Sleep Arrangements and Night Waking at 6 and 12 Months in Relation to Infants' Stress-induced Cortisol Responses

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The objective of this short-term longitudinal study was to examine the concurrent and prospective associations of infants’ sleep arrangements and night waking with cortisol responses to an inoculation at 6 and 12 months, controlling for several key covariates. To our knowledge, this was the first study to concurrently and prospectively link proximity in sleep arrangements and night waking to physiological stress reactivity. A sample of 92 mother–infant dyads participated in the study when the infants were 6 and 12 months of age, although sample sizes were reduced for some analyses. Both proximal cosleeping arrangements and more frequent night wakings’ were associated concurrently with an increased cortisol response to inoculations at both ages. Night waking at 6 months also was associated with a slightly increased cortisol response to inoculation at 12 months. Results aimed at exploring the direction of influence suggested that cosleeping and night waking may influence infant stress physiology rather than the reverse. Adaptive and maladaptive implications of infants’ nocturnal experiences and greater stress-induced cortisol responses are discussed. Copyright © 2009 John Wiley & Sons, Ltd.

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Of increasing interest to researchers and parents are the ways in which the family environment shapes children’s abilities to regulate their responses to future stressors. The current study focused on an important, understudied and often controversial aspect of infants’ family environment—infant sleep arrangements—in relation to physiological stress responses. We also examined infant night waking, a commonly used measure of sleep quality (El-Sheikh, Buckhalt, Keller, Cummings, & Acebo, 2007; Sadeh, 2004), which is sometimes related to cosleeping (e.g. DeLeon & Karraker, 2007). In this study, we asked whether the extent of proximity in sleep arrangements and the frequency of night waking are associated with infant stress responses.

Infant sleep arrangements were considered on a continuum of proximity from bedsharing to roomsharing to solitary sleeping. Sleep arrangements differ in many respects; among the most obvious is the close physical proximity of the parent. In proximal sleep arrangements, the parent is nearby to respond more quickly should the infant waken during the night and signal for parental assistance to meet needs for food, comfort or help in returning to sleep. Indeed, many infants awaken during the night, typically one to three times a night during the first year (Anders, Halpern, & Hua, 1992; Goodlin-Jones, Eiben, & Anders, 1997). By 1 year, most, but not all, infants return to sleep on their own (Goodlin-Jones & Anders, 2004).

Cosleeping, an umbrella term that covers both bedsharing and roomsharing (McKenna, 2000), is an increasingly common practice in the United States (Willinger, Ko, Hoffman, Kessler, & Corwin, 2003) and has long been common internationally (Latz, Wolf, & Lozoff, 1999; Lee, 1992). However, cosleeping has been criticized for overinvolving parents and contributing to infants’ interrupted sleep (France, Blampied, & Henderson, 2003). Little is known about the consequences of interrupted sleep at night for infants’ functioning the next day, but disrupted sleep causes children and adolescents to be sleepy and function more poorly during the day (Goodlin-Jones & Anders, 2004; Sadeh, 2007). Solitary sleeping is often recommended by paediatricians and other sleep experts in the United States as a technique to promote the acquisition of self-soothing behaviours during infancy and as a means of fostering consolidation of sleep (Ferber, 2006; Meltzer & Mindell, 2006).

Understanding the associations of sleep experiences with infant stress reactivity is important for several reasons. Most notably, greater cortisol peaks after exposure to a stressor may represent overactivation of the hypothalamic-pituitary–adrenocortical (HPA) axis, which has been associated with decreases in later immune functioning (Wilson, Megel, Fredrichs, & McLaughlin, 2003) and memory (see Heffelfinger & Newcomer, 2001, for a review). Overactivation of the HPA system is also believed to be a risk marker for later behavioural, physiological and psychological problems (Boyce & Jemerin, 1990). From this perspective, a pattern of heightened physiological responses to stress during infancy might be expected to have negative consequences for children’s health and development. Although little empirical data exist to support connections between sleep arrangements and infants’ physiological stress responses, arguments can be mounted in support of greater and lesser physiological reactivity in relation to cosleeping.

Theoretical support for a pattern of lesser physiological reactivity as a result of cosleeping comes from attachment theory and the value it places on proximity to
caregivers. From this perspective, proximity to the parent (typically measured during the day) is important when the fear-wariness system becomes activated; at these times, the infant seeks closeness and/or contact with a caregiver who provides comfort and functions as a secure base (Ainsworth, Blehar, Waters, & Wall, 1978). Proximity to and ‘refuelling’ at the secure base serve to regulate infants’ behavioural and emotional responses to stressors in the environment. We suggest that proximity to the parent at night might be important for the infant, too, as it may minimize infants’ felt stress. The importance of proximity in the attachment paradigm led us to posit that infant sleep arrangements characterized by nearness to the parent may facilitate prompt and contingent responsiveness during the night and be manifest in less stress reactivity during the day. An additional reason to expect that cosleeping may be associated with lower activation of the HPA axis comes from the evidence that, in early infancy, proximity to the mother’s body seems to help regulate the neurologically immature infant’s body temperature, breathing, arousal patterns, sleep architecture and possibly cortisol levels (McKenna, 2000).

The results of a retrospective study (Waynforth, 2007) support an association between cosleeping and lesser physiological reactivity, indicating that current levels of cortisol produced throughout the day for children between the ages of 3 and 8 years were significantly lower for children who had previously slept in the same room with their parents for at least 2 years. These findings are intriguing; however, prospective, longitudinal data are necessary to examine the association between sleep arrangements and cortisol levels. In addition, bedsharing should be considered apart from roomsharing, as these types of sleep arrangements differ in proximity to the parent. Although combining these two arrangements is consistent with the umbrella use of the term cosleeping, the association between sleep arrangements and cortisol levels may depend on whether infants sleep next to the parents in the same bed rather than simply in the same room.

Although the studies cited above link cosleeping with dampened physiological reactivity, there also are reasons to expect the opposite pattern, that is, cosleeping and greater physiological reactivity. Evidence for this position primarily comes from work examining the link between cosleeping and arousal during sleep. Compared with solitary sleepers, bedsharing infants engage in less deep sleep and more light sleep, have more frequent periods of awakening (e.g. DeLeon & Karraker, 2007; Mindell, 1997; Richard & Mosko, 2004) and have greater sensitivity to environmental stimuli (Richard & Mosko, 2004). Although the direction of association between bedsharing and level of infant arousal is not always clear (e.g. Richard, 1999), this literature suggests that cosleeping infants may have higher levels of overall arousal and greater physiological reactivity.

The research discussed thus far supports a meaningful association between sleep arrangements and physiological arousal and reactivity, and suggests that an important explanatory variable is arousal during sleep. To date, however, there is no direct evidence for links among cosleeping, night waking and HPA activation when infants are exposed to a stressful event. Therefore, the current study examined the associations between sleep arrangements, frequency of night waking and infants’ physiological response to an inoculation.

