Night awakening in infancy: Developmental stability and longitudinal associations with psychomotor development

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Abstract

Fragmented sleep is common in infancy. Although night awakening is known to decrease with age, in some infants night awakening is more persistent and continues into older ages. However, the influence of fragmented sleep on development is poorly known. In the present study, the longitudinal relationship between fragmented sleep and psychomotor development (Bayley-III) was investigated in infants with (≥3 night awakenings, *n* = 81) and without fragmented sleep (≤1 night awakening, *n* = 70) within the CHILD-SLEEP birth cohort at eight and 24 months of age. Differences in parent-reported (BISQ) sleep parameters were studied at eight, 18, and 24 months of age. Group differences in night awakening were stable across all assessment points. Infants with fragmented sleep slept less in total than infants without fragmented sleep and they did not compensate their nocturnal sleep during daytime. Additionally, infants with fragmented sleep spent more time awake at night than infants without fragmented sleep. However, psychomotor development did not differ between infants with and without fragmented sleep at eight or 24 months of age. Our findings indicate that early-onset fragmented sleep did not have a negative effect on psychomotor development within the first two years despite the differences in sleep length among infants with and without fragmented sleep. In the future, more specific domains of cognitive development and various factors affecting sleep fragmentation should be taken into account when studying the developmental effects of night awakening in infancy.

Keywords: night awakening, fragmented sleep, infancy, psychomotor development, sleep

Introduction

Sleep in early infancy is characterised by fragmented short periods of sleep with several nocturnal awakenings (Dahl, 1996; Hysing et al., 2014). The consolidation of sleep is an important developmental task in infancy, and the number of night awakenings decreases with age (Galland, Taylor, Elder, & Herbison, 2012; Hysing et al., 2014; Palmstierna, Sepa, & Ludvigsson, 2008). Consolidated and self-regulated sleep at night can be achieved during the first year of life (Iglowstein, Jenni, Molinari, & Largo, 2003; Moore & Ucko, 1957). However, as many as 20% to 30% of one-year-old infants continue to have fragmented sleep (Adair, Zuckerman, Bauchner, Philipp, & Levenson, 1992; Mindell, Kuhn, Lewin, Meltzer, & Sadeh, 2006).

Night awakening in infancy

Brief nocturnal awakenings are normative between the sleep cycles (Anders, 1978), and they seem not to be problematic in infants who are able to soothe themselves back to sleep without signalling to their parents (Goodlin-Jones, Burnham, Gaylor, & Anders, 2001; Sadeh, Flint-Ofir, Tirosh, & Tikotzky, 2007; Weinraub et al., 2012). Frequent and prolonged night awakenings in infancy could, however, result in shortened sleep duration and a poorer diurnal rhythm, and relate to pathologically fragmented sleep. Moreover, they may pose major concerns to the parents of infants who signal their awakenings and are not able to soothe themselves back to sleep (Sadeh et al., 2007). This signalling behaviour interrupts parents' sleep and can be experienced as disturbing. Night awakenings are, indeed, one of the major parental concerns and most often reported when parents evaluate their child's quality of sleep (Palmstierna et al., 2008).

The parental and child-related factors that are connected with night awakenings have been widely studied. The parental behaviours associated with frequent night awakening are, for example, breastfeeding, high level of parental involvement when falling asleep, and co-sleeping with the infant (Hysing et al., 2014; Sadeh, Mindell, Luedtke, & Wiegand, 2009; Touchette et al., 2005). In addition, a challenging temperament has been linked to frequent night awakening (Touchette et al., 2005). In the diagnostic criteria of paediatric sleep disorders (American Psychiatric Association, 2013), these conditioning factors are considered to potentially contribute to sleep difficulties although the causal direction between these factors and night awakening is not yet fully clear.

It has been proposed that signalled night awakening in infancy could be a precursor for later sleep difficulties (Goodlin-Jones et al., 2001). Indeed, it has been found that the children who had several night awakenings as infants were at risk of having more night awakenings at the age of 18 months (Hysing et al., 2014) and even at 4-6 years of age (Palmstierna et al., 2008; Tikotzky & Shaashua, 2012). Other studies have also supported the notion that sleep difficulties are rather stable over time (Gregory and O'Connor, 2002; Williams, Berthelsen, Walker, & Nicholson, 2015). Only a few cross-sectional studies have compared infants with frequent or prolonged night awakenings to infants without sleep fragmentation. Infants with fragmented sleep have been found to have more night awakenings, reduced sleep efficiency, and increased time spent awake during the night when measured by actigraphy (Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991; Sadeh et al., 2007). Studies on sleep duration have produced mixed results. Acebo et al. (2005) found that infants with night awakenings compensate for their nocturnal sleep with increased napping during the day, whereas Touchette et al. (2005) found that infants with fragmented sleep appear to sleep less in total. In addition, Sadeh et al. (1991) found no differences in sleep duration between infants with and without sleep fragmentation. Thus, it is not clear whether sleep duration differs in infants with fragmented sleep and how stable these possible influences are.

Night awakening and psychomotor development

Although fragmented sleep is normative for young infants, as a persisting difficulty it could pose a risk to the development of the child and the well-being of the whole family. In general, sleeping difficulties have been related negatively to psychomotor development in cross-sectional and longitudinal studies. In the current paper, psychomotor development refers to a broad definition of development (cf., Cioni & Sgandurra, 2013) including cognitive, language, and motor functioning. Previous studies with school-aged children have associated poorer sleep quality, shorter sleep duration, and sleepiness with diminished school performance (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010). In addition, shorter sleep duration has been associated with lower cognitive functioning and emotional and behavioural problems (Astill, Van der Heijden, Van IJzendoorn, & Van Someren, 2012; Paavonen et al., 2010; Touchette et al., 2007). In pre-term infants and toddlers, more matured sleep has been associated with better cognitive functioning (Gertner et al., 2002; Holditch-Davis, Belyea, & Edwards, 2005; Schwichtenberg, Christ, Abel, & Poehlmann-Tynan, 2016) whereas snoring has been associated with lower cognitive functioning (Piteo, Lushington, Roberts, van den Heuvel et al., 2011; Piteo, Lushington, Roberts, Martin et al., 2011; Suratt et al., 2007). However, studies with healthy, typically sleeping infants have shown mixed results. Questionnaire-based studies focusing on sleep in infancy have not observed correlations between different aspects of sleep and overall cognitive functioning (Bernier, Beauchamp, Bouvette-Yurcot, Carlson, & Carrier, 2013; Bernier, Carlson, Bordeleau, & Carrier, 2010; Mindell & Lee, 2015; Spruyt et al., 2008). Interestingly, Scher et al. (2005), who studied sleep using actigraphy, found in their cross-sectional study that nocturnal awakening and higher proportion of motor activity during sleep were negatively correlated with cognitive functioning in healthy ten-month-old infants. In addition, they found that sleep efficiency, i.e., the proportion of total bed time that was spent asleep was associated with better cognitive functioning. However, few longitudinal studies of parent-reported sleep have provided support for the notion that more matured, night-centred sleep in infancy is associated with better cognitive (Dearing, McCartney, Marshall, & Warner, 2001) and language functioning later in childhood (Dearing et al., 2001; Dionne et al., 2011). The sparse longitudinal studies have not focused on night awakenings in early infancy, although it is one of the major parental concerns during infancy (Palmstierna et al., 2008) and, more importantly, infant sleep is thought to have an essential role in the rapid brain maturation that occurs during the first years of life (Dahl, 1996).

