Efficacy of Semielevated Side-Lying Positioning During Bottle-Feeding of Very Preterm Infants

A Pilot Study

Jinhee Park, PhD, MSN, RN; Suzanne Thoyre, PhD, RN, FAAN; George J. Knafl, PhD; Eric A. Hodges, PhD, FNP-BC; William B. Nix, BMET, BA

ABSTRACT

Very preterm (VP, ≤30 wk gestational age) infants are at risk for impaired lung function, which significantly limits their ability to eat. A semielevated side-lying (ESL) position is a feeding strategy that may improve oral feeding by supporting breathing during feeding. The study evaluated the efficacy of the ESL position compared with the semielevated supine (ESU) position on physiological stability and feeding performance of bottle-fed VP infants. Using a within-subject crossover design, 6 VP infants were bottle-fed twice on 1 day, in both the ESL and ESU positions in a random order. Physiological stability (heart rate, oxygen saturation [SaO₂], and respiratory characteristics) and feeding performance (percent intake, proficiency, efficiency, and duration of feeding) were measured before and/or during feeding. Very preterm infants fed in the ESL position demonstrated significantly less variation in heart rate, less severe and fewer decreases in heart rate, respiratory rate that was closer to the prefeeding state, shorter and more regular intervals between breaths, and briefer feeding-related apneic events. No significant differences for SaO₂ or feeding performance were found. The findings indicate that the ESL position may support better regulation of breathing during feeding, thereby allowing VP infants to better maintain physiological stability throughout feeding.

Key Words: bottle-feeding, positioning, preterm infants

In the United States, more than 80,000 babies are born very preterm (VP ≤30-wk gestational age) every year. These infants are at risk for impaired lung function due to early exposure of the immature lungs to extraterine conditions and increased risk for supplemental oxygen or airflow for prolonged periods. Impaired lung function, combined with oral-motor and neurological immaturity, significantly interferes with these infants’ ability to eat, which contributes to frequent feeding difficulties.

Oral feeding behavior emerges from nonlinear and dynamic interactions of multiple systems involved in oral feeding. These systems include, but are not limited to, the oral-motor, neurological, cardiorespiratory, and gastrointestinal systems. Self-organization occurs continuously both within and between the systems to establish stability in response to internal and external inputs. This self-organization process creates functional feeding coordination, that is, suck-swallow-breathe pattern, in which the infant should be able to suck sufficiently to meet his or her nutritional needs for growth, swallow swiftly and effectively to minimize the disruption of breathing and prevent aspiration, and breathe with adequate depth and frequency to maintain physiological stability. Optimal and mature feeding occurs when the infant is able to integrate sucking, swallowing, and breathing during sucking bursts and requires...
only brief catch-up breathing periods between sucking bursts.

However, for VP infants, especially those with lung disease, impaired lung function significantly limits their organizational capacity, thereby generating inefficient feeding coordination that contributes to feeding difficulties. Very preterm infants with lung disease are not able to integrate a sufficient number and depth of breaths into sucking and swallowing rhythms consistently; therefore, breathing is often disrupted, interrupted, abbreviated, and for brief periods, completely absent. Insufficient breathing during feeding affects the infant’s quality of sucking, that is, sucking strength and frequency is decreased to limit the amount of milk transfer to the mouth, thereby decreasing swallowing frequency and minimizing the interruption of breathing that swallowing creates. Although this adaptation may increase infants’ physiological stability, it requires longer feeding durations to accomplish sufficient intake. When immaturity further limits infants’ adaptive capacity to increase breathing by decreasing his or her intake, insufficient breathing results in physiological instability, fatigue, and early cessation of feeding.

Feeding difficulties in VP infants have been reported in several studies, including increased physiological instability, poor sucking patterns, poorly coordinated rhythms of swallowing and breathing, poor intake, and a prolonged length of time before becoming a full oral feeder. If left unresolved, feeding difficulties may persist for years after discharge from the hospital and contribute to chronic growth failure and altered eating patterns. Thus, for VP infants, feeding strategies need to focus on supporting breathing in order to maintain physiological stability throughout feeding and support sufficient feeding endurance to enable adequate nutritional intake for growth.

Optimal positioning of the infant during feeding is a potential strategy for improving breathing during feeding. A semielevated supine (ESU) position is commonly used in the neonatal intensive care unit (NICU) when preterm infants are bottle-fed. This position reduces the work of breathing by facilitating infants’ lung expansion through a 45° to 60° angle of head and trunk elevation. It also enhances the caregiver’s ability to provide support of the head-neck alignment in a neutral position and provides visual access for the feeder to observe infants’ responses to feeding. However, the ESU position may interfere with maintaining adequate patency of the upper airway by allowing the soft palate and tongue to fall back because of gravity, thus contributing to inefficient breathing. Also, gravity increases the transit time of the milk to the back of the oral cavity, so the infant may have less time to control the bolus of milk; this may create the conditions for dysfunctional swallowing, thus increasing the potential for breathing interruptions and aspiration.

