Cycled Light Exposure Reduces Fussing and Crying in Very Preterm Infants

OBJECTIVE: To examine whether cycled lighting (CL) conditions during neonatal care in very preterm infants (<32 weeks' gestational age [GA]) decrease crying and fussing behavior; improve the consolidation of sleep, and influence activity behavior at 5 and 11 weeks' postterm corrected age (CA) compared with preterm infants cared for in dim lighting (DL) conditions.

METHODS: Thirty-seven preterm infants were randomly assigned to CL (7 AM–7 PM lights on, 7 PM–7 AM lights off [n = 17; mean GA: 30.6 ± 0.95 weeks; 9 girls]) or DL (lights off whenever the child is asleep [n = 20; GA: 29.5 ± 2.1 weeks; 8 girls]) conditions. Sleeping, crying, and activity behavior was recorded by using parental diaries and actigraphy at 5 and 11 weeks’ CA.

RESULTS: A significant reduction of fussing (59.4 minutes/24 hours [±25.8 minutes]) and crying (31.2 minutes/24 hours [±14.4 minutes]) behavior and a trend to higher motor activity during daytime was found in CL-exposed infants at 5 and 11 weeks’ CA compared with infants cared for in DL conditions. No significant difference between groups was observed for sleep behavior at 5 and 11 weeks’ CA. Infants in CL conditions showed a trend to improved daily weight gain (average: 3.6 g/d) during neonatal care compared with DL conditions.

CONCLUSIONS: CL conditions in neonatal care have beneficial effects on infant’s fussing and crying behavior and growth in the first weeks of life. This study supports the introduction of CL care in clinical neonatal practice. Pediatrics 2012;130:e145–e151
The American Academy of Pediatrics and the American College of Obstetricians and Gynecologists recommend neonatal care under cycled lighting (CL) conditions (ie, lights on during daytime and lights off at night) instead of care in a continuous 24-hour bright or irregular dim lighting (DL) environment. In fact, several studies have reported beneficial effects of CL on the development of sleep–wake rhythms, the circadian organization, and postnatal growth in preterm infants. \(^6\) For example, Rivkees et al\(^6\) described a significantly faster development of the 24-hour day–night rest-activity pattern using actigraphy at 37 weeks’ gestational age (GA) in infants cared for under CL conditions compared with those cared for under DL conditions.

Although other studies have not replicated these findings,\(^3,7\)–\(^10\) physiologic effects of CL on the development of the sleep–wake rhythms in preterm infants seem plausible. In preterm baboons, the circadian clock located in the suprachiasmatic nucleus of the hypothalamus is responsive to light as early as 125 days,\(^11\) corresponding to 28 weeks of human gestation. Moreover, reports from both nonhuman and human studies show an entrainment of the circadian clock by low-intensity lighting (eg, 180 lux)\(^12,13\) with an intensity-dependent response to light stimuli.\(^14\) Thus, the premature exposure to continuous 24-hour bright or irregular DL in the neonatal care unit may impair the maturation of sleep–wake and circadian regulatory systems. In contrast, an early exposure of preterm infants to CL (ie, in a regular lighting regimen) may lead to a faster development of the infant’s 24-hour sleep–wake rhythm and, therefore, to earlier consolidated nocturnal sleep.

According to a review by Jenni and LeBourgeois,\(^15\) the developing sleep–wake and circadian regulatory systems may be key determinants not only for infant sleep–wake rhythms but also for early crying behavior. Interestingly, no study so far has examined the effects on crying and fussing behavior in the first weeks of life of CL in preterm infants during neonatal care, although daytime crying patterns may be a good marker for the development of behavioral state regulation after birth.\(^15\)

The following questions were addressed in this study. Do preterm infants under CL conditions in neonatal care compared with infants cared in DL conditions show: (1) less daytime crying and fussing behavior (and thus a more matured behavioral state regulation); (2) an accelerated 24-hour sleep–wake rhythm with earlier consolidated sleep; (3) higher motor activity levels during the day and lower levels during the night at 5 and 11 weeks’ CA; and (4) experience a larger weight gain during the neonatal period?