The aim of our investigation was to understand the associations of sleep arrangements and night waking with physiological reactivity, controlling for variables that might confound these associations. In particular, we explored the role of temperament, obstetric risk and demographic characteristics. Compared with infants with easy temperamental characteristics, infants with difficult
temperamental characteristics are more likely to bedshare than sleep on their own (Hayes, Parker, Sallinen, & Davare, 2001), as well as have more sleep problems, including more night waking (Burnham, Goodlin-Jones, Gaylor, & Anders, 2002; Sadeh & Anders, 1993). Temperament is also related to cortisol: infants and young children with difficult temperamental characteristics show elevated basal cortisol levels (Kagan, Reznick, & Snidman, 1987; Schmidt et al., 1997) as well as greater cortisol reactivity (Gunnar, Larson, Herstgaard, Harris, & Brodersen, 1992; Gunnar, Mangelsdorf, Larson, & Hertsgaard, 1989; Zimmermann & Stansbury, 2004). Because our sample was drawn from a longitudinal study of the effects of prenatal stress on development, we added a control variable that indicated the presence of obstetric risk factors. As we had a diverse sample and others have reported cultural differences in rates of cosleeping (e.g. Schachter, Fuchs, Bijur, & Stone, 1989), we also controlled for demographic variables, including ethnicity, education and family income.

The evidence discussed previously suggests that sleep disruptions and arrangements may predict physiological stress functioning. However, it is possible that stress hormones influence both sleep patterns and sleep quality; indeed, there is experimental evidence from human and animal research for this causal direction (see Steiger, 2002, for a review). It is also possible that parents are responding to infant characteristics, such as temperament or sensitivity to environmental stimuli, and that these infant characteristics contribute to differences in infant physiological reactivity. Therefore, another objective of the present study was to investigate other potential relations between sleep arrangements and infant physiology. To do so, we first examined the reasons that parents chose their family’s sleep arrangement, and whether child-driven versus parent-driven reasons were associated with the main variables of interest. We then tested the potential connections of early physiological and sleep characteristics with later sleep arrangements. These analyses should help us understand the potentially bidirectional associations between sleep and stress physiology. The longitudinal design of this study allowed us to explore whether sleep measures and stress physiology at 6 months were associated with sleep arrangements at 12 months.

**The Current Study**

The primary goal of the current short-term longitudinal study was to examine the associations among sleep arrangements, night waking and infants’ stress-induced cortisol responses, and to determine whether these associations remained significant after controlling for infant temperament, obstetric risk and demographic factors such as ethnicity. Infant responses to an inoculation were studied during a well-baby exam, a naturally occurring, externally valid setting to study cortisol reactivity in infants (e.g. Gunnar, Brodersen, Krueger, & Rigatuso, 1996; Ramsay & Lewis, 1994). It has been noted that with age, infants’ behavioural and physiological responses to stressors are dampened and during the second year of life, many healthy infants do not display a cortisol increase in response to stressors such as inoculations (Gunnar, 2006). Therefore, we examined infants’ responses to inoculations at 6 and 12 months. Additionally, the nascent literature on cosleeping and cortisol (Waynforth, 2007) has utilized retrospective reports of cosleeping. We utilized a prospective, longitudinal design in order to avoid problems of retrospective reports and to better address questions of how sleep arrangements are related to stress physiology at different points in infancy.

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Research Objectives

(1) The first research objective was to examine concurrently infant sleep arrangements and night waking in relation to physiological stress responses at 6 and 12 months. We asked whether proximity in sleep arrangements and frequency of night waking were significantly associated with greater or lesser cortisol reactivity to a stressful procedure (i.e. inoculation). Because sleep arrangements and arousal during sleep are closely related, we included potential interactions between sleep arrangements and frequency of night waking.

(2) The second objective was to address the relations of sleep arrangements and night waking with cortisol responses over time. We asked whether sleep arrangements, night waking and cortisol responses at 6 months were associated with greater or lesser cortisol reactivity to an inoculation at 12 months. We again examined potential interactions between sleep arrangements and frequency of night waking.

(3) The third objective was to examine the possibility that characteristics of the young infant contribute to later sleep arrangements. We first examined the reasons families chose different sleep arrangements, and then asked whether sleep arrangements, night waking and cortisol responses at 6 months were associated with sleep arrangements at 12 months.

METHOD

Participants

Ninety-two \(^1\) mothers were drawn from a prospective, longitudinal study of the effects of prenatal psychosocial and neuroendocrine stress on foetal and infant development, conducted at the medical centre of a large university. Sample sizes for some analyses were reduced due to missing data or exclusions made to protect the integrity of the cortisol data (e.g. extreme values, infants fed immediately prior to a saliva sample). Mothers’ age ranged from 19 to 44 years (\(M = 30.28, S.D. = 5.11\)). There were 49 boys (53\%) and 43 girls (47\%). The sample was ethnically diverse: 52\% of the 86 mothers who provided this information were non-Hispanic European American \((n = 48)\), 22\% were Hispanic American \((n = 20)\), 10\% were Asian/Asian American \((n = 9)\) and 10\% were from other ethnic groups \((n = 9)\), which included mothers of African American, Middle-Eastern, Asian Indian/Pakistani, Native American and mixed heritage backgrounds. With respect to educational level, more than half of the mothers had less than a 4-year college degree (63\%; \(n = 58\)). The median family income fell in the range of $70 000–$80 000 annually. Most mothers (90\%) were either married or living with the infants’ biological father.

To be eligible for the larger study that recruited mothers during the prenatal period, women needed to be over 18 years old with a singleton intrauterine pregnancy, English speaking, free of endocrine, hepatic or renal disorders and have a normal uterus and cervix. Additional criteria were that the women did not smoke or use alcohol or drugs and did not use corticosteroid medications. Two infants born at younger than 36.5 weeks gestation (27.5 and 24.5 weeks) were excluded from the analyses; four infants who were between 36.5 and 37 weeks gestation at birth were included because they were stable at birth with Apgar scores equal to or greater than 9 and were admitted to the well-baby nursery (not to the Neonatal Intensive Care Unit).
**Procedure**

Following Institutional Review Board approval, women came to the laboratory for pre- and postnatal assessments. Mothers provided demographic information (including education, ethnicity, income and employment) at their first prenatal lab visit (14–16 weeks gestation). At 6- and 12-month postpartum assessments, mothers completed questionnaires about their infant’s sleep arrangements, feeding and temperament. Also at an average of 6 and 12 months postpartum, a research assistant attended a paediatric well-baby visit at which a caregiver (usually the mother) was present and the infant was scheduled to receive an inoculation. Saliva samples were collected for cortisol analysis prior to and 20 min following the inoculation.

**Measures**

**Demographic information**

At their first prenatal visit, mothers provided information about their ethnicity, educational attainment, family income and marital status. Ethnicity was represented as non-Hispanic European American, Hispanic American, Asian American and other (including African American, Native American and multiethnic). Marital status was represented as not married/living with partner (0) or married/living with partner (1). After birth, a dichotomous variable was also used to represent infant sex (0 = male, 1 = female). Maternal education (8 levels ranging from 'less than high school' to 'a graduate degree') and family income (12 levels ranging from 'under $5000' to ‘over $100 000’) were coded as ordinal variables.