A semielevated side-lying (ESL) position recently has been proposed as a potential strategy that may avoid some of the disadvantages of the ESU position. The ESL position is a common position for an infant feeding naturally at the breast. Better coordination of breathing with swallowing and less disruption of breathing have been reported in breast-feeding than in bottle-feeding. Because the ESL position better mimics the breast-feeding position, infants who feed in the ESL position may be able to assume some of the advantages of breast-feeding positioning to improve their breathing during feeding.

The ESL position may support breathing during feeding by creating conditions for better fluid management. In studies of bottle-feeding infants, it has been found that as the rate of milk flow increases and requires increased swallowing frequency, minute ventilation decreases, primarily as a result of decreased respiratory rate. In the ESL position, the bottle is held at a lowered angle which has a potential to slow the gravitational flow of milk by decreasing the hydrostatic pressure generated by the volume of milk in the inverted bottle. Also, the milk has a slower transit time to the back of the oral cavity, which may allow the infant to have more time to form a bolus and control the movement of that bolus. These potential mechanisms in the ESL position may allow for more control of the bolus and support safer and more efficient swallowing that prevents aspiration and prolonged interruption of breathing.

The ESL position also reduces the work of breathing by requiring less antigravity movement during breathing and promoting better patency of the upper airway that may be a result of reduced gravitational effects on the anatomical tissues (eg, tongue and soft palate).

Given the VP infant’s risk for breathing difficulties during oral feeding, the ESL position may be particularly beneficial for this group of preterm infants. However, despite the potential benefits of the ESL position, only 2 studies regarding the effect of this position on feeding outcomes have been published; 1 of these studies included VP infants. Clark et al compared the effects of the ESL and ESU position on variation in heart rate (HR) and mean oxygen saturation (SaO₂) in 6 VP infants across the transition to full oral feeding during the first and middle 3 minutes of the feeding. Infants better maintained SaO₂ during the middle 3 minutes in the ESL position than in the ESU position. Lau compared feeding outcomes among the upright, ESL, and ESU with 41 relatively “healthy” preterm infants (eg, no lung disease) when infants were taking 1, 2, 3 to 5,
and 6 to 8 oral feedings per day. Outcomes included postmenstrual age (PMA) at full oral feeding and oral feeding skill levels as calculated by proficiency and efficiency; no differences were found between groups. Although these 2 studies contribute to the evidence of the ESL position as a feeding strategy, we still have limited evidence for the effect of the ESL position on breathing, stability of \( \text{SaO}_2 \), and feeding performance in VP infants who are at risk for lung disease. Therefore, this study will examine the efficacy of the ESL position compared with the ESU position both on physiological stability (HR and \( \text{SaO}_2 \)), including respiratory characteristics (RESCs), and feeding performance (ie, overall milk transfer, proficiency, efficiency, and duration of feeding) of VP infants when bottle-fed.

**METHODS**

**Setting and sample**

A convenience sample of 6 VP infants who met the following criteria were recruited from a level III Neonatal Intensive Care Unit in North Carolina: (1) gestational age \( \geq 30 \) weeks; (2) absence of disorders that are potentially associated with feeding difficulties beyond the scope of this intervention, such as cleft palate, paralysis of facial muscles, or grade IV intraventricular hemorrhage; (3) the ability of either the mother or the father to understand and read English; and (4) the parents' willingness to allow the infant to bottle-feed for 2 feedings by the infant's nurse on the study day.

In this nursery, oral feeding begins when infants are physiologically stable, no longer requiring respiratory supports beyond supplemental oxygen, and showing behavioral readiness cues. After initiating oral feeding, oral feedings are offered during scheduled feeding times (typically every 3 hours) contingent upon infants' sustaining readiness for feeding. Coregulated, cue-based feeding techniques are standard in this unit, including pacing strategies. The feeding is determined to be "finished" when the infant is no longer engaged in the feeding, demonstrates physiological instability, or no longer roots for the nipple following its removal for breaks or burping. Feedings are limited to 30 minutes in this nursery. If the infant is unable to consume its prescribed feeding volume, the remainder is provided by nasogastric feeding tube.

**Design**

A within-subject, crossover design was used in which each infant was bottle-fed twice within a 9-hour period of time on a single day, contingent on readiness, in both the ESL and ESU positions in a random order. All study feedings were conducted when infants were oral feeding at least 50% of their prescribed milk for 3 consecutive days, thereby controlling for infant skill level.

**Variables and measures**

**Physiological stability**

Physiological variables included HR, \( \text{SaO}_2 \), and RESCs. Prefeeding measures were defined as HR, \( \text{SaO}_2 \), and RESCs during a 2-minute period before feeding when the infant was calm and quiet and there were no external demands placed on him or her. The feeding period was defined as the period of time when the bottle was in the mouth (ie, not counting burps and break periods).