The current study

As a part of the CHILD-SLEEP longitudinal birth cohort (Paavonen et al., 2017), the aim of the present study was to investigate infant night awakening and its connection with psychomotor development at eight and 24 months of age in infants with and without fragmented sleep. Two groups of infants were formed according to the number of night awakenings reported by the parent when the infants were eight months of age. In the waking group, the infants had three or more night awakenings that were signalled to the parents, whereas in the non-waking group the infants had no more than one night awakening requiring parental intervention. We chose to form the groups at the age of eight months because, at this age, sleep transitions towards more night-centred sleep, and nurturing behaviour during the night no longer plays a major role in sleep behaviour.

We had three specific aims; the first aim was to replicate the previous findings regarding the persistence of night awakenings in infancy at eight, 18 and 24 months of age. Secondly, we wanted to clarify the associations between infant night awakening and other parent-reported sleep quality (time spent awake during the night, sleep onset latency and proportion of night-centred sleep) and duration parameters (duration of total, night-time, and daytime sleep). The third aim was to study the differences between infants with and without fragmented sleep in psychomotor development which was measured with Bayley Scales of Infant and Toddler Development (3rd edition, Bayley 2009) at eight and 24 months of age. We used a longitudinal design, a comprehensive measure of psychomotor development, and several parent-reported sleep parameters, all aimed at shedding more light on the contradictory findings concerning early-onset fragmented sleep and its connections with psychomotor development. Based on previous studies (Gregory & O'Connor, 2002; Hysing et al., 2014) concerning our first aim we hypothesised that night awakening would be a persistent problem, continuing to distinguish the two groups of infants at 18 and 24 months of age. Our hypothesis regarding the second aim was that, paralleling findings from previous studies (Hysing et al., 2016; Palmstierna et al., 2006; Acebo et al., 2005; Sadeh et al., 1991; Touchette et al., 2005), infants with fragmented sleep would differ from infants without fragmented sleep in both sleep quality and duration parameters at eight, 18, and 24 months of age. As for the third aim concerning psychomotor development, we hypothesised that there would not yet be differences in psychomotor development at the age of eight months but persistent night awakenings would become related to cognitive development longitudinally, evidenced as lower psychomotor development at the age of 24 months compared with infants without a history of fragmented sleep.

Method

Participants

This study is a part of the CHILD-SLEEP longitudinal birth cohort in which various aspects of sleep in families with newborn children are being investigated (Paavonen et al., 2017). The study protocol of Sleep for Cognitive, Social and Emotional Development (CHILD-SLEEP) was reviewed by Pirkanmaa Hospital District Ethical Committee (ETL-code: #R11032) and Tampere University Hospital Paediatric Unit granted the approval for the study. The present study comprises of 151 Finnish, Caucasian infants (73 girls and 78 boys), who were 7.5–11.5 months of age at the first assessment (mean age = 247 days, SD = 13.6 days) and 22.5–27.5 months of age at the second assessment (n = 128, mean age = 737 days, SD = 20.6 days). An additional three participants were examined but excluded from further analyses due to prematurity (n = 1), a developmental disorder apparent at birth (n = 1), and native language other than Finnish (n = 1). The descriptive statistics of the sample are shown in Table 1.

The sample of this study was recruited from the prevention sub-study of the main cohort, which will be described in detail elsewhere. The sub-study was aimed at preventing sleep problems in infancy, and the sample was based on the randomisation of 50 healthcare centres in Tampere, Finland, into prevention and control healthcare centres (cluster sampling). Altogether, there were 207 infants in the prevention group and 199 infants in the control group. Families in the prevention group received preventive psychoeducation regarding infant sleep development and strategies to support the quality of sleep during the normal well-child visits to the healthcare centre. The psychoeducation was delivered mainly through information brochures. The control group received standard information during the well-child visits.

The infants were recruited to the current study at the age of eight months. A research assistant contacted the families participating in the prevention sub-study (both prevention and control groups) through phone interview and asked the parents how many times their infant typically woke up during the night between 24.00–06.00. If their child woke up three or more times during the night, they were asked to participate in this study. In addition, a control group of infants who slept through the night or woke up no more than once during the night were also asked to participate. In order to form two groups that were clearly distinguishable from each other in the tendency to wake up at night, infants who were waking up twice a night were not recruited to the study. Consequently, at eight months of age, there were 81 infants in the waking group and 70 infants in the non-waking group who agreed to participate in the psychomotor assessment. From these infants, 70 infants from the waking group and 58 infants from the non-waking group returned for the assessment at 24 months. There were no differences between infants who were retained and those who dropped out of the study after the eight-month assessment in Bayley-III subscales (all $p > .05$) whereas the analyses of sleep quality and duration parameters showed that the infants who dropped out slept longer during the day [t (136)= -2.318, $p = .022$], spent less time awake during the night [t (70.138)= 3.423, $p = .001$], and fell asleep quicker [t (46.32)= 3.33, $p = .002$] than the infants who continued in the study.

There were no differences between the waking group and the non-waking group in child- or mother-related features (child age, gender, number of children in the family, or in maternal education); all *p's* > .05. However, the two groups differed on co-sleeping, X^2 (1, n = 124) = 20.16, $p < .001$, breastfeeding, X^2 (1, n = 138) = 12.25, $p = .002$, the infant's ability to fall asleep alone, X^2 (1, n = 138) = 17.66, $p < .001$. Healthcare centre status was marginally significant, X^2 (1, n = 151) = 3.64, $p = .056$ (Table 1). For the analyses, these variables were categorized to aid the interpretation of the results. Co-sleeping was divided into two categories of less than twice in a month and at least weekly co-sleeping with parents. The ability to fall asleep alone was also divided into two categories of the infant being able to fall asleep alone only once in a week or at least once a day. Breastfeeding had three categories with infants being only breastfed, both breastfed and formula fed, and only formula fed. All these variables were gathered at eight months of age. Over half of the infants in the waking group co-slept weekly with their parents (56.5%), whereas in the non-waking group only 7.3% of the infants co-slept on a weekly basis. 69.7% of the infants in the waking group were able to fall asleep alone only once in a week, whereas in the non-waking group 66.1% of the infants were able to fall asleep alone at least once a day. 58.4% of the infants in the waking group were breastfed and 20.8% were formula fed, whereas in the non-waking group 32.8% were breastfed and 47.5% were formula fed. In the waking group, 55.6% of the infants came from prevention healthcare centres, whereas in the non-waking group 40.0% of infants came from prevention healthcare centres.

Study design

This study comprised of two clinical assessments for both groups of children at the age of eight and 24 months. At the beginning of the eight-month visit, the parents filled out the consent form. After that, the Bayley Scales of Infant and Toddler Development (3rd edition, Bayley 2009) were conducted, and a standard medical examination was performed by a paediatrician (not reported here). In addition, at the end of the first visit, the paediatrician interviewed the parent on sleep- and health-related questions and, if necessary, provided basic sleep psychoeducation, including advice for the sleeping habits of the infant. The entire study protocol included an additional laboratory visit consisting of computer tasks and physiological measurements (not reported here).

In addition to the in-person visits, questionnaires that concerned the whole CHILD-SLEEP cohort were sent to the parents at eight, 18 and 24 months of age.

