Original Article

Comparing the Effects of Cycled and Constant Lighting on Weight Gain and Length of Stay in Neonatal Intensive Care Unit among Premature Neonates: A Two-Group Randomized Controlled Clinical Trial

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ABSTRACT

Background: Environmental lighting can potentially affect weight gain and the length of stay in Neonatal Intensive Care Unit (NICU) among premature neonates. Yet, there are controversies about the best way of lighting in these units. **Objectives:** The aim of this study was to compare the effects of cycled lighting (CL) and constant lighting on weight gain and the length of stay in NICU among premature neonates. **Methods:** This two-group randomized controlled trial was conducted on 78 premature neonates hospitalized in NICU of Mofid Children's Hospital, Tehran, Iran. Neonates in the intervention group were treated, for 15 days, with CL. Neonates in the control group were exposed to constant lighting of the unit. Neonates in both groups were weighed every morning at 07:30 and their length of stay in the unit was recorded in days. Data analysis was done through Chi-square test, independent-samples *t*-test, and Mann–Whitney U-test and the two-way analysis of variance. The random-effects spline model was employed to compare the groups in terms of the trend of weight variations over time. **Results:** Neonates' weight in both groups decreased during the first 7 days of hospitalization and then started to increase from the 8th day. The groups did not significantly differ from each other respecting neonates' weight in the first 8th days ($P = 0.857$), while weight mean in days 9–15 in the intervention group was significantly greater than the control group by at least 25.25 g in the 9th day and 159.95 g in the 15th day ($P < 0.001$). Statistically significant differences were observed between the two groups in terms of daily weight gain (14.63 ± 5.64, 29.17 ± 7.32) with gender being unadjusted ($P = 0.005$) and adjusted ($P = 0.001$). However, no significant between-group differences were observed in terms of the length of stay (18.18 ± 10.21, 18.29 ± 12 days) in NICU with gender being unadjusted ($P = 0.939$) and adjusted ($P = 0.990$). **Conclusions:** CL is effective in improving premature neonates' weight gain but ineffective in shortening their stay in NICU.

KEYWORDS: *Length of stay, Light–dark cycle, Neonatal, Intensive Care Unit, Premature, Infant, Weight gain*

INTRODUCTION

Around 310 million neonates are born annually in the world, while 15% of them are premature.[1] Premature neonates need life support services and hence are hospitalized in Neonatal Intensive Care Unit (NICU). The demand for premature neonates' hospitalization in NICU has significantly increased with scientific and technological advancements.[2]

Hospitalization in NICU poses numerous risks to premature neonates. Major risks are related to invasive and costly procedures,[3] nosocomial infections, sepsis,

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bronchopulmonary dysplasia, necrotizing enterocolitis, retinopathy,[4] impaired growth and development, and poor weight gain.[5] These risks can prolong NICU stay.[4,6] Evidence reports high rates of prolonged hospitalization in developing countries[7] with a mean NICU stay of as high as 33 days.[8]

Environmental stimuli in NICUs, such as continuous and harsh lighting, are among the major factors behind poor weight gain and prolonged NICU stay. Neonates in NICU are almost constantly exposed to harsh lighting,[9] which can make them highly susceptible to growth and sleep disorders, and altered circadian rhythms. Altered circadian rhythms, in turn, decrease arterial oxygen saturation, reduce weight gain, and impair normal metabolism. All these complications can prolong NICU stay.[10,11] Therefore, appropriate lighting is of paramount importance to neonates' weight gain, growth and development, and NICU stay.

There are great controversies about the best way of lighting in NICUs.[12] A study showed that cycled lighting (CL) had no significant effects on weight gain and hospital stay,[13] while another reported its effectiveness in improving weight gain and shortening hospital stay.[14] One study also indicated that CL significantly improved weight gain and had no significant effects on the duration of mechanical ventilation and the length of NICU stay.[15] Furthermore, a study reported no significant difference between the effects of white and red lighting during nursing interventions on neonates' weight gain.[16] Due to the contradictory results of previous studies, further studies are still needed to produce more credible results respecting the best way of lighting in NICUs.

Objectives

The aim of this study was to compare the effects of CL and constant lighting on weight gain and NICU stay among premature neonates.