Heart rate data were collected by a 3-lead electrocardiogram using BioNex Bio-Potential Amplifier (MindWare Technology, Gahanna, Ohio); trended HR, in beats per minute (bpm), was extracted every 1 second using Acknowledge software (BIOPAC Systems Inc, Goleta, California). During the prefeeding and feeding periods, the mean and coefficient of variation of HR (CV; calculated as SD divided by the mean of that period) were calculated. In addition, the percentages of feeding periods that the infant's HR was 10% to 15% (mild), 15% to 20% (moderate), and 20% (severe) above or below the prefeeding HR and below 100 bpm were calculated.

\( \text{SaO}_2 \) data were collected using the Radical-7 Pulse Co-Oximeter (Masimo Corporation, Irvine, California); trended \( \text{SaO}_2 \) was extracted every 1 second using BioLab Data Acquisition Software (MindWare Technology, Gahanna, Ohio). During the prefeeding and feeding periods, the mean and CV of \( \text{SaO}_2 \) were calculated. In addition, the percentages of the feeding periods that the infant's \( \text{SaO}_2 \) was at least 5% below the prefeeding \( \text{SaO}_2 \) and below 85% were calculated. The percentages of feeding periods when \( \text{SaO}_2 \) decreased at least 5% below the prefeeding period were further classified as mild (5%-10%), moderate (10%-15%), or severe (>15%).

Respiratory characteristics data were collected using the respiratory effort monitoring system (Ambu Sleepmate, Glen Burnie, Maryland) that measures chest expansion associated with respiratory effort by an elastic band placed around the chest. Individual respiratory waveforms produced by chest movement were evaluated and validated with amplified breathing and swallowing sounds simultaneously measured with a flat small microphone attached to the infant's neck; respiratory waveform peaks were then marked. The microphone has been used in several feeding studies to measure breathing and swallowing sounds with full and preterm infants. During the prefeeding and first
6 minutes of the feeding period, RR in breaths per minute, the mean and CV of the intervals between breaths, and the frequency and length of feeding-related apneic events were calculated. Feeding-related apneic events were defined as longer than 4 seconds between consecutive respiratory waveform peaks. The first 6 minutes of the feeding period was chosen for respiratory analysis because the method of evaluation and validation of breaths during feeding is new, and the initial minutes of the feeding period have been found to be the most vulnerable physiological period.

**Feeding performance**

Feeding performance measures included overall milk transfer, proficiency, efficiency, and duration of feeding. **Overall milk transfer** refers to the percentage of milk taken by mouth calculated from the prescribed amount of milk during the entire feeding. The amount of milk intake was measured as the amount of milk consumed minus the milk lost on a measured cloth under the infant's chin. **Proficiency** refers to the percentage of milk taken from the prescribed amount of milk during the first 5 minutes of feeding. **Efficiency** refers to the amount of milk consumed in milliliters divided by total feeding time (mL/min). **Duration of feeding** was defined as the total length of the feeding period in minutes, excluding nonfeeding and burping periods.

**Fidelity of feeding position**

To ensure whether the assigned position was delivered properly, feedings were videotaped and continuously coded using the Noldus Observer XT (Noldus Information Technology Inc, Asheville, North Carolina), an observational coding program, and the "infant position" subscale of the dynamic-early feeding skills observational coding scheme. The proportion of the feeding periods that the infant was held in any given position (ie, held in front for the condition of ESU and side-lying for the condition of ESL position) was calculated. Kappa coefficient was 100% both for intrarater and interrater reliability.

**Procedure and intervention**

Written informed consent was obtained from the infant's mother or father, and parents were invited to be present during the study feedings. Two study feedings were conducted in a single day for each infant on the basis of a randomly chosen order of feeding position, within the nursery's routine feeding schedule on a day when any tests that could affect the infant's feeding skills were not scheduled (eg, eye examination). At each data collection, the infant was monitored and videotaped 30 minutes before a feeding. If the infant demonstrated readiness cues, the feeding observation continued until the feeding was completed. If the infant was not ready to eat, the feeding observation was rescheduled for another time. In the ESL position, the infant was placed in a side-lying position on the caregiver's lap with 1 ear facing the ceiling and the head and the trunk elevated to approximately a 45° to 60° angle. In the ESU position, the infant was placed in a reclining position at approximately a 45° to 60° angle to the buttocks on the caregiver's lap. In both feeding positions, the infant's head, neck, and trunk were in a neutral straight alignment, that is, chin tilted down slightly, without the neck being extended and without excessive flexion. The infant was also swaddled with a blanket, providing a flexed body position (see Figure 1).

