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Normal sleep development in infants: findings from two large birth cohorts.

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Abstract

Objective: Sleep difficulties are highly prevalent and often persistent in young children, but sometimes parents are worried about sleep symptoms that belong to the normative range rather than to actual disturbances. Therefore, the aim of this study was to describe the normative development of sleep at the ages of three, six, eight, 12, 18 and 24 months in healthy children.

Methods: The present study is based on two birth cohorts that comprise representative samples of families recruited systematically during pregnancy. In the CHILD-SLEEP cohort, the sample sizes were 1427 at three, 1301 at eight, 1163 at 18, and 950 at 24 months. In the Finnbrain cohort, the sample sizes were 2002 at six months and 1693 at 12 months. Healthy term-born children were eligible for this study. To assess the infants' sleep duration and sleep quality, the Brief Infant Sleep Questionnaire (BISQ) was used in both cohorts and additionally the Infant Sleep Questionnaire (ISQ) in the CHILD-SLEEP cohort. The distributions of the study variables were reported using standard parameters.

Results: We found that sleep quality is highly variable particularly during the first two years of life, but this variability decreased markedly towards the second year. First, sleep latency decreased by the age of 6 months, while night-time sleep began to consolidate during the second year. However, parent-reported sleeping problems were common during the entire study period.

Conclusion: As many families struggle with infants' sleeping problems, the reference values reported in this article can be valuable tools in various clinical settings to define clinically significant deviances in the sleep development and to identify individuals benefitting from counselling and clinical interventions.

KEYWORDS: Sleep, infants, development, normal sleep, sleep duration, sleep quality

Introduction

Sleep difficulties are highly prevalent and often persistent in young children (Fricke-Oerkermann et al., 2007; Williams et al., 2019). They tend to be problematic for the entire family by interrupting the sleep of the other family members. Therefore parents, often seek advice from healthcare professionals to help to solve these problems. However, inter-individual differences in sleep development are large and result in highly variable sleep quality (Iglowstein et al. 2003; Sadeh et al. 2009); sometimes, parents are worried about sleep symptoms that belong to the normative range rather than representing actual disturbances requiring clinical assessment and treatment.

The extensive changes in sleep development during the first two years concern three different dimensions that form the basis of quality sleep. First, sleep-wake rhythms start to mature soon after birth. Among new-born infants, sleep is distributed irregularly during the day and night, but the rhythmicity evolves within a few months so that usually at around three months of age clear signs of a diurnal sleep-wake rhythm can be seen. This development is reflected as more sleep during the night and less sleep during the day (Rivkees, 2003). Second, infants' self-regulation starts to develop during the first year of life (Rothbart et al., 2011), which leads to an improved ability to fall asleep independently. This is one key element in the development of the self-regulated sleep-wake cycle (Burnham et al., 2002) and together with the maturing sleep-wake rhythms they lead to the consolidation of night-time sleep and a reduced number of night awakenings (Hendersson et al., 2012). Finally, sleep needs decrease gradually from birth until adolescence, the decrease being at its fastest during the first two years of age (Iglowstein et al., 2003, Williams et al. 2013).

Age-specific reference values are valuable tools in clinical decision making, in order to differentiate clinically significant deviances from normal development. To date, there are several studies concerning the average sleep duration in early childhood (Iglowstein et al. 2003; Montgomery-Downs et al. 2006; Williams et al. 2013; Xiao-Na et al., 2009) and clinical recommendations for the daily sleeping time in children aged 0-17 years. For example, the National Sleep Foundation recommends 14-17 hours of sleep for new-borns (0-3 months), 12-15 hours for infants (4-11 months) and 11-14 hours for toddlers (1-3 years) (Hirskowitz et al. 2015). The following recommendations are given by the American Academy of Sleep Medicine: 12-16 hours per 24 hours for infants aged 4-12 months and 11-14 hours for children aged 1-2 years (Paruthi et al. 2019).

However, less prior research exists concerning the developmental changes in sleep quality, sleep-wake rhythms or self-soothing. Two existing meta-analyses on sleep development in childhood identified only a few studies regarding infancy and early childhood (Dias, Figueiredo, Rocha, & Field, 2018; Galland, Taylor, Elder, & Herbison, 2012). For instance, Galland et al. (2012) found only four studies concerning sleep-duration in children aged 3-5 months and nine studies of 1-2 year olds. These studies were mainly based on small samples, comprising 20-56 cases (Harrison et al. 2004; Spruyt et al. 2008) or non-random sampling (Sadeh et al. 2009), which can result in selection bias and over-reporting of sleeping problems. Moreover, according to this meta-analysis, no longitudinal studies so far have covered both the sleep duration and sleep quality. Therefore, new studies are necessary to define the boundaries of normative sleep patterns in early childhood.

To ensure the adequate diagnostics and treatment of children's sleeping difficulties, it would be important 1) to screen for sleep disturbances in well-baby clinics, 2) to provide preventive interventions for parents with concerns about sleep development 3) to enhance the availability of behavioural sleep interventions for children with sleeping disorders and 4) to increase the understanding of normal sleep development in children. However, it has been widely recognised that there are significant gaps among clinicians in knowledge concerning paediatric sleep disorders and that few children receive evidence-based care (Honaker & Meltzer, 2015; Owens, 2011). The barriers to their provision were studied recently and inadequate knowledge, training and education on children's sleeping difficulties were the most commonly reported factors (Boerner et al. 2015). One solution to this problem could be the development of effective screening questions and tools for primary care (Honaker & Meltzer et al. 2015).

Therefore, in this study we describe the normative development of sleep at the ages of three, six, eight, 12, 18 and 24 months in healthy children based on two large birth cohorts, in Finland. More specifically, we evaluate the normative ranges in the daytime, night-time and total sleep duration, the development of the sleep-wake rhythm and sleep quality represented by sleep latency, the number of night awakenings, number of signalled night awakenings and the time spent awake at night. We also report the number of naps and the percentage of children being able to self-sooth. We also suggest cut-off points at six time-points to be used in clinical settings to recognise deviant development. The normative parameters reported in this article can be used as reference values to define the normative range for children aged 0-2 years in various clinical settings, such as well-baby clinics.