Methods

Study design and participants

This two-group randomized controlled trial was conducted in NICU of Mofid Children's Hospital, Tehran, Iran. The study population comprised all premature neonates hospitalized in NICU. Inclusion criteria were a gestational age of 30–37 weeks, a birth weight of 1500–2500 g, a 1-min Apgar score of at least 7, absence of life-threatening health conditions or congenital diseases, hospitalization in NICU within the first 6 h after birth, and exclusive breastfeeding by a nonsmoker, nondrug addict, nonalcoholic mother. Neonates were excluded if they became critically ill, died, transferred to other settings, needed surgery, developed jaundice, or needed lengthy nighttime medical or nursing interventions which lasted >30 min.

Sample size was calculated according to the results of a previous study[9] and with a d (or effect size) of 0.5, a Type I error of 0.05, a Type II error of 0.05, a ρ (i.e., coefficient of the correlation of repeated weights) of 0.5, and an m (or number of hospitalization days) of 21.[17] Accordingly, sample size calculation equation ($n_1 = n_2 = [(1 + (m - 1)p)(Z_{1-\alpha/2} + Z_{1-\beta})^2]/md^2$) indicated that sample size was 33–66 in total. Therefore, 78 neonates were consecutively selected from May 2016 to January 2017. Recruited neonates were randomly assigned to control and intervention groups. For random assignment, 39 numbers 1 and 39 numbers 2 were entered into one column in the Microsoft Excel software, and then, the RAND function was used to randomize the numbers. Then, the generated sequence of numbers was used for the random allocation of neonates to the groups.

Instruments

A personal characteristic questionnaire was used for data collection. The items of the questionnaire addressed participants' gender, birth weight, reason for NICU hospitalization, gestational age, 1- and 5-min Apgar scores, route of delivery, daily weight, and the length of NICU stay. The data for this questionnaire were extracted from participants' medical records. Besides, daily weight measurement was performed through a high-precision weighing scale with a precision of 10 g (Advanced Digital Equipment Company, Germany).

Intervention

Neonates in the intervention group were provided with CL, while their counterparts in the control group received constant lighting. CL consisted of 12 h of normal NICU lighting from 07:00 to 19:00 and 12 h of reduced lighting from 19:00 to 07:00. Reduced lighting was created using a sheet of acrylic glass (commercially known as plexiglass) covered by a dimming cotton cover.[9] This sheet and cover had been designed so that they did not interfere with routine care delivery to neonates and were used while neonates were in warmer [Figure 1]. However, when neonates were in incubator, the incubator was covered by a cotton fabric instead of the dimming cover in order to allow air flow in and out of the incubator [Figure 2]. The color, size, and material of the cover were determined after consulting ten nursing managers and pediatricians. The intervention continued at least for 15 days or up to NICU discharge. CL was implemented by the nurses of the study setting. Before the intervention, the first and the second authors provided instructions about the study intervention to all nurses in the morning, evening, and night shifts in three

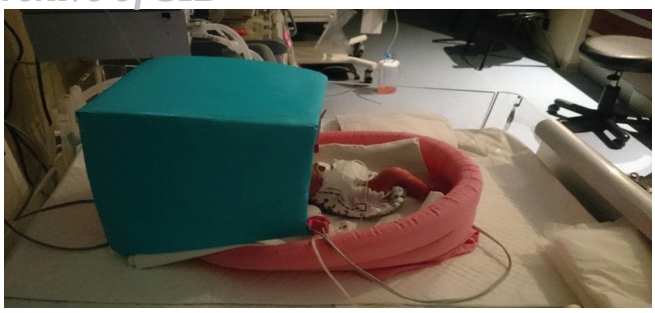

Figure 1: Equipment for lighting reduction while the neonate is in warmer

separate sessions. Moreover, both authors supervised the accurate implementation of the study intervention throughout the study through unannounced NICU visits in different shifts. On the other hand, neonates in the control group were exposed to the constant lighting of the study setting. Every morning throughout the study at 07:30, nurses weighed all participants naked and recorded their weights in their medical records. Due to the nature of the intervention, blinding was not possible.

Ethical considerations

This study was approved by the Research Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (approval code: IR.SBMU.RAM.REC1394.606). In addition, the study obtained registration from the Iranian Registry of Clinical Trials (registration code: IRCT2016073129141N1). The study aim was explained to the parents of all participants and they were assured that their neonates' participation in the study would be voluntary, their information would be kept confidential, and their refusal to participate would not affect care delivery to their neonates. The mothers of neonates in the intervention group were taught about how to use the dimming cover, their questions were answered, and they were assured of their neonates' safety. Finally, informed consent was obtained from all parents.

