Published in final edited form as:

Early Hum Dev. 2003 May ; 72(1): 25–36.

Occurrence of oxygen desaturation events during preterm infant bottle feeding near discharge

Suzanne M. Thoyre* and John Carlson

School of Nursing, The University of North Carolina at Chapel Hill, CB 7460 Carrington Hall,
Chapel Hill, NC 27599-7460, USA

Abstract

Aims—The purpose of this study was to examine the occurrence, severity, pattern, and moderators of oxygen desaturation during preterm infant bottle feeding near the time of discharge from the neonatal intensive care unit (NICU) when fed by mothers.

Study design—Twenty-two very low birthweight (VLBW) infants [birthweight 1155 ± 293 g, gestational age (GA) 28.1 ± 2.0 , postconceptional age (PCA) 36.5 ± 1.6 weeks] were videotaped being bottle-fed by their mothers. Most infants (86%) were discharged within 6 days of the study. Oxygen saturation was continuously monitored and infant feeding behaviors were coded. Oxygen desaturation events ($SpO_2 < 90\%$) were identified and analyzed.

Results—Infants averaged 10.8 events during feeding (range 1–28, S.D. 8.9) and spent, on average, 20% of their feeding time (range 0–70%, S.D. 17.98%) with oxygen levels below 90%. One hundred forty of the desaturation events (59%) were classified as mild (SpO_2 85–89), 47 events (20%) were classified as moderate (SpO_2 81–84), and 51 events (21%) were classified as severe (SpO_2 80). Events were evenly distributed across infants' feeding time. Receiving supplemental oxygen, beginning the feeding with a higher baseline SpO_2 , and being of older PCA predicted lower percentage of feeding time with SpO_2 below 90% ($R^2 = 0.57$). Receiving supplemental oxygen and beginning the feeding with a higher baseline SpO_2 predicted less number of desaturation events during the feeding ($R^2 = 0.44$). Despite similar baseline SpO_2 levels, infants who were on supplemental oxygen had 50% less oxygen desaturation events and spent 33% less time with SpO_2 less than 90%.

Conclusion—VLBW infants continue to have desaturation events during feeding when fed by their mothers near the time of discharge. Further research is needed to understand the effect of hypoxemia on the preterm infant's development of oral feeding skills, to study the effects of supplemental oxygen during feeding, and to further develop interventions to minimize desaturation during feeding.

Keywords

Oxygen desaturation; Preterm infant; Bottle feeding

*Corresponding author. Tel.: +1-919-966-8418; fax: +1-919-843-9969. thoyre@email.unc.edu (S.M. Thoyre).

1. Introduction

A significant clinical problem for very low birthweight (VLBW) infants during early feeding is their coordination of suck–swallow–breathe mechanisms. When breathing pauses become prolonged or when breathing periods between sucks are inadequate or interrupted, infant physiologic regulation may be exceeded with resultant oxygen desaturations [1–7]. Recurrent episodes of hypoxemia, such as may occur through repeated feedings throughout the preterm infant's day, may affect cardiac and pulmonary function, impair preterm infant growth and development of oral feeding skills, and may alter cerebral blood volume and oxygenation which have been implicated in neonatal cerebral injury [2,8–13]. Very little is known about the occurrence of feeding hypoxemia near the time of discharge when preterm infants are fed by their mothers, who typically anticipate being the primary feeder post-discharge [14].

Oxygen desaturation during bottle feeding is impacted by the feeding condition and the health of the infant. During the hospitalization period, preterm infants have a greater incidence of desaturation during bottle feeding than during breast or gavage feeding [3,15–18]. Infants who are bottle-fed while they have an indwelling nasogastric feeding tube have more prolonged and more severe oxygen desaturation events [19]. Preterm infants with chronic lung disease also have a greater incidence of desaturation during feeding [1,2,7]. In addition, preterm infants with lower baseline oxygen saturation (SpO_2) at the outset of feeding have lower mean SpO_2 during the subsequent feeding episode [20] and a higher percentage time of the total feeding time with oxygen below 90% [5].

Lower oxygen saturation during feeding impacts the infant's ability to organize and maintain oral feeding skills. Infants with lower oxygen saturation tend to have shorter sucking bursts, potentially signifying less energy available for sucking. They also tend to organize restorative breathing between sucking bursts poorly, engaging instead, in shorter intervals between sucking bursts [5]. Further study is needed to identify infants who are vulnerable to oxygen desaturation during feeding.

