Bottle-Feeding Challenges in Preterm-Born Infants in the First 7 Months of Life

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Abstract

Preterm infants frequently experience oral feeding challenges while in the neonatal intensive care unit, with research focusing on infant feeding during this hospital stay. There is little data on symptoms of problematic feeding in preterm-born infants in the months after discharge. The purpose of this study was to describe symptoms of problematic bottle-feeding in the first 7 months of life in infants born preterm, compared to full-term infants. Parents of infants less than 7 months old completed an online survey that included the Neonatal Eating Assessment Tool—Bottle-feeding and questions about the infant's medical and feeding history. General linear models were used to evaluate differences in NeoEAT—Bottle-feeding total score and subscale scores by preterm category, considering other significant factors. Very preterm infants had more symptoms of problematic bottle-feeding than other infants. Current age, presence of gastroesophageal reflux, and anomalies of the face/mouth were associated with problematic bottle-feeding.

Keywords

feeding behavior, bottle feeding, premature birth, infant, intensive care, neonatal

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Background and Significance

The development of infant feeding skills begin in utero through organization of various biologic and physiologic mechanisms.[1] When coordination is not fully developed, infant feeding disorders may ensue. Disorders of infant feeding are defined as "conditions that lead to inadequate intake or intolerance of fluids and nutrients in infants under 1 year of age."[2] Disorders of infant feeding most commonly occur in infants born prematurely[3] and in those with complex medical conditions[4]; however, full-term healthy infants can also experience problematic feeding.[5] Acquisition of proper feeding skills in early infancy promotes optimal growth and development in the first year of life. In particular, as the first years of life are a critical period for brain development, it is important to provide appropriate nutrition to optimize infants' neurodevelopmental outcomes.[6] Consequences of infant feeding problems predispose infants to other complications. Premature infants with feeding difficulties are more likely to have speech delay[7] and greater difficulties with the transition to solid foods in the first year of life.[8]

Preterm infants have an increased risk of experiencing feeding difficulties, especially those born earlier than 30 weeks gestational age.[8] These feeding difficulties have been described as impairments in lip and jaw motion, swallowing, and navigating food textures when solids are introduced.[8] Research has delineated differences in the degree and prevalence of feeding problems between early and late preterm infants, with greater dysfunction in oral motor skills in the early preterm infant population.[9] Preterm infants often experience difficulties with feeding while in the neonatal intensive care unit (NICU) that persist well into childhood. Some research has documented feeding problems in preterm infants after discharge.[9-11] However, the current research evidence has been limited by the lack of an accessible parent-report assessment of infant feeding with adequate evidence of reliability and validity.[12]

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Despite World Health Organization (WHO) recommendations for exclusive breastfeeding (EBF) for the first 6 months of life (www.who.int), the Centers for Disease Control (CDC)'s most recent report states only 24.9% of mothers reach this goal.[13] As a consequence, the vast majority of infants are bottle-fed prior to 6 months of age, either with pumped breastmilk, infant formula, or a combination of the two. The rate of EBF for the preterm infant population is likely lower than the national report. During NICU stays, mothers may not always be present to breastfeed on-demand, and they may have difficulties maintaining milk supply, partly due to separation from their infant. Although bottle feeding may be more physiologically challenging for premature infants, many of them may need to learn how to bottle-feed if EBF is not possible. For this reason, it is important to have a better understanding of the problematic feeding symptoms preterm infants are experiencing when bottle-fed after hospital discharge. This understanding will assist in the provision of interventions and support to families. Recently, a valid and reliable parent-report measure was developed that allows for the assessment of symptoms of problematic bottle-feeding in infants less than 7 months old, the Neonatal Eating Assessment Tool (NeoEAT)—Bottle feeding.[14-16] The purpose of this study was to describe symptoms of problematic bottle-feeding in the first 7 months of life in infants born at varying degrees of prematurity, compared to full-term infants, and to explore infant and family factors that contribute to risk of problematic bottle-feeding. The NeoEAT—Bottle feeding measure has been validated in infants up to 7 months of age, the time when bottle feeding is the primary source of nutrition prior to the introduction of solid foods. This study will add to the existing literature on what is known about feeding difficulties through the use of parental report of infant symptoms using a valid and reliable screening tool.

To identify covariates for inclusion in the analysis, a literature search was conducted in CINAHL using the terms infant AND feeding AND premature OR gestational age, with limitations including English language, full-text, and published within the last 10 years. Abstracts were reviewed for relevance. Next, full texts were reviewed of the applicable abstracts to determine the important covariates that were ultimately included in the statistical analysis. Variables were selected from the dataset that most closely measured the selected covariates, explicated below.

Several factors including impaired physiologic function, for a variety of reasons, have been implicated in the development of problematic feeding. Infants born before 30 weeks gestational age are more likely to have feeding problems at age 2 with concomitant neurodevelopmental problems.[8] To explore the contribution of gestational age at birth within this sample, we included a categorical variable that categorized infants by gestational age at birth, in 4 categories consistent with the WHO classification system.[17] With this classification, there were 16 very preterm, 20 moderately preterm, 35 late preterm, and 554 full-term born infants in this study.

While it is understood that prematurity directly affects feeding success, medical comorbidities are both clinically and statistically significant factors that impede successful feeding. Consequently, comorbidities such as congenital heart disease (CHD),[18] bronchopulmonary dysplasia (BPD),[19] structural anomalies of the structures involved with eating,[20] genetic disorders,[21] gastroesophageal reflux (GER),[21] and food allergies[22] must be considered in evaluation of feeding. The presence or absence of these comorbidities were categorized as Yes or No, based on parent report of a confirmed medical diagnosis. Delivery method, whether vaginal or cesarean delivery, may alter the degree of feeding difficulties, with emergency cesarean delivery resulting in the greatest degree of negative neonatal outcomes, such as problematic feeding.[23] Parental report of delivery method was categorized as either Vaginal or Cesarean delivery. The survey did not ask if the Cesarean delivery was scheduled or emergent.