**METHODS**

**Population**

Very preterm infants (\(\leq 32/0/7\) weeks’ GA) were recruited at the Clinic for Neonatology of the University Hospital Zurich (Zurich, Switzerland). Primary exclusion criteria were major cerebral injuries such as intraventricular hemorrhage grade III (according to Papile et al\(^16\)), periventricular leukomalacia or venous infarction (according to Govaert and de Vries\(^17\)), retinopathy of prematurity grade III and IV, congenital malformations, small for GA (birth weight less than the third percentile), prenatal infections, or intrauterine drug exposure. Secondary exclusion criteria were participation in another clinical trial or parental language difficulties. Of 62 possibly eligible infants, 21 parents refused consent for study participation, mainly because the study was too time-consuming. Forty-one infants were thus included in the study population (22 boys, 19 girls). An additional 4 infants had to be excluded from further analysis (dropped out after the first recording \(n = 2\), incomplete diary \(n = 1\), or unexplained high amount of parent-reported “unsoothable crying” as an outlier \(n = 1\)). A total of 37 preterm infants (DL: \(n = 20\), CL: \(n = 17\)) were included in the final analysis.

Written informed consent was obtained from all parents. The ethics committee of the University Children’s Hospital Zurich and the Canton of Zurich approved the study protocol. The study was performed according to the Declaration of Helsinki.

**Time of Enrollment and Randomization**

No information (about which lighting condition could be regarded as being better than the other) was given to the parents regarding the study hypothesis to keep the confounder of knowing the lighting condition as minimal as possible. Enrollment took place after the transfer from intensive to intermediate care at a mean age of 32.16 ± 1.35 weeks’ GA. The transfer required stable conditions of the child and available space in the intermediate care rooms. Two rooms in the intermediate care ward were equipped for each lighting condition, and randomization was performed depending on availability of free space at the time of transfer to intermediate care. In case of available space in both conditions, a table of random numbers was used.

**Lighting Conditions**

The standard lighting regimen on the ward was the DL condition. Every bed was equipped with curtains to be closed whenever the child was asleep or quiet and opened only for feeding periods every 3 to 4 hours for a few minutes. If infants in the intermediate care were still in an incubator, it was covered with green quilts. Room light was turned off whenever possible. The intervention condition was characterized by lights on between 7 AM and 7 PM and off between...
7 PM and 7 AM (CL). During the daytime periods, bed curtains were taken away, and overhead room lights were continuously turned on. Exposure to either condition took place from enrollment until discharge at home. Light levels were measured throughout this period for 10 consecutive days by using an Actiwatch-L monitor (Cambridge Neurotechnology, Cambridge, UK) near the infant’s head (average light intensity levels for DL condition: day, 97.6 ± 45.3 lux; night, 20.8 ± 20.7 lux; average light intensity levels for CL condition: day, 499.3 ± 159.2 lux; night, 28.5 ± 27.5 lux). Daytime light exposure was significantly different between the DL and CL conditions (P < .01, t test for independent variables). The lighting regimens were regularly checked by research assistants. After hospital discharge, no restrictions to lighting conditions were made.

**Data Acquisition at Home**

At 5 weeks’ CA, parents were personally instructed through a face-to-face home visit. The Baby’s Day Diary was explained in detail, and actigraphs were placed on the infant’s ankle. A contact opportunity by telephone was offered at anytime during the recording period. Data and actigraphs were sent back by regular mail after the recording. At 11 weeks’ CA, parents were reminded by telephone, and diaries and devices were sent by mail. Data were collected over the entire year, and no correction for season was made.

**Sleeping and Crying Assessment**

Sleep and crying behavior were recorded every 5 minutes for 3 consecutive days by the parents at 5 and 11 weeks’ CA using the Baby’s Day Diary developed by Barr et al. They were told to fill in the diary when convenient but as often as possible without disrupting their daily activities. The following diary categories were used: “sleep,” “awake and content,” “fussing,” “crying,” and “unsoothable crying.” Fussing indicated that the infant was unsettled and vocalized without continuously crying. Crying reflected periods of prolonged and distressed vocalization. Unsoothable crying was marked when bouts of intense, unsoothable crying occurred. For the variables awake and content, fussing, crying, and unsoothable crying mean hours per day, mean bout frequency per day, and mean bout durations in hours were computed. Total sleep duration per 24 hours and the longest consolidated sleep period at night (LSP) were calculated and averaged over the numbers of recorded days. LSP was defined as the longest sleep period within the hours between midnight and 6 AM and expressed in percentage of these 6 hours (see Anders and Keener19).