Although little is known about how long preterm infants continue to have desaturation events associated with feeding post-discharge, it has been found that preterm infants with chronic lung disease and infants with persistent apnea continue to have significant hypoxemia during feeding at 43- and 52-week postconceptional age (PCA), respectively [4,7]. Very little information exists related to oxygenation during feeding near the time of discharge, a period of time increasingly occurring at an earlier PCA. The age of discharge is now 35–37 weeks for the “healthy” preterm infant and 37- to 42-week PCA for preterms with a history of health problems [21]. During this developmental period, preterm infants vary in neurophysiologic control of breathing [22], ability to safely and efficiently swallow [23], and ability to adapt to the demand that an activity such as oral feeding requires.

Because feeding is a key concern of families' post-discharge, further study is needed to examine whether infants remain vulnerable to hypoxemia during feeding near the time of discharge and, if so, which infants are most vulnerable. Specifically, there were two aims of this study: to describe the occurrence, severity, and pattern of oxygen desaturations during

preterm infant feeding near the time of discharge from the neonatal intensive care unit (NICU), and to explore the moderating effects of infant health, birthweight (BW), maturity (PCA), experience bottle feeding, maternal experience, and supplemental oxygen on the occurrence and severity of desaturation events.

2. Methods

2.1. Subjects

VLBW infants (< 1500 g BW) who were oral feeding at least 50% of their daily intake were eligible for the study. This insured that all infants in the study had achieved a moderate level of feeding skill. Excluded were small for gestation infants and those with conditions that could interfere with oral feeding (e.g., cleft palate, cardiac disease) and infants with grade III intraventricular hemorrhage. The study took place in two Midwest neonatal units and was approved by an Institutional Review Board. Parental consent was obtained before the study.

2.2. Study design

Infants were studied 5 min before and throughout an entire bottle feeding that the mother provided in a quiet parent visitation room. No infants were fed with an indwelling nasogastric or orogastric feeding tube. Mothers were not instructed on feeding technique but were rather observed as they would naturally feed their infant, using their own inclinations as to what intervention they might need (e.g., removing the nipple) when their infant showed signs of distress during the feeding. A pulse oximeter display was visually accessible to the mother throughout the feeding. Feedings were videotaped with a close-up of the infant's face and upper body and a microphone was placed on the bottle rim to enhance feeding sounds on the videotape.

2.3. Data collection

SpO₂ and pulse rate were measured with a pulse oximeter (Ohmeda Biox 3700, Boulder, CO) set to the lowest response averaging time. The oximeter probe was placed on the infant's foot in a position that provided an optimal signal. Respiratory and heart rate data were collected with a standard cardiorespiratory monitor (Siemens 404N). All analog data were digitized by an analog to digital converter and stored on a computer for subsequent analysis. An event marker that, when depressed, simultaneously placed an audio tone on the videotape, was an additional channel on the computer file to allow alignment of behavioral and physiologic data. Oximeter artifact was removed from the data by comparing the pulse oximeter's pulse rate with the cardiorespiratory monitor's heart rate. In addition, instantaneous severe drops in SpO₂ were considered artifacts. Clinically significant oxygen desaturation events were defined as any decrease in SpO₂ below 90% for greater than or equal to 1 s. An interval of 10 s with SpO₂ greater than or equal to 90% separated all events. Desaturation events were categorized as mild (SpO₂ 85–89), moderate (SpO₂ 81–84), and severe (SpO₂ 80). Time from the outset of the feeding that each event occurred and whether the event occurred within the infant's initial, middle, or final third of their feeding were identified. Infant feeding behavior (bottle in or bottle out) was coded from the videotape at one code per second using Stephenson's coding system [24]. Interrater coding agreement was 100% for bottle in/out events. SpO₂ and infant feeding behavior were

aligned for each second of the feeding. Feeding length was defined as the time from the first nipple in mouth through the final nipple out (i.e., included feeding breaks). Infant characteristics of PCA at the time of study, BW, gestational age (GA), experience bottle feeding (calculated as the number of days the infant had an opportunity to bottle feed at least once), and the number of days on supplemental oxygen since birth were determined from chart review. Health of the infant (measured as the mean baseline SpO₂ during the 5-min pre-feeding period) and use of supplemental oxygen at the time of the study (yes/no) were recorded. Maternal demographic data, experience bottle feeding (the number of times the mother had bottle-fed her preterm infant), and the number of infants the mother had parented was derived from maternal self-report.

