did not expect bedtime sample time to be correlated because we instructed mothers to obtain the sample at their own bedtimes, rather than at the time they put their infants to bed.

Dyads were excluded from analysis for any time point in which either the mother or the infant did not have cortisol data, but were included in the overall models based on the mean of the useable samples. We included samples that were taken up to 45 min from waking. For mothers, there were two samples taken between 35 and 45 min after waking and for infants there were eight samples taken between 35 and 45 min after waking. We first conducted sensitivity analyses to see if our results changed after excluding the samples. As results did not change, we included these samples in analyses. We did exclude one sample (mother) that was taken four hours after waking, and this sample was excluded from analyses. We also excluded three women from all regression models due to missing covariate data.

Cortisol levels were slightly higher in breastfed infants than formula-fed infants for all three time points, although the differences were not statistically significant (Table 2). Maternal mean cortisol levels for breastfeeding mothers were similar to those of formula-feeding mothers as well (Table 2).

Overall, mother and infant cortisol levels were positively correlated at bedtime (unadjusted Spearman's $\rho = 0.41$, $p < 0.007$). This association remained significant in multivariable regression models (regression estimate 0.06; 95% CI: 0.10, 1.1; $p = 0.02$) (Table 3). To assess the influence of maternal education and household income on the association, we conducted the multivariable regression analyses with and without these variables. With maternal education excluded (adjusting for infant sex, race, age, and household income), results mirrored those of the adjusted model presented in Table 3 (regression estimate 0.6; 95% CI: 0.10, 1.1; $p = 0.02$). However, with household income excluded (adjusting for infant sex, race, age, and maternal education) the results were similar to the unadjusted results (regression estimate 0.7; 95% CI: 0.20, 1.1; $p = 0.004$ vs. regression estimate 0.6; 95% CI: 0.20, 0.90; $p = 0.004$).

Among breastfeeding dyads, cortisol levels were again positively correlated at bedtime in unadjusted analyses (Spearman $\rho = 0.59$, $p = 0.02$) and adjusted models (regression estimate 0.10; CI: 0.10–2.0; $p = 0.04$) (Table 4). Cortisol levels were not correlated at any of the three time points for formula-feeding dyads in either unadjusted or adjusted analyses. However, there was a suggestion for an inverse association in adjusted analyses between formula-feeding dyads at time 2, but this was not statistically significant (regression estimate -0.5 ; CI: -1.2 , 0.1 ; $p = 0.09$).

4. Discussion

In this study examining cortisol levels of mothers and their infants, we found significant positive associations within dyads at bedtime but not for the two morning assessments. Our data also suggest that these associations may be stronger among breastfeeding mothers and infants, since we observed significant associations between breastfeeding, but not formula-feeding dyads. In previous studies of mothers and infants, cortisol levels were correlated throughout the day (Bright et al., 2011; Middlemiss et al., 2012; Spangler, 1991; Stenius et al., 2008), including in the morning. However, these relationships were found among primarily breastfeeding or mixed feeding (some breastfeeding) dyads with differing demographics from our sample. Specifically, both Stenius et al. (2008) and Spangler (1991)

conducted their studies in primarily white European populations. Additionally, Bright et al. (2011) assessed a predominately white (88%) and highly educated population (all mothers had at least some college education). Thus, the racial and socio-economic demographic composition of our sample, combined with feeding status, may contribute to the differences between our findings and those from these previous studies. However, a recent study by Clearfield et al. (2014) comparing low SES and high SES dyads provides some additional context for our findings. They observed no synchrony in the low SES dyads throughout the day and a significant correlation in the evening assessment only for the high SES dyads. In their study, low SES was defined as a household income at or below 185% of the Federal Poverty Level and high SES was defined by maternal educational attainment of “some college or more” (Clearfield et al., 2014). Similarly in our study, 85% of breastfeeding mothers reported completing some college or more. Since breastfeeding and educational attainment are correlated, these factors could be influencing the synchrony we observed. However, although mean cortisol levels for breastfed infants were higher for all three time points assessed, we did not observe significant differences in mean cortisol levels by feeding status, whereas Clearfield et al. did observe differences when comparing dyads by SES.

A number of other factors could also influence the associations we found. Previous studies have hypothesized a direct transfer of cortisol from mother to baby via human milk (Bright et al, 2011; Patacchioli et al., 1992; Stenius et al., 2008), however the literature examining the transfer or mechanisms of hormonal action via human milk is relatively sparse and inconclusive (Bernt & Walker, 1999; Nemsadze & Silagava, 2010; Tharner et al., 2012; Tu, Lupien, & Walker, 2005; Zanardo et al., 2001). In our study, mothers were instructed to wait until after the first saliva collection before feeding their infants. If cortisol were passed through human milk, we would expect to see higher correlations between breastfeeding mothers and their infants at the second collection that occurred 30 min after waking, since this collection likely took place sometime after feeding. However, since we were not able to measure cortisol levels in human milk, it is difficult to assess the extent to which a biological transfer plays a role.