It has been postulated that socioeconomic status (SES) may predict likelihood of feeding problems, as parents of lower SES may have greater levels of stress compared to higher SES counterparts, hindering their ability to supply structure, routine, or services in the event problems with feeding arise.[24] In addition, Black and Aboud[25] endorse the need for supportive parenting and adequate responses to hunger cues to promote feeding that may be restricted in those with extraneous stressors such as finances. A paucity of evidence exists examining the impact of SES on problematic feeding in premature infants. Parental factors, such as SES, are frequently considered as risk factors for problematic infant feeding. Survey respondents were asked to select annual household income in $10 000 increments ranging from less than $20 000 to more than $100 000. While research has not demonstrated significant differences in feeding problems based on infant sex, the inclusion of infant sex as a biologic variable is recommended by the National Institute of Health's policy to advance personalized medicine and "enhance reproducibility through rigor and transparency".[26]

Methods

This secondary analysis was conducted using data originally collected for several web-based studies to test the psychometric properties and establish norm-reference values for the NeoEAT—Bottle-feeding.[14,16,27] In the

original studies, parent(s) or primary caregivers (hereafter referred to as "parents") were recruited from a variety of sources and invited to complete an online survey that included questions about their infant's health and feeding, and questions to describe themselves, their infants, and their families. Parents were eligible to participate in the original study if they met the following inclusion criteria: (1) at least 18 years of age, (2) the parent or primary caregiver of an infant less than 7 months old who was being fed by mouth (ie, exclusively tube-fed or parenterally-fed infants were excluded), (3) able to read English, and (4) have access to the internet. To be included in the analysis presented in this manuscript, the following criteria had to be met: (1) the infant had to be fed by bottle in the previous 7 days, (2) the parent had to provide complete data for date of birth and due date (for calculation of gestational age at birth and corrected age at time of study), and (3) there had to be less than 10% missing data on the questions on the NeoEAT—Bottle-feeding.

Ethical Approval and Informed Consent

The original study was approved by the Institutional Review Boards at the University of North Carolina at Chapel Hill (reference # 16-2706) and Boston College (reference # 18.087.01). Participants in the original study consented to participate in the online survey-based study by indicating that they met eligibility criteria and selecting that they agreed to participate in the research study. This secondary analysis of de-identified data did not require further Institutional Review Board approval.

Measures

Neonatal Eating Assessment Tool—Bottle-feeding. The NeoEAT—Bottle-feeding is a 64-item parent-report assessment of symptoms of problematic bottle-feeding for infants less than 7 months old. The NeoEAT—Bottle-feeding was content validated with both parents and healthcare providers[14] and has evidence of strong psychometric properties, including acceptable internal consistency reliability (Cronbach's $\alpha = 0.92$) and test-retest reliability ($r = 0.90$, $P < .001$).[27] The NeoEAT—Bottle-feeding also has construct validity with the Infant-Gastroesophageal Reflux Questionnaire-Revised[28] and the Infant Gastrointestinal Symptoms Questionnaire[29] ($r = 0.74$ and 0.64, respectively).[16]

The NeoEAT—Bottle-feeding has 5 subscales that provide information about various aspects of infant feeding including: Infant Regulation, Energy & Physiologic Stability, Gastrointestinal Tract Function, Sensory Responsiveness, and Compelling Symptoms of Problematic Feeding.[16] The Infant Regulation subscale contains 13 items that are indicative of an infant's ability to self-regulate, such as "My baby is calm when eating" (possible range of scores 0-65). The Energy & Physiologic Stability subscale contains 12 items about symptoms related to difficulty maintaining cardiorespiratory stability and coordinating sucking, swallowing, and breathing (possible range of scores 0-60). Example items for this subscale are "My baby needs to rest during feeding" and "My baby holds breath when eating." The Gastrointestinal Tract Function subscale includes 28 items about symptoms of aspiration, excessive gag reflex, gastroesophageal reflux, and gastrointestinal dysfunction, such as "My baby throws up during feeding" and "My baby gets a bloated (big or hard) tummy after eating" (possible range of scores 0-140). The Sensory Responsiveness subscale contains 7 items related to the infant's particularities about feeding, such as "My baby will only eat if food (milk/formula/baby food) is a certain temperature" (possible range of scores 0-35). The last subscale is Compelling Symptoms of Problematic Feeding, which contains 4 items related to compelling indicators of feeding problems, such as "My baby has blood or mucous in stool/poop" (possible range of scores 0-20).

For each item, parents rate the frequency of symptoms on a 5-point Likert scale with answer options ranging from "never" to "always." Sum scores are calculated for each subscale and the total score. Scores are assigned such that higher scores indicate more symptoms of problematic feeding. Total scores range from 0 to 320.

Infant and Family Factors Considered as Covariates. The following infant factors were considered as covariates in this analysis: infant's current age group, infant sex, infant race/ethnicity, family income, BPD, CHD, delivery method, history of breastfeeding difficulty, food allergy, GER, genetic disorder, and structural anomalies of the face, mouth, and gastrointestinal tract. All responses were based on parent report through the online survey.

The infant's date of birth, due date, and date of survey completion were collected to calculate gestational age at birth and current corrected age. Infants were categorized by GA at birth as very preterm (<32 weeks at birth), moderately preterm (32-33 6/7 weeks), late preterm (34-36 6/7 weeks), or full-term (≥37 weeks), consistent with the WHO classification of infant prematurity. Infants were categorized by corrected age into the following age groups: <2 months, 2 months 0 day to 4 months 0 days (ie, 2-4 months), 4 months 1 day to 6 months 0 days (ie, 4-6 months), and 6 months 1 day to 7 months 0 days (ie, 6-7 months).

Table 1. Covariates Considered in the General Linear Models.