Methods

The present study is based on two population-based cohorts in Finland: the CHILD-SLEEP (CS) and the FinnBrain (FB) cohorts. Both are based on representative samples recruited systematically during pregnancy. They are completely independent samples with no overlapping individuals. Both samples represent Urban/Semi-Urban areas in Southern and Western Finland with population of highly respective cultural backgrounds. Health services are similar in both areas and socio-economic differences are generally small in Finland. Both study protocols were approved by the local ethical committees.

The CS cohort was recruited during pregnancy at maternity clinics at about week 32 of pregnancy. The sample comprised Finnish-speaking women who belonged to the area of the Tampere University Hospital, in the hospital district of Pirkanmaa, in southern Finland. The recruitment took place during a routine visit to the maternity clinics in the 32nd week of pregnancy between April 2011 and January 2013. The details of the recruitment procedure have been reported previously (Paavonen et al., 2017). Altogether, 1679 families agreed to initially participate in the study, which is approximately 25% of the target population. The response rates of participation were 84.6% (N=1427) at the age three months, 77.8% (N=1301) at eight months, 69.5% (N=1163) at the age of 18 months and 56.8% (N=950) at the age of 24 months.

The FB cohort consists of another population-based sample gathered in southwest Finland (www.finnbrain.fi). The characteristics of the sample and more detailed description of the recruitment process have been described elsewhere (Karlsson et al., 2018). Briefly, the recruitment of the baseline population took place between December 2011 and April 2015 at the maternal welfare clinics in a geographically defined area, which performed pregnancy ultrasound scans at gestational week 12 for the women eventually referred to give birth at Turku University Hospital in the Southwest Finland Hospital District and the Åland Islands in Finland. The study inclusion criteria were: a sufficient knowledge of Finnish or Swedish and a normal ultrasound screening result. In all, 5790 out of 8895 newly pregnant women visiting the recruitment sites during the specified time period were contacted and informed of the study. Of those informed of the study, a total of N=3808 (66%) mothers and N=2623 (45%) fathers or other partners of the mother decided to participate. Finally, the response rates were 52.6% (N=2002) at the age of 6 months and 44.5% (N=1693) at the age of 12 months.

This study comprises healthy term-born infants in both cohorts. Children who were born at the gestational age of 37 weeks or more (97.7%, N=1464 in the CS and 93.1%, N= 3545 in the FB)

were eligible for this study. In the CS cohort, infants with missing information (N=41) on their gestational age were also considered eligible, as most of the infants were full term (≤ 36 N=35). Children with severe parent-reported chronic illnesses were excluded. The reported illnesses were reviewed by two paediatricians to confirm similar exclusion criteria in both cohorts. Decisions on this aspect were made by consensus. Examples of the excluded illnesses include epileptic syndromes, Down syndrome, Crouzon syndrome, Hirschprung disease, or hereditary blindness, and severe congenital heart anomalies such as Tetralogy of Fallot. In total, the number of excluded cases came to 14 cases in the CS cohort and 13 cases in the FB cohort. In the CS, altogether 173 children participated in a prevention trial, where they received written information from the health-care nurses about children's sleep development. These children were excluded from the study.

Finally, some of the questionnaires were returned late and were therefore excluded from the final analyses. Infants aged 3-4 months (N=1132, 47.8% girls, 52.2% boys), 6-7 months (N=1833, 47.2% girls, 52.8% boys), 8-9 months (N=1102, 47.9% girls, 52.1% boys), 11-15 months (N=1538, 46.5% girls, 53.5% boys), 17-20 months (N=848, 48.1% girls, 51.9% boys), and 22-28 months (N=771, 47.0% girls, 53.0% boys) were eligible for the study.

In the drop-out analysis, we found that in the CS mothers participating in 24 month time point were older ($p<0.001$), had higher educational levels ($p<0.001$), as well as lower levels of anxiety ($p=0.002$), depression ($p=0.001$), and ADHD symptoms ($p=0.005$) than those who did not. In the FB, the responding mothers were at 12 month time point more educated ($p<0.001$), had lower number of children ($p<0.001$), and less depressive symptoms ($p<0.001$) than the mothers who dropped out from the study. As the group differences were small and largely unrelated to the outcome, we present the findings without imputation of missing data.

Methods

This study was questionnaire-based. In both cohorts, the questionnaires were sent to both parents to be filled out by either one of the parents or both of them together. To assess the infants' sleep duration and sleep quality, we used the Brief Infant Sleep Questionnaire (BISQ) in both cohorts and additionally the Infant Sleep Questionnaire (ISQ) in the CS cohort.

The **BISQ** is a 13-item parental questionnaire for screening infant and toddler sleeping problems (Sadeh, 2004). This questionnaire comprises twelve items about sleep duration, sleep latency ("how long does it take to put the child to sleep"), and number and duration of night awakenings. In addition, there are items about bedtime, falling asleep and the preferred sleeping position.

The **ISQ** is another parental questionnaire to evaluate the sleep quality of infants and toddlers (Morrell, 1999). There are altogether seven items related to difficulties getting to sleep, the frequency of night awakenings, and sleep onset problems in the evenings and at night. We used those items that were considered to provide complementary information relative to the BISQ. These items concerned the frequency of sleep onset problems and night awakenings (i.e., how many times per week they appeared), how often the infant required settling back to sleep and how often the infants were taken into their parents' beds because they were not able to fall asleep. There were six to eight response alternatives for the items, but to indicate clinically relevant difficulties the items were dichotomized (the original items and the cut-offs are listed in Table 3). The parents were also asked whether they considered their child to be having sleep difficulties.

We also report the number of naps at the ages of eight, 18 and 24 months based on the CS cohort. The parents' were asked "How many naps does your baby take between 8-20?" with the response alternatives 0, 1, 2, and three or more. Furthermore, the parents were also asked about self-soothing at three, eight, 18 and 24 months. The item was "How often does your baby fall asleep independently without the parent being present?" with the response options being "never", "rarely (less than once a week)", "sometimes (several times per week)", "often (daily at least once)" and "always". This was dichotomized at often/always vs. less to indicate ability of the infant to self-sooth.

