

Sleeping Through the Night: The Consolidation of Self-regulated Sleep Across the First Year of Life

AUTHORS: Jacqueline M. T. Henderson, PhD,^a Karyn G. France, PhD,^b Joseph L. Owens, PhD,^a and Neville M. Blampied, MSc

^aDepartment of Psychology and ^bHealth Sciences Centre, University of Canterbury, Canterbury, New Zealand

KEY WORDS

infancy, sleep patterns, development, longitudinal study

ABBREVIATION

LSRSP—longest self-regulated sleep period

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Address correspondence to Jacqueline M. T. Henderson, PhD, Department of Psychology, College of Science, University of Canterbury, Private Bag 4800, Christchurch, New Zealand. E-mail: jacki.henderson@canterbury.ac.nz

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WHAT'S KNOWN ON THIS SUBJECT: The majority of infants met conventional definitions for sleeping through the night by 12 months of age. Changes in infants' self-regulated sleep, as judged by developmentally and socially valid criteria for sleeping through the night, are unknown.



WHAT THIS STUDY ADDS: This study is the first to investigate infants' sleep-regulation capabilities by comparing 3 criteria for sleeping through the night. Longitudinal data provide an empirical foundation for infants' self-regulated sleep. A new criterion for sleeping through the night is presented.

abstract

FREE

OBJECTIVE: To investigate the consolidation of infants' self-regulated nocturnal sleep over the first year, to determine when infants first sleep through the night from 24:00 to 05:00 hours (criterion 1), for 8 hours (criterion 2), or between 22:00 and 06:00 hours (the family-congruent criterion 3).

METHODS: This was a prospective longitudinal study with repeated measures. Parents of 75 typically developing infants completed sleep diaries for 6 days each month for 12 months. Accuracy of parent reports were assessed by using videosomnography.

RESULTS: The largest mean increase (504 minutes) in self-regulated sleep length occurred from 1 to 4 months. The survival function decreased most rapidly (indicating greatest probability of meeting criteria) for criterion 1 at 2 months, criterion 2 at 3 months, and criterion 3 at 4 months. A 50% probability of meeting criteria 1 and 2 occurred at 3 months and at 5 months for criterion 3. The hazard function identified 2 months (criteria 1 and 2) and 3 months (criterion 3) as the most likely ages for sleeping through the night. At 12 months, 11 infants did not meet criteria 1 or 2, whereas 21 failed to meet criterion 3.

CONCLUSIONS: The most rapid consolidation in infant sleep regulation occurs in the first 4 months. Most infants are sleeping through the night at 2 and 3 months, regardless of the criterion used. The most developmentally and socially valid criterion for sleeping through is from 22:00 to 0:600 hours. At 5 months, more than half of infants are sleeping concurrently with their parents. *Pediatrics* 2010;126:e1081–e1087

Infants' sleep/wake patterns consolidate from birth and throughout the first year of life. The developmental task of sleeping through the night is attained when sleep changes from an even, multiphasic, diurnal distribution at birth to consolidated, uninterrupted sleep during the night. The failure of an infant to sleep through the night, particularly in concert with their parents' own sleep, is a common parental concern. Yet, there is a paucity of reliable empirical data on which clinicians may base appropriate developmental expectations of infants' sleep and for determining the optimal timing for intervention and prevention. This lack of data may, in part, be because of early definitions that failed to consider infants' developmental capabilities together with socially meaningful definitions for sleeping through the night.

Defining sleeping through the night poses challenges. Polysomnographic measures would permit definition in terms of time spent in defined sleep states, but such measures are not available or socially valid for most clinicians or parents. Alternative definitions are posed in terms of what can be observed by parents and essentially involve detecting periods of time during which the infant is inferred to be asleep because he or she is not observed to be awake and signaling their arousal in some way. Given that rapid eye movement-associated arousals are common in infant sleep,^{1,2} sleeping through the night from this second perspective involves increasing the duration of sleep episodes by developing the capacity for self-reinitiation of sleep (self-soothing) after arousals. Pragmatically, a definition should address whether the infant's sleep duration is in phase with his or her parents, with the infant settling to sleep at times convenient to the family and remaining asleep when other family members also are sleeping.