To control for variation in the interactions between the infant and the caregiver during feeding across...
feeding positions, 1 neonatal nurse performed both of the feeding observations per infant and was reminded of the unit’s standardized feeding protocol of coregulated and cue-based feeding techniques and to position the infant appropriately—either for the ESL or ESU feeding. To control for variation in milk flow within and between the types of nipple, all study infants used the same type of nipple that the nursery used (Enfamil Slow Flow; Mead Johnson & Company, Glenview, Illinois), and each infant was fed with the same nipple (cleansed properly) for the 2 study feedings. Ambient stimuli, such as noise and bright light, were minimized by controlling unnecessary personnel and pulling the curtain around the infant’s bedside.

Data analysis

Twelve feedings (6 in ESU position and 6 in ESL position) were analyzed with paired t tests to assess the differences in physiological stability and feeding performance between the 2 feeding positions. Nonparametric Wilcoxon signed rank test was also conducted but no effects on the conclusions were found, so results were not reported. Given the small sample size of this study, statistical significance was set at $P = .10$ for all analyses. Also, $P$ values less than .20 were considered to be an indicative trend to provide evidence of possible significance for future study. The magnitude of difference in outcome variables between the feeding positions will be used to estimate the effect size for future studies.

RESULTS

Characteristics of study infants

Study infants’ characteristics are described in Table 1. Most of the infants were female, and half were white. The infants differed in their PMA and feeding experience (ie, the number of cumulative oral feedings either at breast or bottle) but had similar feeding skills at the time of the study, such that the infants were able to consume on average 58.3% (ranging from 49.4% to 66.1%) of their prescribed milk by mouth for 72 hours prior to the study. All infants required certain types of respiratory support prior to the study, and 2 infants were receiving supplemental oxygen at the time of the study. At discharge, 4 infants had a diagnosis of bronchopulmonary dysplasia using the National Center for Health Statistics (NCHS) database.

Table 1. Characteristics of the study subjects ($n = 6$)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD or n (%)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of the infant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age (wk)</td>
<td>28.1 ± 1.0</td>
<td>26.7-29.4</td>
</tr>
<tr>
<td>Birth weight at birth (g)</td>
<td>1122 ± 233</td>
<td>760-1430</td>
</tr>
<tr>
<td>Apgar score at 1 min</td>
<td>5 ± 2</td>
<td>2-9</td>
</tr>
<tr>
<td>Apgar score at 5 min</td>
<td>8 ± 1</td>
<td>7-9</td>
</tr>
<tr>
<td>Female</td>
<td>4 (66.7)</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>1 (16.7)</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>3 (50.0)</td>
<td></td>
</tr>
<tr>
<td>Latino</td>
<td>2 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Severity of lung disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>3 (50.0)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>1 (16.7)</td>
<td></td>
</tr>
<tr>
<td>Characteristics of the infant at time of study</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postmenstrual age at study (wk)</td>
<td>35.5 ± 2.1</td>
<td>32.7-38.6</td>
</tr>
<tr>
<td>Weight at study (g)</td>
<td>2262 ± 250</td>
<td>1910-2550</td>
</tr>
<tr>
<td>Days on ventilator</td>
<td>1 ± 1</td>
<td>0-3</td>
</tr>
<tr>
<td>Days on CPAP</td>
<td>15 ± 11</td>
<td>7-35</td>
</tr>
<tr>
<td>Days on supplemental oxygen or airflow</td>
<td>19 ± 13</td>
<td>6-34</td>
</tr>
<tr>
<td>Neurobiological risk score</td>
<td>2 ± 2</td>
<td>1-6</td>
</tr>
<tr>
<td>Oxygen use during feeding</td>
<td>2 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Feeding experience</td>
<td>79 ± 56</td>
<td>23-179</td>
</tr>
<tr>
<td>Feeding skill at study (%)</td>
<td>58.3 ± 6.3</td>
<td>49.4-66.1</td>
</tr>
</tbody>
</table>

Abbreviation: CPAP, continuous positive airway pressure.

*Severity of lung disease: Diagnostic criteria for bronchopulmonary dysplasia depending on the duration and degree of supplemental oxygen required at 36 weeks of postmenstrual age.

*Neurobiological risk score (0-28): Scores indicating possible medical conditions that are associated with neurological problems.

*Feeding experience: Number of cumulative nipple feedings from either the bottle or the breast prior to the study.

*Feeding skill at study: Percentage of milk from the prescribed milk consumed by mouth in 72 hours prior to the study.
Institutes of Health consensus definition; 3 infants met the definition of mild bronchopulmonary dysplasia and 1 moderate. On the neurobiological risk score (range of 0-28), which assesses infants’ degree of neurological risk on the basis of medical conditions associated with neurological problems, 5 infants met the definition of low risk for neurological problems (score of 1-2) and 1 intermediate (score 6).

Comparisons of physiological stability

Heart rate

Before feeding for both feeding positions, study infants exhibited comparable HR states (see Table 2). During the feeding period, no difference in the means for HR were observed; however, infants had significantly less variation in HR (ie, lower CV of HR) when fed in the ESL position than in the ESU position.