**Obstetric risk**

Medical interviews and maternal and infant medical records were the sources of information about pregnancy history and risk factors that might affect birth outcomes. The risk factors considered were infection, hypertension, diabetes, oligohydramnios, polyhydramnios, preterm labour, vaginal bleeding, placenta previa and anaemia. A dichotomous variable was created to assess the presence or absence of obstetric risk (0 = no risk factors; 1 = one or more risk factors). Seventy-two percent of infants had no obstetric risk; 25% had one or more obstetric risk factors (obstetric risk data were not available for 3% of infants).

**Infant temperament**

Maternal reports of infants’ temperament at 6 and 12 months of age were assessed using the Pictorial Assessment of Temperament (PAT): Infant Version (Clarke-Stewart, Fitzpatrick, Allhusen, & Goldberg, 2000). The PAT presents the parent with 10 vignettes that portray possible infant responses to potentially distressing situations (e.g. loud noise, wash cloth to face). The response scale ranged from 1 to 3 and yields a single, continuous score of temperamental difficulty using a mean score for 9 of the 10 items (a sleep-related item was omitted for these analyses). Higher scores reflected a more ‘difficult’ child, with the construct of difficulty including negative mood, lack of approach to strangers, slow adaptability to change and high intensity of emotional expression (Carey & McDevitt, 1978). The PAT measure has established reliability and validity and has been shown to work well both as a current and retrospective account of temperament (Clarke-Stewart et al., 2000; Germo, Goldberg, & Keller, 2009).
Sleep arrangements

The Sleep Practices Questionnaire (SPQ; Keller & Goldberg, 2004) was the primary measure of each family’s sleep practices. This questionnaire has been used successfully to gain insight into a number of sleep-related issues (e.g. Germo, Chang, Keller, & Goldberg, 2007). Information about sleep arrangements and the reasons for various sleep locations were used for the current study. At the 6- and 12-month assessments, respondents were asked to identify their child’s usual sleep arrangement within the past month. Possible responses at each age included: ‘own room all night’, ‘parents’ bed all night’, ‘next to parents’ bed all night/cosleeper unit’, ‘across the room/crib in parents’ bedroom all night’ and ‘part of the night in parents’ bed and part of the night in own room’.

New to this study, a sleep arrangement variable was created that represented relative proximity or physical closeness to parents while sleeping (see also Hayes, Fukumizu, Troese, Sallinen, & Gilles, 2007). Solitary sleepers had the most distal sleep arrangement, as they were reported to sleep in their own room all night (6 m: 38%, n = 33; 12 m: 54%, n = 47). Part-night bedsharers/roomsharers were intermediate in terms of proximity to parents during the night. Infants in this group either shared the parents’ bed for part of the night or slept across the room in the parents’ bedroom for the full-night (6 m: 18%, n = 16; 12 m: 17%, n = 15). Full-night bedsharers had the most proximal sleep arrangements: these infants shared the parents’ bed for all of the night, or slept in a sleeper unit attached to or directly next to the parents’ bed all night (6 m: 35%, n = 30; 12 m: 29%, n = 25).

Two dummy coded sleep variables were created for use in the analyses for which cortisol was the dependent variable. Roomsharing/part-night bedsharing and full-night bedsharing were separately coded as 1 and solitary sleeping was the reference group (0). For the analyses predicting 12-month sleep arrangements, the three-level nighttime proximity to the parents’ variable was the dependent measure, with higher scores representing more proximal sleep arrangements (1 = solitary sleeping, 2 = roomsharing/part-night bedsharing, 3 = full-night bedsharing).

Reasons for sleep arrangements

At 6 and 12 months, mothers were asked to endorse relevant reasons for their family sleep arrangements. Some reasons were parent-centred (e.g. ‘More convenient for me’) and others were child-centred (e.g. ‘My infant slept better’). To address study hypotheses, we focused on the two main child-centred reasons to explore the relation between such reasons and the main variables of interest. A three-level variable was created: no child reasons indicated (6 m: n = 33; 12 m: n = 22), either child reason indicated (6 m: n = 43; 12 m: n = 57) or both child reasons indicated (6 m: n = 5; 12 m: n = 10).

Night waking

Infant arousal during sleep was operationalized as the frequency of night waking in the past month, based on maternal report at 6 and 12 months. Mothers reported on the frequency that their infant woke during the night (did not or rarely awoke, woke one or two times a night, woke three or more times a night). Very few mothers reported that their infants woke three or more times per night (6 m: n = 8; 12 m: n = 7); therefore, for the current study, a dichotomous night waking variable was calculated: a value of 0 was assigned if mothers reported that their infants, on average, did not or rarely woke during the night; a value of 1 was assigned if mothers reported that their infants, on average, woke one or more times per night.
To validate the maternal report of night waking, 10 mother–infant pairs from the larger study agreed to participate in a substudy that involved nocturnal audiography recording and sleep diaries. Infant nocturnal wakings for one night were analysed using Adobe Audition Software. Maternal reports of whether or not the infant woke did not differ significantly from audiographic readings of night waking lasting 1 min or more (Fisher’s exact \(p = 0.20\), ns).

**Infant cortisol response to inoculation**

A baseline salivary cortisol sample was collected from infants in the waiting room soon after their arrival at the paediatrician’s office. During both the 6-month and 12-month visit, a nurse administered an inoculation by injection in the infant’s thigh while infants were on their back on the exam table restrained by their mother and nurse. Caregiver behaviour was not constrained after the inoculation. Twenty minutes after the injection, a second cortisol sample was collected from infants; this time frame allowed for the detection of the peak cortisol response in most infants (e.g. Ramsay & Lewis, 1994). Because reactivity was measured at naturally occurring doctors’ visits scheduled at the families’ convenience, time of day was recorded and included in the statistical analyses to control for the circadian cortisol rhythm that is present even in infants (e.g. Spangler, 1991).

Saliva was obtained (without any stimulant) by placing a swab in the infant’s mouth. The swab was then placed in a saliva extraction tube (Roche Diagnostics). Saliva samples were spun and stored at \(-20^\circ\text{C}\) until assayed. Thawed samples were centrifuged at 3000 rpm for 15 min before assay. Salivary cortisol levels were determined by a competitive luminescence immunoassay (LIA; IBL-America, Minneapolis, MN) with reported detection limits of 0.015 \(\mu\text{g/dl}\). The cross reactivity of the assay was <2.5% with cortisone, prednisone and corticosterone and <0.1% with other naturally occurring steroids. The intra- and inter-assay coefficients of variance were 5.5% and 7.6%, respectively. Data reduction for the LIA assay was done by an automated four-parameter logistics computer program (software Mikro Win 2000; Berthold Microplate Luminometer). All samples were assayed in duplicate and averaged.