Hitherto, a variety of definitions and measures have been used.³ Moore and Ucko⁴ defined sleeping through the night as sustained sleep between 24:00 and 05:00 hours (criterion 1). This approach remains influential despite Moore and Ucko failing to provide a reason for their choice of time period. An alternative approach is to determine the maximum length of an infant's behavioral capacity to self-regulate sleep,⁵⁻⁷ characterized by a combination of sustained sleep, quiet wakefulness, and the reinitiation of sleep without parental intervention, termed the longest self-regulated sleep period (LSRSP). The authors of few studies have described changes in the LSRSP, which makes it difficult to directly compare infants' development of the LSRSP.³

Understanding the development of infants' self-regulated sleep and sleeping through the night requires criteria that have developmental validity, reflecting infants' physiologic capabilities for sustained sleep, which from 2 months of age typically exceeds criterion 1,⁸ as well as the behavioral capability of sleep self-regulation. Moreover, the criteria need social validity, capturing both the earlier onset and increasing length of the LSRSP, and congruence between the infant's sleep and that of the parents. In this study, we compared the earlier criteria with new criteria including 8 hours sleep at night during an undetermined period (criterion 2) and a more socially valid criterion requiring an LSRSP of 8 hours between 22:00 and 6:00 hours (criterion 3), encompassing the typical family sleep period. We therefore investigated infant self-regulated nocturnal sleep over the first year to (1) measure developmental changes in LSRSP length each month, (2) measure developmental changes in the initial onset time of the LSRSP, (3) use 3 criteria for sleeping through the night to establish

the ages at which infants first meet, and when they are most likely to meet, each criterion, and (4) compare infants' abilities to meet these criteria and when the majority do so.

METHODS

Participants

Seventy-five parents and their infants (43% female) participated in a study that investigated sleep patterns over the first year of life. Over a specified 12-month recruitment period, 104 participants initially volunteered to take part in the study. Attrition occurred mainly during the first month, and 23 withdrew for the following reasons: maternal or infant illness ($n = 11$); being too busy ($n = 5$); or no reason given, could not be contacted, or failed to return data in the first 2 months ($n = 7$). Inclusion criteria were infants born term and healthy at birth and developing typically. Mothers were approached by antenatal, maternity, and child health nurses, and advertisements were also placed in newspapers. The sample was representative of families of middle socioeconomic class status.⁹ The majority of parents were white New Zealanders; 5% of the mothers and 4% of the fathers were Maori. The majority of infants were first (33%) or second (57%) born. A researcher contacted the primary caregiver by telephone and explained the purpose and requirements of the study. When consent was obtained, demographic data were collected over the telephone and parents were familiarized with the sleep diary. A diary for the following month was supplied after receipt of the previous diary. Parents also were invited to have a time-lapse video recorder for 2 consecutive nights to record their infants' sleep patterns. The study was approved by the human ethics committee of the University of Canterbury and the Royal Plunket Society of New Zealand.

Study Design

We used a prospective longitudinal research design with repeated measures monthly from ages 1 to 12 months.

Measures

Data were obtained from sleep diaries. Parents prospectively recorded their infants' sleep behaviors monthly for 6 days and nights over 12 months. The sleep diaries were separated into "day-sleep" and "night-sleep" sections. The night-sleep section recorded the time the infant was placed into the crib, infant state when placed into the crib, and the duration in minutes to initial sleep onset. Parents recorded the time and duration of each night-awakening sustained for more than 2 minutes (ensuring that each was a complete arousal and not simply a noise associated with rapid-eye-movement sleep or infant self-soothing) and the final "time up" in the morning.

Sleeping Through the Night

Three criteria for sleeping through the night were investigated. To be judged as sleeping through the night, an infant had to meet the criteria for 5 of 6 nights of the week (or on 80% of occasions if there was missing data). The following criteria were used:

Criterion 1: sleeping uninterrupted from 24:00 to 05:00 hours (from Moore and Ucko⁴).

Criterion 2: the 8-hour criterion, sleeping uninterrupted for 8 hours minimum between sleep onset and time awake in the morning.

Criterion 3: the family-congruent criterion, sleeping uninterrupted from 22:00 to 06:00 hours.

