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Relationship of the First Suck Burst to Feeding Outcomes in Preterm Infants

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Abstract

Objective—This study examined the relationship between the number of sucks in the first nutritive suck burst and feeding outcomes in preterm infants. The relationships of morbidity, maturity, and feeding experience to the number of sucks in the first suck burst were also examined.

Methods—A nonexperimental study of 95 preterm infants was used. Feeding outcomes included proficiency (percent consumed in first 5 min of feeding), efficiency (volume consumed over total feeding time), consumed (percent consumed over total feeding), and feeding success (proficiency 0.3, efficiency 1.5 mL/min, and consumed 0.8). Data were analyzed using correlation and regression analysis.

Results and Conclusions—There were statistically significant positive relationships between number of sucks in the first burst and all feeding outcomes—proficiency, efficiency, consumed, and success ($r = 0.303, 0.365, 0.259$, and $\tau = 0.229, P < .01$, respectively). The number of sucks in the first burst was also positively correlated to behavior state and feeding experience ($\tau = 0.104$ and $r = 0.220, P < .01$, respectively). Feeding experience was the best predictor of feeding outcomes; the number of sucks in the first suck burst also contributed significantly to all feeding outcomes. The findings suggest that as infants gain experience at feeding, the first suck burst could be a useful indicator for how successful a particular feeding might be.

Keywords

feeding behavior; feeding efficiency; feeding outcomes; infant feeding

A numbers of factors have been associated with preterm infants' ability to nipple-feed successfully. Among these factors are gestational age, muscle tone, heart rate, respiratory status, behavioral state, energy level, and sucking behaviors.¹⁻³ Nonnutritive sucking (NNS) has been associated with improved behavior state for feeding.^{4,5} Although NNS is often used as an indicator that the preterm infant is ready to initiate oral feedings, there is little evidence that this activity is related to feeding outcomes.⁶ Less attention has been paid to the relationships between the characteristics of nutritive sucking and feeding outcomes. In particular, because there continues to be no standardized criteria for initiating oral feedings or empirically tested feeding patterns most useful for progressing oral feedings, efforts to determine clinically valuable indicators that an infant will be successful at any given oral feeding are needed.

BACKGROUND AND SIGNIFICANCE

Sucking activity has been well studied in preterm infants.^{3,7,8} Sucking is also an activity that is generally easily observable to the person who is feeding the infant.⁹ Thus, examination of sucking characteristics could be helpful in designing a clinically pertinent assessment of whether or not a particular feeding might be successful. The implications of having a useful, easy-to-use method of assessment are many. Most important, perhaps, is that if it is clear that a feeding will be unsuccessful in the period immediately following the feeding start, it is probably prudent to stop the feeding rather than continuing with the feeding, which could otherwise tax the infant unnecessarily.

The purpose of this study was to examine the relationship between the number of sucks in the first nutritive suck burst and feeding outcomes in preterm infants. Factors that influence the first suck, namely infant maturity, severity of illness, prefeeding behavior state, and feeding experience, were also examined. Further analysis to determine variables that predict feeding outcomes was undertaken.

METHODS

A nonexperimental, prospective design was used to collect data during oral feedings from hospitalized preterm infants. The study was approved by the institutional review board and all parents gave written informed consent.

Sample

The sample was recruited over 3 years. Infants were eligible for the study if they were born less than 32 weeks postmenstrual age (PMA) and had no known gastrointestinal, craniofacial, cardiovascular, neurological, or muscular defects. The sample consisted of 95 preterm infants whose PMA at birth ranged from 24 to 32 weeks ($M = 29.3$, $SD = 2.0$). Infants weighed from 550 to 2390 g at birth ($M = 1290.6$, $SD = 397$). There were 48 male and 47 female infants. Seventy-one percent (71%) of the sample were African American and 24% were white. Only 3% were Hispanic.