	Neonatal Eating Assessment Tool—Bottle-feeding Scores					
	Total score	Infant Regulation	Energy & Physiologic Stability	Gastrointestinal Tract Function	Sensory Responsiveness	Compelling Symptoms of Problematic Feeding
Infant Age Group	**<.001**	**<.001**	**<.001**	**<.001**	**.049**	.12
Infant Sex	.71	.50	.73	.53	**.04**	.67
Infant Race/Ethnicity	.74	.66	**.049**	.88	.61	.86
Family Income in USD	.54	**.01**	.55	.21	.17	.18
Bronchopulmonary Dysplasia	**<.001**	.38	**<.001**	**<.001**	**.01**	**<.001**
Congenital Heart Defect	**.02**	**.048**	**.02**	.12	.45	.06
Delivery Method	.69	.98	.88	.91	**.04**	.34
Difficulty Breastfeeding	.39	**<.001**	**.01**	**<.001**	.08	.14
Diagnosed Food Allergy	**.02**	.10	.98	.27	**<.001**	**.02**
Gastroesophageal Reflux	**<.001**	**.01**	**<.001**	**<.001**	**.02**	**<.001**
Genetic Disorder	**.03**	.69	**.03**	.05	.10	**.01**
Structural Anomaly of the Face, Mouth, or Gastrointestinal Tract	**.001**	.15	**.01**	**.01**	.05	**<.001**

Note. Data presented are *P* values; covariates with a significant effect on the Neonatal Eating Assessment Tool—Bottle-feeding total score or subscale score, defined as a *P*-value of <.05 (noted in bold), were included in the initial multiple-covariate model for each outcome variable. USD = United States Dollars.

Parents were asked to identify the infant's sex (male or female) and the category that best described their infant's race/ethnicity and their family's total yearly income in United States Dollars (categories shown on Table 1). Next, they were asked if their infant had ever been diagnosed with any of the following (response options were to endorse or not endorse): bronchopulmonary dysplasia, congenital heart defect, food allergy, genetic disorder, or structural anomaly of the face, mouth or gastrointestinal tract. For gastroesophageal reflux, parents were asked "Does your child have gastroesophageal reflux?" with response options of yes, no, or unsure. Delivery method was determined by asking parents: "How was your baby born?" with response options being vaginal delivery or cesarean section. Parents were asked a general question about whether their infant experienced difficulty with breastfeeding during infancy. Responses were coded as yes or no.

Statistical Analysis

Data were analyzed using SPSS version 24 (IBM Corp, Armonk, NY). Descriptive statistics were used to describe the demographic and clinical characteristics of the sample. To examine symptoms of problematic bottle-feeding in infants born at varying degrees of prematurity, general linear models with post-hoc pairwise comparisons using *t* test adjusted for multiple comparisons (Tukey Honest Significant Difference) were used to compare the NeoEAT—Bottle-feeding total score and subscale scores among the 4 preterm categories (very preterm, moderately preterm, late preterm, and full-term).

To examine infant and family factors that contribute to problematic bottle-feeding, 12 potential covariates previously determined based on the literature (see Table 1) were tested for multicollinearity using Pearson's product moment correlation. None of the covariates were found to be highly correlated with each other ($r \geq 0.5$), so multicollinearity was determined to not be a problem and all covariates remained for consideration. Each of 12 potential covariates were then tested in the general linear models 1 at a time for each outcome variable (ie, total score and each of 5 subscale scores). Covariates that were found to be statistically significant in the single covariate model were included in the initial multiple-covariate model. The covariates that were considered in the initial multiple-covariate models for each outcome are provided in Table 1. The initial multiple-covariate models were adjusted by removing non-significant covariates using backward elimination. The final model included the preterm category and covariates significant at the 0.05 level. Statistical significance was set at $\alpha = 0.05$ (two-tailed) for all statistical tests.

Table 2. Infant Characteristics by Age Group, Preterm Category, and Sex (N = 625).

	Very preterm		Moderately preterm		Late preterm		Full-term	
0-2 months, n	6		3		7		132	
2-4 months, n	5		12		12		143	
4-6 months, n	5		4		12		156	
6-7 months, n	0		1		4		123	
	Male	Female	Male	Female	Male	Female	Male	Female
n	9	7	8	12	18	17	268	286
Total, n (%)	16 (3)		20 (3)		35 (6)		554 (88)	

Note. In the total sample (N = 625), there were 322 female infants (52%) and 303 male infants (48%). Very Preterm = <32 weeks, Moderately Preterm = 32-33 6/7 weeks, Late Preterm = 34-36 6/7 weeks, Full-Term = ≥37 weeks.

Results

Sample

Data from 625 parents of infants less than 7 months old were included in this analysis. The sample included both typically developing infants and premature infants. Not all infants in the sample were NICU graduates, although presumably many of those born prior to 35 weeks' gestation spent some period of time in the NICU prior to hospital discharge. Infant characteristics by age group, preterm category, and infant sex are provided on Table 2. Demographic characteristics of infants, parent respondents, and their families are provided on Table 3. The medical conditions and feeding characteristics of infants in the sample are provided on Table 4.

Table 3. Demographic Characteristics of Infant, Parent, and Family (N = 625).

Characteristic	n (%)
Respondent's Relationship to Infant	
Mother	586 (93.8)
Father	31 (5)
Other	8 (1.3)
Infant Race/Ethnicity	
Asian	22 (3.5)
Black/African American	42 (6.7)
Hispanic/Latino	42 (6.7)
White	406 (65)
Other	16 (2.6)
More than one race	97 (15.5)
Family Type	
Two-parent	550 (88)
One-parent	60 (9.6)
Other	15 (2.4)
Family Income in USD (n = 622)	
<$20 000	56 (9)
20-29 999	61 (9.8)
30-39 999	70 (11.2)
40-49 999	54 (8.6)
50-59 999	60 (9.6)
60-69 999	41 (6.6)
70-79 999	57 (9.1)
80-89 999	31 (5)
90-99 000	25 (4)
>100 000	167 (26.7)

Note. USD = United States Dollars.