Analyses

Infant age was determined when the diary was completed; for example, if the infant had turned 1 month of age

(ie, between 1.0 and 1.9 months) then data would be treated as 1-month data, and so forth. For each daily diary, the start time and duration of each LSRSP (ie, the total duration in minutes of the longest sleep period uninterrupted by signaling) for each night's sleep was identified. A mean LSRSP start time (24-hour clock) and duration (in minutes) was calculated for each individual infant over 6 days at each age, and an average was calculated over all infants at that age. Because some parents did not return diaries at some months (sometimes because of infant illness), and some participants entered the study at 2 months, there was variability in the number of diaries returned at each age point. There was no significant difference in the age at which infants met criterion 1 if the parents commenced diaries at 1 month (mean [SD]: 3.7 months [2.1]) or at 2 months (mean [SD]: 4.2 months [2.0]; $P < .29$ [not significant]). Data from both groups, therefore, were combined for subsequent analysis.

Survival analysis measures the length of time (survival) until an event is experienced, which in this study is the time taken to meet the criteria for sleeping through the night. This is indicated by the (1) survival function or the probability of not meeting the criterion of sleeping through beyond a specific period of time, (2) median survival time, when the probability of the sample meeting the criterion is 0.5, and (3) hazard function, which identifies the interval of highest probability (or "risk") for meeting each criterion. Differences in numbers of infants surviving (ie, meeting each of the criteria) were assessed by using the Gehan-Wilcoxon test. Cumulative percentages were calculated to establish the proportion of infants who met each of the 3 criteria at each age in the first year.

Reliability Assessment

Reliability of parental recording was assessed by comparing diaries with videosomnography¹⁰ over 2 consecutive nights for 41% of the participants and coded by 2 trained coders. There was no significant difference in socioeconomic status⁹ between the infants whose parents volunteered to have the time-lapse video recorder in their homes (mean [SD]: 3.0 [1.14]) and parents of infants who did not (mean [SD]: 2.7 [1.44]; $P < .45$ [not significant]). There was a high level of agreement between the video and parent records using point-by-point agreement¹¹ for (1) evening bedtime (97%), (2) infant state when placed into the bed (93%), (3) frequency of night-awakening (97%), and (4) time up in the morning (97%).

RESULTS

Figure 1 presents the mean onset time and duration of the LSRSP. The mean start time for the LSRSP over the first year steadily decreased from 22:30 hours at 1 month to 20:30 hours at 12 months, with the greatest rate of change evident in the first 3 and last 3 months. The greatest increase in LSRSP length occurred across the first 4 months, followed by a minimal rate of change from ages 5 to 9 months and a steady increase from ages 10 to 12 months. The largest increase in mean LSRSP duration (113.7 minutes [from 326.2 to 439.9 minutes]) occurred from ages 1 to 2 months. The second largest increase (42 minutes [from 326.0 to 439.0 minutes]) occurred from 2 to 3 months. The total increase from 1 to 4 months was 178.3 minutes (close to 3 hours), but there were only small, and sometimes variable, additional increases thereafter up to 12 months.

Table 1 lists the number of infants who had not met the criteria at the beginning of each of the age intervals, the number of infants who met the criteria

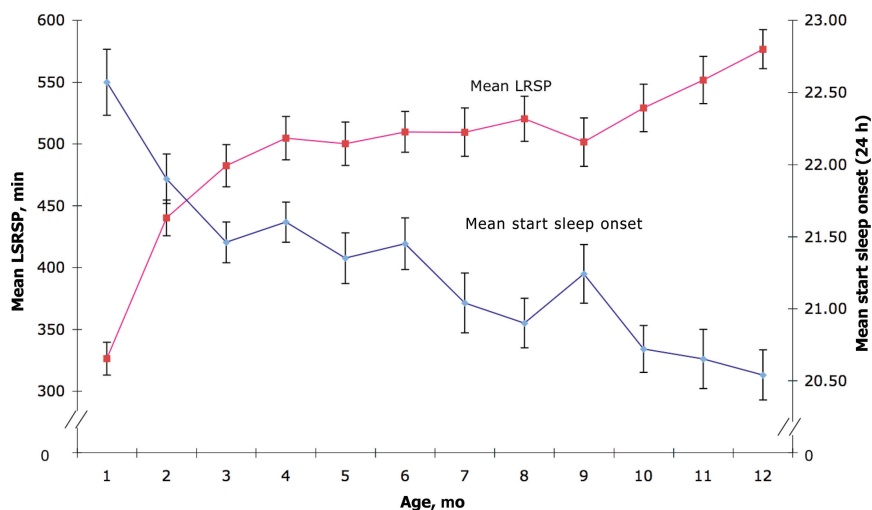


FIGURE 1 Mean start time of nocturnal sleep onset and mean LSRSP at each age in the first year of life. Bars at each data point represent the SEM.