Measures

Sucking was measured using a stretch-sensitive chin strain gage (Parks Medical, Ore). The gage, which has demonstrated reliability in measuring sucking events,¹⁰ is compatible with and does not change the functionality of the standard nipples used to feed preterm infants. The gage was placed under the infant's chin and secured to the skin at the zygomatic bones with hypoallergenic tape. The strain gage was connected to a plethysmograph that detected changes in electrical resistance as the gage was further stretched with sucking activity. As the strain gage is sensitive to even slight movement of the mandible, it is possible to distinguish chewing on the nipple and other nonsucking activity from true sucking.⁶

Feeding outcomes included proficiency, efficiency, consumed, and success.³ Proficiency was measured by determining the percentage of prescribed volume taken in the first 5 minutes of the feeding (expressed as a proportion). Efficiency was the total volume taken over total feeding time. Consumed was measured by determining the percentage of prescribed volume taken over the total feeding time (expressed as a proportion). Success was a computed variable based on proficiency, efficiency, and consumed. A feeding was classified as "successful" if proficiency was ≥ 0.3 (30%), efficiency was ≥ 1.5 mL/min, and consumed was ≥ 0.8 (80%). That is, the infant who fed successfully by this definition, consumed one third of the prescribed volume in the first 5 minutes of the feeding and consumed at least three quarters of the prescribed amount by the end of the feeding, and did this by taking in at least 1.5 mL/min. To consider this another way, if the infant was

prescribed 30 mL, at least 10 mL would be consumed in the first 5 minutes and at least 24 mL over the entire feeding. At a rate of 1.5 mL/min, the nipple time would be 18 minutes.

Infant maturity was measured by postmenstrual age (PMA), which is the gestational age at birth plus the chronological age after birth. Severity of illness was measured using the Neonatal Medical Index (NMI).¹¹ Classifications on the NMI range from 1, for infants born weighing more than 1000 g without major complications, to 5, for infants born weighing less than 1000 g with very serious complications. The NMI for each infant was calculated at 30 weeks PMA. Behavior state was measured using the Anderson Behavior State Scale (ABSS), a 12-category scale that measures sleep and wakefulness, with 1 being deep sleep and 12 being hard crying.^{12,13} Behavioral state data were collapsed for analysis into 6 levels: light sleep (states 1 and 2), active sleep (states 3 and 4), drowsy (state 5), quiet awake (states 6 and 7), active awake (states 8 and 9), and agitated (states 10–12).⁴ Feeding experience was defined as the cumulative number of bottle feeding attempts. Experience data were collected daily by feeding record review.

Procedures

Infants enrolled in the study were started on oral (bottle) feedings at 32 weeks PMA. Data were collected at 1 bottle feeding per day for 2 to 3 weeks according to the infant's severity of illness; this resulted in 920 observed feedings. The nurse assigned to care for the infant for the shift provided routine prefeeding care, such as diaper change and vital signs, after which a trained data collector attached the chin strain gage. Data from the plethysmograph were recording using a computerized data acquisition system and were stored to disk. Infants were allowed to feed orally until one of the following conditions occurred: all prescribed formula was consumed; no sucking activity was observed for 2 minutes; or signs of physiological stress were observed (ie, oxygen saturation below 85%, bradycardia, apnea, loss of muscle tone, or other signs of fatigue).

Following the feeding, the sucking data were transformed to printed tracings; 715 useable tracings were obtained. These were coded by a trained coder using a system developed in previous studies where a suck was defined as having a duration of less than 1 second and a suck burst was defined as 1 or more suck with less than 2 seconds between each suck.⁶ A 20% random selection of coded data was reviewed by the principal investigator, who is also trained in the coding system. Less than 1% error was detected.