The distribution of each cortisol measurement at each age was examined for outlying values; values that were greater than 3 S.D. away from the mean were excluded from analyses (6-m baseline, \(n = 1\); 6-m reactivity, \(n = 3\); 12-m baseline, \(n = 2\); 12-m reactivity, \(n = 4\)). In addition, three infants were excluded from further analysis because they were fed immediately before the collection of the first saliva sample at either the 6- or 12-month inoculation. An additional four participants were missing sleep arrangements data at 6 months. Therefore, analyses utilizing 6-month cortisol and sleep arrangements data were based on a sample of 72 and analyses utilizing 12-month cortisol and sleep arrangements data were based on a sample of 80 infants. After the exclusion of the outlying values, the distribution of each cortisol sample remained positively skewed (skewness/S.D. >6.7); thus, the cortisol values utilized in the analyses were transformed using a log-10 transformation.

**Data analytic plan**

First, descriptive information was obtained about sleep arrangements at 6 and 12 months, as well as change in sleep arrangements between the two ages. Second, bivariate correlations and chi-square analyses were conducted to determine whether demographic and medical variables needed to be controlled in the main analyses (in addition to temperament, obstetric risk and time of day, which were...
controlled for in all main analyses). Additionally, average cortisol levels at 6 months were controlled for in the analyses predicting 12-month cortisol responses. Generalized estimating equations (GEE) models were then used to examine the three research objectives. GEE models are a regression-based, non-parametric and appropriate approach to examine repeated measures (e.g. Ballinger, 2004; Zeger, Liang, & Albert, 1988) and produce more efficient and unbiased estimates when data are correlated than ANOVA-based models (e.g. Zeger & Liang, 1986). To test for differences in cortisol reactivity (change in cortisol levels from pre- to post-inoculation) based on bedsharing, roomsharing and night waking, interactions between cortisol sample (pre- versus post-inoculation) and each independent variable were tested sequentially.

RESULTS

Means and standard deviations of the major study variables by sleep arrangement are presented in Table 1.

Stability in Sleep Arrangements

Relative stability was found in infants’ sleep location between 6 and 12 months ($\chi^2 = 41.79, p < 0.001$). Ninety-four per cent of the solitary sleepers at 6 months were solitary sleepers at 12 months; only 6% of infants who slept alone all night at 6 months were later reported to be part-night bedsharers/roomsharers. Of those who were full-night bedsharers at 6 months, 57% remained full-night bedsharers at 12 months; 23% were reported at 12 months to be solitary sleepers and 20% were reported to be part-night bedsharers/roomsharers. Of those who were part-night bedsharers/roomsharers at 6 months, 38% were reported to have the same sleeping arrangement at 12 months, 38% were reported at 12 months to be full-night bedsharers and 24% were reported to be solitary sleepers.

Although for most families there was relative stability in sleep arrangements between the two ages, 26 families reported changes from 6 to 12 months: of these, 9 families made a shift to a more proximal sleep arrangement and 17 families made a shift to a less proximal sleep arrangement. To understand why some families made a change between the two ages, we tabulated the reasons reported by mothers for choosing the sleep arrangement practised by their family at 12 months. Mothers who made a change to a more proximal sleep arrangement most commonly indicated that they choose their 12-month sleep arrangement because it allowed for better sleep for themselves or their partner, it was more convenient for them and/or they had a desire to be and feel closer to their infants. Perhaps most importantly, only a third of mothers who changed to a more proximal sleep arrangement indicated that they choose their family’s sleep arrangement because of characteristics of the infant (e.g. the infant slept better). Mothers who made a change to a less proximal sleep arrangement cited a number of the same reasons. The most commonly indicated reasons that these mothers choose their less proximal 12-month sleep arrangement were because it allowed for better adult sleep, it was more convenient, it made them feel closer to their infant, it made feeding easier and/or it seemed safer for the infant. Slightly less than half of mothers who made a change to a less proximal sleep arrangement indicated that their family’s sleep arrangement was selected because of characteristics of the infant (e.g. the infant slept better).
Table 1. Means (and standard deviations) of cortisol (nmol/l) values by sleep arrangement and night waking (6 m n = 72; 12 m n = 80)

<table>
<thead>
<tr>
<th>6-month sleep arrangements</th>
<th>12-month sleep arrangements</th>
<th>6-month night waking</th>
<th>12-month night waking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solitary sleepers</td>
<td>Part-night bedsharers/roomsharers</td>
<td>Full-night bedsharers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-month Raw cortisol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-inoculation</td>
<td>8.68 (9.17)</td>
<td>7.08 (7.86)</td>
<td>12.79 (22.13)</td>
</tr>
<tr>
<td>Post-inoculation</td>
<td>13.62 (9.38)</td>
<td>22.99 (47.73)</td>
<td>15.66 (22.35)</td>
</tr>
<tr>
<td>6-month Log-transformed cortisol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-inoculation</td>
<td>0.79 (0.34)</td>
<td>0.63 (0.58)</td>
<td>0.82 (0.45)</td>
</tr>
<tr>
<td>Post-inoculation</td>
<td>1.05 (0.27)</td>
<td>1.03 (0.48)</td>
<td>0.99 (0.39)</td>
</tr>
<tr>
<td>12-month Raw cortisol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-inoculation</td>
<td>5.61 (3.99)</td>
<td>6.57 (4.44)</td>
<td>7.44 (5.55)</td>
</tr>
<tr>
<td>Post-inoculation</td>
<td>10.04 (9.58)</td>
<td>11.65 (8.94)</td>
<td>12.64 (10.03)</td>
</tr>
<tr>
<td>12-month Log-transformed cortisol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-inoculation</td>
<td>0.66 (0.28)</td>
<td>0.73 (0.33)</td>
<td>0.77 (0.30)</td>
</tr>
<tr>
<td>Post-inoculation</td>
<td>0.84 (0.39)</td>
<td>0.92 (0.39)</td>
<td>0.99 (0.31)</td>
</tr>
</tbody>
</table>
Stability in Night Waking

In terms of night waking, across sleep arrangements, 63% of infants were reported to wake one or more times per night at 6 months; by 12 months, this proportion dropped to 49%. Night waking was not significantly associated with sleep arrangements at either 6 months ($\chi^2 = 5.35, p = 0.07$) or 12 months ($\chi^2 = 1.25, p = 0.57$). Most of the less frequent night wakers at 6 months were solitary sleepers (57%); 10% were roomsharers/part-night bedsharers and 33% were full-night bedsharers. The greatest proportion of frequent night wakers at 6 months was full-night bedsharers (41%); another 33% were solitary sleepers and 26% were roomsharers/part-night bedsharers. Most of the less frequent night wakers at 12 months were solitary sleepers (73%); 9% were roomsharers/part-night bedsharers and 18% were full-night bedsharers. At 12 months, 35% of the more frequent night wakers were solitary sleepers, 39% were roomsharers/part-night bedsharers and 26% were full-night bedsharers.