TABLE 1 Life Table Data of the Number of Infants Entering Each Age Interval

Age Interval, mo	No. of Infants Who Had not Met the Criterion at the Beginning of the Age Period			No. of Infants Who Met the Criterion During the Interval		
	Criterion 1	Criterion 2	Criterion 3	Criterion 1	Criterion 2	Criterion 3
1	75	75	75	6	3	0
2	69	72	75	24	19	12
3	45	53	63	8	13	16
4	37	40	47	9	8	7
5	28	32	40	5	3	4
6	23	29	36	1	3	1
7	22	26	35	3	4	4
8	19	22	31	1	0	1
9	18	22	30	2	3	2
10	16	19	28	2	2	3
11	14	17	25	2	2	2
12	12	15	23	1	4	2
Number who never met criteria	—	—	—	11	11	21

Shown are the number of infants who had not met the criteria (criterion 1: 24:00–05:00 hours; criterion 2: 8 hours; and criterion 3: 22:00–06:00 hours) at the beginning of each age interval; the number of infants who met the criterion in each interval; and the number of infants who never met the criteria in the first year.

during the interval, and the number who never met the criteria during the first year. The age at which most infants met criteria 1 ($n = 24$) and 2 ($n = 19$) was 2 months; for criterion 3 ($n = 16$), it was 3 months. By 12 months, all but 11 infants had met criteria 1 and 2, but 21 had failed to meet criterion 3.

Survivor Function

The survivor function illustrates the probabilities for not meeting each cri-

terion over the 12 age intervals and is shown in Fig 2A.

Over the 12 age intervals, the probability that an infant would still be waking decreased, with the most rapid decreases (Fig 2A) between 2 and 3 months for criteria 1 and 2 and between 3 and 4 months for criterion 3, which indicates the age intervals at which infants have the highest probability of meeting these criteria. The median survival times, when the probabil-

ity of meeting the criteria is .5, were at the end of the third- and fourth-month intervals for criteria 1 and 2, respectively, and at the end of the 4-month interval for criterion 3.

It took significantly longer (Gehan-Wilcoxon test) for infants to meet criterion 3 compared with criteria 1 ($P < .003$) and 2 ($P < .04$); however, there was no significant difference in the time it took for infants to meet criteria 1 or 2. Fig 2A shows that there was a higher probability of failing to meet criterion 3 at each age interval compared with the other 2 criteria.

Hazard Function

The hazard function indicates the age intervals at which infants are most likely to meet the 3 criteria and are plotted in Fig 2B. For criteria 1 and 2, the slope is the steepest from 1 to 2 months, and the highest hazard functions are 0.39 and 0.28, respectively. The slope for criterion 3 is steepest from 2 to 3 months (hazard function: 0.27), which indicates that infants are most likely to sleep through the night in this interval.

Fig 3 presents the cumulative percentage of infants who met each of the 3 criteria over 12 months. The most marked increase occurred from ages 1 to 4 months. A higher percentage of infants met criterion 1 at each age compared with criteria 2 and 3. At age 1 month, 12% and 4% of the infants met criteria 1 and 2, respectively, but all infants had failed to meet criterion 3. The age at which $\geq 50\%$ of the infants met each criterion was 3 months for criterion 1 (58%), 4 months for criterion 2 (58%), and 5 months for criterion 3 (53%). From ages 6 to 9 months, there was a small increase in the percentage of infants who met all the criteria, from 74% to 82% (criterion 1), 66% to 75% (criterion 2), and 54% to 63% (criterion 3). The increase continued, and by 12 months, 87%, 86%, and