Symptoms of Problematic Bottle-feeding

Figure 1 presents means for the NeoEAT—Bottle-feeding total score and subscale scores by the preterm category along with the post-hoc pairwise comparison results. The results of the general linear models after accounting for significant covariates are presented on Table 5.

NeoEAT—Bottle-feeding Total Score. The NeoEAT—Bottle-feeding total score was significantly different among the 4 preterm categories ($F_{3, 621} = 7.23$, $P = .03$). Post-hoc analyses revealed that significant difference exists only between very preterm infants (M = 129.38, SD = 32.79) and all other preterm categories: moderately preterm (M = 91.25, SD = 29.98; $P = .004$), late preterm (M = 96.97, SD = 32.49; $P = .008$), and full-term infants (M = 90.63, SD = 33.64; $P < .001$; Figure 1). No other statistically significant differences were found between the other preterm categories.

When considering covariates that have potential to influence problematic bottle-feeding, the infant's current age group and having bronchopulmonary dysplasia (BPD), gastroesophageal reflux (GER), or a structural anomaly of the face, mouth, or gastrointestinal tract were found to significantly contribute to the NeoEAT—Bottle-feeding total score (Table 5). The NeoEAT—Bottle-feeding total score decreased as infant age increased, with infants in the current age group 6 to 7 month having scores 27.5 points lower than infants less

Table 4. Infant Medical and Feeding Characteristics (N = 625).

Characteristic	n (%)
Bronchopulmonary Dysplasia	
Yes	10 (1.6)
No	615 (98.4)
Congenital Heart Defect	
Yes	18 (2.9)
No	607 (97.1)
Delivery Method	
Vaginal delivery	390 (62.4)
Cesarean section	195 (31.2)
Difficulty Breastfeeding	
Yes	182 (29.1)
No	289 (46.2)
Diagnosed Food Allergy	
Yes	28 (4.5)
No	597 (95.5)
Gastroesophageal Reflux	
Yes	106 (17)
No	494 (79)
Unsure	25 (4)
Genetic Disorder	
Yes	6 (1)
No	619 (99)
Structural Anomaly of the Face, Mouth, or Gastrointestinal Tract	
Yes	17 (2.7)
No	608 (97.3)

Note. Infant could have more than 1 condition.

than 2 months ($t = -7.5$, $P < .001$). Infants with BPD had a NeoEAT—Bottle-feeding total score 34.22 points higher than infants without BPD ($t = 2.47$, $P = .01$) and infants with GER had a NeoEAT—Bottle-feeding total score 22.44 points higher than infants without GER ($t = 6.67$, $P < .001$). Infants with a structural anomaly of the face, mouth, or gastrointestinal tract had NeoEAT—Bottle-feeding total scores that were 16.58 points higher than infants without structural anomalies ($t = 2.23$, $P = .03$). After accounting for these significant covariates, difference in the NeoEAT—Bottle-feeding total score among the preterm categories became non-significant ($F_{3, 614} = 0.58$, $P = .63$).

Infant Regulation Subscale. The Infant Regulation subscale score was significantly different among the 4 preterm categories ($F_{3, 621} = 1.67$, $P = .01$); however post-hoc analyses found that there was no statistically significant difference between any pair of the preterm categories (Figure 1). In the analyses of considering covariates that have potential to influence problematic bottle-feeding, the infant's current age group, having a history of difficulty with breastfeeding, and family income were found to be the factors significantly contributing to the Infant Regulation subscale score (Table 5). The subscale score for Infant Regulation significantly decreased as infant age increased, with infants in the current age group 6 to 7 months having scores 17.76 points lower than infants less than 2 months old ($t = -8.87$, $P < .001$). Infants who had a history of difficulty with breastfeeding had an Infant Regulation subscale score 7.59 points lower than infants whose parents indicated no difficulty with breastfeeding ($t = -5.62$, $P < .001$). Infants whose parents indicated their family income was between $30-39 999 USD and $40-49 999 USD had Infant Regulation subscale scores that were 6.58 and 6.71 points lower, respectively, than infants whose parents indicated their family income was more than $100 000 USD ($t = -2.8$, $P = .005$; $t = -2.66$, $P = .008$). After accounting for these significant covariates, difference in the Infant Regulation subscale score among the preterm categories became non-significant ($F_{3, 453} = 0.19$, $P = .91$).

Energy & Physiologic Stability Subscale. The subscale score for Energy & Physiologic Stability was significantly different among the four preterm categories ($F_{3, 621} = 7.11$, $P < .001$). In the post-hoc analyses, very preterm infants had significantly higher scores on the Energy & Physiologic Stability subscale (M = 21.44, SD = 10.49) compared to moderately preterm infants (M = 11.55, SD = 6.27; $P = .001$), late preterm infants (M = 12.83, SD = 5.7; $P = .001$), and full-term infants (M = 12.74, SD = 7.6; $P < .001$; Figure 1). No other statistically significant differences were found between the other preterm categories.

The covariates that were found to significantly contribute to the subscale score for Energy & Physiologic Stability were the infant's current age group, the infant's race, BPD, GER, having a history of difficulty with breastfeeding, and having a structural anomaly of the face, mouth, or gastrointestinal tract (Table 5). As infant current age increased, their Energy & Physiologic Stability subscale score decreased, with infants in the current age group 6-7 month having scores 7.9 points lower than infants less than 2 months ($t = -8.23$, $P < .001$). Having BPD increased the Energy & Physiology Stability subscale score by 9.7 points ($t = 3.14$, $P = .002$), while having GER increased the subscale score by 3.47 points ($t = 4.03$, $P < .001$) and having a structural anomaly of the face, mouth, or gastrointestinal tract increased the subscale score by 3.99 points ($t = 2.26$, $P = .03$). Infants who had a history of difficulty with breastfeeding had an Energy & Physiologic