Potential Control Variables

Zero-order correlations between major study variables are presented in Table 2. Infant sex, family income, maternal education and child-centred reasons for sleep arrangements were significantly associated with cortisol or sleep arrangements at 6 or 12 months and therefore were included as covariates in subsequent analyses. Based on chi-square analyses, ethnicity was significantly associated with sleep arrangements at 6 months ($\chi^2 = 42.43, p < 0.001$) and at 12 months ($\chi^2 = 27.87, p < 0.001$). At both ages, the majority of non-Hispanic European American infants were solitary sleepers (6 m: 57%, 12 m: 69%); a minority was full-night bedsharers (6 m: 18%, 12 m: 18%) or roomsharers/part-night bedsharers (6 m: 25%, 12 m: 13%). A similar distribution was demonstrated by participants who were characterized as ‘Other’ (solitary 6 m: 42%, 12 m: 56%; bedsharers 6 m: 43%, 12 m: 33%; roomsharers 6 m: 14%, 12 m: 14%). The majority of participants of other ethnicities were full-night bedsharers (Hispanic American 6 m: 69%, 12 m: 47%; Asian American 6 m: 78%, 12 m: 44%) as compared with roomsharers/part-night bedsharers (Hispanic American 6 m: 19%, 12 m: 26%; Asian American 6 m: 0%, 12 m: 33%) or solitary sleepers (Hispanic American 6 m: 13%, 12 m: 26%; Asian American 6 and 12 m: 22%).

At both ages, ethnicity was also significantly associated with night waking (6 m: $\chi^2 = 14.09, p = 0.003$; 12 m: $\chi^2 = 10.33, p = 0.016$). At the 6-month assessment, night waking was least common among non-Hispanic European American infants (i.e. less frequent night wakers = 61%; more frequent night wakers = 39%), followed by Asian American infants (less frequent night wakers = 56%; more frequent night wakers = 44%) and finally Hispanic American infants (less frequent night wakers = 44%; more frequent night wakers = 56%). All of the participants classified as ‘Other’ were described by their mothers as more frequent night wakers. At the 12-month assessment, more non-Hispanic European Americans were more frequent night wakers (60%) than were less frequent night wakers (40%). For the rest of the participants, a greater percentage of infants were described as more frequent night wakers (Hispanic American: 58%; Asian American: 78%; other: 56%) than as less frequent night wakers (Hispanic American: 42%; Asian American: 22%; other: 44%).

Because differences in baseline cortisol levels have been found in relation to infant state following a car trip (e.g. Larson, Gunnar, & Hertsgaard, 1991), zero-order correlations were conducted to determine whether infant state in the car...
Table 2. Zero-order correlations among study variables (6 m \( n = 74 \); 12 m \( n = 80 \))

<table>
<thead>
<tr>
<th>Major study variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 6-month Proximity of sleep arrangement&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>×</td>
<td>0.65***</td>
<td>0.17***</td>
<td>0.44***</td>
<td>0.03</td>
<td>-0.08</td>
<td>0.16</td>
<td>0.19&lt;sup&gt;+&lt;/sup&gt;</td>
<td>0.06</td>
<td>0.14</td>
<td>0.11</td>
<td>0.04</td>
<td>0.05</td>
<td>-0.08</td>
<td>-0.44***</td>
<td>-0.27*</td>
</tr>
<tr>
<td>2. 12-month Proximity of sleep arrangement&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>×</td>
<td>0.06</td>
<td>0.34**</td>
<td>-0.14</td>
<td>0.02</td>
<td>0.24*</td>
<td>0.19&lt;sup&gt;+&lt;/sup&gt;</td>
<td>0.11</td>
<td>0.17</td>
<td>0.04</td>
<td>0.09</td>
<td>-0.04</td>
<td>0.02</td>
<td>-0.28**</td>
<td>-0.25*</td>
<td></td>
</tr>
<tr>
<td>3. 6-month Night waking (0 = no night waking)</td>
<td>×</td>
<td>0.20&lt;sup&gt;+&lt;/sup&gt;</td>
<td>0.27*</td>
<td>0.10</td>
<td>-0.10</td>
<td>-0.10</td>
<td>-0.06</td>
<td>0.09</td>
<td>0.15</td>
<td>-0.07</td>
<td>0.08</td>
<td>-0.32**</td>
<td>-0.19&lt;sup&gt;+&lt;/sup&gt;</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. 12-month Night waking (0 = no night waking)</td>
<td>×</td>
<td>-0.11</td>
<td>-0.03</td>
<td>-0.05</td>
<td>-0.33**</td>
<td>0.08</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.14</td>
<td>0.04</td>
<td>-0.11</td>
<td>-0.20&lt;sup&gt;+&lt;/sup&gt;</td>
<td>-0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. 6-month Pre-inoculation cortisol levels&lt;sup&gt;c&lt;/sup&gt;</td>
<td>×</td>
<td>0.46***</td>
<td>0.20&lt;sup&gt;+&lt;/sup&gt;</td>
<td>0.25*</td>
<td>-0.29**</td>
<td>-0.04</td>
<td>0.03</td>
<td>0.14</td>
<td>0.26*</td>
<td>0.08</td>
<td>0.08</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. 6-month Post-inoculation cortisol levels&lt;sup&gt;c&lt;/sup&gt;</td>
<td>×</td>
<td>0.01</td>
<td>0.33**</td>
<td>-0.24*</td>
<td>-0.03</td>
<td>-0.01</td>
<td>0.04</td>
<td>0.25*</td>
<td>0.04</td>
<td>-0.01</td>
<td>0.26*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. 12-month Pre-inoculation cortisol levels&lt;sup&gt;c&lt;/sup&gt;</td>
<td>×</td>
<td>0.29**</td>
<td>-0.09</td>
<td>-0.16</td>
<td>-0.17</td>
<td>0.23*</td>
<td>0.08</td>
<td>0.25*</td>
<td>-0.08</td>
<td>-0.04</td>
<td>0.26*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Variable                                                                 | Coefficient | SE | p Value  
|--------------------------------------------------------------------------|-------------|----|----------|
| 8. 12-month Post-inoculation cortisol level<sup>c</sup>                  | × 0.31**     | 0.07 | <0.01  
| 9. Obstetric risk                                                        | × 0.18      | 0.11 | <0.14  
| 10. 6-month Temperament                                                  | × 0.47***   | 0.11 | <0.04  
| 11. 12-month Temperament                                                  | × 0.03      | 0.04 | <0.10  
| 12. Child-centred reasons for 6-month sleep arrangement                  | × 0.26*     | 0.15 | <0.04  
| 13. Child-centred reasons for 12-month sleep arrangement                | × 0.21+     | 0.05 | <0.09  
| 14. Infant sex<sup>b</sup>                                               | × 0.35***   |      |         
| 15. Family income                                                        | ×           |      |         
| 16. Maternal education                                                   | ×           |      |         

<sup>a</sup> = solitary sleeping; 1 = part-night bedsharing/roomsharing; 2 = bedsharing.
<sup>b</sup> = male; 1 = female.
<sup>c</sup> = Log-transformed values (nmol/l).
ride to the doctor’s office, as well as 5 min prior to the inoculation, was associated with sleep arrangements, night waking or cortisol. The only significant association was at the 6-month visit: state 5 min prior to the inoculation was significantly associated with pre-inoculation cortisol levels \((r = -0.26, p = 0.018)\). Therefore, this state variable was controlled for in all of the 6-month cortisol analyses.