Measures

Sleep quality and duration parameters

The present study utilised the questionnaires for the main cohort that were sent to the parents when the child was eight, 18, and 24 months of age. The questionnaire at eight months was a paper-and-pencil questionnaire, sent through postal mail, whereas the questionnaires at 18 and 24 months of age were web-based, and sent to the parents via email. Sleep quality and duration were measured using the Brief Infant Sleep Questionnaire (BISQ; Sadeh, 2004). Sleep quality included the duration of wakefulness during the night (between 22.00-06.00), the latency to fall asleep, and the proportion of night-centred sleep, thus describing the stage of maturity of sleep. Sleep duration referred simply to the amount of sleep and included duration of nocturnal (between 19.00- 07.00) and daytime sleep (between 07.00-19.00) in hours and in minutes and total sleep duration as a sum of night-time and daytime sleep. The test-retest reliabilities for the BISQ questionnaire variables are r = .82 for night-time sleep duration, r = .89 for daytime sleep duration, r = .88 for number of night awakenings, r = .95 for the time spent awake during the night, and r = . 94 for sleep onset latency (Sadeh, 2004).

To validate the inclusion criteria, the number of night awakenings were also gathered from the questionnaire, in addition to the phone interview. We analysed the questionnaire data concerning the number of night awakenings at eight months of age. In line with the phone interview, the questionnaire data showed that the waking group had more night awakenings compared to the non-waking group, t (127) = 10.77, $p < .001$. However, the phone interview and the questionnaire were not conducted at the same time and the definition of the night-time was not identical, and therefore the number of night awakenings in both groups were not entirely constant as can be seen from Table 2. The phone interview data were considered to be more informative due to the tight definition of night-time (24.00–06.00), representing the severity of night awakening difficulties in that particular time more precisely than the data gathered with the questionnaire.

Psychomotor development

Psychomotor development was measured using the Bayley Scales of Infant and Toddler Development (3^{rd} edition, Bayley 2009), which is a widely used and robust measure of infant development. It consists of five different subscales measuring cognitive, receptive and expressive language, and fine and gross motor functioning. All the subscales were conducted by a trained examiner who was unaware of the child's group status. During the assessment, the child sat on the parent's lap except for the gross motor scale, which was conducted on the floor. Raw scores of the five different subscales were transformed into standardised scores with the original norms (M = 10 ± 3). From these standardised scores, three combined indexes (M = 100 ± 15) of cognitive, language (receptive and expressive language) and motor (fine and gross motor) development were drawn. Analyses were conducted separately for the five different subscales. Analyses were also conducted with the three combined indexes which showed similar findings. Due to the sake of brevity, and to reduce the number of statistical tests, only the results of the subscales are presented.

Statistical analysis

Statistical analyses were carried out using version 23 of the SPSS statistical software package. All the outcome variables were continuous and their distributions were screened using box-plots and scatterplots and, after visual inspection of the distributions, no extreme outliers were observed. Outcome variables with naturally skewed distributions (number of night awakenings and the time spent awake during the night) were corrected with log transformation. After the transformation, the distributions of the number of night awakenings and the time spent awake during the night exhibited only minor skewness. The data were analysed using Linear Mixed Models (LMM). This method was chosen in order to compare longitudinally the average change within the two groups and it allowed us to utilise also incomplete data. LMM is fairly robust to small deviations of normality (Lo & Andrews, 2015) and therefore, we decided to analyse the log transformed number of night awakenings and the time spent awake during the night also with LMM.

To analyse the group differences and the effect of time (i.e., assessment time points at 8, 18, and 24 months of age) on the outcome measures (night awakening, sleep quality and duration parameters, and psychomotor development), we conducted linear mixed models for each of the dependent variables. Both within-subjects (time) and between-subjects effects (group status) and their interaction were analysed. In the analysis of different sleep quality and duration parameters, a random intercept was included in the analyses whereas the models concerning psychomotor development did not include a random intercept due to better model fit without a random intercept. In the case of statistically significant main effects, the differences between subgroups were further analysed using Bonferroni-corrected post hoc tests. Effect sizes for the pairwise comparisons are indicated by Cohen's *d*. First, we ran a model that included the within factor of time, between factor of group, interaction of time x group, and the different covariates. Initially, the questionnaire data variables that differentiated between the two groups and factors that are known to be associated with night awakenings were tested as potential covariates in our analyses (co-sleeping, breastfeeding, the ability to fall asleep alone, and healthcare centre status). In case of a statistically significant main effect, the covariate was included in the final model. The alpha level was set to $p = .05$.

Results

Descriptive statistics of the sleep quality and duration parameters are presented in Table 2. Means, standard deviations, and range of the different Bayley-III subscales at eight and 24 months of age are presented in Table 3 separately for both groups. Table 4 summarises the statistics of the final models for the different sleep quality and duration parameters and Bayley-III subscales.

The persistence of night awakening

The LMM of the number of night awakenings revealed main effects of time, (F [1, 206.48] = 12.07, $p = .001$, $d = .35$) and group, (F [1, 203.53] = 21.24, $p < .001$, $d = .63$). In general, the number of night awakenings decreased from 18 months ($M = 1.2$, $SD = 1.1$) to 24 months of age ($M = .9$, $SD = .9$). In addition, the waking group ($M = 1.3$, $SD = 1.0$) had more night awakenings than the non-waking group ($M = .7$, $SD = .9$). The covariates co-sleeping, breastfeeding and the ability to fall asleep did not have a significant effect on the night awakening at 18 or 24 months of age (all p's > .67). Pairwise comparisons verified that the waking group and the non-waking group differentiated in the number of night awakenings at 18 months (t [114] = 2.99, $p = .003$, $d = .55$) and 24 months of age (t [90] = 3.08, $p = .003$, $d = .64$). Figure 1 illustrates the group differences in the night awakenings across time.

Night awakening and its connection to parent-reported sleep quality parameters

In the LMM of the time spent awake during the night, significant main effects of time (*F* [2, 134.23] = 34.63, *p* < .001) and group (*F* [1, 134.20] = 24.75, *p* < .001) were observed. The infants spent more time awake during the night at eight months (*M* = 24 min, *SD* = 24 min) as compared to 18 months (*M* = 9 min, *SD* = 16 min), *p* < .001, *d* = .57, and 24 months of age (*M* = 8 min, *SD* = 11 min), *p* < .001*, d* = .66*,* whereas the time spent awake at 18 months and 24 months did not differ, *p* = 1.00, *d* = .06. The infants in the waking group spent more time awake during night time (*M* = 17 min, *SD* = 22 min) than the non-waking group (*M* = 10 min, *SD* = 17min), *p* = .001, *d* = .35.

The analysis of sleep onset latency at bedtime showed only a covariate main effect of the ability to fall asleep alone (*F* [1, 138.61] = 8.77, *p* = .004, *d* = .39). Overall, sleep onset latency was longer for infants who were able to fall asleep alone only once in a week (*M* = 23 min, *SD* = 17 min) compared to infants who were able to fall asleep alone at least once in a day (*M* = 17 min, *SD* = 13 min).

The proportion of night centred-sleep showed a main effect of time (*F* [2, 132.03] = 136.18, *p* < .001). The proportion increased with age, as the eight-month-olds (*M* = 75%, *SD* = 6.1%) differed from the 18-month-olds ([*M* = 83%, *SD* = 4.9%], *p* <.001, *d* = 1.35) and 24-month-olds ([*M* = 84%, *SD* = 5.1%], *p* <.001, *d* = 1.25). No differences between the 18-month-old and 24-month-old infants were found (*p* = .154, *d* = .17).