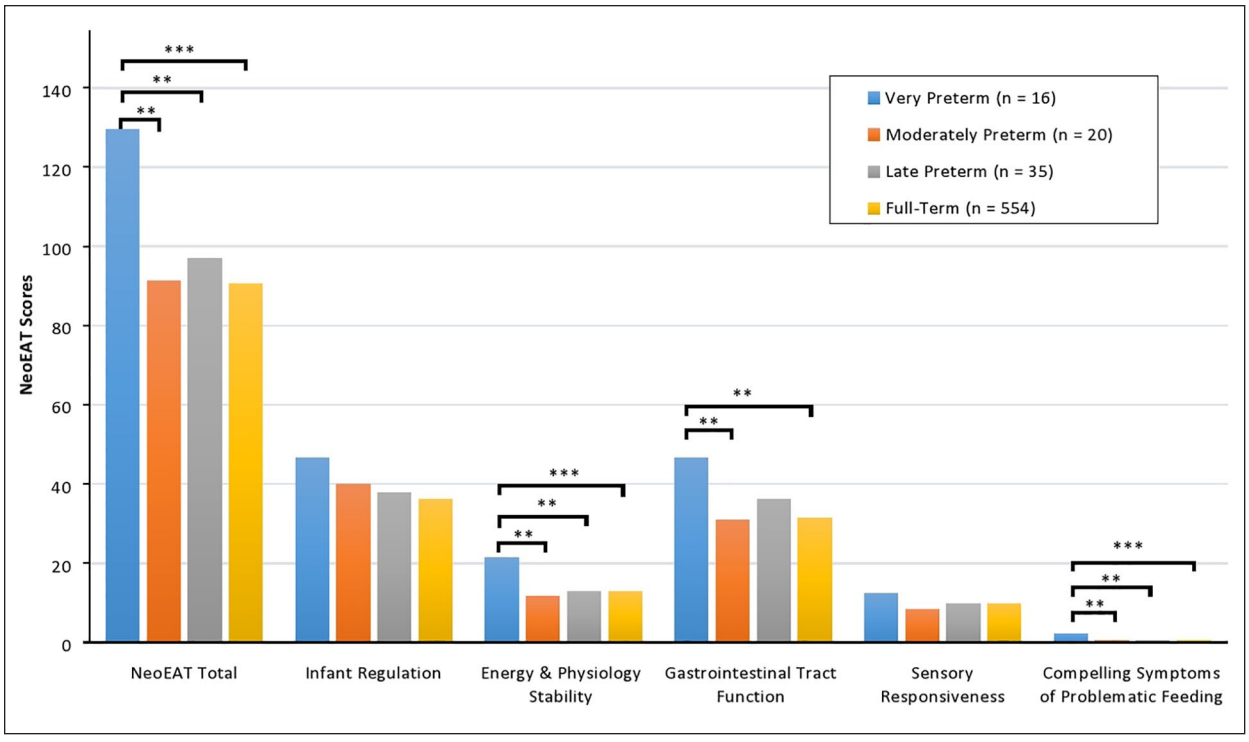

Figure 1. NeoEAT total and subscale scores by preterm category.

Stability subscale score 1.32 points higher than infants without a history of breastfeeding difficulty ($t = 2.06$, $P = .04$). The infant's race was further examined using post-hoc pairwise comparisons as it has multiple categories. We found that a statistical difference exists only between infants whose parents identified them as White (M = 12.42, SD = 7.76) and infants whose parents identified them as Hispanic/Latino (M =16.55, SD = 8.18; $P = .03$). No other race categories were significantly different in terms of the subscale score for Energy & Physiologic Stability. After accounting for these significant covariates, difference in the Energy & Physiologic Stability subscale score among the preterm categories became non-significant ($F_{3, 454} = 1.02$, $P = .38$).

Gastrointestinal Tract Function Subscale. The Gastrointestinal Tract Function subscale score was significantly different among the 4 preterm categories ($F_{3, 621} = 5.16$, $P = .002$). In the post-hoc analyses, we found that very preterm infants had significantly higher scores on the Gastrointestinal Tract Function subscale (M = 46.49, SD = 25.17) compared to moderately preterm infants (M = 30.9, SD = 17.43; $P = .025$) and full-term infants (M = 31.37, SD = 13.08; $P = .002$; Figure 1). No other statistically significant differences were found between the other preterm categories.

When considering infant and family factors, the infant's current age group and having BPD, GER, or a history of difficulty breastfeeding were found to be the significant contributing factors for the Gastrointestinal Tract Function subscale (Table 5). The Gastrointestinal Tract Function subscale scores decreased with increasing infant current age group. Specifically, infants in the 6 to 7-month age group had an Gastrointestinal Tract subscale score 9.6 points lower than infants less than 2 months ($t = -4.58$, $P < .001$). Infants with BPD had scores that were 28.81 points higher ($t = 4.26$, $P < .001$), while infants with GER had scores 14.42 points higher than those infants without these diagnoses ($t = 7.71$, $P < .001$). Infants with a history of difficulty with breastfeeding had scores on the Gastrointestinal Tract Function subscale that were 4.73 points higher than infants without a history of breastfeeding difficulty ($t = 3.4$, $P = .001$). After accounting for all of these significant covariates, difference in the subscale score for Gastrointestinal Tract Function by the preterm category became non-significant ($F_{3, 460} = 1.68$, $P = .17$).

Sensory Responsiveness Subscale. The subscale score for Sensory Responsiveness was significantly different among the four preterm categories ($F_{3, 621} = 1.39$, $P = .007$); however post-hoc analyses revealed that there was no statistically significant difference between any

Table 5. General Linear Model Results Comparing Symptoms of Feeding Problems Between Very Preterm, Moderate Preterm, Late Preterm, and Full-term Born Infants After Adjustment for Significant Infant and Family Factors.