**Activity Assessment**

Activity scores were measured by using the Actiwatch Mini (Cambridge Neurotechnology) at 5 weeks’ CA and the Actiwatch AW4 (Cambridge Neurotechnology) at 11 weeks’ CA for 30-second epochs. The actigraphs were placed on the infant’s ankle and fixed by using a soft sleeve bandage. Because 3 days of rest-activity behavior has been shown to be insufficient,20 motor activity was recorded over 10 days at the 2 time points mentioned earlier. Mean activity counts per 24 hours, for the nighttime (7 PM–7 AM) and the daytime (7 AM–7 PM) as well as the day/night ratio, were calculated.6 Days were excluded when data were missing for >2 consecutive hours (9 days at 5 weeks’ CA and 8 days at 11 weeks’ CA were excluded). Mean days of recording were 8.7 (range: 3–11 days) and 8.5 (range: 5–11 days) for 5 and 11 weeks, respectively.

**Growth, Socioeconomic Status, and Development**

The infant’s weight was measured daily until feeding was properly established and then every 2 to 3 days until discharge.

Socioeconomic status (SES) was estimated by means of a sum score of 2 standardized 6-point scales of paternal occupation and maternal education ranging from 12 (lowest SES) to 2 (highest SES). This measure was used in previous studies and was shown to be a reliable and valid indicator of SES in our community.21,22 The Bayley Scales of Infant Development II123 were routinely collected at 9 to 12 months’ and 24 months’ CA as part of our follow-up program of preterm infants (GA ≥32 0/7 weeks’ postmenstrual age). SES and Bayley data were used not as primary outcome measures but as demographic variables to indicate comparability between the 2 study groups.

**Statistical Analysis**

Means and SDs are presented for demographic variables. Unpaired t tests, Mann–Whitney U tests, and the χ² test were used for group comparisons depending on whether the variable was considered normally distributed (SPSS 14 for Windows, SPSS Inc, Chicago, IL). For the simultaneous analysis of age and group effects, as well as for analyzing covariates (GA, gender, and length of exposure), linear mixed models were calculated with S-PLUS 8.0 for Windows (Insightful Corp, Seattle, WA). A P value ≤.05 was considered significant (a trend ≤.1).

**RESULTS**

The characteristics of the 37 infants are shown in Table 1. No significant group differences were found for any variable, including gender, GA, birth weight, length of hospital stay, and light exposure. The distribution of the months of recording at 5 and 11 weeks’ CA (effect of season) as well as the type of feeding (fully breastfed, partially breastfed, or bottle-fed) were not different between groups.
Table 2 lists the descriptive statistics for the sleeping and crying variables. Except for the variable “bout duration fussing,” no significant interactions between the 2 factors of age (5 vs 11 weeks’ CA) and group (DL versus CL) were found. Thus, a separate analysis of the effects for age and group was possible.

After controlling for infant’s age, significant group differences were found for fussing and crying. Infants in the CL condition showed 39.4 minutes less fussing and 31.2 minutes less crying per 24 hours than infants in the DL group. None of these variables were influenced by GA, gender, or length of exposure. Sleep variables showed no differences between the 2 groups.

For the variable bout duration fussing, there was a significant interaction between the 2 factors, indicating that at 5 weeks’ CA, infants in the CL condition displayed a shorter fussing duration than infants in the DL condition; this difference was no longer observed at 11 weeks’ CA. Because of this significant interaction, the results of the mixed model of bout duration fussing are not presented in Table 2 but rather the significance of the age and group differences.

Activity variables are listed in Table 3 and were analyzed for the effects of age and group separately when no interaction occurred. A general age effect could be observed with increasing motor activity between 5 and 11 weeks’ CA. A group difference for “activity count per 24 hours” and a trend for “activity count per daytime” were found. Infants nursed in the CL condition were more active during the 24-hour period, in particular at 5 weeks’ CA, and showed a trend toward more activity during daytime. None of these variables were influenced by GA, gender, or length of exposure.

Daily weight gain during exposure showed a trend toward an increased weight gain in CL-exposed infants (CL: 30.3 ± 7.0 g/d; DL: 26.7 ± 4.7 g/d [P = 0.07]), who gained an average of 3.6 g/d more than infants in the DL condition (medium effect size, d = 0.60). Weight gain from birth until the start of exposure was equal in the 2 groups. No significant relationship between birth weight and weight gain (r = 0.07; P = 0.68), length of exposure and weight