Night awakening and its connection to parent-reported sleep duration parameters

In the LMM of total sleep duration, the main effects of time (*F* [2, 153.25] = 92.10, *p* < .001) and group (*F* [1, 135.72] = 6.05, *p* = .015, *d* = .28) were significant. The duration of total sleep decreased with age from eight months (*M* = 790 min, *SD* = 68.4 min) to 18 months ([*M* = 736 min, *SD* = 58.4 min], *p* < .001, *d* = .75) and to 24 months ([*M* = 708 min, *SD* = 50.8 min], *p* < .001, *d* = 1.25), as well as from 18 months to 24 months of age, *p* < .001, *d* = .51. Overall, the waking group (*M* = 735 min, *SD* = 71.6 min) slept less in total than the non-waking group (*M* = 754 min, *SD* = 66.1 min).

Analysis of the duration of night-time sleep showed a main effect of time (*F* [2, 177.81] = 6.91, *p* = .001). The duration of night-time sleep increased in infants from eight months (*M* = 594 min, *SD* = 57.8 min) to 18 months ([*M* = 611 min, *SD* =48.5 min], *p* = .002, *d* = .27), and decreased from 18 to 24 months ([*M* = 596 min, *SD* = 43.1 min], *p* = .026, *d* = .31), whereas the duration of night-time sleep at eight months and 24 months of age did not differ; *p* = 1.00, *d* = .03.

Analysis of the amount of daytime sleep also showed a significant main effect of time (*F* [2, 142.97] = 137.67, *p* < .001). The amount of daytime sleep diminished from eight months (*M* = 196 min, *SD* = 58.1 min) to 18 months ([*M* = 124 min, *SD* = 41.8 min], *p* < .001, *d* = 1.32) and again to 24 months of age ([*M* = 112 min, *SD* = 41.8 min], *p* < .001, *d* = 1.32). In addition, the decrease from 18 months to 24 months of age was significant, *p* = .026, *d* = .25.

Night awakening and its association with psychomotor development

The descriptive statistics of the Bayley-III subscales are summarised in Table 3 separately for both groups. The statistical information of the final models are presented in Table 4. The LMM of the cognitive subscale showed a main effect of time (*F* [1, 238.74] = 17.06, *p* < .001, *d* = .35). Infants received better age-corrected scores on cognitive functioning at eight months (*M* = 12.2, *SD* = 1.8) than at 24 months (*M* = 11.2, *SD* = 2.3).

Regarding the receptive language subscale, a significant main effect of time (F [1, 278] = 313.774, $p < .001$, d = 1.48) was observed. The infants received better age-corrected scores at 24 months of age (M = 12.1, SD = 2.5) than at eight months (M = 7.8, SD = 1.5). For expressive language, no significant main effects or interactions were observed (all p's > .44).

In the analysis of the fine motor subscale, no significant main effects or interactions were found (all p's > .06). The LMM of the gross motor subscale showed a main effect of time (F [1, 268.56] = 9.79, p = .002, d = .30), with the infants receiving better age-corrected at 24 months of age (M = 9.4, SD = 2.0) than at eight months of age (M = 8.5, SD = 2.6). Most importantly, the absence of group main effects in the psychomotor development data indicated that there were no significant differences between the waking group and the non-waking group in any of the subscales (all p's > .20).

Discussion

The aim of the present longitudinal study was to investigate the persistence of night awakening in infancy and its connection to other sleep quality and duration parameters, and to psychomotor development. To this aim, the waking group and the non-waking group were formed on the basis of parent-reported number of night awakenings when the infants were eight months of age. We measured the quality and duration of sleep at the age of eight, 18, and 24 months using parental questionnaires. The assessment of psychomotor development was conducted at eight and 24 months of age. It was hypothesised that the two groups of infants would show a persistent difference in the number of night awakenings at each time point and that they would also differ in other parent-reported aspects of sleep. In addition, we expected that the waking group would not differ from the non-waking group on psychomotor development at the age of eight months whereas they were expected to differ at the age of 24 months, indicating a less optimal developmental trajectory due to early-onset fragmented sleep.

Our results supported the hypothesis that night awakening is persistent in many infants: the waking group had more night awakenings than the non-waking group even at the ages of 18 and 24 months. This finding is in line with previous studies indicating that children with several night awakenings are at risk of continued sleep fragmentation also during childhood (Gregory & O'Connor, 2002; Hysing et al., 2014). However, the number of night awakenings diminished with age also in the waking group, even though the differences between the groups remained significant.

The hypothesis regarding differences in other sleep quality and duration parameters between the two groups was also supported. Although both groups evidenced the normative decrease in daytime and total sleep (Anders & Keener, 1985; Sadeh et al., 2009) from eight to 24 months of age, an important finding was that the waking group slept less in total. They also spent more time awake during the night than the non-waking group. Previous studies have reported mixed results regarding differences in total sleep time between infants with and without sleep fragmentation, some yielding support for the compensation of nocturnal sleep loss by napping longer during daytime (Acebo et al., 2005) and others suggesting that the groups do not differ in total sleep time (Sadeh et al., 1991). Our results are in line with Touchette et al. (2005), who stated that infants with several night awakenings sleep less in total and that they do not compensate for their lack of sleep during the day.

Our hypotheses concerning psychomotor development were only partially supported. In line with our hypothesis, the waking group and the non-waking group did not differ on cognitive, receptive and expressive language, or fine and gross motor development at the age of eight months. Contrary to our expectations and some other studies indicating that more matured sleep in infancy is connected with later cognitive (Dearing et al., 2001; Sadeh et al., 1991) and language development (Dionne et al., 2011), the waking group and the non-waking group also did not differ in cognitive, language, or motor development at the age of 24 months. Instead, our results are consistent with Bernier et al. (2010, 2013) showing that the sleep of one-year-old infants was unrelated to overall cognitive development at four years of age. In addition, cross-sectional studies with one-year-old infants have indicated that sleep characteristics are not associated with overall cognitive development (Mindell & Lee, 2015; Spruyt et al., 2008). The current study thus indicates that early fragmented sleep is not related to the general psychomotor development of children, at least not when their development is followed until they are two years of age. One explanation for the previous contradictory results could relate to the variability of the methods used to study development in infancy. In our study, psychomotor development in infancy was measured using a robust and widely used method that utilises different aspects of development. In addition, previous studies have studied correlations between different sleep parameters and development, whereas in our study we investigated differences between two clearly distinguishable groups, i.e., infants with and without fragmented sleep.

In our study, the infants with frequent night awakenings did not sleep more during the day than other infants: it seems that they do not compensate for their lack of sleep during the day. It has been suggested that fragmented sleep in infants would result in restricted sleep duration (Acebo et al., 2005). Sleep restriction and/or disturbed nocturnal sleep could then longitudinally have harmful effects on development. In the current study, fragmented sleep did not have a negative effect on overall psychomotor development at the age of 24 months even though the infants in the waking group slept less in general compared to the non-waking group. It is possible that the influence of fragmented sleep on psychomotor development would be evident longitudinally when the infants get older or with infants who continue to have severe sleep fragmentation at older ages. Only sparse studies have investigated shorter and longer sleep duration in connection with psychomotor development. In school-aged children, shorter sleep duration has been negatively associated with cognitive development (Paavonen et al., 2010; Touchette et al., 2007). In addition, Touchette et al. (2007) suggested that shortened sleep duration before 3-4 years of age would be longitudinally associated with slower cognitive development even if sleep duration normalises. Within the first two years of life, our results are not consistent with this suggestion, but more research is clearly necessary to determine the long-term influences of sleep fragmentation during the early years.