Based on the findings concerning potentially confounding variables, GEE analyses to address the association of sleep arrangements and night waking with infant cortisol reactivity controlled for time of day, obstetric risk and infant temperament as well as infant sex, family income, maternal education and ethnicity (dummy coded with non-Hispanic European American as the reference group). State prior to the inoculation was controlled for in only the 6-month analyses; for the 12-month analyses only, average cortisol levels at 6 months and child-centred reasons for sleep arrangement were included as controls.

**Sleep Arrangements, Night Waking and Cortisol Responses at 6 Months**

We first examined whether concurrent associations were evident between infant sleep arrangements, night waking and physiological stress responses at the 6-month inoculation. Results indicated that two of the control variables were significantly associated with cortisol levels: time of day and ethnicity (see Table 3). Specifically, cortisol levels were lower later in the day (relative to earlier in the day). In addition, Hispanic Americans had significantly higher cortisol levels than non-Hispanic European Americans.

There was also a main effect of cortisol sample (pre- versus post-inoculation). Specifically, post-inoculation cortisol levels were significantly higher than pre-inoculation levels. With regard to cortisol levels and the major study variables, there was no significant main effect of sleep arrangements or night waking, nor was there a significant interaction of bedsharing or roomsharing/part-night bedsharing with night waking.

However, the interactions between cortisol sample and each independent variable were significant, indicating that cortisol reactivity differed depending on the frequency of night waking and sleep arrangement. The interaction between cortisol sample and night waking is shown in Figure 1. Infants who woke more frequently at night had a greater cortisol increase in response to the inoculation than infants who woke less frequently at night; less frequent night wakers had similar cortisol levels both pre- and post-inoculation. The interactions between cortisol sample and each of the two dummy coded variables for sleep location (i.e. bedsharing versus solitary sleeping; roomsharing/part-night bedsharing versus solitary sleeping) are also displayed in Figure 1. Infants in both cosleeping arrangements had greater cortisol responses to the inoculation than solitary sleepers, who had similar cortisol levels both pre- and post-inoculation.

**Sleep Arrangements, Night Waking and Cortisol Responses at 12 Months**

We next examined whether concurrent associations were evident between infant sleep arrangements, night waking and physiological stress responses at the 12-month inoculation. None of the control variables were significantly associated with cortisol levels at 12 months, with the exception of average cortisol levels at the 6-month inoculation (see Table 3). Specifically, average cortisol levels at 6 months were positively associated with cortisol levels at 12 months.
Table 3. Generalized estimating equations (GEEs) examining the association between cortisol, sleep location and night waking at 6 months (n = 72) and 12 months (n = 80)

<table>
<thead>
<tr>
<th>predictor</th>
<th>Unstandardized estimate (S.E.)</th>
<th>Unstandardized estimate (S.E.)</th>
<th>Unstandardized estimate (S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1: 6-month cortisol, predictors at 6 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cortisol samplea</td>
<td>0.24 (0.05)</td>
<td>0.24 (0.05)</td>
<td>0.23 (0.05)</td>
</tr>
<tr>
<td>Bedsharing (0 = solitary sleeping)</td>
<td>−0.04 (0.08)</td>
<td>0.09 (0.06)</td>
<td>0.06 (0.07)</td>
</tr>
<tr>
<td>Roomsharing/part-night bedsharing (0 = solitary sleeping)</td>
<td>0.05 (0.10)</td>
<td>−0.08 (0.07)</td>
<td>0.06 (0.08)</td>
</tr>
<tr>
<td>Night waking (0 = no night waking)</td>
<td>0.13 (0.08)</td>
<td>0.07 (0.05)</td>
<td>0.04 (0.06)</td>
</tr>
<tr>
<td>Time of day</td>
<td>−0.03 (0.01)*</td>
<td>−0.02 (0.01)*</td>
<td>−0.01 (0.01)</td>
</tr>
<tr>
<td>Temperament</td>
<td>−0.01 (0.11)</td>
<td>−0.03 (0.10)</td>
<td>−0.11 (0.09)</td>
</tr>
<tr>
<td>Infant genderb</td>
<td>0.12 (0.07)</td>
<td>0.09 (0.05)*</td>
<td>0.15 (0.06)*</td>
</tr>
<tr>
<td>Family income</td>
<td>0.03 (0.02)†</td>
<td>−0.005 (0.01)</td>
<td>−0.01 (0.01)</td>
</tr>
<tr>
<td>Hispanic American</td>
<td>0.28 (0.10)**</td>
<td>0.10 (0.08)</td>
<td>0.07 (0.08)</td>
</tr>
<tr>
<td>Asian American</td>
<td>0.08 (0.11)</td>
<td>0.13 (0.08)</td>
<td>0.15 (0.09)*</td>
</tr>
<tr>
<td>Other</td>
<td>0.09 (0.11)</td>
<td>−0.04 (0.08)</td>
<td>−0.05 (0.09)</td>
</tr>
<tr>
<td>Maternal education</td>
<td>0.002 (0.002)</td>
<td>0.0007 (0.001)</td>
<td>0.002 (0.001)</td>
</tr>
<tr>
<td>Obstetric risk of pregnancy</td>
<td>−0.14 (.09)</td>
<td>−0.06 (0.06)</td>
<td>0.02 (0.08)</td>
</tr>
<tr>
<td>Infant state 5 min prior to inoculation</td>
<td>0.004 (.003)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Model Wald χ²</td>
<td>48.59***</td>
<td>66.51***</td>
<td>56.64***</td>
</tr>
<tr>
<td>Night waking × cortisol sample</td>
<td>0.55 (0.02)**</td>
<td>0.60 (0.02)**</td>
<td>0.12 (0.06)*</td>
</tr>
<tr>
<td>Bedsharing × cortisol sample</td>
<td>0.89 (0.09)**</td>
<td>0.84 (0.12)**</td>
<td>0.11 (0.11)</td>
</tr>
<tr>
<td>Roomsharing/part-night bedsharing × cortisol sample</td>
<td>0.82 (0.17)**</td>
<td>0.77 (0.17)**</td>
<td>0.001 (0.11)</td>
</tr>
<tr>
<td>Bedsharing × night waking</td>
<td>−0.09 (0.15)</td>
<td>0.08 (0.12)</td>
<td>0.02 (0.12)</td>
</tr>
<tr>
<td>Roomsharing × night waking</td>
<td>−0.19 (0.29)</td>
<td>−0.38 (0.15)*</td>
<td>0.55 (0.21)*</td>
</tr>
</tbody>
</table>

*aPre-inoculation versus post-inoculation cortisol.
*b0 = male; 1 = female.
*cReference group is non-Hispanic European American.
There was a significant main effect of cortisol sample. As was evidenced at the 6-month inoculation, cortisol levels were significantly higher post-inoculation relative to pre-inoculation. There was no significant main effect of sleep arrangements or night waking, nor was there a significant interaction between bedsharing and night waking. However, there were significant interactions of cortisol sample with night waking as well as each sleep arrangement. There was also a significant interaction between roomsharing/part-night bedsharing and night waking at 12 months.