2.4. Statistical analysis

The Statistical Analysis System for Windows (Version 8) (SAS Institute, Cary, NC) was used for data analysis. Descriptive statistics were calculated for infant and maternal characteristics, feeding length, and desaturation variables. Correlations of desaturation variables (percentage of the feeding time with SpO₂ < 90%, number of desaturation events), infant variables (requiring supplemental oxygen, baseline SpO₂, BW, GA, PCA, experience bottle feeding, number of days on supplemental oxygen), and maternal parity were examined. Regression analysis estimated joint effects of variables on the percentage of time infant's SpO₂ was < 90% and on the number of desaturation events.

3. Results

Twenty-two VLBW infants were studied. Infant and maternal characteristics are summarized in Table 1. Infants were near discharge (median 3 days) with 86% discharged to their home within 6 days of the study. Infants were of similar feeding skill (all were able to nipple feed at least 50% of their feedings) but differed in PCA at time of study (range 33.5–40 weeks). Infants also varied in their history of supplemental oxygen requirement (range 1–97 days). Seven infants were receiving supplemental oxygen at the time of the study; six of these infants remained on supplemental oxygen at 36-week PCA. Baseline SpO₂ was within a clinically acceptable range. Mothers had bottle-fed their infants at least five times before the study feeding. Ten mothers had not parented a previous infant (45%), seven mothers had parented one previous full-term infant (32%), one mother had parented one previous preterm infant (5%), and four mothers had parented two or more full-term infants (18%).

Descriptive data of the feeding variables are provided in Table 2. A total of 238 desaturation events was considered valid. Infants averaged 10.82 separate desaturation events during feeding and spent, on average, 20% of their feeding time with oxygen levels below 90%. A total of 140 of the desaturation events (59%) was classified as mild (SpO₂ 85–89), 47 events (20%) were classified as moderate (SpO₂ 81–84), and 51 events (21%) were classified as severe (SpO₂ 80). Events had a mean duration of 29.53 s (range 1–416 s) and were evenly distributed across infants' feeding time with 30.7% occurring during the first third of the feeding, 32% occurring during the middle third, and 37.3% occurring during the final third. Of all minutes of the feeding, the initial minute of the feeding had the highest number of desaturation events. Most of the desaturation events occurred while the infant had the bottle nipple in the mouth as opposed to during a feeding break (62.2% vs. 37.8%). Forty-two

percent of the desaturation events were preceded by another desaturation event within the previous 30 s.

Correlations between percentage of time with $\text{SpO}_2 < 90\%$, number of desaturation events, infant receiving supplemental oxygen, baseline SpO_2 , BW, GA, PCA, days bottle feeding, days on oxygen, and maternal parity appear in Table 3 as simple Pearson correlation coefficients. Maternal parity was treated as a dichotomous variable (0 = no previous parenting experience, 1 = prior experience with parenting) because we were interested in whether previous experience parenting was associated with infant oxygen status during feeding and, in this sample, one mother had parented eight children while the maximum for all other women was two previous children. No statistically significant correlations were found between maternal experience with parenting and the other variables. Higher percentage of feeding with $\text{SpO}_2 < 90\%$ was associated with a higher number of desaturation events ($p = 0.01$), not receiving supplemental oxygen ($p = 0.05$), higher BW ($p = 0.05$), lower PCA ($p = 0.01$), and less experience bottle feeding ($p = 0.01$). A higher number of desaturation events were associated with higher percentage of feeding with $\text{SpO}_2 < 90\%$ ($p = 0.01$) and lower baseline SpO_2 ($p = 0.01$). Not surprisingly, requiring oxygen near the time of discharge was strongly correlated with requiring oxygen for more days during the hospitalization period ($p = 0.01$). BW and GA were also highly correlated variables ($p = 0.01$), both reflecting birth maturity. Similarly, PCA and number of days bottle feeding were highly correlated ($p = 0.01$), an expected result because these variables reflect maturity. Infants who required oxygen for a longer period of time had more experience feeding by the time of the study, that is, their transition time to full oral feeding was lengthened ($p < 0.01$), and they were of higher PCA ($p = 0.05$). Lower BW infants were more likely to be on supplemental oxygen for a longer number of days ($p = 0.01$), to continue to require supplemental oxygen at the time of study ($p = 0.05$), to be of higher PCA at the time of the study ($p = 0.05$), and to have more experience bottle feeding ($p = 0.01$).