Data analysis

The collected data were analyzed through the SPSS software v. 13.0 (SPSS Inc., Chicago, IL, USA). Mean, median, standard deviation, and interquartile range were used to describe numerical variables, while absolute and relative frequencies were employed to describe categorical variables. Chi-square and Fisher's exact tests were conducted to compare the groups with each other in terms of categorical variables such as gender, route of delivery, and reason for hospitalization. Moreover, independent-samples *t*-test and Mann–Whitney U-test were conducted to compare the groups respecting numerical variables such as birth weight and Apgar scores. The two-way analysis of variance was also used to adjust the effects of gender and compare the

Figure 2: Equipment for lighting reduction while the neonate is in incubator

groups respecting weight gain and NICU stay. The random-effects spline model[18] was also employed to compare the groups in terms of the trend of weight variations over time.

Results

The primary sample of the study comprised 78 premature neonates. Before allocation, two participants voluntarily withdrew from the study and were replaced with two new ones with the inclusion criteria. Thus, 39 were allocated to the intervention and 39 to the control groups. After that, four neonates from the intervention group and six neonates from control group were excluded due to different reasons. Accordingly, the study was completed with 33 neonates in each group [Figure 3].

All neonates were exclusively breastfed. No statistically significant differences were observed between the groups respecting neonates' route of delivery, reason for hospitalization, gestational age, and 1- and 5-min Apgar scores ($P > 0.5$). However, the groups significantly differed respecting gender [$P = 0.041$; Table 1].

A weight loss was observed in both groups during the first 7 days of hospitalization (i.e., the first 7 days after birth). However, from the 8th day, neonates in both groups started to gain weight. Weight gain in the intervention group was significantly greater than the control group with both gender being unadjusted ($P = 0.005$) and adjusted [$P = 0.001$; Tables 2 and 3].

As mentioned in the method section, the intervention was continued for at least 15 days or up to the time of NICU discharge. Among 66 neonates, 34 were discharged before 15 days. In other words, only 32 neonates were hospitalized for at least 15 days. On the other hand, according to Figure 4, the mean weight variations in both groups were almost initially downward and then

Table 1. Between-group comparisons respecting neonates' demographic characteristics[a]

Variables	Category	Groups		Test statistics	*P*
		Control	Intervention		
Gender				4.19	0.041[b]
	Female	16 (48.5)	8 (24.2)		
	Male	17 (51.5)	25 (75.8)		
Route of delivery				1.98	0.159[b]
	Normal vaginal	6 (18.2)	11 (33.3)		
	Cesarean section	27 (81.8)	22 (66.7)		
Reason for hospitalization				1.95	0.163[c]
	Respiratory distress syndrome	32 (97.0)	29 (87.9)		
	Apnea of prematurity	1 (3.0)	4 (12.1)		
Gestational age (weeks)	-	32.67±1.96	32.97±1.81	0.65	0.517[d]
Birth weight (g)	-	1911.0±363.63	1903.0±340.41	0.28	0.928[d]
1 min Apgar, median (IQR)	-	7 (1)	7 (1)	0.55	0.580[e]
5 min Apgar, median (IQR)	-	8 (1)	8 (2)	0.11	0.914[e]

[a]Data are presented as *n* (%) or mean±SD, [b]Chi-squared test, [c]Fisher's exact test, [d]*t*-test, [e]Mann-Whitney U test. SD: Standard deviation, IQR: Interquartile range

Table 2: The means of weight and weight change in both groups

Hospitalization day	*n*		Weight change (mean±SD)	
	Control	Intervention	Control	Intervention
1	33	33	−26.33 ± 27.41	−18.48 ± 17.87
2	33	33	−33.03 ± 42.97	−29.69 ± 39.72
3	33	33	−20.18 ± 47.14	−18.48 ± 18.39
4	33	33	−35.45 ± 25.18	−26.66 ± 44.06
5	33	33	−33.93 ± 47.36	−18.18 ± 18.27
6	33	31	−34.54 ± 29.05	−12.78 ± 18.49
7	31	31	−11.29 ± 32.48	−9.67 ± 28.62
8	31	31	17.56 ± 21.14	19.67 ± 28.01
9	27	29	10.37 ± 18.49	19.62 ± 26.95
10	25	27	12.96 ± 21.45	21.11 ± 25.77
11	20	27	12.95 ± 19.19	19.62 ± 26.38
12	18	24	18.51 ± 22.48	21.48 ± 26.55
13	15	21	16.15 ± 21.73	17.03 ± 28.52
14	15	19	17.69 ± 21.96	20.38 ± 25.99
15	15	17	14.23 ± 17.24	25.38 ± 26.11