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>5 Weeks’ CA</th>
<th>11 Weeks’ CA</th>
<th>Differences Age</th>
<th>Statisticsb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DL (n = 20)</td>
<td>CL (n = 17)</td>
<td>DL (n = 20)</td>
<td>CL (n = 17)</td>
</tr>
<tr>
<td>Wake and content, h/24 h</td>
<td>6.8 ± 2.28</td>
<td>7.7 ± 2.31</td>
<td>7.0 ± 3.18</td>
<td>8.4 ± 2.48</td>
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<tr>
<td>Fussing, h/24 h</td>
<td>2.2 ± 1.44</td>
<td>1.25 ± 1.19</td>
<td>1.75 ± 2.14</td>
<td>0.95 ± 1.60</td>
</tr>
<tr>
<td>Crying, h/24 h</td>
<td>1.11 ± 0.92</td>
<td>0.64 ± 0.55</td>
<td>0.90 ± 0.99</td>
<td>0.35 ± 0.61</td>
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<tr>
<td>Unsoothable crying, h/24 h</td>
<td>0.05 ± 0.07</td>
<td>0.03 ± 0.10</td>
<td>0.04 ± 0.08</td>
<td>0.01 ± 0.04</td>
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<tr>
<td>Bout frequency fussing, n/24 h</td>
<td>5.01 ± 3.34</td>
<td>5.01 ± 4.32</td>
<td>4.92 ± 4.10</td>
<td>3.46 ± 3.14</td>
</tr>
<tr>
<td>Bout duration fussing, h/bout</td>
<td>0.44 ± 0.28</td>
<td>0.25 ± 0.13</td>
<td>0.29 ± 0.26</td>
<td>0.20 ± 0.17</td>
</tr>
<tr>
<td>Bout frequency crying, h/24 h</td>
<td>4.17 ± 2.80</td>
<td>3.79 ± 2.22</td>
<td>3.80 ± 3.00</td>
<td>1.76 ± 2.22</td>
</tr>
<tr>
<td>Bout duration crying, h/bout</td>
<td>0.36 ± 0.54</td>
<td>0.19 ± 0.15</td>
<td>0.23 ± 0.17</td>
<td>0.15 ± 0.10</td>
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<tr>
<td>Sleep, h/24 h</td>
<td>13.76 ± 1.03</td>
<td>14.31 ± 1.89</td>
<td>14.31 ± 0.95</td>
<td>14.22 ± 1.40</td>
</tr>
<tr>
<td>LSP, %</td>
<td>65.27 ± 20.00</td>
<td>59.10 ± 21.82</td>
<td>75.03 ± 18.77</td>
<td>81.07 ± 19.90</td>
</tr>
</tbody>
</table>

Sleeping and crying variables were analyzed as a function of age and group (if the interaction between the 2 groups was significant, no effects are reported).

* Reported as mean (SD), in hours (decimal) or numbers of bouts.

b Mixed model analysis (f).
gain (r = 0.1; P = .55), or age at discharge from hospital and weight gain (r = 0.13; P = .43) was observed.

**DISCUSSION**

The particular novelty of this study is the focus on the effect of CL during neonatal care on crying and fussing behavior; previous investigations have reported the influence on other types of outcomes.2–6 Here we describe a reduction of fussing and crying behavior at ages 5 and 11 weeks’ CA when preterm infants are exposed to CL during neonatal care compared with exposure in a DL environment. Furthermore, infants under CL conditions exhibited higher motor activity over 24 hours at ages 5 and 11 weeks’ CA and a trend toward better weight gain during hospitalization than infants in the DL condition. No effects on sleep behavior were observed.

Infants exposed to CL showed a shorter fussing duration at 5 weeks’ CA compared with DL-exposed infants, who reached this level only at 11 weeks’ CA. This finding indicates a more rapid maturation of behavioral state regulation in the intervention group and confirms the hypothesis that environmental conditions in the neonatal ward not only influence the 24-hour day–night rhythm of activity and sleep but also infant daytime crying behavior after hospital discharge. The parents recorded the behavior of their infants after discharge by using the Baby’s Day Diary, an established and validated (by using audio recordings) method for crying assessment.18,25,26 As others have reported, we found a crying peak at age 5 weeks27,28 and a reduction of crying and fussing by 11 weeks29,30 as well as a daily distribution with more fussing and crying in the evening hours (data not shown). We note that the infants in the CL group could have had their crying peak earlier with an even more pronounced reduction, which may have been missed by the first recording at age 5 weeks’ CA. However, even if we missed the crying peak, the magnitude of the reduction is still remarkable (an average of 59.4 minutes less fussing and 31.2 minutes less crying per 24 hours in infants cared for in CL conditions). Infant behavioral state regulation may be impaired because of the lack of maternal intrauterine entrainment and the sudden exposure to irregular lighting conditions in the hospital. In fact, several studies have reported an impaired behavioral state regulation and increased excessive crying in preterm infants.31–33 Thus, regular light conditions may prevent or at least reduce increased crying behavior and improve the regulation of the infant’s behavioral state.