Outcome variable: NeoEAT—Bottle-feeding total score				
Parameters	Estimate	SE	*t*-value	*P*-value
Intercept	147.09	15.94	9.23	<.001
Preterm Category				
Full-Term (index group)	0	–	–	–
Late Preterm	0.94	5.28	0.18	.86
Moderately Preterm	−8.01	6.90	−1.16	.25
Very Preterm	6.27	10.81	0.58	.56
Infant Age Group				
<2 months (index group)	0	–	–	–
2-4 months	−3.04	3.39	−0.9	.37
4-6 months	−11.95	3.36	−3.56	<.001
6-7 months	−27.5	3.67	−7.5	<.001
Bronchopulmonary Dysplasia				
No (index group)	0	–	–	–
Yes	34.22	13.85	2.47	.01
Gastroesophageal Reflux				
No (index group)	0	–	–	–
Yes	22.44	3.36	6.67	<.001
Unsure	20.08	6.23	3.22	.001
Structural Anomaly of the Face, Mouth, or Gastrointestinal Tract				
No (index group)	0	–	–	–
Yes	16.58	7.45	2.23	.03
Outcome variable: Infant Regulation subscale score				
Parameters	Estimate	SE	*t*-value	*P*-value
Intercept	47.02	1.85	25.45	<.001
Preterm Category				
Full-Term (index group)	0	–	–	–
Late Preterm	0.56	2.87	0.19	.85
Moderately Preterm	2.65	3.75	0.71	.48
Very Preterm	−0.5	3.61	−0.14	.89
Infant Age Group				
<2 months (index group)	0	–	–	–
2-4 months	−0.83	1.81	−0.46	.65
4-6 months	0.18	1.82	0.1	.92
6-7 months	−17.76	2.0	−8.87	<.001
Difficulty Breastfeeding				
No (index group)	0	–	–	–
Yes	−7.59	1.35	−5.62	<.001
Family Income in USD				
>$100 000 (index group)	0	–	–	–
$90-99 999	−2.34	3.45	−0.68	.5
$80-89 999	−4.66	3.15	−1.48	.14
$70-79 999	−2.36	2.46	−0.96	.34
$60-69 999	−7.49	2.74	−2.73	.007
$50-59 999	−3.59	2.54	−1.42	.16
$40-49 999	−6.71	2.52	−2.66	.008
$30-39 999	−6.58	2.35	−2.8	.005
$20-29 999	−1.71	2.47	−0.69	.49
<$20 000	−3.11	8.16	−0.38	.7

(continued)

Table 5. (continued)

Outcome variable: Energy & Physiologic Stability subscale score				
Parameters	Estimate	SE	*t*-value	*P*-value
Intercept	32.77	3.72	8.8	<.001
Preterm Category				
Full-Term (index group)	0	–	–	–
Late Preterm	−0.78	1.36	−0.57	.57
Moderately Preterm	−2.94	1.77	−1.66	.1
Very Preterm	0.44	2.40	0.18	.85
Infant Age Group				
<2 months (index group)	0	–	–	–
2-4 months	−4.76	0.86	−5.54	<.001
4-6 months	−8.31	0.87	−9.61	<.001
6-7 months	−7.90	0.96	−8.8	<.001
Difficulty Breastfeeding				
No (index group)	0	–	–	–
Yes	1.32	0.64	2.06	.04
Bronchopulmonary Dysplasia				
No (index group)	0	–	–	–
Yes	9.70	3.09	3.14	.002
Gastroesophageal Reflux				
No (index group)	0	–	–	–
Yes	3.47	0.86	4.03	<.001
Unsure	2.47	1.46	1.70	.09
Structural Anomaly of the Face, Mouth or Gastrointestinal Tract				
No (index group)	0	–	–	–
Yes	3.99	1.77	2.26	.03
Infant Race/Ethnicity				
More than one race (index group)	0	–	–	–
Asian	0.25	1.75	0.14	.89
Black or African American	−1.66	1.47	−1.13	.26
Hispanic or Latino	3.03	1.44	2.10	.04
White	−1.17	0.87	−1.35	.18
Other	0.49	1.88	0.26	.79
Outcome variable: Gastrointestinal Tract Function subscale score				
Parameters	Estimate	SE	*t*-value	*P*-value
Intercept	66.42	7.11	9.34	<.001
Preterm Category				
Full-Term (index group)	0	–	–	–
Late Preterm	1.73	2.98	0.58	.56
Moderately Preterm	−5.51	3.89	−1.42	.16
Very Preterm	−8.34	5.27	−1.58	.11
Infant Age Group				
<2 months (index group)	0	–	–	–
2-4 months	−2.51	1.89	−1.33	.18
4-6 months	−8.18	1.90	−4.31	<.001
6-7 months	−9.60	2.10	−4.58	<.001
Difficulty Breastfeeding				
No (index group)	0	–	–	–
Yes	4.73	1.39	3.40	.001

(continued)

Table 5. (continued)

Outcome variable: Gastrointestinal Tract Function subscale score				
Parameters	Estimate	SE	*t*-value	*P*-value
Bronchopulmonary Dysplasia				
No (index group)	0	–	–	–
Yes	28.81	6.77	4.26	<.001
Gastroesophageal Reflux				
No (index group)	0	–	–	–
Yes	14.42	1.87	7.71	<.001
Unsure	6.83	3.17	2.15	.03
Outcome variable: Sensory Responsiveness subscale score				
Parameters	Estimate	SE	*t*-value	*P*-value
Intercept	17.33	3.01	5.75	<.001
Preterm Category				
Full-Term (index group)	0	–	–	–
Late Preterm	−0.17	1.03	−0.16	.87
Moderately Preterm	−1.35	1.34	−1.01	.31
Very Preterm	0.07	2.09	0.03	.98
Infant Age Group				
<2 months (index group)	0	–	–	–
2-4 months	0.01	0.66	0.02	.98
4-6 months	0.93	0.65	1.43	.15
6-7 months	2.39	0.78	3.09	.002
Bronchopulmonary Dysplasia				
No (index group)	0	–	–	–
Yes	5.45	2.63	2.07	.04
Infant Sex				
Male (index group)	0	–	–	–
Female	1.20	0.48	2.50	.01
Delivery Method				
Vaginal Delivery (index group)	0	–	–	–
Cesarean Section	−1.23	0.52	−2.38	.02
Diagnosed Food Allergy				
No (index group)	0	–	–	–
Yes	4.27	1.13	3.77	<.001
Outcome variable: Compelling Symptoms of Problematic Feeding subscale score				
Parameters	Estimate	SE	*t*-value	*P*-value
Intercept	4.35	0.76	5.73	<.001
Preterm Category				
Full-Term (index group)	0	–	–	–
Late Preterm	−0.24	0.26	−0.93	.35
Moderately Preterm	−0.26	0.33	−0.78	.44
Very Preterm	−0.06	0.52	−0.12	.90
Bronchopulmonary Dysplasia				
No (index group)	0	–	–	–
Yes	2.56	0.67	3.80	<.001
Gastroesophageal Reflux				
No (index group)	0	–	–	–
Yes	0.74	0.16	4.56	<.001
Unsure	0.003	0.30	0.01	.99
Structural Anomaly of the Face, Mouth or Gastrointestinal Tract				
No (index group)	0	–	–	–
Yes	1.38	0.36	3.81	<.001