The sleep data was carefully screened to identify extreme outliers. Potential errors were excluded. Both daytime and night-time sleep durations were required to be reported at the age of 0-1 years, but thereafter reporting no daytime sleep was considered acceptable. The accepted range for the total sleep duration was 6-21 hours at all time points. There were three excluded cases at the age of three months in the CS cohort and two cases at the age of six months and two at the age of 12 months in the FB cohort. There were no exclusion criteria for other sleep variables.

Sleep parameters

The studied sleep variables were: 1) the total sleep duration during the daytime, night-time and total sleep per 24 hours in hours (BISQ); 2) the sleep onset time in the evening in minutes (BISQ) and sleep onset difficulties at night (ISQ) (sleep latency ≥ 20 minutes during the night); 3) night awakenings: the average number of night awakenings between 22-06 (BISQ), the average number of night awakenings per week (5-7 nights a week vs. less) (ISQ), and the number of night awakenings between 00-06 per night when the child requires re-settling (ISQ) (≥ 2 times per night or ≥ 4 times per night vs less); 4) parents' reports of the child having sleep problems (none, mild,

severe) based on the BISQ and (none, mild, moderate, severe) based on the ISQ; 5) whether the child falls asleep independently (BISQ), how often the child falls asleep independently (own item); and 6) the number of naps (own item). The cut-off values for ISQ variables were based on clinical expertise to indicate problems that might be clinically relevant.

Statistical methods

The distributions of the study variables were reported using standard parameters. Means and standard deviations, minimum and maximum values and the 10th, 25th, 75th and 90th percentiles were reported. The percentages and their 95% confidence intervals (CIs) were reported for the categorical variables. The skewness of the distributions of the continuous variables was visually inspected. The differences between girls and boys were compared using either the t-test (daytime, night-time, total sleeping time, proportion of daytime sleep, and bedtime) or the Kruskal-Wallis test (sleep onset latency, number of night awakenings, time awake at night) depending on the distribution of the variable. Significant group differences were reported.

Results

Characteristics of the two samples are reported in Table 1.

As reported in Table 2, the average total sleep duration decreased from 14.4 h at the age of three months to 11.9 h at the age of two years (Figure 1). The range was very high particularly in early childhood, but it decreased markedly during the follow up. While the nocturnal sleeping time (19-07) remained stable during the two years being about 9.1 – 10.2 h per night, the daytime sleep (07-19) decreased from 5.3 h at three months to 1.9 h at two years (Figures 2-3). Consistent with this, the proportion of daytime sleep decreased from 36.5 % for three month olds to 15.7 % for two year olds (Figure 4).

The number of naps decreased from two at the age of eight months to one at the age of two years. More specifically, at eight months most of the children had two (71.6%, N=786) or three or more naps (23.7%, N=260), while only 4.7% (N=52) had just one nap. At 18 months, almost all children were reported to have only one nap per day (97.8%, N=829), while having two naps (2.0%, N=17) or no naps at all (0.2%, N=2) was rare. By the age of two years, the number of children without naps increased slightly to 2.7% (N=21). However, the majority were still napping once a day (97.0%, N=746). Only two children (0.3%, N=2) took naps twice a day.

The ability to self-soothe was relatively uncommon in our samples throughout the follow-up; the highest rate was seen at the age of 18 months, when it reached 50.2% (Table 3).

The average sleep onset decreased during the first year from 38 to 22 minutes remaining on a similar level thereafter (Table 2). However, yet about 25% of the children were still reported to have long sleep-onset latencies, exceeding 30 minutes (Table 3).

Night awakenings were common at all time points. The average number of night awakenings was 2.1-2.5 during the first year but it decreased to an average of 1.1 awakenings per night in 18 month olds and 0.9 in two year olds (Table 2). However, the range was large being, for example, at eight months from zero to 21. Moreover, in two year olds, 28.4% of the children still woke up every night or almost every night between 00-06 and 14.9% had at least two night awakenings for which they needed resettling (Table 3). However, they rarely required resettling several times a night; the rates for ≥ 4 per night ranged from 13.6% to 2.1% (Table 3).

Importantly, even though children often woke up during the night, sleep onset difficulties at night were less common. On average, the total time spent awake at night (between 00-06) decreased with age, from 24 minutes at eight months to six minutes at two years (Table 2). Moreover, prolonged sleep onset latency at night (≥ 20 minutes) decreased respectively, from 16.9% at three months to 2.2% at two years (Table 3).

In Figure 5, we report the proposed cut-off values for sleep latency, night awakenings and the time spent awake at night based on the 10th, 25th, 75th and 90th percentiles at all time-points. In this figure the cut-offs, coloured orange (to be evaluated in more detail) and red (clinical assessment recommended), could be useful for screening clinically significant cases. Infants exceeding the 75th or 90th percentile have worse sleep quality than most of the other infants (75% or 90% of the infants, respectively) and they may suffer from clinically relevant sleep disturbances.

The parent reported sleeping problems were common with rates ranging from 21.6% (at 24 months) to 39.7% (at 8 months) in the CS cohort and 27.8% (at 12 months) to 30.7% (at 6 months) in the FB cohort. Severe problems were reported only for a minority of children (in 0.6% to 1.1% in the CS cohort and 1.9% and 2.2% in the FB cohort) (Figure 6).

The only sex differences we found across the time points were that: 1) girls slept more during the day than the boys both at three (5.4 h vs. 5.1 h, $p=0.006$), and eight months ($p=0.017$). 2) They also had a longer sleep onset latency than the boys at three months (40.4 vs. 35.3 min, $p_{KW}=0.005$) while the boys had more night awakenings at three months than the girls (2.3 vs. 2.1, $p_{KW}<0.001$).

Discussion

The aim of this study was to describe the normative sleep quality in early childhood based on two large birth cohorts. We found that parents commonly considered that their children were having sleeping problems; they were concerned about every fourth child, with the highest prevalence being reported at eight months (39.7%). We also found that sleep quality is highly variable particularly during the first year of life, but this variability decreased markedly towards the second year. The improving sleep quality was first seen in the decreasing sleep latency; settling down to sleep is difficult for many infants at the age of three months, but after it becomes easier. Consolidation in the night-time sleep was seen during the second year when the frequency of night awakenings decreased significantly towards 18 months of age.