To examine changes in HR, cutoffs for mild (10%-15%), moderate (15%-20%), and severe (>20%) increases and decreases in HR were calculated per feeding observation on the basis of the prefeeding mean HR for a given feeding. These cutoffs were used to calculate the percentage of the feeding period for each category. For example, if the prefeeding mean HR was 149.9 bpm, the percentage of feeding period with HRs between 164.9 and 172.4 bpm (ie, mild increase), between 172.4 and 179.9 bpm (ie, moderate increase), greater than 179.9 bpm (ie, severe increase), 127.4 and 134.9 bpm (ie, mild decrease), between 119.9 and 127.4 bpm (ie, moderate decrease), and less than 119.9 bpm (ie, severe decrease) was calculated.

Compared with being fed in the ESU position, infants fed in the ESL position tended to spend more time with moderate and severe increases in HR from the prefeeding period; however, no significant difference was found (see Table 3). When fed in the ESL position, infants spent significantly less time with moderate and severe decreases in HR from that of the prefeeding period, compared with the ESU position. Using clinically significant criteria for bradycardia (ie, HR below 100 bpm), infants fed in the ESL position spent significantly less time with a decrease in HR below 100 bpm than in the ESU position.

For increases in HR, even when the mean percentage of the feeding period for the 2 feeding positions was not very close, the difference in mean values was not statistically significant. This occurrence is a consequence of large variability (eg, the percentage of feeding period with a moderate increase in HR had means of 5.2 and 17.2 for the 2 positions and \( P = .190 \), but the SD for the ESL position was 27.3).

Oxygen saturation

Before feeding for both feeding positions, infants were in comparable \( \text{SaO}_2 \) states. During the feeding period, there were no significant differences in mean and \( \text{CV} \) of \( \text{SaO}_2 \) between the feeding positions; however, a trend of less variation in \( \text{SaO}_2 \) (ie, lower \( \text{CV} \) of \( \text{SaO}_2 \)) was observed in the ESL position than in the ESU position.

Like HR, \( \text{SaO}_2 \) cutoffs for each category were calculated on the basis of the prefeeding period for a given feeding and were used to calculate the percentage of feeding time for each category. No significant differences were found in the percentages of feeding time with \( \text{SaO}_2 \) for any categories.

Respiratory characteristics

Before feeding for both feeding positions, infants were in comparable respiratory states (see Table 4). During the first 6 minutes of the feeding period, infants showed significantly higher RR, which was closer to that of the prefeeding period, when fed in the ESL position than in the ESU position. The interval between breaths was significantly shorter, and there was a trend of less variation in breath intervals (ie, lower \( \text{CV} \)) in the ESL position. Infants also experienced significantly briefer feeding-related apneic events (ie, breathing pauses > 4 seconds) in the ESL position.

### Table 2. Comparisons of heart rate between feeding positions (n = 6)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Feeding position</th>
<th>( T )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prefeeding period</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean of HR (bpm)</td>
<td>ESU 154.9 ± 6.7</td>
<td>ESL 154.1 ± 7.4</td>
<td>−0.62</td>
</tr>
<tr>
<td>CV of HR</td>
<td>0.02 ± 0.01</td>
<td>0.02 ± 0.01</td>
<td>−1.37</td>
</tr>
<tr>
<td><strong>Feeding period</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean of HR (bpm)</td>
<td>ESU 162.9 ± 7.7</td>
<td>ESL 166.4 ± 10.8</td>
<td>1.18</td>
</tr>
<tr>
<td>CV of HR</td>
<td>0.07 ± 0.01</td>
<td>0.04 ± 0.02</td>
<td>−4.33</td>
</tr>
</tbody>
</table>

Abbreviations: bpm, beats per minute; CV, coefficient of variation; ESL, semielevated side-lying; ESU, semielevated supine; HR, heart rate.

Data are expressed as mean ± SD.
Table 3. Comparisons of percentage of feeding period with defined changes in heart rate between feeding positions (n = 6)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>ESU</th>
<th>ESL</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of feeding period with</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild increases in HR*</td>
<td>18.6 ± 23.1</td>
<td>9.6 ± 10.2</td>
<td>−0.84</td>
<td>.438</td>
</tr>
<tr>
<td>Moderate increases in HR*</td>
<td>5.2 ± 7.3</td>
<td>17.2 ± 27.3</td>
<td>1.38</td>
<td>.226</td>
</tr>
<tr>
<td>Severe increases in HR*</td>
<td>2.7 ± 6.2</td>
<td>12.9 ± 20.9</td>
<td>1.54</td>
<td>.183</td>
</tr>
<tr>
<td>Percentage of feeding period with</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild decreases in HR*</td>
<td>1.7 ± 1.7</td>
<td>1.9 ± 2.6</td>
<td>0.18</td>
<td>.861</td>
</tr>
<tr>
<td>Moderate decreases in HR*</td>
<td>1.1 ± 0.8</td>
<td>0.6 ± 0.6</td>
<td>−2.59</td>
<td>.049</td>
</tr>
<tr>
<td>Severe decreases in HR*</td>
<td>2.2 ± 1.2</td>
<td>0.8 ± 0.7</td>
<td>−3.46</td>
<td>.018</td>
</tr>
<tr>
<td>&lt;100 bpm</td>
<td>0.7 ± 0.6</td>
<td>0.3 ± 0.5</td>
<td>−5.09</td>
<td>.004</td>
</tr>
</tbody>
</table>

Abbreviations: bpm, beats per minute; ESL, semielevated side-lying; ESU, semielevated supine; HR, heart rate.