Even though in the current study the effects of fragmented sleep are not seen in overall development, it is possible that differences could be observed in more specific neurocognitive functions such as attention and executive functioning. This notion is supported by prior studies suggesting that sleep is connected with higher-order cognitive functioning, but not with general cognitive ability as early as the preschool years (Bernier et al., 2013; Bernier et al., 2010; Sadeh, Gruber, & Raviv, 2003) and at school age (Astill et al., 2012; Randazzo, Muehlbach, Schweitzer, & Walsh, 1998). Associations between night awakenings and sustained attention and working memory have been found in school-age children (Sadeh, Gruper, & Raviv, 2002). In addition, a longitudinal study by Sadeh et al. (2015) found that larger number of night awakenings at one year of age predicted poorer attention regulation at three to four years. Finally, the role of sleep on more specific cognitive processes is also supported by experimental studies investigating the effects of napping on infant word-learning and memory consolidation (Gomez, Bootzin, & Nadel, 2006; Seehagen, Konrad, Herbert, & Schneider, 2015). In future studies, including data collected within the CHILD-SLEEP cohort, the influence of early-onset fragmented sleep on more specific domains of cognitive development, as well as the stability of these possible effects, should be further investigated.

Interestingly, in our study, co-sleeping with the parent, the infants' ability to fall asleep alone, and whether the child was breastfed at 8 months of age did not have an influence on the number of night awakenings longitudinally at 18 or 24 months of age whereas in other studies concurrent and also long-term associations between these factors have been found (Hysing et al., 2014; Sadeh, et al., 2009; Touchette et al., 2005). However, the ability to fall asleep alone was connected to sleep onset latency, suggesting that night awakening should not be studied in isolation but rather in conjunction with relevant associated factors.

In the present study, we relied only on parental reports of infant sleep and did not utilise more objective information, such as actigraphy, which was also gathered as part of the CHILD-SLEEP cohort. We were interested in night awakenings signalled to the parents, and thus parental questionnaires were considered the best measure to this aim. The studies that have compared parental questionnaires, parent-reported sleep diaries, and actigraphy measures have found them to have moderate to strong correlations (Sadeh, 2004). The main differences between the actigraphy and questionnaire data have regarded the number of night awakenings, with the parental questionnaires underestimating the number of night awakenings.

One specific feature of the current study was that the sample was drawn from the prevention sub-study in which half of the infants were from the so-called prevention healthcare centres and the rest from the control healthcare centres. The families in the prevention healthcare centres received preventive psychoeducation on infant sleeping habits through brochures, whereas the control healthcare centres received no preventive sleep material. However, infants in both groups came from both healthcare centres. In addition, the healthcare status of the child was taken into account in our analyses and in the models, and it did not have significant effects on the different sleep quality and duration parameters and psychomotor development. To verify that including the prevention healthcare centre did not confound our results regarding psychomotor development and sleep parameters, we conducted the analyses again using only infants from the control healthcare centre. The results remained largely unchanged despite reduced sample size. Therefore, it could be concluded that the inclusion of infants from the prevention healthcare centres did not confound our results. Another potential limitation concerning our sample was that the group status was determined at the age of eight months and kept the same irrespective of the number of night awakenings at 18 and 24 months of age. Therefore, it is possible that an infant with fragmented sleep at eight months of age could have developed to sleep without night awakenings by the age of 24 months. However, we were interested in the effects of early-onset fragmented sleep and on the group level, the two groups differed in the number of night awakenings even at the age of 24 months. There may also be moderating factors that were not controlled in this study. Our sample consisted of Caucasian infants of mainly middle class origin and, therefore, the generalisability of the results to other ethnicities and sociodemographic groups is limited. In overall, the limitations of the study should be taken into account in considering the generalisability of the results.

In conclusion, while infants with fragmented sleep showed persistence in night awakening and stable differences also in other sleep quality and duration parameters compared to infants without fragmented sleep, general psychomotor development in infancy from eight to 24 months of age did not differ between the groups. In our sample, the infants with fragmented sleep slept less in total than the infants without fragmented sleep, and they did not compensate for their lack of sleep during the day. Within the CHILD-SLEEP cohort, we will be able to investigate whether waking infants continue to have shorter total sleep time at older ages. Further studies are also needed to find out whether short overall sleep duration could be an additional factor contributing to night awakening, together with other factors such as temperament and parental behaviour. In addition, our findings suggest that night awakening should not be studied in isolation but rather in conjunction with relevant associated factors. Finally, in addition to overall psychomotor development, more precise neurocognitive factors such as attention and executive functions should also be studied in order to find out whether fragmented sleep could be connected to more specific facets of cognitive development.

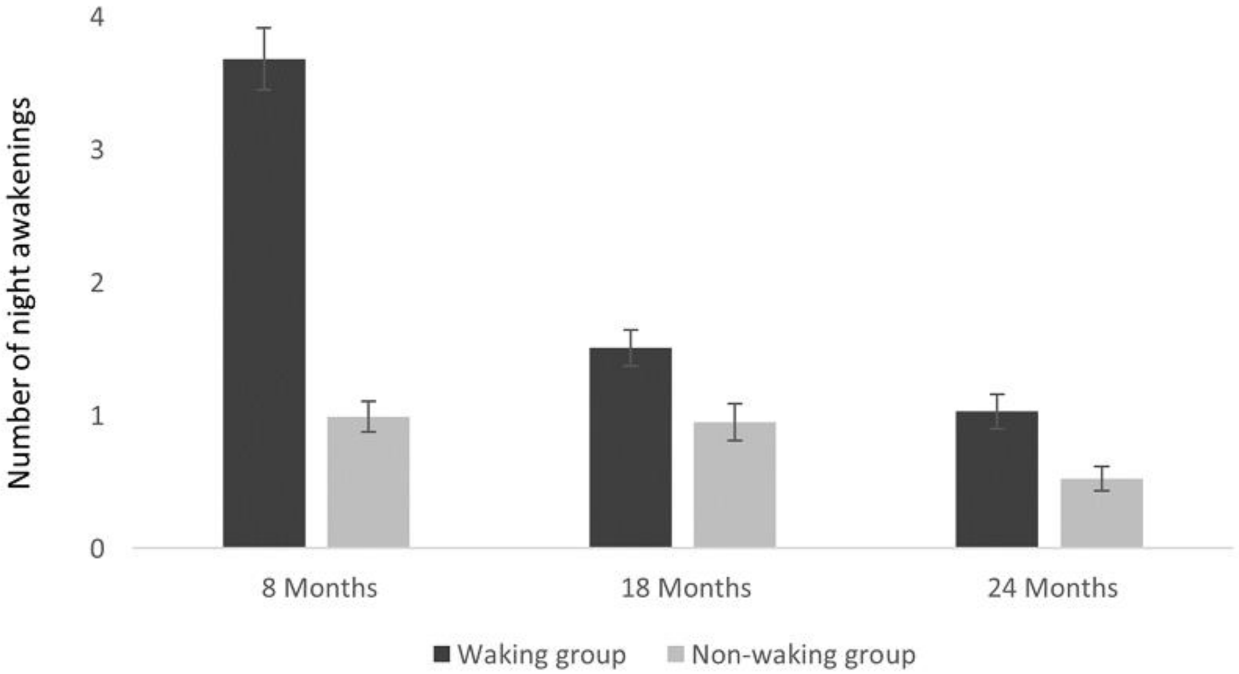
Table 1

Descriptive statistics according to group

	Waking group		Non-waking group	
	n	%	*n*	%
Gender				
girls	37	51.4	35	48.6
boys	43	55.1	35	44.9
Siblings				
yes	28	45.9	33	54.1
no	50	58.8	35	41.2
Mother's education				
> 15 years	38	54.3	32	45.7
< 15 years	42	53.2	37	46.8
Health care centre				
prevention	45	61.6	28	38.4
control	36	46.2	42	53.8
Co-sleeping				
< 2 times a month	39	43.3	4	56.7
> once in a week	30	88.2	51	11.8
Breastfeeding				
breastfed only	45	69.2	20	30.8
breastfed and formula fed	16	57.1	12	42.9
formula fed only	16	35.6	29	64.4
Falling asleep alone				
once in a week	53	71.6	21	28.4
once in a day	23	35.9	41	64.1

Figure 1.