The results of the regression analyses are presented in Tables 4 and 5. The tables show the final regression models after elimination of nonsignificant or collinear variables. Receiving supplemental oxygen, beginning the feeding with a higher baseline SpO_2 , and being of older PCA predicted lower percentage of feeding time with $\text{SpO}_2 < 90\%$. These variables explained 57% of the variation in percentage of feeding with $\text{SpO}_2 < 90\%$. Receiving supplemental oxygen and beginning the feeding with a higher baseline SpO_2 explained 44% of the variation in the number of desaturation events. To determine if the regression relationships would also represent the data if we had chosen more conservative oxygen desaturation values, we re-ran the regression analyses using only moderate and severe desaturation events (i.e., $\text{SpO}_2 < 85\%$). We found that the same variables (receiving supplemental oxygen and baseline oxygen) were significant predictors of oxygen desaturation events with SpO_2 less than 85%, explaining 64% of the variance in the number of these more severe events.

To further explore the effects of supplemental oxygen on desaturation during feeding, we compared infants receiving supplemental oxygen ($n = 7$) with those not receiving supplemental oxygen at the time of the study ($n = 15$) (see Table 6). All infants who received oxygen during the study were also on supplemental oxygen between feedings. Both

groups, however, had infants who had been on oxygen greater than 28 days (100% vs. 53%). An independent samples' *t*-test revealed that infants who received supplemental oxygen had significantly lower percentage of their feeding time with SpO₂ less than 90%, [$t(18.5) = -3.24, p < 0.01$]. These infants had significantly lower BW, [$t(20) = -2.47, p = 0.02$], had a history of more days on supplemental oxygen, [$t(20) = 5.06, p < 0.001$], and were more experienced at bottle feeding, [$t(15.6) = 3.1, p < 0.01$]. Feedings between these two groups did not differ in their length, the number of times mothers stopped the feeding to provide pacing, a rest period, or to burp the infant, or in the percentage of the feeding that the infant spent resting vs. feeding. Despite similar baseline SpO₂ levels, infants who were on supplemental oxygen had 50% less oxygen desaturation events and spent 33% less time with SpO₂ below 90%. Low baseline SpO₂ was more predictive of oxygen desaturation if infants were not on supplemental oxygen.

4. Discussion

We have demonstrated that VLBW infants continue to have frequent oxygen desaturation events during bottle feeding near the time of discharge from the NICU when fed by their mothers. On average, infants spent 20% of their feeding time with SpO₂ levels < 90%, values that were significantly lower than the normal range of oxygen saturation for preterm infants of this PCA during non-feeding periods [22,25]. Slightly over one-half of the desaturation events were mild (59%) and greater than 40% were moderate to severe (< 85% SpO₂). The first minute of the feeding was the most vulnerable minute of the feeding for desaturation events. However, when each infant's feeding was divided into thirds, desaturation events were fairly evenly distributed with slightly more events occurring during the final third of the feeding.

Most desaturation events occurred during bottle-in-mouth periods; however, 37.8% of the events occurred after the bottle was removed, that is, during a feeding break. Many of these events were related to the previous bottle-in-mouth period. For example, mothers removed the nipple when they noted that their infant had not been breathing adequately or there were behavioral stress cues, the SpO₂ was decreasing and a desaturation event ensued. Interestingly, mothers often resumed feeding their infant before the infant's SpO₂ had fully recovered to the pre-feeding baseline level. More understanding is needed on how an infant behaviorally demonstrates full recovery from a desaturation event (e.g., are they more likely to seek the nipple when stimulated). Inadequate opportunity for full recovery from a desaturation event may contribute to the high likelihood of another event occurring within 30 s.