*Data are expressed as mean ± SD.

*Increases in HR between 10% and 15% prefeeding mean HR.

*Increases in HR between 15% and 20% prefeeding mean HR.

*Increases in HR at least 20% prefeeding mean HR.

*Decreases in HR between 10% and 15% prefeeding mean HR.

*Decreases in HR at least 20% prefeeding mean HR.

**Analyses of standard deviation**

Analyses of SD were also conducted to assess variation in each physiological variable; however, the findings for SD were the same as for CV, with 1 exception. Variation in intervals between breaths was significant when analyzing SD of interval between breaths (P = .056). This finding indicates the infants fed in the ESL position breathed with significantly more regular intervals between breaths than in the ESU position.

**Comparisons of feeding performance**

Compared with being fed in the ESU position, infants fed in the ESL position tended to consume slightly more milk (ESU position = 92.7%, ESL position = 95.2%), with slightly lower proficiency (ESU position = 44.3%, ESL position = 42.3%) and higher efficiency (ESU position = 2.4 mL/min, ESL position = 2.5 mL/min); however, none of these effects were significant. Only a trend of longer feeding period was observed in the ESL position.

Table 4. Comparisons of respiratory characteristics between feeding positions (n = 6)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>ESU</th>
<th>ESL</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefeeding period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory rate (per min)</td>
<td>56 ± 8</td>
<td>59 ± 12</td>
<td>1.34</td>
<td>.236</td>
</tr>
<tr>
<td>Mean of interval between breaths (s)</td>
<td>1.07 ± 0.13</td>
<td>1.04 ± 0.18</td>
<td>−1.41</td>
<td>.219</td>
</tr>
<tr>
<td>CV of interval between breaths</td>
<td>0.22 ± 0.10</td>
<td>0.22 ± 0.10</td>
<td>0.21</td>
<td>.843</td>
</tr>
<tr>
<td>Feeding period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory rate (per min)</td>
<td>42 ± 6</td>
<td>48 ± 6</td>
<td>2.67</td>
<td>.044</td>
</tr>
<tr>
<td>Mean of interval between breaths (s)</td>
<td>1.41 ± 0.20</td>
<td>1.26 ± 0.15</td>
<td>−2.13</td>
<td>.087</td>
</tr>
<tr>
<td>CV of interval between breaths</td>
<td>1.86 ± 0.43</td>
<td>1.55 ± 0.13</td>
<td>−1.96</td>
<td>.107</td>
</tr>
<tr>
<td>Number of feeding-related apneic events b</td>
<td>18 ± 5</td>
<td>18 ± 5</td>
<td>0.16</td>
<td>.880</td>
</tr>
<tr>
<td>Mean length of feeding-related apneic events (s)</td>
<td>9.6 ± 1.1</td>
<td>8.4 ± 1.3</td>
<td>−2.16</td>
<td>.083</td>
</tr>
</tbody>
</table>

Abbreviations: CV, coefficient of variation; ESL, semielevated side-lying; ESU, semielevated supine.

*Data are expressed as mean ± SD.

bDefined as breathing pauses longer than 4 s during the feeding period.
position than in the ESU position ($P = .182$; ESU position = 11.6 min, ESL position = 13 min).

**Fidelity of feeding position**

For the majority of the feeding time, infants were placed in each of the assigned positions (ESU position: mean = 97.3%, range = 91%-100%; ESL position: mean = 99.7%, range = 99%-100%).

**DISCUSSION**

It is well known that during oral feeding, normal breathing patterns are modulated by the act of sucking and swallowing. Several studies involving both term and preterm infants have shown that breathing alternation while feeding reduces minute ventilation by decreasing inspiration time, breathing frequency, and tidal volume.\(^2\)\(^3\)\(^4\) However, the decrease in ventilation has a greater impact on VP infants than on healthy full-term infants because of their reduced capacity to self-organize changes in ventilation due to immaturity and/or compromised lung function.\(^7\)\(^8\)

