Early Human Development 88 (2012) 847–852

Contents lists available at SciVerse ScienceDirect

Early Human Development

journal homepage: www.elsevier.com/locate/earlhumdev

Relationship between duration of crying/fussy behavior and actigraphic sleep measures in early infancy

Hitomi Shinohara, Hideya Kodama *

Department of Maternity Child Nursing, Akita University Graduate School of Medicine and Faculty of Medicine, Japan

ARTICLE INFO

Article history:
Received 12 April 2012
Received in revised form 21 June 2012
Accepted 22 June 2012

Keywords:
Infants
Crying
Sleep development
Actigraph
Co-sleeping
Active sleep

ABSTRACT

Objective: The objective of the study is to understand the relationship between sleep development and crying episodes during early infancy more accurately by longitudinal and objective sleep evaluations.
Design: The study is designed as a prospective longitudinal study of infants in the first 4 months of life.
Methods: This study included 31 healthy term infants. At approximately 4- to 6-week intervals, when the infants were aged 4–6 weeks, 8–10 weeks, and 14–16 weeks, their mothers recorded the duration of crying/fussy behavior of infants in a timetable and attached an actigraph to the infants for 3 days. The relationship between 24-h crying/fussy behavior duration and actigraphic sleep measures was examined from both a cross-sectional (age group) and longitudinal (within-infants) perspective. Interactions with diverse covariates were studied by multiple regression analysis.
Results: A significant correlation was found between 24-h crying/fussy behavior duration and proportion of active sleep in infants at 14–16 weeks and in within-infant relationships. Among potential covariates, gestational age and co-sleeping had a significant impact on proportion of active sleep. Results of multiple regression analysis showed that gestational age and co-sleeping were positively associated with proportion of active sleep, whereas 24-h crying/behavior duration was not associated with proportion of active sleep.
Conclusions: Subsiding of early crying and decreasing of proportion of active sleep are parallel phenomena in some infants. However, this association was thought to be attributable to the influence of covariates, including co-sleeping or gestational age. The underlying mechanisms regulating these developmental processes might overlap with one another, as covariates that affect one process could affect the other.

1. Introduction

Infant crying increases after birth, peaks at around 5 to 6 weeks of age, and tends to subside by 3 months [1,2]. This early period of crying sometimes becomes a source of serious concern for parents. If increased crying during this period is a transient phenomenon reflecting a normal part of development, then even if crying is severe, it is not a serious problem. However, there are marked individual differences in the pattern of crying during early infancy. For example, the age at which crying peaks ranges from 3 to 12 weeks [1]. The amount of crying at the peak also varies, ranging from a daily total crying duration of less than 20 min in mild cases to more than 3 h in severe cases with the so-called colic [3]. Furthermore, a considerable number of infants continue to have symptoms after 3 months [4].

Increased crying in early infancy may be related to rapid sleep development during this period. In newborns, sleep and wakefulness follow an ultradian rhythm of approximately 4 h, with only minor differences between daytime and night. However, by the end of the first 3 months of life, most infants have developed a diurnal sleep–wake cycle, with wakefulness concentrated in the daytime and sleep at night [5,6]. During the peak period of crying, crying episodes tend to cluster in the early evening, when infants are usually awake for the longest period during the day [2]. During this same period, sleep structure goes through rapid changes. Active sleep, the infant's equivalent of rapid eye movement sleep, which is predominant in the newborn period, subsides, and quiet sleep becomes predominant [5,6]. Simultaneously, active sleep onset of the sleep cycle, which is characteristic of neonatal sleep, rapidly diminishes [5]. If a significant linkage between sedation of crying and sleep development exists during early infancy, there may also be a significant linkage between severe or prolonged crying and disrupted sleep development [7].

However, conclusions of previous studies on association between crying and sleep–wake rhythm during early infancy have been controversial [7–11]. Most studies using maternal reports of infant sleep have suggested a link between total sleep time and duration of crying episodes [8–10]. Contrarily, Kirjavainen et al. [7] reported that 6-week-old infants with excessive crying had sleep duration and sleep structure that were similar to control infants, when infant sleep was assessed by ambulatory polysomnography. Their report is currently one of the few reports to have analyzed the relationship between sleep in infants and crying

* Corresponding author at: 010-8543 1-1-1 Hondo, Akita-shi, Japan. Tel.: +81 18 884 6513; fax: +81 18 884 6500.
E-mail address: kodamah@hs.akita-u.ac.jp (H. Kodama).

0378-3782/$ – see front matter © 2012 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.earlhumdev.2012.06.005

duration using the objective sleep assessments [7,11]. However, the relatively small sample size and the fact that it was a cross-sectional survey conducted at 6 weeks of age must be carefully considered. At 6 weeks after birth, the sleep–wake rhythm is dynamically developing, meaning that variations in sleep measures are large. In addition, individual differences in sleep measures themselves are large, which may mask a significant relationship between infant crying and sleep development parameters. A study with a longitudinal design may delineate more accurate relationships of these developmental processes.

The aim of this study was to better understand the relationship between sleep development and crying episodes during early infancy by longitudinal and objective sleep evaluations. Sleep of each infant during the first 4 months of postnatal life, when dynamic changes in sleep occur, was evaluated using an actigraph, a wristwatch-like acceleration sensor, three times at approximately 4- to 6-week intervals, and the relationship between the obtained sleep measures and duration of crying/fussy behavior was examined.