In our study, during the first six months the average sleeping time was slightly higher than reported previously in a meta-analysis (Galland et al. 2009), but after that it changed vice versa so that the parents' reported shorter sleeping times than have been reported previously. The average sleeping time was 14.4 h at three months and 13.7 h at six months, while the corresponding figures in the meta-analysis were 13.6 h at three months and 12.9 h at six months. However, among two year olds shorter total sleeping times (11.9 h) were reported, compared to previous studies, such as the 12.5 h reported by Sadeh et al. (2009) and 13.2 h reported by Iglowstein et al. (2003). This difference could reflect cross-cultural differences in children's sleeping habits (Jenni et al. 2009), or secular changes. For example, a recent Spanish study reported a decreasing trend in children's sleeping times between 1987 and 2011 (de Ruiter et al. 2016).

Although most of the previous studies about children's sleep development are based on questionnaires, studies using polysomnography have yielded rather similar mean estimates of sleep duration, although with less variability than in the parental reports. For example, at the age of three months, the total sleeping time evaluated using PSG decreased from 14.5 ± 1.0 h at three months to 11.0 ± 1.5 h at two years (Louis et al. 1997), which is in close correspondence to what we found. Additionally, similarly to our findings, they reported that the decrease was mainly due to a decrease in diurnal naps from 4.5 ± 1.2 h at three months to 1.8 ± 0.5 h at two years (the respective figures in our study being 5.3 ± 1.5 h and 1.9 ± 0.7 h).

The large variation in sleep duration in early childhood is not well understood. Some of the inter-individual variability is normative with no adverse effects, representing differences in the need for sleep. However, children with daily sleeping times far outside the normative range can suffer from

sleeping disturbances and other medical concerns that need assessment (Hirshkowitz et al. 2015). Twin studies have indicated that infant sleep duration is mainly explained by the shared environment while shared genetic factors usually had only a modest effect (Brescianini et al. 2011; Fisher et al. 2012; Touchette et al. 2013). It has been found that lower maternal education, being male, having older children in the family, maternal antenatal depression or insomnia, infant TV/video viewing, the introduction of solids at an age <four months and day care attendance are associated with shorter sleeping times (McDonald et al. 2014; Morales-Munoz et al. 2018; Nevarez et al. 2010; O'Connor et al., 2007). Therefore, the sleeping times in early childhood most likely reflect various genetic, prenatal, and environmental factors.

It is well-known that infants' diurnal sleep-wake rhythms develop during the first months being driven by a preceding increase in nocturnal melatonin secretion (Rivkees 2003). Daytime sleep then decreases gradually until approximately the age of three to four years when sleep becomes monophasic (Thiedke 2001; Sadeh et al. 2009). In accordance with this, we found daytime sleep to decrease by 3.4 h (from 5.3 h to 1.9 h) during the first two years approximately following the rate of decreasing total sleep, while night-time sleep remained at about 10 h during the entire follow-up study period. Similar findings were reported in an Italian longitudinal study comprising 704 infants who were followed up monthly from the age of one month to 12 months (Bruni et al. 2014). In the study night-time sleep duration was relatively stable being around 9.8 h, while between six to 12 months the amount of daytime sleep decreased from 3.3 h to 2.0 h, which was reflected in a decrease of the total sleeping time (12.8 h at six months and 11.8 h at 12 months).

However, there are extensive inter-individual differences in the development of the sleep-wake rhythm suggesting that it depends on environmental or genetic factors. Indeed, the sleep-wake rhythm develops on the basis of environmental cues such as lighting, social signals and feeding. Previously, it has been reported that regular light exposure during the day is related to better/longer night-time sleep (Harrison 2004; Iwata et al. 2016). Moreover, daytime naps are related to later bedtimes, shorter night-time sleeps and poorer sleep quality, both in younger (Paavonen et al. 2019) and older children (Akacem et al. 2015). Finally, maternal eveningness (i.e. late chronotype) has also been linked to more daytime sleep as well as with more sleep onset problems and later bedtime (Morales-Munoz et al., 2019). This effect could be mediated through life-style preferences related to the maternal chronotype, although genetic or hormonal factors might also play a role.

The ability to fall asleep independently increased during the follow up and reached its highest at the age of two years. Previously, it has been reported based on videosomnography that still at the age of

12 months, 50% of infants typically required parental intervention to get back to sleep after an awakening (Goodlin-Jones et al. 2001). It has also been reported that longer parental response times to infant awakenings at bedtime at three months predict better ability of self-soothing at 12 months (Burnham et al., 2002). If inability to self-soothe is associated with high number of night awakenings, it may indicate sleep-association disorder which can be effectively treated using behavioural interventions supporting independence at bed-time (Melzer 2010).

According to our study, sleep onset was at its longest at six months (40 min) and decreased to approximately 20 minutes thereafter. We assume that this reflects the development of self-regulation and improvements in the sleep-wake rhythm. Despite this, a relatively large proportion of children from all time points had difficulties settling down to sleep, and long sleep-onset latencies (≥ 30 minutes) were common. Children who are still having difficulties to fall asleep in the second year of age benefit from clinical evaluation, because difficulties with the onset of sleep typically reflect adverse environmental factors, such as inadequate sleep hygiene due to a lack of bed-time routines (Allen et al. 2016; Mindell et al. 2009). On the other hand, sleep onset problems may result from circadian rhythm disturbances (i.e., delayed sleep-phase) or behavioural insomnia (i.e., bedtime resistance), both of which can be effectively treated using behavioral interventions (Melzer et al. 2010; Vriend & Corkum 2011).