One of the strategies neonates employ to self-organize physiological changes during activities such as feeding is to increase their HR to provide the necessary oxygen and nutrients to tissues in response to reduced minute ventilation.\(^3\)\(^5\) The increase in HR is considered a compensatory process, possibly indicating that the infant is coping with the physiological demands of feeding to maintain homeostasis. Large increases in HR may indicate that feeding is placing excessive physiological demands on the infant. However, for VP infants, especially those with respiratory problems, decreased ventilation while feeding may be too great to be recovered through this compensatory process and can be frequently associated with decreases in HR. The decrease in HR is considered a potentially life-threatening event, which could result from stimulation of the sensory receptors in the pharyngeal-laryngeal area by microaspiration of food, gastroesophageal reflux, or a large bolus of milk, or stimulation of carotid body chemoreceptors caused by a decrease in SaO\(_2\).\(^6\) Although the degree of change in HR that can be tolerated by VP infants while feeding is unknown, it is not uncommon to see changes in HR within 10% above or below the resting HR.\(^9\) In this study, VP infants exhibited significantly less variation in HR, spent less time with moderate (15%-20%) and severe (> 20%) decreases in HR, and less bradycardia (ie, <100 bpm) when fed in the ESL position as compared with the ESU position. The findings suggest that VP infants fed in the ESL position are able to handle the physiological demands of feeding more effectively by modulating their HR through a compensatory process. However, when fed in the ESU position, the adaptive capacity of the VP infant may be exceeded, thereby resulting in increased variation in HR, and more time with moderate and severe decreases in HR and bradycardia (ie, <100 bpm). These findings may reflect the increased physiological challenges faced by VP infants when they are fed in the ESU position as compared with the ESL position.

The findings in HR are inconsistent with a previous study that found no difference in variation in HR of VP infants over time between the ESL and ESU positions.\(^16\) However, the study by Clark\(^16\) examined only a subset of the feeding (first and middle 3 minutes of feeding); this difference in delineating study variables may have contributed to discrepancies in the findings of the 2 studies.

Another major physiological variable used in this study is SaO\(_2\). In this study, no statistically significant difference in SaO\(_2\) between the feeding positions was found. Only a trend of less variation in SaO\(_2\) in the ESL position than in the ESU position was evident. This finding differs from the study by Clark et al\(^16\) that showed a significant interaction effect of time and position, suggesting that the mean SaO\(_2\) decreased in the first 3 minutes of feeding in both positions; however, in the middle 3 minutes of feeding, the mean SaO\(_2\) increased in the ESL position and decreased further in the ESU position.\(^16\) Again, the difference in findings between the current and previous studies can be explained by the fact that the study by Clark et al used only a subset of the feeding. Also, in this study, VP infants had relatively healthy cardiorespiratory conditions and had attained a moderate degree of feeding skill. Thus, the study infants might have been able to modulate their breathing or HR in response to the demands of feeding without severely compromising their cardiorespiratory status, which could cause oxygen desaturation. Finally, the number of observations in the current study was smaller than that in the study by Clark et al, so statistically significant differences were not evident. However, a trend of less variation in SaO\(_2\) in the ESL position suggests that future examination of the effect of the ESL position on SaO\(_2\) is warranted.

The findings in RESCs indicate that VP infants show decreased RR and longer and more irregular intervals between breaths during the feeding period than during the prefeeding period in both feeding positions. These findings are similar to previous findings that suggest decreased minute ventilation during oral feeding.\(^2\)\(^5\)\(^4\) However, when VP infants were fed in the ESL position, the impact of feeding on breathing was lessened compared with the ESU position as evidenced by significantly higher RR, shorter and more regular intervals between breaths, and briefer feeding-related events.
apneic events. These findings suggest that the infants in our study were better able to integrate breathing into the suck, swallow, and breathe sequence with less interruption in the ESL position than in the ESU position.

Two major mechanisms of the ESL position may contribute to the observed physiological benefits over the ESU position. First, the ESL position is the natural position that is assumed by infants when they are fed at the breast. The physiological benefits of breast-feeding for preterm infants are well documented. Previous researchers have found that during breast-feeding, as compared with bottle-feeding, preterm infants better coordinate breathing with swallowing, resulting in less disruption of breathing.

This study’s findings reveal that VP infants are better able to regulate breathing during feeding by demonstrating higher RR that is closer to their prefeeding states, shorter and more regular intervals between breaths, and briefer feeding-related apneic events in the ESL position compared with the ESU position. These findings are similar to those of previous studies that demonstrated the physiological advantages of breast-feeding as compared with bottle-feeding.

Although this study does not include a direct comparison of the physiological responses to feeding between the ESL position and breast-feeding, for VP infants who are not able to receive exclusive breast-feeding the ESL position might be physiologically advantageous over other bottle-feeding positions.

The second potential mechanism of the ESL position is that it may create conditions for infants to better manage the flow of milk. Several studies have demonstrated that under more rapid milk flow conditions, breathing is more interrupted as a consequence of the increased bolus size of each suck and to the concomitantly increased in swallowing frequency.