Note. USD = United States Dollars.

pair of the preterm categories (Figure 1). In the analyses of considering covariates that have potential to influence problematic bottle-feeding, the infant's current age group, infant's sex, delivery method, BPD, and diagnosed food allergy were found to be the significant factors for the Sensory Responsiveness subscale score (Table 5). Unlike the other subscales, the subscale score for Sensory Responsiveness significantly increased as infant age increased, with infants in the current age group 6 to 7 months having scores 2.39 points higher than infants less than 2 months old ($t = 3.09$, $P = .002$). Female infants had scores that were 1.2 points higher than male infants on Sensory Responsiveness ($t = 2.5$, $P = .01$), while infants who were delivery by cesarean section had scores that were 1.23 points lower than infants delivered vaginally ($t = -2.38$, $P = .02$). Having a diagnosed food allergy resulted in a score on the Sensory Responsiveness subscale that was 4.3 points higher than infants without food allergy ($t = 3.77$, $P < .001$) and having BPD increased the score by 5.45 points compared to infants without BPD ($t = 2.07$, $P = .04$). After accounting for these significant covariates, difference in the Sensory Responsiveness subscale score among the preterm categories became non-significant ($F_{3, 574} = 0.34$, $P = .79$).

Compelling Symptoms of Problematic Feeding Subscale. The Compelling Symptoms of Problematic Feeding subscale score was significantly different among the 4 preterm categories ($F_{3, 621} = 6.46$, $P = .03$). Post-hoc analyses found that very preterm infants had significantly higher scores on the Compelling Symptoms of Problematic Feeding subscale (M = 2.25, SD = 3.47) compared to moderately preterm infants (M = 0.45, SD = 0.6; $P = .003$), late preterm infants (M = 0.49, SD = 0.98; $P = .001$), and full-term infants (M = 0.59, SD = 1.55; $P < .001$; Figure 1). When considering covariates, the following factors were found to significantly contribute to the subscale score for Compelling Symptoms of Problematic Feeding: BPD, GER, and having a structural anomaly of the face, mouth, or gastrointestinal tract. That is, infants with BPD had scores 2.56 points higher on the Compelling Symptoms of Problematic Feeding subscale than infants without BPD ($t = 3.8$, $P < .001$), while having GER increased the subscale score by 0.74 points compared to infants without GER ($t = 4.56$, $P < .001$). Infants with a structural anomaly of the face, mouth, or gastrointestinal tract had scores on the Compelling Symptoms of Problematic Feeding subscale that were 1.38 points higher than infants without these types of anomalies ($t = 3.81$, $P < .001$). After accounting for all of these significant covariates, difference in the subscale score for Compelling Symptoms of Problematic Feeding by the preterm category became non-significant ($F_{3, 617} = 0.47$, $P = .71$).

Discussion

This secondary analysis is one of the first studies to explore symptoms of problematic feeding in infants born preterm compared to full-term infants in the first 7 months of life after NICU discharge using a valid and reliable measure of infant bottle-feeding. The results of this study demonstrated that very preterm infants (<32 weeks GA at birth) had significantly more symptoms of problematic bottle-feeding compared to their moderately preterm (32-34 weeks GA), late preterm (34-37 weeks GA), and full-term (≥37 weeks GA) counterparts. These findings were true for the NeoEAT—Bottle-feeding total score, Energy & Physiologic Stability subscale, Gastrointestinal Tract Function subscale, and Compelling Symptoms of Problematic Feeding subscale. Interestingly, in a study by Park and colleagues on older infants and children (6 months-7 years old) with a history of preterm birth, both very preterm and moderate to late preterm infants were found to have more symptoms of problematic feeding compared to full-term born infants.[10] The lack of statistical difference between the moderately preterm and late preterm infants compared to full-term infants in this study is likely a reflection of small sample sizes in these groups, but may also reflect increased variability in problematic bottle-feeding in late preterm and full-term infants in the first months of life. Because of the natural variability in feeding behaviors and skills, it can be difficult for healthcare providers to differentiate problematic feeding from feeding that falls within the range of expected; norm-reference values available for the NeoEAT—Bottle-feeding[15] may help providers make this determination more easily.

We found multiple infant and family factors that significantly contribute to increased symptoms of problematic bottle-feeding in the first 7 months of life. After considering these significant covariates, differences in the NeoEAT—Bottle-feeding total score and all 5 subscale scores among the preterm categories became non-significant. This finding suggests that symptoms of problematic feeding infants born preterm are not solely due to the degree of prematurity, rather multiple infant and family factors may be just as important to determine types and severity of feeding problem in this population.