2. Methods

2.1. Subjects

The study protocol was approved by the Ethics Committee of Akita University Graduate School of Medicine (no. 1614). We approached mothers who delivered normal babies at a private prenatal clinic a few days after childbirth, and approximately 50% of mothers we approached agreed to participate in this study. To establish an optimal study population, the eligibility criteria included a singleton delivery, partnered, Japanese language as the mother tongue, and normal course of pregnancy without obstetric, medical, or psychiatric complications. Mothers who drank any alcohol and/or smoked, and who planned to work within a few months postpartum were also excluded. Mothers who underwent Cesarean section were not excluded, if their conditions after childbirth were normal. The mothers who participated in the study received written and verbal explanations about the nature of the study and the ethical considerations. Consent to participate was obtained in writing from each mother. In appreciation of participation, we presented a few packs of disposable diapers to the mothers.

Finally, 31 healthy term infants (15 boys, 16 girls) were included in this study. The infants were born at 37 to 41 weeks of gestation (mean ± SD: 39.0 ± 1.3 weeks) with birth weights of 2400 to 3810 g (3118 ± 356 g). For all infants, gestational age had been determined or confirmed by at least two time ultrasound measurements of a crown–rump length during the first trimester. One infant was born by Cesarean section. The mean age of mothers was 32.7 years (±5.5, 20–43 years). Fifteen mothers were primiparas and 16 were multiparas. At approximately 4- to 6-week intervals, when the infants were aged 4–6 weeks, 8–10 weeks, and 14–16 weeks, each mother was asked to record the duration of crying/fussy behavior of her infant in a timetable and to attach an actigraph to her infant.

2.2. Measurement of sleep measures in infants by actigraph

Sleep–wake rhythms and sleep structure of the infants were monitored by a miniature actigraph (Micro-mini RC, Ambulatory Monitoring Inc., NY, USA). The validity of actigraphy-derived sleep–wake measures compared with measures obtained from direct observations or traditional polysomnography has been demonstrated in infants [12–15]. Before using the actigraph, the wristband was changed to a short cloth band that would not cause irritation. At each measurement point, mothers were requested to attach the actigraph to the left ankle of infants for 3 successive days. The ankle attachment was preferable to the wrist attachment as it has been reported to be less disturbing to infants [12]. During the study period, the mothers were requested to avoid exposing their babies to obvious artifacts from externally induced movement, such as rocking in a cradle or moving on a baby stroller. Motility levels were sampled in the zero-crossing mode in 1-min epochs. The resolution of the actigraph was set at 0.01 G/s. The activity data recorded by the actigraph was later downloaded using ACTme software (ver. 3.10.0.3, Ambulatory Monitoring Inc.), and then sleep measures were analyzed using Action-W software (ver. 2.4.20, Ambulatory Monitoring Inc.). During the study, time intervals when the device was removed, for example, during bathing, were recorded in a timetable by the mothers.

As most infants at this stage had regular and frequent naps during the day, in-bed times (= down interval) cannot be clearly determined. Thus, an arbitrary measurement time interval (custom interval), in which no distinction was made between down and wakening time intervals, was applied for analysis. The epochs of wake, active sleep and quiet sleep time during the period of all measurements were determined by an algorithm developed by Sadeh et al. [13]. The periods during which the device had been removed (mostly, bath time) were determined as "bad epochs", and regarded as wake time. Regarding the determined custom interval, the following sleep–wake measures were determined: (a) 24-h sleep duration (the total amount of sleep for a 24-h period, expressed as a percentage); (b) nocturnal sleep duration (the total amount of sleep time between 20:00 and 08:00, expressed as a percentage); (c) diurnal sleep duration (the total amount of sleep time between 08:00 and 20:00, expressed as a percentage); and (d) proportion of active sleep (percentage of active sleep time per total sleep time). The values of sleep measures of infants at each measuring point were determined as means of the 3-day measures.

2.3. Measurement of duration of crying/fussy behavior in infants

A timetable for recording crying/fussy behavior in infants was prepared based on a previous report [16]. Based on observations by mothers, crying/fussy behavior and sleep start/end times of the infant were recorded with a (↔) in columns of 5-min intervals from 0 to 24 h. In general, we requested that recording be started at 08:00 and be continued for the same 3 days during which the actigraph was attached. "Fussy" was defined any time the baby was unsettled, irritable, or fractious, and then the mother was trying to soothe her baby, such as being held, rocking or comforting. Mothers were also asked to provide child care-related information, including feeding status, parent's co-sleeping with the baby and sleeping positions of infants. Later, from the timetables, total duration of crying/fussy behavior (crying/fussy behavior duration) was calculated. The mean value during the 3-day period was defined as the 24-h crying/fussy behavior duration in the infant at each measurement point.

2.4. Statistical analysis

IBM SPSS Statistics (ver. 20.0 Static Base and Advanced Statistics, IBM, NY, USA) was used for all statistical analysis. The distribution of the data for 24-h crying/fussy behavior duration or each sleep measure studied was assumed to be normal and homoscedastic according to the Kolmogorov–Smirnov test; thus, parametric testing was performed. One-way repeated measures analysis of variance (ANOVA) was conducted to determine an overall difference of means of 24-h crying/fussy behavior duration or each sleep measure by age. Greenhouse–Geisser correlations were performed when the assumption of sphericity was violated. If the ANOVA was significant, Bonferroni multiple comparison procedure was used as a post hoc test. Two-way (group × age) repeated measures ANOVA was performed to determine the differences of 24-h crying/fussy behavior duration or each sleep measure between different infant profiles or child care factor groups, with respect to primipara, gestational ages (<40 weeks or not), sex, birth weight (<3000 g or not), breast feeding, or co-sleeping. The relationship between 24-h crying/fussy behavior duration and each sleep measure was examined from both the cross-sectional (age group)