It could also be that the relationship between maternal and infant cortisol may be driven more by environmental factors and not by the transfer via human milk. Specifically, the increased physical interactions that occur as a result of breastfeeding appear to play a substantial role. Greater skin-to-skin contact that occurs between breastfeeding dyads and is known to affect the synchrony of infant cortisol levels (Mörelus et al, 2012) may explain the synchrony we observed. In addition, we know that shared environment contributes to greater cortisol synchrony among dyads. This could explain the correlations we observed in the evening levels if breastfeeding dyads spent more time interacting closely throughout the day. Despite a number of potential pathways, the association between breastfeeding dyads at the bedtime assessment only warrants additional study. Results from our exploratory work should help guide future research examining cortisol synchrony.

There are some limitations to this study. First, we did not collect saliva samples directly from mothers and infants. Instead, we instructed mothers to collect their own samples and samples from their infants. We did not employ any tactics to remind mothers to collect the samples or include objective assessments to track when samples were collected, such as

bottle cap timers or sensors. We relied on maternal documentation to report the time of collection for each sample, which may be less reliable. We provided instructions for mothers to collect saliva samples upon waking for both themselves and their infants. We did not, however, ask mothers to wake their children to collect samples or report how they knew their infants were awake. Some infants could have woken without their mother's knowledge, so the first morning sample collection may have been delayed by some undetermined amount of time. We also measured cortisol via saliva and not serum. A strong positive correlation between salivary and serum cortisol has been reported in the research literature, but saliva has the advantages of eliminating stress associated with a blood draw and enabling research study participants to collect samples themselves in the home environment (Al-Ansari, Perry, Smith, & Landon, 1982; Calixto, Martinez, Jorge, Moreira, & Martinelli, 2002; Chou et al., 2011; Gallagher, Leitch, Massey, McAllister-Williams, & Young, 2006; Jessop & Turner-Cobb, 2008; Woodside, Winter, & Fisman, 1991; Woolston, Gianfredi, Gertner, Paugus, & Mason, 1983). A familiar environment is especially important when evaluating cortisol levels in infants (Bober et al., 1988).

Second, we were not able to formally compare partially breastfeeding dyads to exclusively breastfeeding dyads due to the older age of infants in our sample (mean age was just over 8 months) and the limited sample size. While our sample size is comparable to similar studies (Bright et al., 2011; Middlemiss et al., 2012; Spangler, 1991; Stenius et al., 2008), we stratified our analyses by breastfeeding status, which decreased our sample size per group, and then adjusted for covariates, which decreased our power to detect differences even further. We did, however, conduct exploratory analyses examining the two groups separately. We did not observe differences in correlations between maternal and infant cortisol levels of partially compared to fully breastfeeding dyads. A younger sample of infants and a larger overall sample of dyads would have allowed us to compare infants receiving both formula and human milk to exclusively breastfed and exclusively formula-fed infants. Finally, infant cortisol samples collected by mothers may be imperfect. Although we instructed mothers to wait until the first morning sample was collected before feeding their infants, and then to rinse and wipe the baby's mouth before the second sample was collected, this may not have happened. Feeding infants either human milk or formula prior to collecting saliva may contaminate the sample (Magnano, Diamond, & Gardner, 1989). Additionally, we did not ask if mothers were providing human milk exclusively through the breast or a bottle, which may be an important consideration for future studies.

We also did not collect information on whether mothers spent the day with their infants, or whether infants spent time that day in some form of child care. We did not ask mothers if the assessment was conducted on a typical day, although we did ask them to report any unusual events, such as illness. We also do not have specific details about the frequency or timing of feedings for the group of mothers who were partially breastfeeding. This information could prove useful when considering correlations in those dyads throughout the day. Despite these limitations, this study provides new information on associations between maternal and infant cortisol, especially among women who were not breastfeeding their infants.

We do note that in our study, breastfed infants had higher mean levels of salivary cortisol at each of the three time points, compared to formula-fed infants. This finding is consistent

with Cao et al. (2009) who found that cortisol levels were considerably higher in breastfed infants than in formula-fed infants. Additionally, we did not observe a cortisol awakening response among breastfed or formula-fed infants. This finding is consistent with previous studies that have found variability in the development of the circadian rhythm in the first year of life (Antonini, Jorge, & Moreira, 2000; Bright et al, 2011; de Weerth, Zijl, & Buitelaar, 2003; Groschl, Rauh, & Dorr, 2003). In fact, we observed a slight decrease in mean cortisol level in both groups of infants over the course of the day. However, the lack of a cortisol awakening response is possible if mothers were late collecting the first morning sample.