Data analysis

Coded data were entered into a database and checked for accuracy; less than 0.5% error was detected. Descriptive statistics were computed for all variables. For outcomes measured at the ordinal or interval level, Pearson product moment correlation coefficient was used to examine relationships (proficiency, efficiency, and consumed). For outcomes measured at the nominal level, Kendall τ was used to examine relationships (success). Regression analysis was used to develop predictive models for the feeding outcomes. Multiple regression analysis was used for the outcomes proficiency, efficiency, and consumed, while logistic regression was used for the outcome success. All regression analyses used a forward stepwise approach. The level of significance was set at $P < .05$.

RESULTS

All infants enrolled in the study were started on oral feedings at 32 weeks PMA, thus maturity increased by 1 for each day on study. Infants remained on study until 34 or 35 weeks PMA. The majority of the sample (49%) had moderate severity of illness as measured by the NMI (NMI = 3), while 28% had mild complications (NMI = 1 or 2), and 23% had

severe complications (NMI = 4 or 5). The majority of infants were in either light sleep (25%), active sleep (18%), drowsy (22%), or quiet awake (26%) states at prefeeding. Only 5% were in active awake states and 4% were in agitated states. Infants had varying degrees of feeding experience. All infants started the study at 32 weeks PMA, and thus had no experience at oral feeding at that time. Over the course of the 2- to 3-week study period, the overall feeding experience ranged from 0 to 131 bottle-feeding events ($M = 57.7$, $SD = 30.8$).

Table 1 shows the characteristics of the feeding outcomes. An average of 41% of the prescribed volume was taken in the first 5 minutes, with an average percent consumed of 59% and an average efficiency of 2.9 mL/min. Of the 715 feedings used in this analysis, 192 (27%) were classified as successful, as previously described, while 523 (73%) were not.

The number of sucks in the first suck burst was highly variable, ranging from 1 to 161 ($M = 17.2$, $SD = 20.3$). Table 2 shows the relationships between the number of sucks in the first suck burst and the feeding outcomes. Also shown in Table 2 are the relationships between sucks in the first suck burst and feeding outcomes to those variables thought to influence sucking activity—maturity, severity of illness, behavior state, and feeding experience.

There were statistically significant positive relationships between the number of sucks in the first burst and all feeding outcomes—proficiency, efficiency, consumed, and success ($r = 0.303, 0.365, 0.259$, and $\tau = 0.229$, $P < .01$, respectively). As the number of sucks in the first suck burst increased so did feeding proficiency, efficiency, consumed, and success. The number of sucks in the first burst was also positively correlated at a statistically significant level to behavior state and feeding experience ($\tau = 0.104$ and $r = 0.220$, $P < .01$, respectively). More active prefeeding behavior state and more experience feeding were related to an increased number of sucks in the first suck burst. As expected, there was a statistically significant inverse relationship between number of sucks and morbidity ($\tau = -0.107$, $P < .01$); less ill infants had more sucks in the first suck burst than more ill infants. All feeding outcomes had statistically significant positive relationships with maturity, behavior state, and feeding experience. More mature, more active, and more experienced infants had greater feeding proficiency, efficiency, consumed, and success. Morbidity was not statistically correlated with any of the outcome measures.

Regression analysis was used to examine the significant relationships found during correlation analysis to identify a subset of independent variables that best predict feeding outcomes. The results of these analyses are shown in Table 3. Each outcome was predicted by feeding experience and number of sucks in the first suck burst. Behavior state also contributed to the prediction of proficiency, efficiency, and consumed but not to the prediction of success.

Nineteen percent of the variation in feeding proficiency was predictable (Adjusted $R^2 = 0.196$; $F_{3,721} = 59.708$, $P = .000$). Feeding experience contributed 14.5% of the variance in proficiency ($t = 9.467$, $P = .000$). After controlling for the prior variables in the model, the number of sucks accounted for an additional 4.7% of the variance in proficiency ($t = 6.332$, $P = .000$), while behavior state accounted for an additional 0.7% ($t = 2.421$, $P < .05$). That is, by knowing the number of feeding opportunities (feeding experience), the number of sucks in the first suck burst, and the prefeeding behavior state, we can predict the proficiency of the feeding about 20% of the time.