A greater percentage of time during feeding with SpO₂ less than 90% was more often found in infants who did not receive supplemental oxygen during the feeding, had lower baseline SpO₂, were bottle feeding at an earlier PCA with less experience bottle feeding, and had a history of fewer days on oxygen and greater BW. A greater number of desaturation events during feeding occurred for infants who were not receiving supplemental oxygen and who had lower baseline SpO₂. The infants in this study who are classically thought of as vulnerable to hypoxemia during feeding (those of smaller BW who require supplemental oxygen for a longer period of time and who may have chronic lung disease) were, in fact,

less vulnerable. These findings are contrary to the belief that “healthy” preterm infants are less vulnerable to hypoxemia during feeding than infants with lung disease. Supplemental oxygen during feeding may have protected these infants from greater number and severity of oxygen desaturation. An alternative explanation may be that infants who were requiring supplemental oxygen were considered more vulnerable to hypoxemia by their mothers and were then fed with closer monitoring of oxygen status. In addition, these infants had been hospitalized for a longer length of time and their mothers may have come to know their signs of distress and learned more effective ways to support their infants’ physiologic stability during feeding. Even though nipple removals did not occur more often with infants on supplemental oxygen, their mothers may have tipped the bottle back to provide a break from milk flow and to encourage breathing more often. More research is needed in this area.

Supplemental oxygen has been found to decrease apneic events, minimize the negative effect of brief apnea on infant oxygenation, and overall, lessen the number and duration of desaturation events in preterm infants [12,26,27]. The mechanism by which supplemental oxygen may prevent desaturation events or decrease their severity is unknown; however, it is hypothesized that supplemental oxygen increases the end-expiratory lung volume thereby improving ventilation/perfusion matching [28]. More research is needed to examine the effect of supplemental oxygen on early preterm infant feeding skills and to determine which infants may benefit most from the use of supplemental oxygen during feeding.

It was surprising to find that the percentage of feeding time with $SpO_2 < 90\%$ was not higher in infants born very early (lower BW). This observation may be explained by the fact that these infants generally were of greater PCA at the time of the study as these infants tend to progress in feeding skills at a slower rate and often begin oral feeding at an older PCA. In our study, infants of younger PCA were more vulnerable to oxygen desaturation during feeding. These infants tended to be born at an older GA, were of higher BW, and started oral feeding at a younger PCA. At the time of study, these infants also had less experience oral feeding.

On average, infants’ baseline SpO_2 was below what is currently recommended as an optimal level before feeding [5] and lower than the fifth percentile for normative data on preterm infant oxygen saturation levels at discharge [22]. An increase in vulnerability to hypoxemia with lower baseline SpO_2 is consistent with several other studies conducted with preterm infants of this age. Poets et al. [22] found that lower baseline SpO_2 was correlated with an increase in transient desaturations. Adams et al. [28] found that preterm infants with lower baseline SpO_2 were more vulnerable to hypoxemic events with even brief interruptions in their breathing. In infants with chronic lung disease, McEvoy et al. [29] reported less number and duration of desaturation events when infants’ SpO_2 was maintained at a level of 94–96% rather than 87–91%.

5. Conclusions and implications

Findings from this study extend the understanding of the risk of bottle feeding to preterm infants’ physiologic regulation. Preterm infants continued to have desaturation events during bottle feeding near the time of discharge from the NICU when fed by their mothers,

particularly those infants who had little oral feeding experience, who were of younger PCA, and those with lower baseline oxygen saturation before feeding. Even though a preterm infant may maintain a normal SpO₂ in room air, the physiologic demand created by the activity of feeding may increase their oxygen requirements beyond their ability to maintain physiologic regulation. VLBW infants may require pulse oximetry monitoring during oral feeding until they consistently maintain oxygenation throughout the demand of oral feeding. In this sample, supplemental oxygen had a significant protective function during feeding and may be required for more preterm infants during feeding. Further research is warranted to understand the consequences of transient hypoxemia during feeding on the preterm infant's development of oral feeding skills, to study the effects of supplemental oxygen during feeding, and to further develop interventions to minimize desaturation during feeding.

Acknowledgments

The authors would like to extend appreciation to the mothers and infants who participated in this study and to John L. Doyne Hospital in Milwaukee, WI and Meriter Hospital in Madison, WI for affording access to participants.

This study was supported by the National Institute of Nursing Research, Fellowship NR07052-02 and by the University of North Carolina at Chapel Hill, School of Nursing.