Our data confirmed that one to three awakenings per night is common in early childhood. Almost all children woke up 1-3 times at night, while a minority slept through the night (16.5% at three and 22.3% at eight months). Similar figures concerning the prevalence of night awakenings have been reported previously. For example, Sadeh et al. (2009) reported the average frequency of night awakenings to decrease from 1.9 times per night at the age of 0-2 months to 0.8 at 24-36 months. However, this study was not based on a population-based sample but was collected over the Internet via advertising, which may result in selection bias. Weinraub et al. (2012) on the other hand reported developmental changes in infants' night awakenings between six to 36 months in a sample of more than 1200 infants and found that the percentage of children waking their parents up more than six to seven nights per week dropped from 25% at six months to less than 10% at 36 months, corresponding to our rates.

Therefore, night awakenings are a normative feature for children under one year of age. This is supported by recent studies in which the number of night awakenings and staying awake at night (<age 1 yr) were not associated with adverse developmental consequences (Mäkelä et al. 2018; Pennestri et al., 2018). However, during the second year, the average number of night-awakenings

decreased significantly. In two year olds, only one third had frequent night awakenings (28.4% at least 5 times a week), suggesting that these children might benefit from further clinical assessment and treatment, particularly when the number of awakenings is more than two per night.

Treatment for night-awakenings depends on its primary cause. They may be caused by problems in the circadian sleep-wake rhythm (Paavonen et al. 2019) or somatic illnesses such as atopy or allergies (Bruni et al. 2017). Moreover, sleep breathing disturbances are also related to worsened quality of sleep (Katila et al. 2019). Finally, night awakenings can also indicate sleep-association disorder, and in these cases behavioural interventions to support self-soothing should be considered (Burnham et al., 2002; Melzer 2010; Mindell et al. 2006).

General considerations

Infants' sleep development is highly variable, but rapid changes take place already during the first years of life. While parent reported sleeping difficulties are highly prevalent, not all these problems represent clinically significant cases. For example, sleep onset difficulties or night-awakenings are unspecific symptoms that can be either normative or caused by various sleep disorders. Sleep development is a bio-psycho-social process. It builds on the circadian sleep-wake rhythm and sleep homeostasis (Borbely et al. 2016), but at the same time it is influenced by developmental, biological, social and cultural factors (Sadeh et al. 2010). Therefore, parents' concerns and perceptions about infant sleep are highly variable and mirror their personal preferences and cultural backgrounds.

To be able to support their infant's sleep development optimally, parents need information on the normative development of sleep. Prevention programmes based on information on normative development and factors affecting sleep development are known to be useful (Mindell et al. 2011). Information should be easily accessible and available to all families. Based on this study, we suggest age-specific cut-off values to identify individuals who are suffering from deviant sleep quality (Figure 5). These children could benefit from clinical assessments and interventions. Further studies in clinical settings are, however, needed to evaluate the positive and negative predictive values of these cutoffs. Sleeping problems in early childhood are multifactorial and therefore the clinical evaluation should include an evaluation of the factors underlying the sleep problem. Somatic illnesses, environmental factors and difficulties in child-parent interaction can be related to sleeping problems.

Limitations

This study is based on two large and representative birth cohorts. However, the data is based on parent-reported questionnaires that could be prone to report bias. It is possible that some parents over-report their concerns over child's sleep particularly if they are tired, stressed or depressed themselves. At the same time, they also bring up the important aspect of how parents experience their child's sleep patterns. Therefore, the estimates presented in this article are likely to be valuable in clinical settings where clinical interviews are based on similar subjective parental estimates. We recommend that after a screening phase, the assessment should be continued with sleep logs to obtain a prospective report on the sleep quantity and quality. Another limitation is that the sample sizes differed from time point to time point, decreasing over the time. However, a considerably large sample was still available at 12 months and two years. Further studies are needed to study the predictive validity of the different sleeping problems, i.e., to define problems that tend to be persistent. Some sleeping difficulties might be temporary and self-limiting, while other difficulties probably require longer follow up and better interventions. Previously, it has been reported that persistent, rather than transient, sleeping difficulties contribute to maternal depression, parenting stress, and subsequent child behavior problems (Wake et al. 2006).

Conclusions

Significant number of parents reported sleeping problems. This suggests that many families would benefit from sleep interventions such as psychoeducation, preventive interventions or behavioural interventions. In early childhood, when rapid developmental changes take place (i.e. improving sleep-wake rhythms, self-regulation, followed by improved sleep quality and decreased sleep need), it is particularly important to know the average developmental sleep trajectories. Reference values indicating deviant or delayed sleep development can assist clinicians to identify children who might benefit from clinical assessment and sleep interventions. The reference values reported in this article could be used in various clinical settings to aid the prevention and treatment of sleeping problems in early childhood. Effective behavioural interventions exist and they should be available to all infants with sleep disturbances (Corkum et al., 2018; Mindell et al. 2011, Moturi et al., 2010, Vriend & Corkum 2011). As sleeping difficulties are related to negative developmental consequences, such as emotional and behavioral symptoms (Chaput et al. 2017; Ednick et al., 2009; Spruyt 2019; Turnbull et al., 2013), while adequate sleep duration and lower odds of sleep disturbances are related to higher wellbeing scores (Thumann, 2019), their treatment is always highly valuable.

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Table 1. Description of the two samples.

		CHILD-SLEEP ¹	FinnBrain ²
		Mean \pm SD (Range)	Mean \pm SD (Range)
Birth weight (g)	in grams	3589 \pm 447 (2290 – 5780)	3601 \pm 467 (1780 – 5470)
Gestational age (weeks)	in weeks	40.1 \pm 1.1 (37.0 – 42.6)	40.0 \pm 1.2 (37.0 – 42.6)
Maternal age	in years	31.0 \pm 4.3 (19 – 47)	30.7 \pm 4.3 (18 – 45)
Paternal age	in years	33.1 \pm 4.3 (20 – 57)	32.0 \pm 5.3 (18 – 60)
		N (%)	N (%)
Number of children in the family	one	498 (47.2%)	974 (53.2%)
	two	364 (34.5%)	611 (33.4%)
	three or more	193 (18.3%)	246 (13.4%)
Breastfeeding	full	727 (64.5%)	149 (12.4%)
	partial	254 (22.5%)	699 (58.3%)
	no	146 (13.0%)	350 (29.2%)

1. Data concerns the respondents at three months.

2. Data concerns the respondents at six months.

Table 2. Normative sleep development in children aged 3 months to 2 years.