Thirty-five percent of the variance in efficiency was predicted (adjusted $R^2 = 0.352$; $F_{4,726} = 99.919$, $P = .000$). Four predictor variables—feeding experience, number of sucks, behavioral state, and maturity—were significant. Feeding experience contributed 26.6% of the variance in efficiency ($t = 13.342$, $P = .000$). The number of sucks in the first suck burst

then accounted for an additional 8.31% of the variance in efficiency ($t = 8.31$, $P = .000$). Behavior state accounted for an additional 0.9% ($t = 3.268$, $P = .001$) and maturity accounted for an additional 0.7% ($t = 2.796$, $P = .005$). That is, by knowing the number of feeding opportunities (feeding experience), the number of sucks in the first suck burst, the prefeeding behavior state, and the infant's PMA, we can predict the efficiency of the feeding about 35% of the time.

Seventeen percent of the variance in consumed was predicted (adjusted $R^2 = .177$; $F_{3,727} = 53.182$, $P = .000$). Three predictor variables—feeding experience, number of sucks, and behavior state—were significant. Feeding experience contributed 14% of variance for efficiency ($t = 9.545$, $P = .000$). The number of sucks in the first suck burst accounted for an additional 2.9% of variance ($t = 4.781$, $P = .000$), while behavior state accounted for an additional 1.1% ($t = 3.13$, $P = .002$). That is, by knowing the number of feeding opportunities (feeding experience), the number of sucks in the first suck burst, and the prefeeding behavior state, we can predict the percent consumed about 17% of the time.

Using logistic regression, 17% of the variance in success was predicted (adjusted $R^2 = 0.169$; $\chi^2_{3,692} = 92.125$, $P = .000$). Only 2 variables, feeding experience and the number of sucks in the first suck burst, were significant. Feeding experience contributed 12.6% of the variance to success while the number of sucks in the first suck burst accounted for an additional 3.3% of the variance.

DISCUSSION

The number of sucks in the first suck burst was found to be related to the infant's maturity, prefeeding behavior state, and feeding experience. Infants who were older, more awake, and who had more feeding experience had more sucks in the first burst. That is, as infants matured, they gained feeding experience and were more likely to be in more active behavior states; these infants had more sucks in the first suck burst. Strong relationships were found between the number of sucks in the first nutritive suck burst and feeding outcomes. In particular, more sucks in the burst were related to increased proficiency, efficiency, and percent consumed, and thus to greater feeding success. These outcomes were also found to be strongly related to infant maturity, prefeeding behavior state, and, particularly, feeding experience. Feeding experience was the best predictor of feeding outcomes. The number of sucks in the first suck burst also contributed to the variance in feeding outcomes. To a much lesser extent though, prefeeding behavior state contributed significantly to the variance in outcomes.

An alert behavior state is presumed to be ideal for feeding. An alert infant is thought to be more aware and ready to feed.¹⁴ In fact, a number of studies have documented that infants who are fed in a quiet alert state are more likely to be successful at oral feedings.^{13,15} However, other researchers have found that more active states, including all but those associated with agitation, result in improved feeding outcomes.¹⁶ In this study, while behavior state was moderately associated with feeding outcomes, it did not predict a clinically significant amount of the variance in those outcomes.

Sucking is observed in utero and is present in even very young preterm infants. However, the ability to suck nutritively requires time to develop; this development occurs in patterns that have been previously described.^{6,17,18} In infants born preterm, the synchrony of sucking with swallowing and breathing is irregular.¹⁹ This results in infant fatigue, probably as the result of interrupted breathing related to swallowing, when a suck results in a large amount of fluid being taken in.²⁰ It is not until 32 to 34 weeks that the mechanisms of suck-swallow-breathe become functionally coordinated.¹⁹ However, even before there is fully coordinated

sucking and swallowing, infants are fed orally. And, even without coordination of suck-swallow-breathe, infants can safely feed orally, as has been repeatedly demonstrated through research.²¹