References

1. Craig CM, Lee DN, Freer YN, Laing IA. Regulations in breathing patterns during intermittent feeding in term infants and preterm infants with bronchopulmonary dysplasia. *Dev Med Child Neurol*. 1999; 41:616–24. [PubMed: 10503920]
2. Garg M, Kurzner SI, Bautista DB, Keens TG. Clinically unsuspected hypoxia during sleep and feeding in infants with bronchopulmonary dysplasia. *Pediatrics*. 1988; 81:635–42. [PubMed: 3357725]
3. Poets CF, Langner MU, Bohnhorst B. Effects of bottle feeding and two different methods of gavage feeding on oxygenation and breathing patterns in preterm infants. *Acta Paediatr*. 1997; 86:419–23. [PubMed: 9174231]
4. Rosen CL, Glaze DG, Frost JD. Hypoxemia associated with feeding in the preterm infant and full-term neonate. *AJDC*. 1984; 138:623–8. [PubMed: 6428217]
5. Shiao SY, Brooker J, DiFiore T. Desaturation events during oral feedings with and without a nasogastric tube in very low birth weight infants. *Heart Lung*. 1996; 25:236–45. [PubMed: 8635924]
6. Shivpuri CR, Martin RJ, Carlo WA, Fanaroff AA. Decreased ventilation in preterm infants during oral feeding. *J Pediatr*. 1983; 103:285–9. [PubMed: 6875726]
7. Singer L, Martin RJ, Hawkins SW, Benson-Szekely LJ, Yamashita TS, Carlo WA. Oxygen desaturation complicates feeding in infants with bronchopulmonary dysplasia after discharge. *Pediatrics*. 1992; 90:380–4. [PubMed: 1518692]
8. Groothuis JR, Rosenberg AA. Home oxygen promotes weight gain in infants with bronchopulmonary dysplasia. *Am J Dis Child*. 1987; 141:992–5. [PubMed: 3618573]
9. Jenni OG, Wolf M, Hengartner M, Siebenthal K, Keel M, Bucher HU. Impact of central, obstructive and mixed apnea on cerebral hemodynamics in preterm infants. *Biol Neonate*. 1996; 70(2):91–100. [PubMed: 8864428]
10. Livera LN, Spencer SA, Thorniley MS, Wickramasinghe YA, Rolfe P. Effects of hypoxaemia and bradycardia on neonatal cerebral haemodynamics. *Arch Dis Child*. 1991; 66(4 Spec):376–80. [PubMed: 2025027]
11. Perlman JM, Volpe JJ. Episodes of apnea and bradycardia in the preterm newborn: impact on cerebral circulation. *Pediatrics*. 1985; 76(3):333–8. [PubMed: 4034294]

12. Samuels MP, Poets CF, Southall DP. Abnormal hypoxemia after life-threatening events in infants born before term. *J Pediatr.* 1994; 125:441–6. [PubMed: 8071755]
13. Urlesberger B, Kaspirek A, Pichler G, Muller W. Apnoea of prematurity and changes in cerebral oxygenation and cerebral blood volume. *Neuropediatrics.* 1999; 30:29–33. [PubMed: 10222458]
14. Thoyre S. Challenges mothers identify in bottle feeding their preterm infants. *Neonatal Netw.* 2001; 20:41–50. [PubMed: 12143838]
15. Bier JB, Ferguson A, Anderson L, Solomon E, Voltas C, Oh W, et al. Breast feeding of very low birth weight infants. *J Pediatr.* 1993; 123:773–8. [PubMed: 8229489]
16. Chen C, Wang T, Chang H, Chi C. The effect of breast- and bottle-feeding on oxygen saturation and body temperature in preterm infants. *J Hum Lact.* 2000; 16(1):21–7. [PubMed: 11138220]
17. Dowling DA. Physiological responses of preterm infants to breast-feeding and bottle-feeding with the orthodontic nipple. *Nurs Res.* 1999; 48:78–85. [PubMed: 10190834]
18. Meier P. Bottle- and breast-feeding: effects on transcutaneous oxygen pressure and temperature in preterm infants. *Nurs Res.* 1988; 37:36–41. [PubMed: 3340577]
19. Shiao SY. Comparison of continuous versus intermittent sucking in very-low-birth-weight infants. *JOGNN.* 1997; 26(3):313–9. [PubMed: 9170595]
20. Thoyre, S. Co-regulation in preterm infant feeding [dissertation]. Madison (WI): University of Wisconsin; 1997.
21. Rawlings JS, Scott JS. Postconceptional age of surviving preterm low-birth-weight infants at hospital discharge. *Arch Pediatr Adolesc Med.* 1996; 150:260–2. [PubMed: 8603218]
22. Poets CF, Stebbens VA, Alexander JR, Arrowsmith WA, Salfield SAW, Southall DP. Arterial oxygen saturation in preterm infants at discharge from the hospital and six weeks later. *J Pediatr.* 1992; 120:447–54. [PubMed: 1538297]
23. Hanlon MB, Tripp JH, Ellis RE, Flack FC, Selley WG, Shoesmith HJ. Deglutition of apnoea as indicator of maturation of suckle feeding in bottle-fed preterm infants. *Dev Med Child Neurol.* 1997; 39:534–42. [PubMed: 9295849]
24. Stephenson, GR. The SSR system in social research. Madison (WI): Software Assistance; 1984.
25. Ng A, Subhedar RA, Shaw NJ. Arterial oxygen saturation profiles in healthy preterm infants. *Arch Dis Child, Fetal Neonatal Ed.* 1998; 79:F64–6. [PubMed: 9797629]
26. Sekar KC, Duke JC. Sleep apnea and hypoxemia in recently weaned premature infants with and without bronchopulmonary dysplasia. *Pediatr Pulmonol.* 1991; 10:112–6. [PubMed: 2030919]
27. Watkin SL, Spencer SA, Pryce A, Southall DP. Temporal relationship between pauses in nasal airflow and desaturation in preterm infants. *Pediatr Pulmonol.* 1996; 21:171–5. [PubMed: 8860072]
28. Adams JA, Zabaleta IA, Sackner MA. Hypoxemic events in spontaneously breathing premature infants: etiologic basis. *Pediatr Res.* 1997; 42:463–71. [PubMed: 9380437]
29. McEvoy C, Durand M, Hewlett V. Episodes of spontaneous desaturations in infants with chronic lung disease at two different levels of oxygenation. *Pediatr Pulmonol.* 1993; 15:140–4. [PubMed: 8327275]