	3 mo	6 mo	8 mo	12 mo	18 mo	24 mo
	mean \pm SD (range)	mean \pm SD (range)	mean \pm SD (range)	mean \pm SD (range)	mean \pm SD (range)	mean \pm SD (range)
Daytime sleep, hours	5.3 \pm 1.5 (1.0-10.5)	3.7 \pm 1.2 (0.5-9)	3.4 \pm 1.0 (1.0-9.0)	2.5 \pm 0.8 (0.5-6.0)	2.1 \pm 0.7 (0.7-5.5)	1.9 \pm 0.7 (0-5.0)
Night sleep, hours	9.1 \pm 1.4 (2.0-12)	9.9 \pm 1.1 (2.5-12)	9.9 \pm 1.0 (6.0-12.0)	10.2 \pm 1.0 (3.5-12.0)	10.2 \pm 0.8 (5.5-12.0)	10.0 \pm 0.8 (6.8-12.0)
Total sleep, hours	14.4 \pm 1.8 (6-20.5)	13.7 \pm 1.4 (6-21)	13.3 \pm 1.2 (8.0-21.0)	12.8 \pm 1.1 (6.5 – 16.0)	12.3 \pm 0.9 (8.0-16.0)	11.9 \pm 0.9 (8.3-14.5)
Daytime sleep, %	36.5 \pm 8.4 (10.0-76.5)	27.0 \pm 7.2 (4.6-50.0)	25.7 \pm 6.5 (8.3-53.9)	19.6 \pm 5.8 (4.8-46.2)	16.9 \pm 4.8 (6.0-38.5)	15.7 \pm 5.0 (0-40.0)
Sleep onset latency, minutes	38.0 \pm 34.3 (0-420)	25.4 \pm 20.4 (0-180)	22.4 \pm 16.3 (0-120)	21.7 \pm 20.0 (0-300)	19.7 \pm 14.2 (0-120)	25.4 \pm 19.5 (0-210)
Number of night awakenings	2.2 \pm 1.3 (0-15)	2.5 \pm 1.8 (0-15)	2.4 \pm 1.8 (0-21.5)	1.8 \pm 1.5 (0-13.5)	1.1 \pm 1.1 (0-11)	0.9 \pm 0.9 (0-6)
Time awake at night, minutes	53.3 \pm 50.2 (0-480)	27.3 \pm 29.2 (0-300)	23.7 \pm 25.7 (0-180)	16.8 \pm 25.0 (0-300)	8.5 \pm 22.7 (0-480)	6.1 \pm 11.0 (0-120)
Bedtime, hh:mm	21:46 \pm 1:13 (18:00-02:10)	20:54 \pm 1:00 (18:00-02:00)	20:53 \pm 0:56 (18:20-02:00)	20:39 \pm 0:50 (18:15-02:00)	20:41 \pm 0:43 (18:30-23:00)	20:54 \pm 0:41 (18:45-23:30)

Table 3. The prevalence of other sleeping problems and self-soothing

Sleep quality	Cut-off	3 mo	8 mo	18 mo	24 mo
		% (N) (95% CI)	% (N) (95% CI)	% (N) (95% CI)	% (N) (95% CI)
How many times a week do you have problems settling him/her on average?	≥ 5 nights a week	7.6% (6.1-9.2%)	12.0% (10.1-13.9%)	3.4% (2.2-4.6)	8.8% (6.8-10.8%)
How many nights a week does your baby wake on average (between 24:00-06:00)?	≥ 5 nights a week	83.5% (81.3-85.7%)	77.7% (75.2-80.2%)	36.1% (32.9-39.3%)	28.4% (25.2-31.6%)
How many times does your baby wake each night and need resettling on average?	≥ 2 times per night	48.8% (45.8-51.8%)	56.0% (53.0-59.0%)	22.0% (19.2-24.8%)	14.9% (12.4-17.4%)
How many times does your baby wake each night and need resettling on average?	≥ 4 times per night	7.1% (5.6-8.6%)	13.6% (11.5-15.7%)	4.7% (3.3-6.1%)	1.8% (0.9-2.7%)
If your baby wakes, how long does it take for your baby to go back to sleep on average?	≥ 20 min	16.9% (14.6-19.2%)	6.8% (5.3-8.3%)	4.8% (3.4-6.2%)	2.2% (1.1-3.3%)
How often do you end up taking your baby into your bed because he/she is upset and won't sleep?	≥ 5 nights a week	14.8% (12.6-17.0%)	25.3% (22.7-28.0%)	16.6% (14.1-19.1%)	11.1% (8.8-13.4%)
How often does your baby fall asleep independently without the parent being present	often/always	30.6% (27.9-33.3%)	49.4% (46.2-52.6%)	50.2% (46.8-53.6%)	46.7% (43.2-50.2%)

Figure 1. Total sleep time in infants aged 3 to 24 months.