Group differences in the averaged number of night awakenings across time



Note. Error bars depict the standard error of mean.

Table 2
Means and standard deviations of sleep quality and duration parameters from the BISQ questionnaire according to group

	Waking group		Non-waking group	
	M (SD)	Range	M (SD)	Range
8 mo				
Sleep quality				
Night awakenings	3.8 (2.0)	0 – 12	0.9 (0.8)	0 – 4.5
Awake during the night (min)	30.6 (25.7)	0 – 120	15.4 (20.3)	0 – 120
Sleep latency (min)	24.8 (16.9)	0 – 90	18.4 (15.3)	2 – 90
% of night-time sleep	75.9 (5.8)	62 – 87	74.6 (6.5)	50 – 85
Sleep duration				
Total sleep (min)	778.8 (72.7)	600 – 960	801.9 (63.5)	540 – 930
Night-time sleep (min)	589.9 (58.4)	450 – 750	596.9 (57.4)	420 – 690
Daytime sleep (min)	188.4 (53.6)	90 – 310	205.0 (62.3)	110 – 420
18 mo				
Sleep quality				
Night awakenings	1.5 (1.1)	0 – 5	0.9 (1.0)	0 – 4
Awake during the night (min)	11.7 (16.0)	0 – 90	7.1 (15.3)	0 – 90
Sleep latency (min)	22.2 (17.2)	1 – 67.5	15.5 (11.1)	0 – 60
% of night-time sleep	83.7 (4.7)	68 – 93	83.1 (5.2)	67 – 100
Sleep duration				
Total sleep (min)	728.4 (63.0)	570 – 930	739.3 (52.1)	600 – 900
Night-time sleep (min)	608.8 (52.7)	450 – 720	613.3 (43.3)	480 – 720
Daytime sleep (min)	119.6 (40.8)	45 – 300	126.4 (43.1)	0 – 300
24 mo				
Sleep quality				
Night awakenings	1.0 (0.9)	0 – 4	0.5 (0.6)	0 – 2.5
Awake during the night (min)	11.1 (12.3)	0 – 50	4.9 (9.0)	0 – 50
Sleep latency (min)	23.9 (18.1)	0 – 90	18.0 (12.3)	1 – 60
% of night-time sleep	84.9 (5.1)	60 – 96	84.4 (5.0)	64 – 100
Sleep duration				
Total sleep (min)	694.8 (45.3)	600 – 780	720.1 (54.2)	630 – 900
Night-time sleep (min)	589.4 (46.4)	450 – 660	605.9 (37.2)	540 – 660
Daytime sleep (min)	105.4 (38.9)	30 – 300	114.2 (45.1)	0 – 300

Table 3

Means, standard deviations and range of standard points of Bayley-III subscales according to group

	Waking group		Non-waking group	
	M (SD)	Range	M (SD)	Range
8 mo				
Cognitive	12.2 (1.8)	8 – 16	12.1 (1.7)	8 – 16
Receptive language	7.8 (1.5)	4 – 11	7.8 (1.5)	4 – 11
Expressive language	10.3 (1.7)	6 – 14	10.1 (1.9)	6 – 14
Fine motor	10.9 (2.1)	6 – 17	10.9 (2.4)	5 – 17
Gross motor	8.7 (2.4)	4 – 14	8.2 (2.8)	3 – 15
24 mo				
Cognitive	11.2 (2.3)	7 – 19	11.1 (2.3)	5 – 17
Receptive language	12.4 (2.5)	6 – 19	11.7 (2.5)	1 – 17
Expressive language	10.0 (2.8)	4 – 15	9.9 (2.7)	2 – 15
Fine motor	11.6 (2.1)	7 – 18	11.1 (1.8)	7 – 15
Gross motor	9.4 (2.3)	5 – 18	9.3 (1.6)	5 – 15

Table 4

Statistics of the final models for different sleep parameters and Bayley-III subscales

	ICC	Estimate	SE	95% CI	*t*	*p*
Night awakening	.70					
Intercept		.51	.11	.30 – .72	4.74	< .001
Time						
18 mo vs 24 mo		.45	.13	.20 – .70	3.59	< .001
waking group vs non-waking group		.54	.13	.30 – .79	4.32	< .001
Awake during the night	.41					
Intercept		4.74	1.56	1.65 – 7.83	3.04	.003
Time						
8 mo vs 24 mo		15.79	2.36	11.14 – 20.45	6.70	< .001
18 mo vs 24 mo		1.37	1.68	-1.95 – 4.69	.82	.415
Group						
waking group vs non-waking group		6.46	1.89	2.72 – 10.20	3.43	.001
Sleep onset latency	.62					
Intercept		15.69	2.00	11.73 – 19.67	7.81	< .001
Time						
8 mo vs 24 mo		.26	1.86	-3.41 – 3.93	.14	.889
18 mo vs 24 mo		-2.74	1.69	-6.08 – .61	-1.62	.108
Group						
waking group vs non-waking group		3.94	2.12	-.24 – 8.14	1.86	.065
Ability to fall asleep						
once in a week vs once in a day		6.25	2.11	2.07 – 10.42	2.96	.004
Proportion of night-centred sleep	.31					
Intercept		83.92	.67	82.60 – 85.24	125.61	< .001
Time						
8 mo vs 24 mo		-9.07	.63	-10.32 – -7.83	-14.39	< .001
18 mo vs 24 mo		-1.09	.55	-2.18 – .007	-1.97	.051
Group						
waking group vs non-waking group		.87	.72	-.56 – 2.31	1.21	.230
Total sleep time	.56					
Intercept		717.77	6.49	704.95 – 730.60	110.56	< .001
Time						
8 mo vs 24 mo		82.24	6.07	70.26 – 94.21	13.57	< .001
18 mo vs 24 mo		27.46	5.46	16.65 – 38.26	5.03	< .001
Group						
waking group vs non-waking group		-19.43	7.90	-35.06 – -3.80	-2.46	.015
Night-time sleep	.55					
Intercept		600.74	6.28	588.37 – 613.10	95.64	< .001
Time						
8 mo vs 24 mo		-2.45	6.08	-14.50 – 9.59	-.40	.687
18 mo vs 24 mo		15.08	5.70	3.84 – 26.32	2.64	.009
Group						