This study’s premise is that in the ESL position, the lowered angle of the bottle may slow the gravitational flow of milk by decreasing the hydrostatic pressure generated by the volume of milk in the inverted bottle. Although this study does not include a direct measure of the rate of milk flow in each position, the potentially slower flow of milk by gravity in the ESL position may permit infants to swallow less and, in turn, have fewer interruptions of breathing. In the ESL position, gravity decreases the transit time of the milk to the back of the oral cavity, thereby providing more time for the infant to form a bolus and control its movement, safer and more efficient swallowing will lessen breathing interruptions. This additional transit time may also allow the infant to raise the distal portion of the tongue in order to slow the flow of milk and delay swallowing, thereby providing additional time for breathing. Therefore, better fluid management by several potential mechanisms of the ESL position may minimize the interruption of breathing during feeding, which allows the infant to maintain greater physiological stability throughout the feeding. Further study of these mechanisms with added measurement of swallowing is needed.

In this study, no significant findings for any of the feeding performance measures were found; however, a trend of longer duration of feeding was observed in the ESL position. This finding is consistent with the study by Lau that found no differences in infants’ oral feeding skills as calculated by proficiency and efficiency among the ESL, ESU, and semireclined positions. Several factors of the trend of longer duration of feeding in the ESL position can be explained and support further examination. The longer duration of feeding may indicate that infants are able to maintain engagement in the activity of feeding for a longer period of time. Als, in her synactive theory of development, proposed that the first task of preterm infant development is to achieve control over the autonomic system and that this autonomic system development affects and supports the development of an infant’s motor and state systems. Thoyre and Brown also report that physiological conditions that occur during feeding have a significant effect on infants’ engagement in feeding. In the current study, the greater physiological stability in the ESL position than that observed in the ESU position may serve to conserve the necessary energy that supports infants’ engagement in feeding at the behavioral level for a longer period of time.

Despite longer duration of feeding in the ESL position, infants in this study consumed similar amounts of their prescribed milk in both feeding positions (ie, mean 92.7% and 95.2% of the prescribed milk in the ESU and ESL positions, respectively). The potentially faster flow of milk in the ESU position may encourage infants to consume the milk faster. When fed in the ESL position, infants may be allowed to feed at a slower pace, which may provide additional time to control the bolus for safe and efficient swallowing. This may contribute to greater physiological stability throughout the feeding as evidenced by the findings for the physiological parameters. The longer duration of feeding may also indicate that the infant’s stomach fills more slowly, which has been found to be beneficial to lessen gastroesophageal reflux and facilitate bolus clearance time in preterm infants during gavage feeding.

LIMITATIONS OF THE STUDY

First, the limitation of this study includes its small sample size. Because of the small sample size and the exploratory nature of the study, a P value of .10 was considered significant and a P value of less than .20 was considered indicative of a trend. These cutoffs were
used to test for differences in multiple related measures of HR, SaO₂, RESCs, and feeding performance between the feeding positions. In future studies with larger sample sizes, it will be more appropriate to use a cutoff that adjusts conventional value of .05 to account for multiple comparisons. Second, this study is limited to those infants who have a moderate level of feeding skill at the time of the study, so effects of the ESL position on younger, less experienced, and less skillful feeders are unknown. Since feeding skill level was selected as the criteria of the timing of the study, infants varied in PMA and feeding experience. Findings of the study could be confounded by this variability. A future study with a larger sample that examines the effect of position across the transition from gavage to full oral feeding would increase confidence in the findings and allow for evaluating the effects of potential covariates (eg, feeding skills, PMA, or experience). Finally, although short-term physiological benefits were found in this study, long-term benefits for infants who are consistently fed in this way are still unknown. Therefore, subsequent study to extend these findings is needed.

**IMPLICATIONS OF THE STUDY**

The results of this study have several implications for both clinical practice and research. Feeding position is a feeding strategy that can readily be applied to neonatal care. However, because of limited experimental evidence, no precise and consistent feeding position has been recommended. This study provides sufficient evidence to support clinical exploration of the effect of feeding position on infant feeding outcomes. This study also provides a foundation for developing a randomized controlled trial in a larger group to investigate the effects of the ESL position more definitively.

**CONCLUSIONS**

The findings of this pilot study demonstrate the efficacy of the ESL position on maintaining greater physiological stability in VP infants during feeding than the ESU position and support further study. When fed in the ESL position, VP infants had less variation in HR and less severe and fewer decreases in HR. In addition, infants fed in the ESL position had higher breathing frequency that was closer to their prefeeding state, shorter and more regular intervals between breaths, and briefer feeding-related apneic events. Although the findings for SaO₂ and feeding performance were not statistically significant, the trends of less variation in SaO₂ and longer duration of feeding in the ESL position support further examination of the ESL position using these variables. Thus, the pilot results suggest that the ESL position lessened the impact of feeding on breathing and increased HR stability in VP infants. Further studies in a larger sample are warranted to examine the effects of the ESL position more definitively.

**References**