The interaction of cortisol sample with night waking and each sleep arrangement indicated that cortisol reactivity differed depending on the frequency of night waking and the type of sleep arrangement. As was the case at 6 months, infants who woke more frequently at night had greater cortisol increases in response to the inoculation than infants who had less interrupted sleep (see Figure 2). Twelve-month-old infants who woke less frequently at night had similar cortisol levels both pre- and post-inoculation. In addition, at 12 months, both bedsharers and roomsharers/part-night bedsharers had greater cortisol responses to the inoculation than solitary sleepers (see Figure 2).

Displayed in Figure 3 is the significant interaction between roomsharing/part-night bedsharing and night waking at 12 months. Roomsharing/part-night bedsharing infants who reportedly woke less frequently had lower cortisol levels than roomsharing/part-night bedsharing infants who woke more frequently. For solitary sleeping infants, the pattern was the opposite: cortisol responses were lower for more frequent night wakers compared with less frequent night wakers.

**Sleep and Cortisol Variables at 6 Months and Cortisol Responses at 12 Months**

Our next objective was to understand the relations of sleep arrangements and night waking with cortisol responses over time. To do so, we tested whether sleep...
arrangements or night waking at 6 months predicted cortisol levels at 12 months (see Table 3). Two control variables were significantly associated with cortisol levels: infant gender and average cortisol levels at the 6-month inoculation. Specifically, females had significantly higher overall cortisol levels than males and higher cortisol levels at the 6-month inoculation were associated with higher cortisol levels at the 12-month inoculation.

Consistent with the previous analyses, there was a significant main effect of cortisol sample such that cortisol levels were higher post- relative to pre-inoculation. There were no significant main effects of sleep arrangement at
6 months or night waking at 6 months on 12-month cortisol levels, nor were there significant interactions between bed- or roomsharing and cortisol sample or between bedsharing and night waking.

A significant interaction was evident between roomsharing/part-night bedsharing and night waking (see Figure 3). For infants who were roomsharers/part-night bedsharers at 6 months, 12-month cortisol responses were similar regardless of whether they woke more or less frequently at 6 months. For infants who were solitary sleepers at 6 months, 12-month cortisol responses were higher if they woke less frequently at night. There was also a trend-level interaction between night waking at 6 months and cortisol sample (see Figure 2). More frequent night wakers displayed slightly greater cortisol responses to the inoculation than less frequent night wakers.

Sleep and Cortisol Variables at 6 Months in Relation to 12-month Sleep Arrangements

The third and final objective of this study was to examine the possibility that characteristics of the young infant contributed to later sleep arrangements. Specifically, we conducted analyses to determine whether the sleep and cortisol variables at 6 months were related to sleep arrangements at 12 months. The dependent variable was the three-level variable for nighttime proximity to the parents at 12 months (1 = solitary sleeping, 2 = roomsharing/part-night bedsharing, 3 = full-night bedsharing). Predictors included 6-month night waking, the dummy coded sleep arrangement variables at 6 months (bedsharing and roomsharing/part-night, with solitary sleeping as the reference group) and average cortisol levels at 6 months. Control variables included temperament at 6 months, time of day, obstetric risk, infant sex, family income, ethnicity and maternal education.

Results indicated that sleep arrangements at 6 months were significantly associated with the proximity of the sleep arrangement at 12 months. Specifically, relative to solitary sleeping, both bedsharing (coefficient = 1.20, S.E. = 0.19, \( p < 0.001 \)) and roomsharing/part-night bedsharing (coefficient = 1.29, S.E. = 0.21, \( p < 0.001 \)) at 6 months were associated with more proximal sleep arrangements at 12 months. There were no significant main effects for any of the other variables.

However, a significant interaction emerged between roomsharing/part-night bedsharing and night waking. Infants who were solitary sleepers at 6 months had a more proximal sleep arrangement at 12 months if they were reported to wake less frequently at 6 months. In contrast, infants who were roomsharers/part-night bedsharers at 6 months had less proximal sleep arrangements at 12 months if they woke less frequently at 6 months; they had more proximal sleep arrangements at 12 months if they were reported to wake more frequently at 6 months.

DISCUSSION

The current, short-term longitudinal study was designed to examine whether there were differences in infant cortisol reactivity in relation to the controversial childrearing practice of cosleeping as well as to infants’ night waking. To date, little has been known about the links between various sleep arrangements and infants’ physiological arousal during the day. This is the first study to have
prospectively examined relations among sleep arrangements, night waking and cortisol responses at two points during infancy. The results of the current study provided evidence that night waking was associated with cortisol reactivity both concurrently and prospectively; sleep arrangements were associated with cortisol reactivity concurrently at both time points.

Interestingly, greater reactivity was demonstrated by infants who shared a bed with parents, shared a room with parents or woke more frequently at night. At 6 and 12 months, relative to solitary sleeping, sleep arrangements that afforded more proximity to the parent, including both bedsharing and roomsharing, were associated with greater cortisol reactivity in response to the inoculation. These analyses controlled for the frequency of night waking, suggesting that interrupted sleep is not the mechanism by which cosleeping is associated with a greater physiological stress response (discussed more fully below).

Longitudinal analyses from 6 to 12 months did not support an association between either of the cosleeping arrangements and reactivity differences. Although there was relative stability in sleep arrangements, for some families there was a change in sleep arrangements between the two time points. Perhaps the difference in the cross-sectional and longitudinal associations between sleep arrangements and cortisol indicates that cosleeping may be associated with short-term differences in reactivity that may not persist over time.

A consistent finding in both concurrent and longitudinal analyses was that infants who woke more frequently (one or more times) at night had greater cortisol reactivity in response to the inoculation than infants who woke less frequently (not at all or rarely) at night. To our knowledge, this was the first study to link sleep arrangements and sleep disruption in infancy to stress-induced cortisol responses. Our study specifically focused on the frequency of night waking. Of note, this non-clinical sample of infants did not wake up often enough to allow use of a continuous measure of infant night waking. To fully understand the experience of nocturnal awakening, future research should study samples that include more frequent night wakers, utilize a continuous measure of night waking and include measures of the intensity and duration of night waking in relation to infant cortisol responses. The current study relied on maternal reports of night waking. These maternal reports were validated on a subsample of families; there is also evidence for high agreement between maternal report and actigraphy measurements for some sleep variables (e.g. Sadeh, 2004). However, future research should include multiple measures of night waking to more fully understand how it is related to infant stress responses.

When bedsharing is characterized as a sleep problem, it is often because of its association with frequent and prolonged night waking as well as the assumption that night waking is problematic for parents and infants even though not all parents perceive them this way (Gaylor, Burnham, Goodlin-Jones, & Anders, 2005; Goldberg & Keller, 2007). In the existing literature (e.g. DeLeon & Karraker, 2007; Mindell, 1997), bedsharing is associated with more awakenings during sleep. However, the results of our study, based on a community sample, did not consistently point to more night waking among cosleepers. Our results indicated that night waking and sleep arrangements were each independently associated with cortisol reactivity, controlling for the effect of the other sleep variables. In addition, some of the results suggest a complex interaction between roomsharing and night waking. Taken together, the results of this study speak to the importance of not confounding these two measures of the infants’ sleep experience.