5. Conclusions

Our findings indicate that maternal and infant salivary cortisol levels were not correlated in the morning – especially among formula-feeding dyads. Mother and infant cortisol levels were, however, positively correlated at bedtime, but this association was likely driven by breastfeeding dyads. Given the importance of breastfeeding, future studies should examine these research questions in larger samples of both breast- and formula-feeding dyads, and include measures throughout infancy to assess longitudinal associations of maternal and infant cortisol.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Demographic characteristics of the 54 mother/infant dyads participating in the Newborn Epigenetics Study (NEST) study.

	Formula-feeding dyads (<i>n</i> = 34)	Breastfeeding dyads (<i>n</i> = 20)
Maternal characteristics	Mean (SD)	
Prepregnancy body mass index, weight kg/height m ²	27.9 (8.0)	26.0 (7.0)
	<i>N</i> (%)	
Single parent	6 (17.6)	3 (15.0)
Race		
White	17 (50.0)	15 (75.0)
Black	15 (44.1)	4 (20.0)
Asian/Pacific Islander	2 (5.9)	1 (5.0)
Hispanic/Latina	0 (0.0)	1 (5.0)
Education		
High school degree	9 (26.5)	3 (15.0)
Some college or technical degree	5 (14.7)	1 (5.0)
College or graduate degree	20 (58.8)	16 (80.0)
Annual household income		
<\$25,000	11 (32.4)	2 (10.0)
\$25,000–49,999	9 (26.5)	5 (25.0)
>\$50,000	14 (41.1)	13 (65.0)
Infant characteristics	Mean (SD)	
Age, months	8.1 (2.2)	8.2 (2.1)
Weight-for-length z-score	0.3 (2.8)	−0.2 (1.5)
	<i>N</i> (%)	
Sex, female	15 (44.1)	9 (45.0)
Race		
White	16 (47.1)	14 (70.0)
Black	15 (44.1)	6 (30.0)
Asian/Pacific Islander	3 (8.8)	0 (0.0)
Hispanic/Latino(a)	1 (2.9)	1 (5.0)

Table 2

Mean (standard deviation) cortisol levels ($\mu\text{g/dl}$) for mothers and infants at each time point.

	Mean (SD)		<i>p</i> value
	Formula-feeding dyads (<i>n</i> = 34)	Breastfeeding dyads (<i>n</i> = 20)	
Mothers			
Awakening	0.39 (0.16)	0.35 (0.27)	0.86
30 min after waking	0.45 (0.17)	0.38 (0.19)	0.81
Bedtime	0.07 (0.07)	0.08 (0.10)	0.81
Infants			
Awakening	0.59 (0.87)	0.75 (1.23)	0.55
30 min after waking	0.46 (0.54)	0.61 (1.03)	0.64
Bedtime	0.29 (0.45)	0.35 (0.67)	0.48

Table 3

Multivariable adjusted^a regression estimates (95% Confidence Interval) for mean change in infant cortisol per 1 µg/dl increase in maternal cortisol at each point time and all time points combined.

	Change in mean infant cortisol	
	Estimate (95% CI)	<i>p</i> value
Awakening (<i>n</i> = 48)	0.3 (−0.2, 0.8)	0.25
30 min after waking (<i>n</i> = 47)	−0.1 (−0.6, 0.4)	0.55
Bedtime (<i>n</i> = 40)	0.6 (0.1, 1.1)	0.02
All time points combined (<i>n</i> = 50)	0.2 (−0.4, 0.8)	0.50

^a Adjusted for infant sex, race, age, maternal education, and family income.

Table 4

Multivariable adjusted^a regression estimates (95% Confidence Interval) for mean change in infant cortisol per 1 µg/dl increase in maternal cortisol at each point time and all time points combined by breastfeeding status.

	Formula-feeding dyads (<i>n</i> = 34)		Breastfeeding dyads (<i>n</i> = 20)	
	Estimate (95% CI)	<i>p</i> value	Estimate (95% CI)	<i>p</i> value
Awakening	0.2 (−0.7, 1.2)	0.62	0.3 (−0.4, 0.9)	0.37
30 min after waking	−0.5 (−1.2, 0.1)	0.09	0.3 (−0.6, 1.3)	0.41
Bedtime	0.6 (−0.1, 1.3)	0.10	1.0 (0.1, 2.0)	0.04
Overall	−0.1 (−0.9, 0.7)	0.77	0.8 (−0.1, 1.8)	0.08

^a Adjusted for infant sex, race, age, maternal education, and family income.