In contrast, we found no effects of CL care on sleep variables at ages 5 and 11 weeks’ CA. LSP was selected as the principal sleep variable because the hours between midnight and 6 AM are a reliable marker for sleeping through the night according to Anders and Keener.19 However, LSP may not have been sensitive enough to detect small differences between the CL and DL groups. Alternatively, differences between groups may have occurred at earlier time points, which were missed in our study. The values of total sleep duration per 24 hours at ages 5 and 11 weeks’ CA (although known to be overestimated when compared with actigraph recordings34) are comparable to previous studies19,35 but were not different between the 2 conditions. Although Mirmiran et al40 could also not detect any difference in sleep–wake patterns by video recordings, Mann et al40 reported a positive effect of CL on the sleep behavior of preterm infants after discharge. However, comparability between studies is hampered because of large differences in study designs and methods (eg, different lighting regimens, bright light exposure, length and methods of follow-up).

The observed overall increase in motor activity from 5 to 11 weeks’ CA is in line with previous studies reporting an increase of motor activity behavior in the first months.35 The trend to higher activity during daytime in CL infants supports the hypothesis of an improved 24-hour day–night entrainment and is consistent with the findings of Rivkees et al6. The trend to a faster weight gain when exposed to CL during neonatal care is also in accordance with the results of other studies.2,3,5 In fact, exposure to CL with no curtains at daytime could have made infants and their needs more

**TABLE 3** Descriptive Statistics and Mixed Model Analysis for Activity Variables at 5 and 11 Weeks’ CA

<table>
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<tr>
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</tr>
<tr>
<td>Activity count per 24 h</td>
<td>72.74 ± 24.60</td>
<td>100.19 ± 57.82</td>
<td>161.49 ± 65.25</td>
<td>166.62 ± 90.51</td>
</tr>
<tr>
<td>Activity count per night time</td>
<td>25.29 ± 8.07</td>
<td>34.63 ± 18.93</td>
<td>48.42 ± 19.90</td>
<td>40.73 ± 13.75</td>
</tr>
<tr>
<td>Activity count per daytime</td>
<td>47.45 ± 17.31</td>
<td>65.56 ± 39.78</td>
<td>113.07 ± 50.59</td>
<td>125.90 ± 78.72</td>
</tr>
<tr>
<td>Day/night ratio</td>
<td>1.89 ± 0.38</td>
<td>1.86 ± 0.40</td>
<td>2.53 ± 1.17</td>
<td>2.95 ± 0.98</td>
</tr>
</tbody>
</table>

Activity variables were analyzed as a function of age and group (if the interaction was significant, no effects for the 2 factors are reported).

- **Weeks’ CA**: Reporting as mean ± SD, in hours (decimial).
- **Mixed model analysis (SE).**
- **Interaction between group and age.** Mann–Whitney U test.
- *P < .05, †P < .1.
visible to the nursing staff, possibly resulting in higher feeding frequency. A recent Cochrane review also concluded that the trends for positive growth outcome favored the CL condition, although statistical power of the studies remained relatively weak. The CL exposure with a mean of nearly 500 lux in our study can be regarded as comparable to other investigations. Furthermore, an intensity-dependent response to light stimuli is known. Thus, lower light intensities in other studies may have accounted for the failure to detect any differences between infants cared in CL and DL conditions. When interpreting the findings of this study, some limitations need to be kept in mind. First, the sample size in our study was relatively small, although comparable to other investigations. Because the procedures (using a diary) were relatively time-consuming for the parents (5-minute epochs with a minimum of 5 different variables), >2 time points of assessment were not possible, and recording for >3 days was not feasible. Furthermore, no correction for lighting conditions after discharge was made, which may have affected the findings of some of the outcome variables. The findings of this study indicate that CL conditions in neonatal care have beneficial effects on infant’s fussing and crying behavior, as well as growth, in the first weeks of life. Thus, the study supports the American Academy of Pediatrics recommendation for introducing CL care in clinical neonatal practice.

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32. Hunziker UA, Barr RG. Increased carrying behavior, as well as growth, in the first weeks of life. Thus, the study supports the American Academy of Pediatrics recommendation for introducing CL care in clinical neonatal practice.


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