Having BPD contributed significantly to the NeoEAT—Bottle-feeding total score and all subscale scores, except for Infant Regulation. These findings are consistent with previous findings that BPD and chronic lung disease are important factors in

determining feeding outcomes in preterm-born children at older ages.[10,30]

Symptoms of problematic bottle-feeding improved with increasing infant age for the NeoEAT—Bottle-feeding total score and all subscales, except for the Sensory Responsiveness subscale, where it actually increased with increasing infant age, and Compelling Symptoms of Problematic Feeding, where it was not a significant covariate. These results suggest that maturation of the infant results in improvement of symptoms of problematic bottle-feeding, which is consistent with the literature showing improvement in a variety of symptoms with maturation in the first months of life.[31] The increase in scores on the Sensory Responsiveness subscale with increasing infant age may also reflect maturation of the infant, greater awareness of the sensory aspects of bottle-feeding, and the transition from reflexive sucking to voluntary sucking, when some infants begin showing more symptoms of problematic feeding related to the sensory components of feeding.

Presence of GER, having a structural anomaly of the face, mouth, or gastrointestinal tract, and having a history of breastfeeding difficulty were also significant covariates across multiple subscales. Having GER resulted in higher NeoEAT—Bottle-feeding total scores and higher scores on all subscales except Infant Regulation and Sensory Responsiveness. GER has also been associated with problematic feeding in other studies.[10] The mechanism for the relationship between GER and problematic feeding is not well understood. It may be causative, with symptoms of GER causing discomfort leading to disinterest in feeding, or there may be an underlying component, such as poor vagal tone,[32] that places infants at risk for GER and problematic feeding concurrently.

A history of breastfeeding difficulty was found to be a significant contributor to problematic bottle-feeding in this sample, regardless of preterm category. Sanchez and colleagues also found that early cessation of breastfeeding was associated with problematic feeding at 3 years old.[30] Early difficulties with breastfeeding may go beyond the breastfeeding experience and be an early symptom of more generalized difficulties with feeding. Healthcare providers should ask about early breastfeeding difficulties and consider this a risk factor when assessing for later concerns about problematic feeding.

Many of the findings from this study were consistent with other available literature, but there were a few unexpected findings. Higher income levels were found to be associated with more symptoms of problems on the Infant Regulation subscale, which was the opposite finding of Black & Aboud, who found impaired ability to respond to infant cues such as hunger in the setting of extrinsic stressors.[25] Hispanic and Latino infants were found to have more symptoms of problems on the Energy & Physiologic Stability subscale compared to White infants; we do not have a clear understanding of why this was true. Female infants, infants delivered by cesarean section, and infants with diagnosed food allergies were found to have more problems on the Sensory Responsiveness subscale. All of these findings warrant further investigation to better understand their contributions to symptoms of problematic feeding.

Implications for Practice

These data may help healthcare providers assess risk and determine need for treatment and/or feeding specialty care in infants born preterm or with other diagnoses found to significantly contribute to problematic bottle-feeding. It is important to have an understanding of the problems associated with bottle feeding, as this is the alternative to breastfeeding and the most common mode of feeding for infants. Acknowledging the risk factors that predispose infants to bottle feeding trouble may prompt clinicians to recognize these issues early after discharge to provide parents with suggestions and techniques that may reduce these challenges. This study supports and validates parent report of challenges with infant feeding and the usefulness of the NeoEAT—bottle feeding measure as a method of infant feeding assessment. Compared to other measures of infant feeding, the NeoEAT tool can be used by clinician or caregiver without prior training. The NeoEAT accurately reflects the variables we know to impede successful feeding. Clinicians should consider the addition of this screening tool into daily practice as a simple and accurate way of identifying feeding challenges that may warrant intervention, frequent follow-up or specialty referral.

Implications for Research

Research is needed on many aspects of feeding in the first year of life after NICU discharge. Longitudinal studies that explore the evolution and development of problematic feeding from the initiation of oral feeding in the NICU through the first year of life after NICU discharge are needed to better understand both risk factors and protective factors. Additionally, research is needed to evaluate the effectiveness of strategies used to treat problematic feeding in infancy to better understand which infants respond best to these strategies in order to promote personalized care. Exploration of symptoms of problematic breastfeeding among preterm-born infants is also needed.

Limitations

The primary limitation of this study was the relatively small sample sizes for the preterm-born infants, with only 16 infants born very preterm, 20 born moderately preterm, and 35 born late preterm. Additionally, the very preterm category of <32 weeks GA at birth represents a wide range of preterm infants. Future studies should aim to include larger samples of preterm infants, and further separate the very preterm category into infants born within small GA ranges (eg, <24, 24-26, 26-28, 28-30, and 30-32 weeks GA at birth). This study relied entirely on parent-report, which has been found to be a reliable source of information. Validation with medical records or healthcare provider diagnoses could strengthen future work. There may also have been infants with undiagnosed conditions, such as GER or ankyloglossia, which may have contributed to symptoms of problematic feeding. Differentiating between types of structural anomalies (eg, cleft palate vs ankyloglossia) would be beneficial in future studies.

Conclusion

This study found that very preterm infants (born <32 weeks gestation at birth) had significantly more symptoms of problematic bottle-feeding than infants born full-term, moderately preterm, or late preterm. Factors such as BPD, GER, and congenital anomalies of the face, mouth, and gastrointestinal tract were significant contributors to symptoms of problematic bottle-feeding even when the degree of prematurity was considered. Additionally, early difficulty with breast-feeding was a risk factor for later difficulties with bottle-feeding. While there was improvement in symptoms of problematic bottle-feeding with increasing infant age across many subscales, this is likely a reflection of improvement of medical factors and infant maturation. These findings support the need for frequent assessment of feeding in preterm-born infants after NICU discharge and provides clinicians with information regarding particular medical factors that place infants at risk for feeding difficulty beyond the NICU. The identification of infants who are struggling with bottle-feeding may facilitate interventions within the primary care setting or referral to feeding experts to improve long-term outcomes and decrease the likelihood of negative sequelae that could persist into late childhood. More research is needed to understand the feeding difficulties preterm-born children encounter across the early years of life and how medical factors as well as feeding-related practices in the NICU relate to later feeding experiences.

Author Contributions

RRH, JP, and BFP contributed to the conception of the study, study design, study analysis, and results interpretation. RRH drafted the paper and JP and BFP critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

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