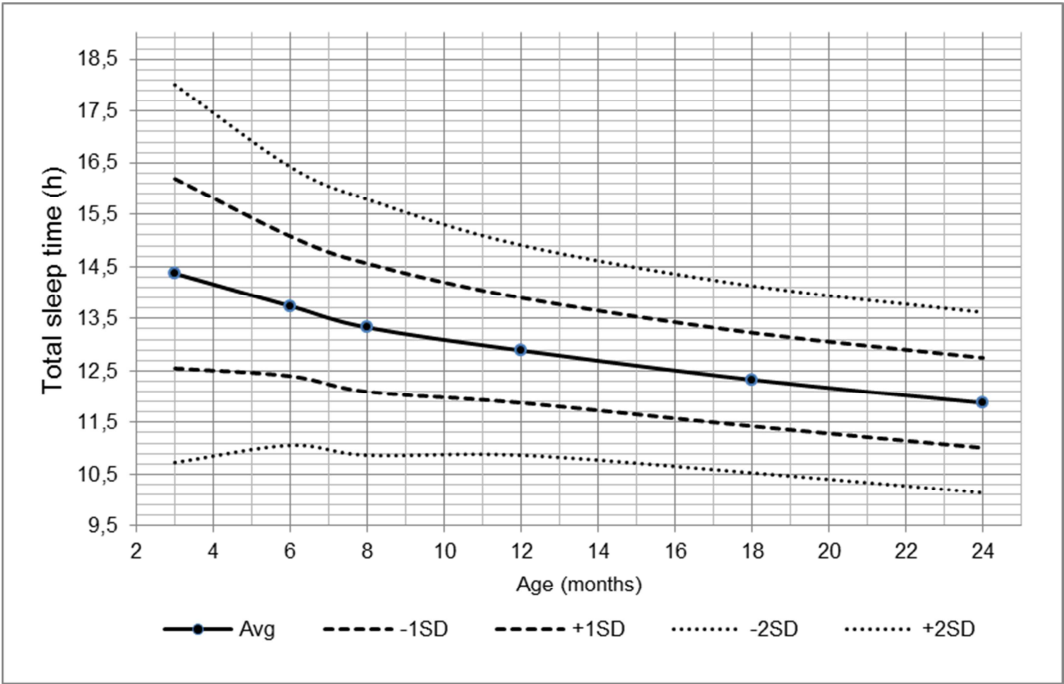


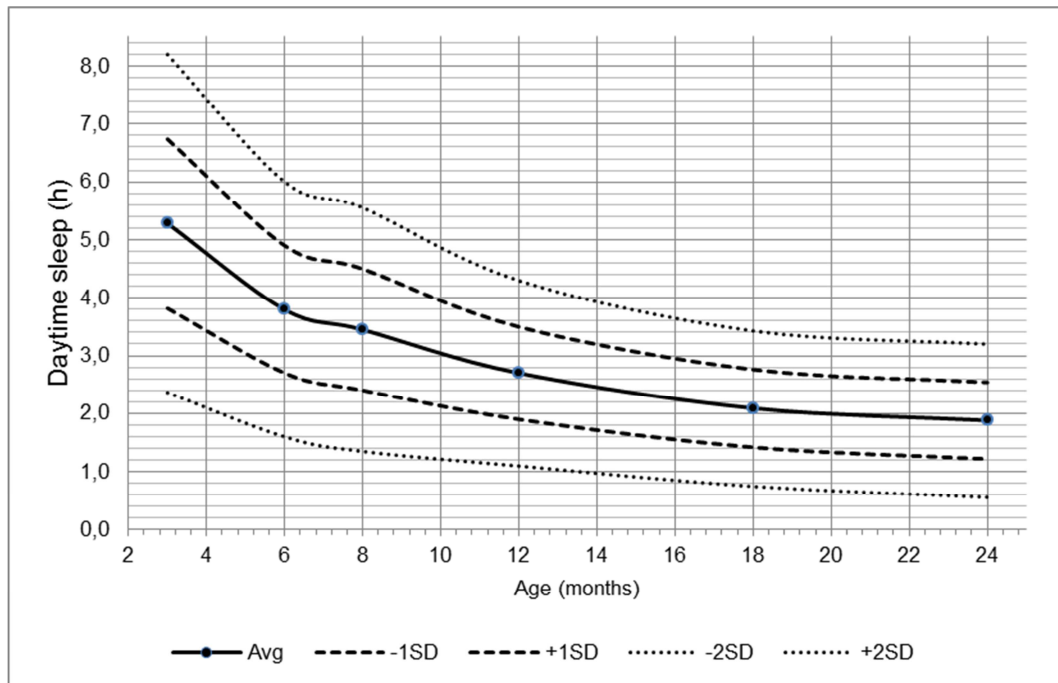
Figure 2. Daytime sleep duration in infants aged 3 to 24 months.

Figure 3. Night-time sleep duration in infants aged 3 to 24 months.

