

# Sleep and neuropsychological development among infants and toddlers

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## Abstract

Sleep quantity and quality have been verified to influence cognitive function in adult and children, while little is known about such relation among young children. This study aims to explore the concurrent association between sleep and neuropsychological development in infants and toddlers. 1102 children aged 2-30 months old from 16 hospitals in 8 provinces of China were involved in the survey. Main caregivers were asked to fill out the Brief Infant Sleep Questionnaire (BISQ) and the Bayley Scales of Infant Development I (BSID-I) was conducted to evaluate children's neuropsychological development. Results showed that in average infants slept 12.40 (12.30-12.51) hours over 24 hours, woke up 1.77 (1.69-1.84) times per night and woke 0.50 (0.45-0.54) hour through the night. Prolonged night waking duration was negatively associated with the Mental Development Index (MDI) only among toddlers aged 1-2.5 years old ( $\beta=-0.10$ ,  $p=0.045$ ). No association between sleep and psychomotor development was found. This study underscores the high prevalent fragmental sleep in Chinese infants and toddlers that indicates for concurrent slow cognitive development.

**Keywords:** infants; sleep; night waking; cognition development

## Introduction

The important role of sleep on cognitive function has been widely acknowledged in elderly population and healthy adults (Pilcher & Huffcutt, 1996; Van Dongen, Maislin, Mullington, & Dinges, 2003; Yaffe, Falvey, & Hoang, 2014). Furthermore, a recent meta analysis has confirmed the positive relation between sleep duration and cognitive performance among 5 to 12 years old children (Astill, Van der Heijden, Van Ijzendoorn, & Van Someren, 2012).

Comparing with preschoolers and adults, infants and toddlers spend much more time on sleep when their brains develop rapidly during the first few years (Peirano & Algarin, 2007). On the other hand, the sleep-wake state has

long been considered to be the product of central nervous system (CNS) maturation (Bruni et al., 2010; Kohyama, 1998).

In addition, early well-being is critical for later global health. For instant, a longitudinal study shows that cognitive abilities such as attention, processing speed and memory during infancy and toddlerhood, are predictive for children's executive functions including working memory, inhibition and shifting at 11 years old (Rose, Feldman, & Jankowski, 2012).

Despite of the abundant evidences in children, only sporadic studies have explored the role of sleep in infants' cognitive development with most of them coming from laboratory settings with small sample sizes and narrow age ranges (e.g., Ednick, Cohen, & McPhail, 2009), or clinical samples (e.g., snoring) (Piteo, Kennedy, et al., 2011; Piteo, Lushington, et al., 2011). Therefore, we conducted a large-scale cross-sectional study aiming to disclose the relation between sleep and cognitive development among infants and toddlers.

## Methods

From October 2012 to March 2013 in collaboration with one downtown hospital and one suburban hospital in each of the eight provinces in mainland China (i.e., Inner Mongolia, Hunan, Hebei, Guangxi, Yunnan, Shandong, Zhejiang and Jiangsu), we recruited children who came in the clinic for regular health examination. Shanghai Children's Medical Centre Human Ethics Committee granted ethical approval for this study (SCMCIRB-2012047), and written informed consent was obtained from caregiver of each participant.

## Participants

In all, 1102 children within the age range of 2-30 month-old born over 37 weeks of gestational age were enrolled.

Children were excluded if they were twins or triplets, had any congenital diseases or adverse birth outcomes.

### Measures

**Sleep assessment** Parents or primary caregivers completed the Chinese version of Brief Infant Sleep Questionnaire (BISQ)(A Sadeh, 2004; AVI Sadeh & MINDELL, 2009) adopted from the cross-culture study of Mindell et al. (2010) The respondents were asked to describe their child’s sleep during the last two weeks.

**Cognition assessment** General cognitive functioning was assessed with the Bayley Scales of Infant Development (BSID-I), the standardized diagnostic test of cognitive development delay for children aged 2-30 months in mainland China. Based on the test scoring, Mental Development Index (MDI) and Psychomotor Development Index (PDI) were derived. All assessments were conducted by well-trained pediatricians.

### Statistical analyses

An initial examination of the data was performed to test for normality and outliers. If normality was not fulfilled then the data was transformed accordingly, e.g., night waking duration was analyzed by  $\log_{10}$  (raw data +1) transformation.

The MDI and PDI across gender, parental education level and area were compared by ANOVA. The associations between sleep parameters and Bayley scores were tested by partial correlation adjusted for children’s age. Linear regression analysis was applied to test the predictive effect of sleep parameter on Bayley scores. Children’s age, gender, maternal education level and recruited province were entered as control confounders in each model. The statistical significance level was set at 0.05.

## Results

The mean age of the 1102 children was 371.95 (375.24-386.56) days, 53.8% (593/1102) of the sample were boys. Boys and girls were of similar age ( $t(1100)=-1.16, p=0.246$ ).

### Infant sleep and night waking

On average, infants slept 12.40 (12.30-12.51) hrs every day. No differences of total sleep were found between girls and boys ( $t(1089)=0.88, p=0.378$ ).

Figure 1 showed infants’ night waking frequency and duration across age groups. In general, infant woke up 1.77 (1.69-1.84) times per night and woke 0.50 (0.45 - 0.54) hr through the night. Overall, boys woke up more frequently than girls ( $t(1097)=2.22, p=0.027$ ). No differences of total night waking duration were found between girls and boys ( $t(1082)=1.56, p=0.145$ ).