SD: Standard deviation

Table 3: Between-group comparisons respecting the means of weight gain and length of Neonatal Intensive Care Unit stay before and after adjusting for gender

Variable	Groups		Test statistics[b]	*P*[b]	Test statistics[c]	*P*[c]
	Control	Intervention				
Weight gain[a]	14.63 ± 5.64	29.17 ± 7.32	−7.98	<0.001	56.75	<0.001
Length of NICU stay, day	18.18 ± 10.21	18.39 ± 12.01	0.54	0.939	<0.0001	0.990

[a]Weight gain is calculated through dividing the difference between discharge weight and the 9th day weight by the length of NICU stay in days; [b]Unadjusted comparison through the independent-samples *t*-test; [c]Gender-adjusted comparison via the two-way ANOVA. NICU: Neonatal Intensive Care Unit, ANOVA: Analysis of variance

upward. Due to these reasons, the random-effects spline model was the best statistical method to compare the study groups and the gender groups respecting the trend of weight variations. Its results showed that the mean of male neonates' weight was significantly greater than female participants by 215.64 g, suggesting the significant effects of gender on weight (P = 0.005). Moreover, the mean of neonates' weight in the intervention group was insignificantly greater than the control group by 0.35, 0.70, 1.05, 1.40, 1.75, 2.10, 2.45, and 2.8 g in days 1–8, respectively (P = 0.857). However, weight mean in the intervention group was

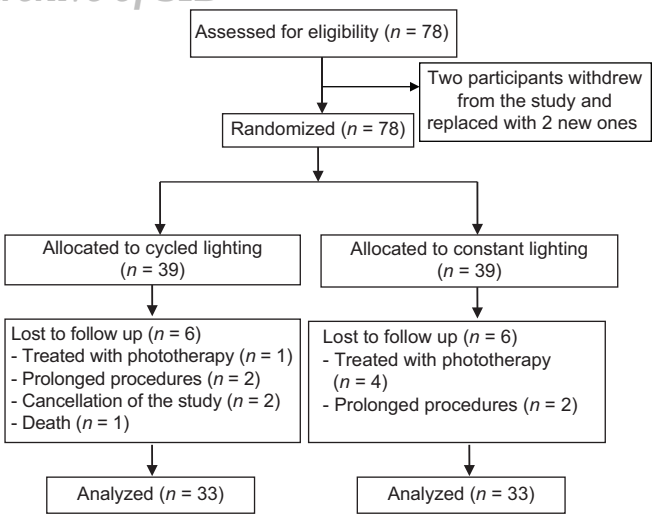

Figure 3: The consort flow diagram of the study

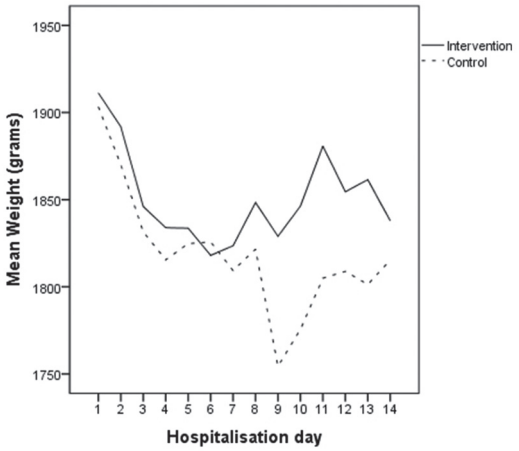

Figure 4: The mean neonates' weight in the control and intervention groups by the day of hospitalization

Table 4: The results of the random-effects spline model for comparing the groups in terms of the trend of weight variations over time

Parameter	Category	Estimate	SE	*P*
Intercept	-	1952.21	46.56	-
Gender	Female	–215.64	76.98	0.005
	Male	0	-	
Hospitalization day	-	–5.46	1.38	<0.001
Hospitalization day - 8[+a]	-	17.79	2.74	<0.001
Group × hospitalization day	Intervention	0.35	1.94	0.857
	Control	0	-	
Group × (hospitalization day - 8)[+]	Intervention	22.10	3.80	<0.001
	Control	0	-	
Variance of random effects	-	90037	13785	-

[a] $(Hospitalization\ day - 8)^{+} = \begin{cases} 0 & Hospitalization\ day \leq 8 \\ Hospiatalixattionday - 8 & :Hospitalizationday > 8 \end{cases}$ SE: Standard error

significantly greater than the control group by 25.25, 47.70, 70.15, 92.60, 115.05, 137.50, and 159.95 g in days 9–15, respectively [$P < 0.001$; Table 4].