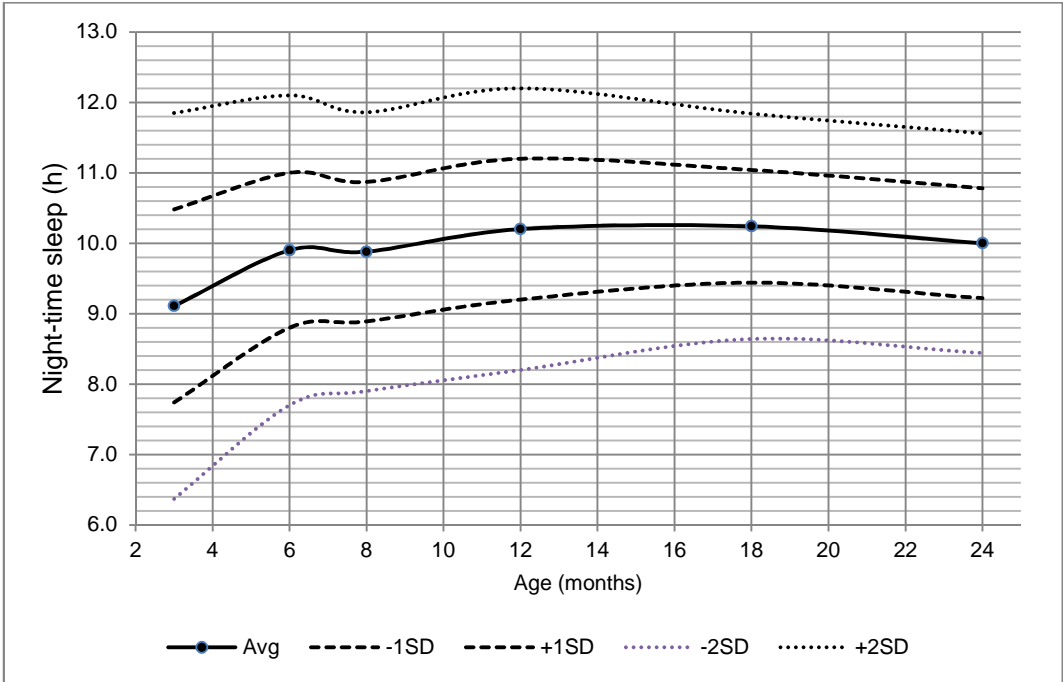


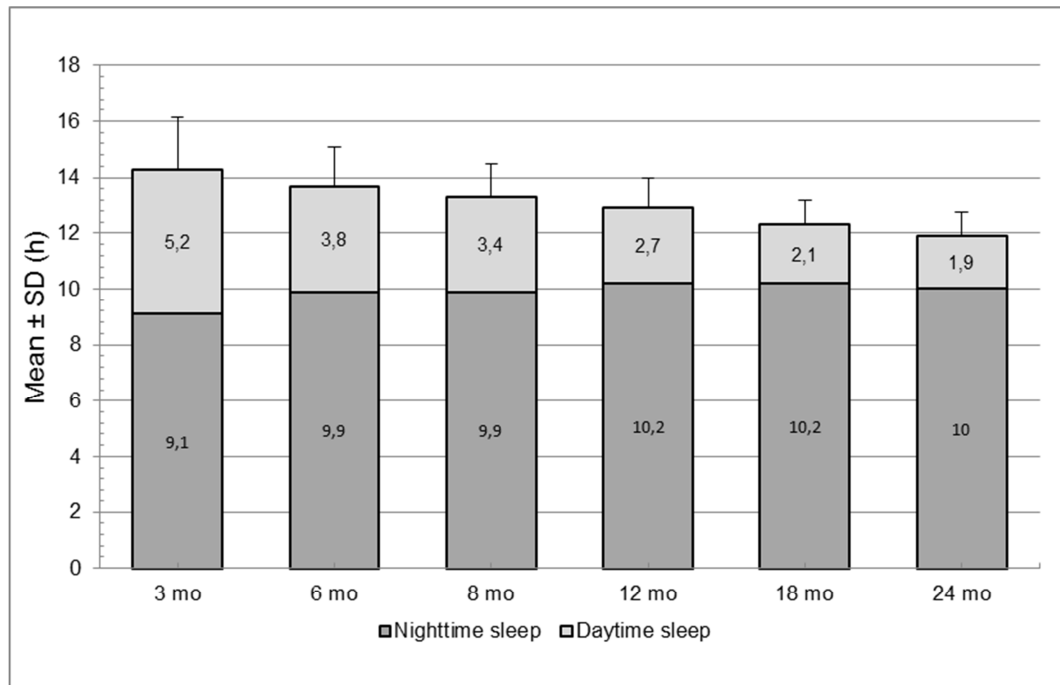
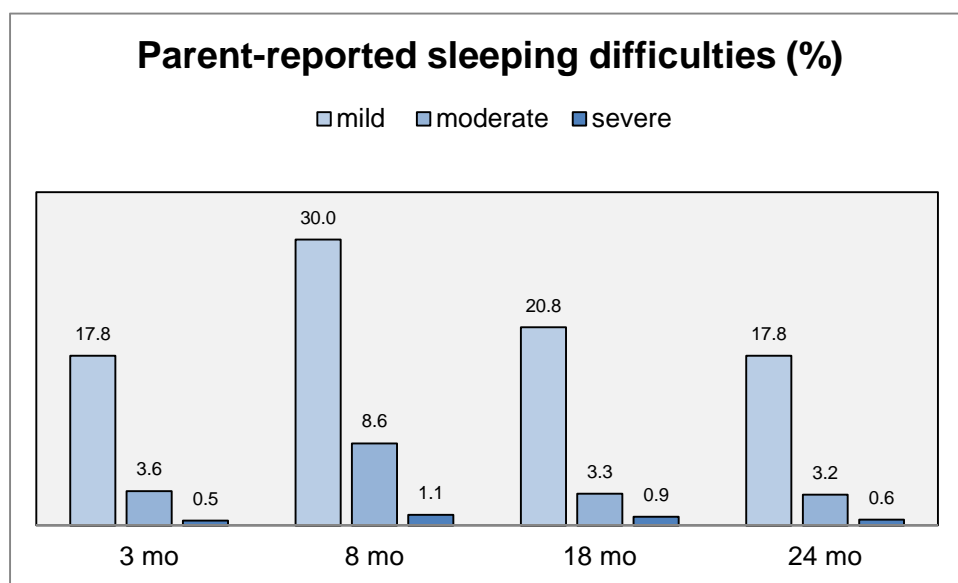
Figure 4. Sleep-wake rhythm in infants aged 3 to 24 months.

Figure 5. Distribution of infants' sleep quality in 3 to 24 months of age (10th, 25th, 50th, 75th and 90th percentiles¹ reported).

Sleep latency (min)	10 th pt	25 th pt	50 th pt	75 th pt	90 th pt
3 mo	10	15	30	60	90
6 mo	8	10	20	30	60
8 mo	7	10	20	30	45
12 mo	5	10	15	30	40
18 mo	5	10	15	30	38
24 mo	5	15	20	30	45
Night awakenings (N)	10 th pt	25 th pt	50 th pt	75 th pt	90 th pt
3 mo	1,0	1,5	2,0	3,0	4,0
6 mo	0,5	1,0	2,0	3,0	4,5
8 mo	0,5	1,0	2,0	3,0	4,5
12 mo	0,0	1,0	1,5	2,5	4,0
18 mo	0,0	0,5	1,0	1,5	2,5
24 mo	0,0	0,0	1,0	1,0	2,0
Awake at night (min)	10 th pt	25 th pt	50 th pt	75 th pt	90 th pt
3 mo	10	20	40	60	120
6 mo	0	10	20	30	60
8 mo	1	8	15	30	60
12 mo	0	2	10	20	45
18 mo	0	0	3	10	29
24 mo	0	0	2	8	15

1. The percentiles reported in the Table indicate the sleep quality parameters below which the given percentage of infants within each age group fall. For example, the 10th percentile at 3 months (10 minutes) is the value below which 10% of the infants can be found (i.e. 10% of the infants have sleep onset latency 10 minutes or less).

Figure 6. Parent reported sleep problems for infants aged 3 to 24 months.

Highlights

- Sleeping problems are commonly reported in infancy.
- Infants' sleep quality is highly variable during the first two years of life.
- The changes in sleep quality during development are extensive.
- Infants with deviant sleep quality might benefit from sleep interventions.
- Distribution percentiles could be used as age-specific reference values.