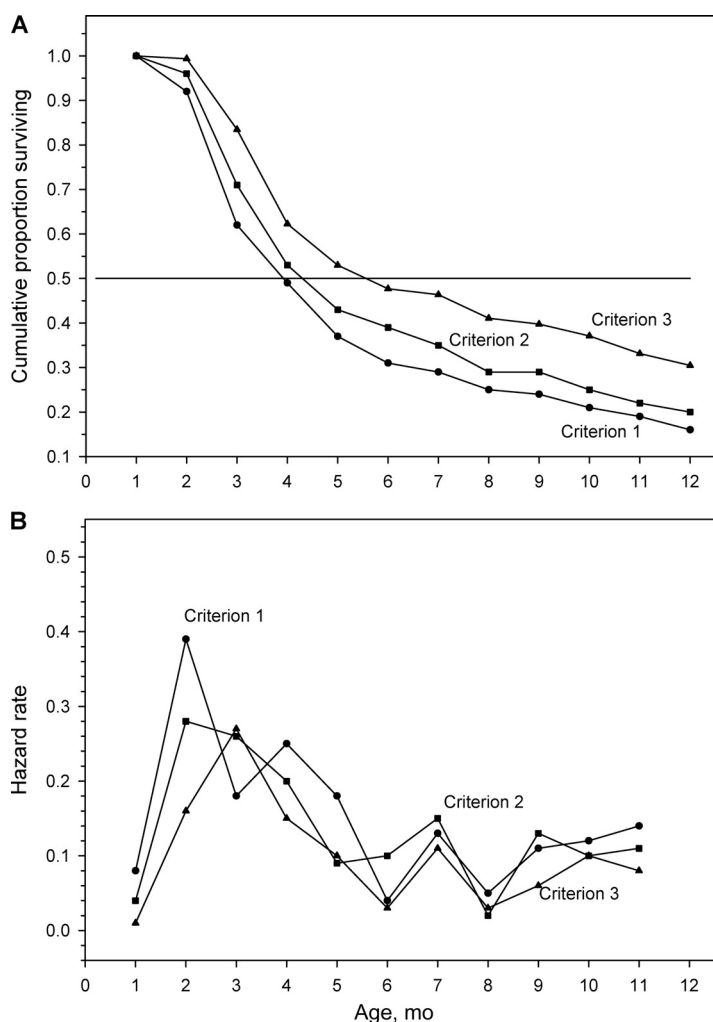


FIGURE 2 Survivor and hazard functions of the total sample for criterion 1 (24:00–05:00 hours), criterion 2 (8 hours), and criterion 3 (22:00–06:00 hours) across the first year of life. Drawn in the top graph is the median line showing the point at which there is a 50% probability of meeting the criteria.

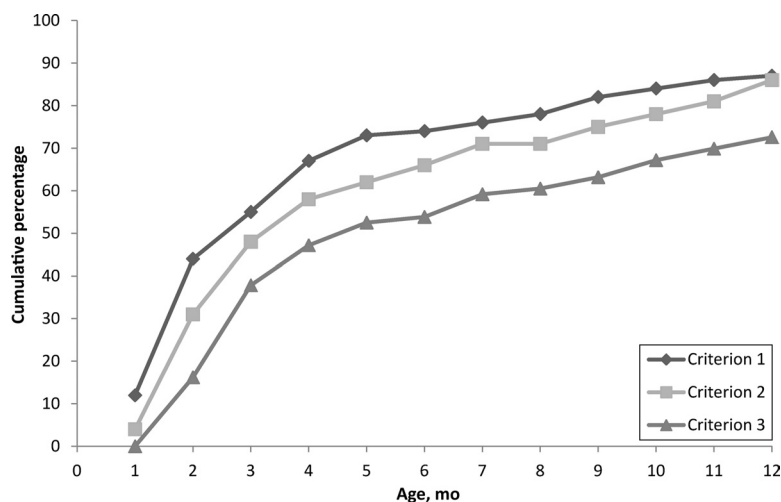


FIGURE 3 The cumulative percentage of infants who met criterion 1 (24:00–05:00 hours), criterion 2 (8 hours), and criterion 3 (22:00–06:00 hours) each month across the first year of life.

73% of infants were sleeping through the night as judged by criteria 1, 2, and 3, respectively.