The pattern of greater physiological sensitivity to stressors displayed by infants who participate in cosleeping arrangements and who wake more frequently
at night raises the possibility that these infants will later display the behavioural, physiological and psychological problems associated with sustained, heightened cortisol reactivity (Boyce & Jemerin, 1990). It is important to note that some research suggests that by the second year of life infants enter a relative ‘hypo-responsive’ period, whereby average increases in cortisol in response to stressors are not evident (e.g. Gunnar & Donzella, 2002). In our study, in general, less frequent night wakers and solitary sleepers fit this pattern, and did not display cortisol increases in response to the inoculation. However, more frequent night wakers and cosleepers demonstrated stress responsiveness during the first year of infancy. If this pattern does not abate as the child ages, there may be potentially negative consequences in multiple domains of development (e.g. Boyce & Jemerin, 1990).

We emphasize that our findings do not necessarily demonstrate maladaptive activation of the HPA axis. The infants with increased reactivity could be showing an adaptive response as they mount the resources they need to manage challenges. In this way, small, elevated cortisol levels may not mean a failure to cope adequately with a stressor, but instead may signal a child’s adaptive cognitive and behavioural functioning (Sapolsky, 1997). Acute stress responses can be adaptive and can promote survival through the responses of neural, cardiovascular, autonomic, immune and metabolic systems (McEwen, 2008). Whether or not the pattern of increased reactivity is adaptive or maladaptive may also depend on how long the elevated stress response persists as well as contextual influences. Recovery from stressors is an understudied yet essential aspect of the adaptiveness of the stress response (e.g. Linden, Earle, Gerin, & Christenfeld, 1997; Stewart & France, 2001). When reactivity is followed by an adaptive recovery, it may actually enhance the functioning of the stress system (Bugental, 2004; McEwen, 1998). In addition, high stress reactivity may confer health benefits under conditions of high support, whereas negative health effects may result under adverse conditions (Ellis & Boyce, 2008).

Future research might include aspects of contextual support, such as maternal sensitivity and security of attachment. There is evidence that maternal sensitivity during a stressor may influence infant cortisol reactivity (e.g. Gunnar et al., 1992). Although maternal behaviour was not restricted after the inoculation, during the inoculation mothers restrained their babies with the help of the nurse. Because cortisol levels reflect events approximately 15–20 min prior (e.g. Ramsay & Lewis, 1994), variation in maternal sensitivity would more likely affect infant recovery rather than reactivity. However, future research would benefit by measuring maternal sensitivity during the stressful task. An additional limitation of the present study that should be addressed by future research is the reliance on only two cortisol measurements. In particular, the ‘baseline’ or pre-inoculation cortisol sample was taken at the doctor’s office; there are suggestions that infant cortisol taken after a car ride may be lower than normal (e.g. Gunnar & Donzella, 2002; Larson et al., 1991). We aimed to address this limitation by examining bivariate associations between the main variables of interest and infant state prior to the inoculation, and controlling for this variable when necessary. Future research should measure cortisol multiple times before the stressor, particularly when the infant is still at home.

Another issue to be addressed in future research is whether infants who wake frequently at night or who practise cosleeping continue to display a pattern of increased cortisol reactivity. In general, overall night waking decreases with age; however, some ‘problem’ sleepers continue to wake during the night into childhood (e.g. Gaylor et al., 2005; Goodlin-Jones, Sitnick, Tang, Liu, & Anders, 2008). It is
unclear whether differences in reactivity are demonstrated once infants no longer cosleep or as night waking decreases with age. The results of a recent retrospective study with somewhat older children suggest that these associations may be temporary: children who had coslept for at least 2 years since birth had lower cortisol levels throughout the day than children who had not participated in such earlier sleep arrangements (Waynforth, 2007). Further follow-up of our sample is needed to determine whether early sleep arrangements and sleep disruptions have long-term consequences for children’s stress functioning.

The results from this study indicate that aspects of sleep architecture and the family environment during infancy are linked to greater cortisol reactivity to stressful procedures. There are several possible explanations for the greater reactivity to inoculations displayed by bedsharers, room sharers and more frequent night wakers. Cosleeping infants are more likely to engage in less deep and more light sleep than solitary sleepers (e.g. DeLeon & Karraker, 2007; Mindell, 1997; Richard & Mosko, 2004). To the extent that proximal sleep arrangements and night waking degrade sleep quality, infants who cosleep and who wake more at night may have a compromised level of functioning during the day and, therefore, have greater stress-induced cortisol responses. This line of reasoning is consistent with evidence that older children who have interrupted sleep function more poorly the next day (Goodlin-Jones & Anders, 2004). A pattern of greater reactivity could also reflect sensory differences in sleep arrangements, which then produce physiological differences in infants (e.g. Richard & Mosko, 2004).

It is also plausible that differences in cortisol reactivity are leading to differences in sleep characteristics (e.g. Steiger, 2002), although we did not find support for this direction of influence in our study. Exploratory analyses revealed that 12-month sleep arrangements were not associated with cortisol variables at 6 months. There may be individual differences in physiological sensitivity to environmental stimuli that make infants wake more frequently at night as well as more physiologically sensitive to the inoculation. Parents may also respond to individual differences in infant sensitivity when choosing sleep arrangements. Therefore, infant characteristics such as temperament or sensitivity to environmental stimuli may actually be driving parent choices about sleep arrangements as well as affecting infant night waking and physiological reactivity. However, exploratory analyses did not support this direction of influence in our study. Families who changed sleep arrangements between 6 and 12 months gave similar reasons for their sleep arrangements, regardless of whether they moved to a more or less proximal sleep arrangement. There were also few bivariate associations between child-centred reasons for sleep arrangements and sleep arrangements, night waking or infant cortisol. In addition, the relations of sleep arrangements and night waking with infant stress physiology remained after controlling for temperament (and, when significant at the bivariate level, the presence of child-centred reasons for sleep arrangements). However, future research should more fully explore the possibility that other infant characteristics influence sleep arrangements, sleep quality and reactivity. Consistent with an epigenetic systems view (e.g. Gottlieb, 1991), there are likely multiple as well as bidirectional pathways linking sleep characteristics and stress physiology.

CONCLUSION

The present prospective, short-term longitudinal study aimed to examine the associations among sleep arrangements, night waking and stress-induced
physiological responses during infancy. Results indicated that more frequent night wakers and cosleepers displayed greater cortisol reactivity to an inoculation. The findings show that there are important associations between nighttime sleep behaviours and heightened HPA activity among infants during their first year of life. Although chronic HPA overactivation may have long-term adverse effects on later adjustment, differences in reactivity during infancy could be temporary and adaptive in the short term.

Notes

1. Sample sizes vary due to missing data.
2. There were no significant differences in cortisol levels or reactivity ($F < 0.038$, $p > 0.85$) or night waking ($t < -0.85$, $p > 0.41$) between part-night bedsharers and roomsharers. Therefore, as both groups represent a moderate degree of infant–parent proximity at night, the two groups were combined.

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