The means of NICU stay in the control and intervention groups were 18.18 ± 10.21 (with a range of 6–46) and 18.39 ± 12.01 (with a range of 5–44) days, respectively. Between-group difference respecting the mean of NICU stay was not statistically significant neither with gender being unadjusted ($P = 0.939$) nor with gender being adjusted ($P = 0.990$).

Discussion

This study aimed to compare the effects of CL and constant lighting on weight gain and NICU stay among premature neonates. Neonates in both groups were found to lose weight during the first 7 days of the intervention. The mean of weight in the intervention group was not significantly different from the control group in the first 8 days. From the 8th to the 15th days, neonates in both groups started to gain weight. The mean of weight in the intervention group was significantly greater than the control group during the study. Weight loss in the 1st week and weight gain in the 2nd week of the study can be attributed to the fact that almost all neonates physiologically lose 10%–15% of their birth weight in the 1st week after birth and then start to gain weight.[9] Of course, the significantly higher weight in the 2nd week of the study in the intervention group can be due to the positive effects of CL.

In line with our findings, an earlier study also reported that the mean of neonates' weight in the CL group was 150 g more than the control group at the 21st day of their study. Moreover, they found CL effective in improving oxygen saturation, promoting heart rate stability, and establishing a regular daily melatonin rhythm.[9] Another study reported that CL using a mirror-like light filter from 20:00 PM to 05:30 AM, which protected neonates in incubator from exposure to visual wavelengths of light and significantly improved weight gain among premature neonates.[19] Similarly, a study proved that CL (i.e., darkness from 19:00 to 07:00 and normal lighting from 07:00 to 19:00) caused significant positive physiological changes compared with constant lighting.[20] Together with our study, all these studies highlight the importance of CL to premature neonates' health, growth, and development. However, some studies contradicted our findings. For instance, a study on very low-birth-weight premature neonates showed that constant 24-h near darkness using light-reducing goggles for at least 4 whole weeks had no significant positive effects on weight

gain.[21] An explanation for this contradiction is the fact that constant near darkness does not stimulate the healthy development of circadian rhythms. Moreover, placing goggles on premature neonates' face can be annoying and irritating and can negatively affect neonates' weight gain. Another study also showed no significant difference between the effects of CL and dim lighting (both started in hospital and continued after hospital discharge) on weight gain of premature infants.[22] This insignificant difference between the effects of CL and dim lighting on weight gain may be due to the similar effects of CL and dim lighting on weight gain. Another explanation may be the fact that CL at home was implemented by parents without the direct supervision of the researchers. Consequently, parents might have had no close adherence to the CL protocol of that study. By applying LD cycle, environmental stress and the complications of premature infants in the NICU can be reduced, resulting in better weight gain of the premature infants.

Our findings also showed that CL had no significant effects on premature neonates' NICU stay. In contrast, a study revealed that CL significantly shortened NICU stay among premature neonates.[9] This discrepancy might be attributed to the differences in the NICU settings and the used cycled protocols in the studies. The length of premature neonates' stay in NICU is a good indicator for assessing the quality of health-care services.[23] Prolonged NICU stay can impose heavy costs on both neonates' families and health-care systems. Therefore, prospective multicenter studies are recommended to determine the factors behind the length of NICU stay among premature neonates.

One of the most important limitations of the present study was its nonblind design. Moreover, the sample size was relatively small, and the study setting was a single NICU. Therefore, the findings should be generalized to other settings with caution. Further multicenter investigations are still needed to provide strong evidence respecting the effects of CL on weight gain and NICU stay among premature neonates.

Conclusion

The present study showed the ineffectiveness of CL in shortening NICU stay and its effectiveness in significantly improving weight gain among premature neonates during the first 15 postnatal days. The findings of this study can be used to improve nursing students' knowledge about the positive effects of CL. Moreover, NICU nurses can use the findings to improve neonatal outcomes among premature neonates hospitalized in NICUs. Simple inexpensive nursing measures, such as CL, can also improve parental satisfaction through improving neonatal outcomes without imposing heavy costs on parents and health-care systems.

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Conflicts of interest

There are no conflicts of interest.

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