Table 1Characteristics of the sample ($N = 22$): 10 males, 12 females

Variable	Mean	S.D.	Range
<i>Infants</i>			
BW (g)	1155	293	620–1500
GA (weeks)	28.1	2.0	25–32
PCA (weeks)	36.5	1.6	33.5–40
Days before discharge	5	8	1–38
Days bottle feeding	16	6.62	6–30
Days on oxygen	41.91	33.54	1–97
Oxygen in use during feeding (%)	31.8		
SpO ₂ during baseline period (%)	93.23	2.64	90–98
<i>Mothers</i>			
Age (years)	26.27	6.69	15–37
Education (years)	13.82	3.68	8–20
Parity	2	1.8	1–9
Experience parenting a previous infant (%)	55		
Income level ^a	4	2	1–7
Experience feeding (number of bottle feedings) ^b	13.95	11.09	5–47
Anticipation of feeding involvement (%) ^c	80	16	50–100

^a 1 = US\$10,000; 2 = 10,000–11,999; 3 = 12,000–14,999; 4 = 15,000–24,999; 5 = 25,000–34,999; 6 = 35,000–49,999; 7 = 50,000.

^b Number of nipple feedings mother has participated in.

^c Percentage of feedings mother expects to participate in post-discharge.

Table 2

Description of feedings and desaturation events

	Mean	S.D.	Range
<i>Feeding variables</i>			
Length of feeding (min)	21	11.3	6–43.5
Time with SpO ₂ < 90% (s)	302	378.9	1–1202
Percentage of feeding SpO ₂ < 90%	20.13%	17.98%	0–70.19%
<i>Desaturation events (n = 238)</i>			
Number of desaturation events per infant ^a	10.8	8.9	1–28
Length of desaturation events (s)	29.5	57.4	1–416

^aSpO₂ < 90% for 1 or more seconds with 10 or more seconds of higher SpO₂ separating events.