waking group vs non-waking group		-9.07	6.62	-22.17 – 4.02	11.37	.173
Daytime sleep	.35					
Intercept		117.34	5.63	106.21 – 128.47	20.85	< .001
Time						
8 mo vs 24 mo		84.04	5.49	73.21 – 94.87	15.32	< .001
18 mo vs 24 mo		11.87	4.45	3.05 – 20.68	2.67	.009
Group						
waking group vs non-waking group		-10.06	6.35	-22.63 – 2.51	-1.58	0.116
Cognitive subscale	.10					
Intercept		11.11	.24	10.64 – 11.58	46.72	< .001
Time						
8 mo vs 24 mo		1.02	.25	.53 – 1.50	4.13	< .001
Group						
waking group vs non-waking group		.09	.23	-.37 – .55	.40	.689
Receptive language subscale	.01					
Intercept		11.94	.22	11.50 – 12.38	53.82	< .001
Time						
8 mo vs 24 mo		-4.29	.24	-4.77 – -3.82	-17.71	< .001
Group						
waking group vs non-waking group		.31	.24	-.17 – .79	1.28	.202
Expressive language subscale	.25					
Intercept		9.89	.28	9.33 – 10.45	35.04	< .001
Time						
8 mo vs 24 mo		.20	.29	-.36 – .76	.69	.488
Group						
waking group vs non-waking group		.15	.25	-.33 – .64	.62	.534
Fine motor subscale	-.05					
Intercept		11.25	.22	10.81 – 11.68	50.81	< .001
Time						
8 mo vs 24 mo		-.48	.26	-.98 – .03	-1.86	.064
Group						
waking group vs non-waking group		.22	.25	-.27 – .71	.88	.380
Gross motor subscale	.27					
Intercept		9.24	.24	8.77 – 9.70	38.90	< .001
Time						
8 mo vs 24 mo		-.88	.28	-1.43 – -.33	-3.13	.002
Group						
waking group vs non-waking group		.22	.28	-.33 – .77	.79	.428

Note. ICC = intraclass correlation, SE = standard error.

References

Acebo, C., Sadeh, A., Seifer, R., Tzischinsky, O., Hafer, A., & Carskadon, M. A. (2005). Sleep/wake patterns derived from activity monitoring and maternal report for healthy 1- to 5-year-old children. *Sleep, 28*, 1568-1577. doi:10.1093/sleep/28.12.1568

Adair, R., Zuckerman, B., Bauchner, H., Philipp, B., & Levenson, S. (1992). Reducing night waking in infancy: A primary care intervention. *Pediatrics, 89*(4), 585-588.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.) Arlington, VA: American Psychiatric Publishing.

Anders, T. F., & Keener, M. (1985). Developmental course of nighttime sleep-wake patterns in full-term and premature infants during the first year of life. I. *Sleep, 8*, 173-192. doi:10.1093/sleep/8.3.173

Astill, R. G., Van der Heijden, K. B., Van IJzendoorn, M. H., & Van Someren, E. J. W. (2012). Sleep, cognition, and behavioral problems in school-age children: A century of research meta-analyzed. *Psychological Bulletin, 138*, 1109-1138. doi:http://dx.doi.org/10.1037/a0028204

Bayley, N. (2009). *Bayley scales of infant and toddler development* (*3rd ed. Finnish version*). Helsinki, Psykologien Kustannus.

Bernier, A., Beauchamp, M. H., Bouvette-Turcot, A-A., Carlson, S. M., & Carrier, J. (2013). Sleep and cognition in preschool years: Specific links to executive functioning. *Child Development, 84*, 1542-1553. doi: 10.1111/cdev.12063

Bernier, A., Carlson, S. M., Bordeleau, S., & Carrier, J. (2010). Relations between physiological and cognitive regulatory systems: Infant sleep regulation and subsequent executive functioning. *Child Development, 81*, 1739-1752. doi: 10.1111/j.1467-8624.2010.01507.x

Cioni, G., & Sgandurra, G. (2013). Normal psychomotor development. *Handbook of Clinical Neurology, 111*, 3.

Dahl, R. E. (1996). The impact of inadequate sleep on children's daytime cognitive function. *Seminars in Pediatric Neurology, 3*, 44-50. doi:10.1016/S1071-9091(96)80028-3

Dearing, E., McCartney, K., Marshall, N. L., & Warner, R. M. (2001). Parental reports of children's sleep and wakefulness: Longitudinal associations with cognitive and language outcomes. *Infant Behavior & Development, 24*, 151-170. doi:http://dx.doi.org/10.1016/S0163-6383(01)00074-1

Dewald, J. F., Meijer, A. M., Oort, F. J., Kerkhof, G. A., & Bögels, S. M. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Medicine Reviews, 14*, 179-189. doi:10.1016/j.smrv.2009.10.004

Dionne, G., Touchette, E., Forget-Dubois, N., Petit, D., Tremblay, R. E., Montplaisir, J. Y., & Boivin, M. (2011). Associations between sleep-wake consolidation and language development in early childhood: A longitudinal twin study. *Sleep: Journal of Sleep and Sleep Disorders Research, 34*, 987-995. doi:10.5665/SLEEP.1148

Galland, B. C., Taylor, B. J., Elder, D. E., & Herbison, P. (2012). Normal sleep patterns in infants and children: A systematic review of observational studies. *Sleep Medicine Reviews, 16*, 213-222. doi:10.1016/j.smrv.2011.06.001

Gertner, S., Greenbaum, C. W., Sadeh, A., Dolfin, Z., Sirota, L., & Ben-Nun, Y. (2002). Sleep-wake patterns in preterm infants and 6 month's home environment: Implications for early cognitive development. *Early Human Development, 68*, 93-102. doi:http://dx.doi.org/10.1016/S0378-3782(02)00018-X

Gómez RL, Bootzin RR, Nadel L (2006). Naps promote abstraction in language-learning infants. Psychological Science, 17, 670–674. doi:10.1111/j.1467-9280.2006.01764.x

Goodlin-Jones, B. L., Burnham, M. M., Gaylor, E. E., & Anders, T. F. (2001). Night waking, sleep-wake organization, and self-soothing in the first year of life. *Journal of Developmental and Behavioral Pediatrics, 22*, 226-233. doi:10.1097/00004703-200108000-00003

Gregory, A. M., & O'Connor, T. G. (2002). Sleep problems in childhood: A longitudinal study of developmental change and association with behavioral problems. *Journal of the American Academy of Child & Adolescent Psychiatry, 41*, 964-971. doi:10.1097/00004583-200208000-00015

Holditch-Davis, D., Belyea, M., & Edwards, L. J. (2005). Prediction of 3-year developmental outcomes from sleep development over the preterm period. *Infant Behavior and Development, 28*, 118-131. doi:10.1016/j.infbeh.2004.12.001

Hysing, M., Harvey, A. G., Torgersen, L., Ystrom, E., Reichborn-Kjennerud, T., & Sivertsen, B. (2014). Trajectories and predictors of nocturnal awakenings and sleep duration in infants. *Journal of Developmental and Behavioral Pediatrics : JDBP, 35*, 309. doi:10.1097/DBP.0000000000000064

Iglowstein, I., Jenni, O. G., Molinari, L., & Largo, R. H. (2003). Sleep duration from infancy to adolescence: Reference values and generational trends. *Pediatrics, 111*, 302-307. doi:10.1542/peds.111.2.302

Lo, S., & Andrews, S. (2015). To transform or not to transform: Using generalized linear mixed models to analyse reaction time data. *Frontiers in Psychology, 6*, 1171. doi:10.3389/fpsyg.2015.01171