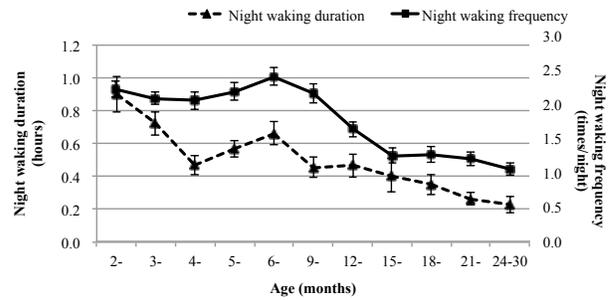


Figure 1: Night waking of children at different age periods.

### Association between night waking and cognitive developments

The mean MDI and PDI score was 103.13 (102.12-104.14) and 101.97 (101.03-102.91). There was no gender difference regarding to MDI and PDI scores ( $p>0.05$ ). Parental education levels were highly correlated ( $r=0.73, p<0.001$ ) and both were significantly associated with MDI and PDI ( $p<0.001$ ).

Partial correlation, controlled for age, showed that infant night waking frequency and total night waking duration were negatively associated with MDI ( $r=-0.06, p=0.040$ ;  $r=-0.08, p=0.014$ ), but not associated with PDI ( $r=-0.01, p=0.740$ ;  $r=-0.04, p=0.229$ ). Infant total sleep duration was correlated with neither the MDI nor the PDI ( $r=-0.03, p=0.342$ ;  $r<0.01, p=0.885$ ).

Linear regressions indicated that prolonged night waking duration had an adverse impact on MDI only among toddlers aged 1-2.5 years old ( $\beta=-0.10, p=0.045$ ). Neither total sleep duration or night waking frequency predicted for MDI in the model (Table 1).

Table 1: Linear regression model of Bayley MDI.

Age	<12m			12m-30m		
	Beta	t	p	Beta	t	p
Total sleep duration	-0.03	-0.77	0.445	0.04	0.93	0.354
Night waking frequency	-0.03	-0.78	0.449	0.02	0.44	0.661
Night waking duration#	<-0.01	-0.03	0.980	<b>-0.10</b>	<b>-2.01</b>	<b>0.045</b>

# Night waking duration was log transformed.

## Discussion

This study underscores the high prevalent and long lasting night waking problem among Chinese infants and toddlers with equivalent total sleep duration comparing with previous meta-analysis (Galland Taylor, B.J., Elder, D.E., & Herbison, P., Galland, Taylor, Elder, & Herbison, 2012). Moreover, longer night waking duration is predictive for slower cognitive development especially during the transition period from infancy to toddlerhood.

The current results showed that night waking duration negatively predicted for cognitive development only among toddlers beyond one year old and highlighted the impairments of sleep fragmentation. Previous study involving 1385 Chinese Kindergarten children aged 5.7 years old also showed that children with parental reported difficulties in maintaining sleep scored peculiarly lower in verbal IQ (tested by Wechsler Preschool and Primary Scale of Intelligence-Revised) (Liu et al., 2012).

More and more studies reveal the importance of infant sleep quality, rather than sleep duration, which associates with infants' cognitive functions. On one hand, frequent and persistent night waking definitely disturbed sleep continuity, and the consequent increasing of stress level could impair infants' mental performance (Anders, Keener, & Kraemer, 1985; Charmandari, Kino, Souvatzoglou, & Chrousos, 2003). Alternatively, both night waking and impaired cognition could be resulted from CNS diseases and other life stress events such as early problematic parenting (Bernier, Carlson, & Whipple, 2010; DeLeon & Karraker, 2007). On the other hand, night waking could be a representation of circadian sleep dysregulation that has been suggested as a predictor for later poor cognitive regulation (Bernier & Carlson, 2010; Dearing, McCartney, Marshall, & Warner, 2001).

The positive effect of sleep on motor development in children was not supported in the current study. A previous study using procedural tasks (e.g., the serial reaction time task, the finger sequence tapping task and the mirror tracing task) confirmed the absence of sleep-dependent gain in motor skills in children (Fischer, Wilhelm, & Born, 2007), which could partially due to the less established sensorimotor integration in young brain (Wilhelm, Prehn-kristensen, & Born, 2012).

There are two major limitations of this study. Firstly, this study was based on parental report. Future studies evaluating sleep by both objective and subjective methods may wish to confirm the results. Secondly, the current study was designed as a cross-sectional survey, so that only concurrent associations between sleep and cognition were derived. Nevertheless, under the context of development, the correlations and predictive directions between sleep and cognitive function are not always uniform (Freudigman & Thoman, 1993; Gertner et al., 2002; Scher, Steppe, & Banks, 1996). Further study is required to complement the role of sleep on cognition among young.

## Conclusion

Parent-reported night waking problem in Chinese infants and young toddlers was more prevalent than that in other countries and sustained during the first few years. Our findings underline the negative prediction of the sustained long night waking on young children's cognitive development. Thus, apart from the increasing awareness involved in infant sleep duration, pediatricians and other professionals should pay more attention to the fragmental sleep. The current study provides both scientific and clinical

values as our results could be referenced for future parental-educated sleep intervention programs to effectively improve sleep in young children (Bonuck & Grant, 2012; Hall, Saunders, Clauson, Carty, & Janssen, 2006; Price, Wake, Ukoumunne, & Hiscock, 2012).

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