Table 3

Pearson correlations

	Percentage of feeding SpO ₂ < 90%	Number of events	On oxygen	Baseline SpO ₂	BW	GA	PCA	Days bottle feeding	Days on oxygen	Maternal parity
Percentage of feeding SpO ₂ < 90%	–	0.56**	–0.46*	–0.42	0.44*	0.34	–0.57**	–0.57**	–0.42	–0.07
Number of events	0.56**	–	–0.31	–0.58**	0.06	0.06	0.10	–0.09	–0.03	0.33
On oxygen	–0.46*	–0.31	–	–0.03	–0.48*	–0.37	0.28	0.53*	0.75**	0.27
Baseline SpO ₂	–0.42	–0.58**	–0.03	–	0.03	0.19	0.11	0.03	–0.19	0.05
BW	0.44*	0.06	–0.48*	0.03	–	0.79**	–0.48*	–0.61**	–0.78**	–0.32
GA	0.34	0.06	–0.37	0.19	0.79**	–	–0.45*	–0.61**	–0.69**	–0.24
PCA	–0.57**	0.10	0.28	0.11	–0.48*	–0.45*	–	0.79**	0.50*	0.22
Days bottle feeding	–0.57**	–0.09	0.53*	0.03	–0.61**	–0.61**	0.79**	–	0.72**	0.19
Days on oxygen	–0.42	–0.03	0.75**	–0.19	–0.78**	–0.69**	0.50*	0.72**	–	0.32
Maternal parity (0.1)	–0.07	0.33	0.27	0.05	–0.32	–0.24	0.22	0.19	0.32	–

* $p < 0.05$.

** $p < 0.01$.

Table 4

Variables predicting percentage of feeding with SpO₂ < 90% (N = 22)

Source	df	Sum squares	Mean square	F value	p
Model	3	3853.34	1284.45	7.89	0.0014
Error	18	2931.89	162.88		
Total	21	6785.23			

Variable	df	Coefficient	S.E.	T	P
Percentage of feeding SpO ₂ < 90%	1	20.13	2.72	7.40	0.0001
On Oxygen	1	-13.39	6.11	-2.19	0.042
Baseline SpO ₂	1	-2.53	1.02	-2.48	0.023
PCA	1	-4.66	1.79	-2.60	0.018

PCA= Postconceptual age.

R² = 0.57.

Formula: Percentage feeding SpO₂ < 90% = 20.13+(-13.39) On oxygen+(-2.53) Baseline SpO₂+(-4.66) PCA.

Table 5

Variables predicting number of desaturation events ($N = 22$)

Source	df	Sum squares	Mean square	F Value	p
Model	2	735.56	367.78	7.53	0.0039
Error	19	927.72	48.83		
Total	21	1663.27			

Variable	df	Coefficient	S.E.	T	p
Number of desaturation events	1	10.82	1.49	7.26	0.0001
On oxygen	1	-6.15	3.20	-1.92	0.070
Baseline SpO ₂	1	-1.89	0.55	-3.43	0.003

$R^2 = 0.44$.

Formula: Number of desaturation events = 10.82+(-6.15) On oxygen+(-1.89) Baseline SpO₂.

Table 6

Characteristics of preterm infants receiving supplemental oxygen at the time of the study compared to infants not receiving supplemental oxygen

	Receiving oxygen (<i>n</i> = 7) <i>M</i> ± S.D. (range)	No oxygen (<i>n</i> = 15) <i>M</i> ± S.D. (range)
Percentage SpO ₂ < 90 ^{a, **}	8.2 ± 5.9 (0–15)	25.8 ± 19.1 (1–70)
Number of desaturation events	6.9 ± 7.2 (1–21)	12.7 ± 9.2 (1–28)
Feeding length (s)	1036 ± 462 (365–1579)	1361 ± 749 (358–2612)
Number of nipple removals	5.1 ± 2.3 (2–9)	5.9 ± 2.6 (2–10)
Bottle-in length (s)	647 ± 301 (297–1182)	940 ± 552 (339–2159)
Bottle-out length (s)	389 ± 290 (68–866)	421 ± 353 (19–1440)
Percentage of feeding bottle out	35 ± 16 (17–55)	29 ± 15 (5–55)
SpO ₂ baseline period	92.71 ± 2.50 (90–97)	93.47 ± 2.75 (90–98)
BW (g) [*]	952 ± 289 (620–1350)	1249 ± 250 (672–1500)
GA (weeks)	27 ± 1.9 (25–29.5)	28.6 ± 2.1 (25.5–32)
PCA (weeks)	37.2 ± 1.3 (35.5–39)	36.2 ± 1.7 (33.5–40)
Days bottle feeding ^{a, **}	21 ± 4.6 (15–30)	13.7 ± 6.2 (6–24)
Days on oxygen ^{***}	77.9 ± 14.8 (63–97)	25.1 ± 25.4 (1–72)
Gender	three males, four females	seven males, eight females
Parity	57% multiparous	53% multiparous

^a *t* Adjusted for unequal variance.

^{*} *p* < 0.05.

^{**} *p* < 0.01.

^{***} *p* < 0.001.