Mindell, J., Kuhn, B., Lewin, D., Meltzer, L., & Sadeh, A. (2006). Behavioral treatment of bedtime problems and night wakings in infants and young children - an American Academy of Sleep Medicine review. *Sleep, 29*, 1263-1276. doi: https://doi-org.helios.uta.fi/10.1093/sleep/29.10.1263

Mindell, J. A., & Lee, C. (2015). Sleep, mood, and development in infants. *Infant Behavior & Development, 41*, 102-107. doi:http://dx.doi.org.helios.uta.fi/10.1016/j.infbeh.2015.08.004

Moore, T., & Ucko, L. E. (1957). Night waking in early infancy: Part I. *Archives of Disease in Childhood, 32*, 333-342. doi:10.1136/adc.32.164.333

Paavonen, E. J., Saarenpaa-Heikkila, O., Polkki, P., Kylliainen, A., Porkka-Heiskanen, T., Paunio, T. (2017). Maternal and paternal sleep during pregnancy in the CHILD-SLEEP birth cohort. *Sleep Medicine, 29*, 47-56. doi:10.1016/j.sleep.2016.09.011

Paavonen, E. J., Räikkönen, K., Pesonen, A., Lahti, J., Komsi, N., Heinonen, K., . . . Porkka-Heiskanen, T. (2010). Sleep quality and cognitive performance in 8-year-old children. *Sleep Medicine, 11*, 386-392. doi:10.1016/j.sleep.2009.09.009

Palmstierna, P., Sepa, A., & Ludvigsson, J. (2008). Parent perceptions of child sleep: A study of 10,000 swedish children. *Acta Paediatrica, 97*, 1631-1639. doi:http://dx.doi.org/10.1111/j.1651-2227.2008.00967.x

Piteo, A. M., Lushington, K., Roberts, R. M., Martin, A. J., Nettelbeck, T., Kohler, M. J., & Kennedy, J. D. (2011). Parental-reported snoring from the first month of life and cognitive development at 12 months of age. *Sleep Medicine, 12*, 975-980. doi:http://dx.doi.org/10.1016/j.sleep.2011.07.006

Piteo, A. M., Lushington, K., Roberts, R. M., van den Heuvel, C. J., Nettelbeck, T., Kohler, M. J., . . . Kennedy, J. D. (2011). Prevalence of snoring and associated factors in infancy. *Sleep Medicine, 12*, 787-792. doi:http://dx.doi.org/10.1016/j.sleep.2011.01.019

Randazzo, A. C., Muehlbach, M. J., Schweitzer, P. K., & Walsh, J. K. (1998). Cognitive function following acute sleep restriction in children ages 10-14. *Sleep, 21*, 861. doi:10.1093/sleep/21.8.861

Sadeh, A. (2004). A brief screening questionnaire for infant sleep problems: Validation and findings for an internet sample. *Pediatrics, 113*, e570-e577. doi:10.1542/peds.113.6.e570

Sadeh, A., De Marcas, G., Guri, Y., Berger, A., Tikotzky, L., & Bar-Haim, Y. (2015). Infant sleep predicts attention regulation and behavior problems at 3-4 years of age. *Developmental Neuropsychology, 40*, 122-137. doi:10.1080/87565641.2014.973498

Sadeh, A., Flint-Ofir, E., Tirosh, T., & Tikotzky, L. (2007). Infant sleep and parental sleep-related cognitions. *Journal of Family Psychology, 21*, 74-87. doi:http://dx.doi.org/10.1037/0893-3200.21.1.74

Sadeh, A., Gruber, R., & Raviv, A. (2002). Sleep, neurobehavioral functioning, and behavior problems in school-age children. *Child Development, 73*, 405-417. doi:10.1111/1467-8624.00414

Sadeh, A., Gruber, R., & Raviv, A. (2003). The effects of sleep restriction and extension on school-age children: What a difference an hour makes. *Child Development, 74*, 444-455. doi:http://dx.doi.org/10.1111/1467-8624.7402008

Sadeh, A., Lavie, P., Scher, A., Tirosh, E., & Epstein, R. (1991). Actigraphic home-monitoring sleep-disturbed and control infants and young children: A new method for pediatric assessment of sleep-wake patterns. *Pediatrics, 87*, 494-499.

Sadeh, A., Mindell, J. A., Luedtke, K., & Wiegand, B. (2009). Sleep and sleep ecology in the first 3 years: A web-based study. *Journal of Sleep Research, 18*, 60-73. doi: 10.1111/j.1365-2869.2008.00699.x

Scher, A. (2005). Infant sleep at 10 months of age as a window to cognitive development. *Early Human Development, 81*, 289-292. doi:10.1016/j.earlhumdev.2004.07.005

Schwichtenberg, A. J., Christ, S., Abel, E., & Poehlmann-Tynan, J. A. (2016). Circadian sleep patterns in toddlers born preterm: Longitudinal associations with developmental and health concerns. *Journal of Developmental and Behavioral Pediatrics : JDBP, 37*, 358. doi: 10.1097/DBP.0000000000000287

Seehagen S, Konrad C, Herbert JS, Schneider S (2015). Timely sleep facilitates declarative memory consolidation in infants. Proceedings of the National Academy of Sciences, 112, 1625–1629. doi:10.1073/pnas.1414000112

Spruyt, K., Aitken, R. J., So, K., Charlton, M., Adamson, T. M., & Horne, R. S. C. (2008). Relationship between sleep/wake patterns, temperament and overall development in term infants over the first year of life. *Early Human Development, 84*, 289-296. doi:10.1016/j.earlhumdev.2007.07.002

Suratt, P. M., Barth, J. T., Diamond, R., D'Andrea, L., Nikova, M., Perriello, V. A.,Jr, . . . Rembold, C. (2007). Reduced time in bed and obstructive sleep-disordered breathing in children are associated with cognitive impairment. *Pediatrics, 119*, 320-329. doi:10.1542/peds.2006-1969

Tikotzky, L., & Shaashua, L. (2012). Infant sleep and early parental sleep-related cognitions predict sleep in pre-school children. *Sleep Medicine, 13*, 185-192. doi:10.1016/j.sleep.2011.07.013

Touchette, E., Petit, D., Paquet, J., Boivin, M., Japel, C., Tremblay, R. E., & Montplaisir, J. Y. (2005). Factors associated with fragmented sleep at night across early childhood. *Archives of Pediatrics & Adolescent Medicine, 159*, 242. doi: 10.1001/archpedi.159.3.242

Touchette, E., Petit, D., Séguin, J. R., Boivin, M., Tremblay, R. E., & Montplaisir, J. Y. (2007). Associations between sleep duration patterns and behavioral/cognitive functioning at school entry. *Sleep, 30*, 1213-1219. doi:10.1093/sleep/30.9.1213

Weinraub, M., Bender, R. H., Friedman, S. L., Susman, E. J., Knoke, B., Bradley, R., . . . Williams, J. (2012). Patterns of developmental change in infants' nighttime sleep awakenings from 6 through 36 months of age. *Developmental Psychology, 48*, 1511-1528. doi:http://dx.doi.org/10.1037/a0027680

Williams, K. E., Berthelsen, D., Walker, S., & Nicholson, J. M. (2015). A developmental cascade model of behavioral sleep problems and emotional and attentional self-regulation across early childhood. *Behavioral Sleep Medicine, 00*, 1-21. doi: 10.1080/15402002.2015.1065410