DISCUSSION

To our knowledge, this is the first study to examine consolidation in infants' self-regulated nocturnal sleep as judged by 3 different criteria for sleeping through the night and to present a new socially and developmentally valid criterion, while also documenting changes in mean onset time and duration of the LSRSP across the first year. Self-regulated sleep consolidates most rapidly in the first 4 months, and at age 3 months there was evidence of concordance between the initial sleep onset time (21.46 hours) and the LSRSP (8.2 hours) and typical family sleep schedules. From 4 to 9 months, the rate of change plateaus, consistent with the results of previous studies.^{6,7,12–14} The LSRSP begins to lengthen again between 10 and 12 months.

The rapid increase in LSRSP over the first 3 months is consistent with the rapid increase over the same period in the longest sustained sleep period (LSP), a sustained period of sleep that precedes an arousal or awakening.^{2,8} The LSP is the precursor of sleeping through, because the LSRSP requires both sustained sleep and the capacity for independent resumption of sleep via self-regulated soothing after an awakening. The LSRSPs we observed increasingly exceeded LSP durations when systematically compared with data across ages from Anders et al^{1,2,8} and from a developmental perspective reflect the emergence of infants' self-regulation and self-soothing capacities.

Two months was the most likely age for infants to be sleeping through the night when the less stringent criteria (1 and 2) were used, which is consistent with previous reports.^{15–17} The use of criterion 1 prevented previous authors from establishing whether the

infants were sleeping longer than 5 hours and, if so, whether they could sustain the 8 hours of sleep needed for family congruence. Criterion 3 was the most difficult to achieve, and nearly one-third (28%) of the sample failed to meet it, versus 15% who failed to meet criteria 1 and 2. Undoubtedly, this is because criterion 3 not only requires the infant to maintain an 8-hour LSRSP but also to initiate sleep earlier in the evening and sustain sleep through to 06:00 hours.

Survival analysis permitted the systematic comparison of 3 criteria for sleeping through during the first year of life, and our findings support the contention that criterion 3 should be used to define sleeping through the night for children from the age of 4 months. This criterion is met by 50% of infants at 5 months of age, is congruent with family sleep patterns, and falls within typical sleep times. The alternative criteria lack social validity in that they ignore congruence with family sleep patterns and lack specificity with regard to sleep phase. Adopting criterion 3 from 4 months of age also has implications for interventions intended to prevent infant sleep difficulties. Prevention should occur in synchrony with developmental tasks,^{18,19} which in this case is the task of self-regulating sleep throughout the night. It also should aim to achieve socially valid outcomes, as embodied in crite-

riterion 3. To achieve this, prevention interventions should target the management of infant sleep in the first 3 months of life.

We also are the first study, to our knowledge, to replicate the pioneering study by Moore and Ucko,⁴ who reported the cumulative percentage of infants sleeping through from 24:00 to 5:00 hours. Our rates were ~20% lower from ages 2 to 4 months and narrowed to ≤5% from ages 6 to 12 months. This similarity was unexpected given the methodologic and conceptual differences between the 2 studies,³ whereas the discrepancies are probably explained by the use of retrospective recall by Moore and Ucko.⁴

This study has limitations that may restrict the generality of the results. The participants were not fully representative of populations with ethnic and socioeconomic diversity. Those who dropped out of the study may have had infants who were liable to have greater regulatory problems, so the developmental trajectories reported may be relatively favorable. Only additional research can clarify this issue.

CONCLUSIONS

The most rapid consolidation in infants' nocturnal sleep occurs within the first 4 months of life. During this period, infants are most likely to meet 3 different criteria for sleeping

through the night and have a mean LSRSP that exceeds 8 hours. Criterion 3 (22:00–6:00 hours) should be adopted as the standard criterion for defining what sleeping through the night means for infants in their first year because of its developmental and social validity. Our longitudinal data provide a reliable empirical foundation for advice about infant sleep development and provide a context for clinicians to discuss sleep issues with parents.²⁰ Prevention efforts should focus in the first 3 months, beginning as early as 1 month for intervention to be synchronous with the onset of sleeping through the night. Additional research is now needed to establish the factors that precede and predict infant sleep problems.

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