No studies have previously examined the relationship or predictive nature of nutritive sucking to feeding outcomes. In particular, no attempt has been made to use the characteristics of nutritive sucking early in a feeding to predict how well the infant might feed. In this study, the number of sucks in the first suck burst was moderately related to feeding outcomes and predicted the significant, if small amounts of, variance in those outcomes. However, the amount of feeding experience an infant had received showed even stronger relationships to outcomes and predicted a much larger percentage of the variance in those outcomes. Feeding experience, that is, the opportunity to feed orally more often, has been the focus of an increasing number of recent studies. These studies have shown that more experience generally results in improved feeding outcomes.^{16,22} The findings of this analysis supports previous findings and suggest that knowledge of feeding experience coupled with observation of early-in-the-feeding sucking behaviors could be useful for predicting success at feeding.

CONCLUSION

The development of oral feeding skills in the preterm infant is a process that involves maturation as well as skill acquisition. In this study, more sucks in the first suck burst was related to better feeding outcomes. However, perhaps more significantly, better feeding outcomes were most strongly predicted by feeding experience, or the number of opportunities the infant had to nipple-feed. There has been little research about learning in the preterm infant. However, recent research on habituation²³ and conditioning²⁴ suggest that preterm infants do learn from their environmental experiences. Moreover, there is mounting evidence suggesting that opportunities to nipple-feed may enhance the development of feeding skills.^{5,22,25} The full implications of the research on feeding experience are not known. Studies designed to test differing amounts of feeding experience provided under a variety of conditions need to be conducted.

Nurses must continually assess all available feeding behaviors to make the best possible decisions about how an infant is feeding. Sucking behavior is readily observable and could be used as an indicator of possible feeding outcomes. It is possible that feeding protocols using the characteristics of the first suck burst as a guide to decision making could be developed. However, research testing the safety and efficacy of using observation of sucking behavior as a predictor of feeding outcome is needed before conclusions can be made about the widespread implementation of this as an intervention. In the meantime, nurses and parents should be encouraged to carefully observe infant behavior during feedings and to monitor feeding progress using infant behaviors.

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Table 1

Characteristics of feeding outcomes

Feeding outcomes	Mean	SD	Range
Proficiency, %	41.3	27.1	0–100
Efficiency, mL/min	2.86	2.33	0–17.3
Consumed, %	59.4	34.8	0–100

Table 2

Relationships between variables

Variable	1	2	3	4	5	6	7	8	9
1. Sucks/burst	1.000								
2. Proficiency	0.303 [*]	1.000							
3. Efficiency	0.365 [*]	0.702 [*]	1.000						
4. Consumed	0.259 [*]	0.819 [*]	0.598 [*]	1.000					
5. Success	0.229 [*]	0.796 [*]	0.604 [*]	0.692 [*]	1.000				
6. Maturity	0.041	0.166 [*]	0.210 [*]	0.231 [*]	0.107 [*]	1.000			
7. Illness	-0.107 [*]	-0.061	-0.058	-0.063	-0.037	-0.062	1.000		
8. Behavior	0.104 [*]	0.134 [*]	0.157 [*]	0.152 [*]	0.080 [†]	0.038	0.017	1.000	
9. Experience	0.220 [*]	0.381 [*]	0.516 [*]	0.375 [*]	0.334 [*]	0.600 [*]	0.065	-0.042	1.000

^{*} Correlation significant at <.01.[†] Correlation significant at <.05.

Table 3

Regression analyses for feeding outcomes

Predictor variables	df	R	R ²	Adjusted R ²	F	P
Proficiency [*]	3, 721				59.708	.000
Feeding experience		0.381	0.145	0.144		
Number of sucks		0.439	0.192	0.190		
Behavior state		0.446	0.199	0.196		
Efficiency [*]	4, 726				99.919	.000
Feeding experience		0.516	0.266	0.265		
Number of sucks		0.582	0.339	0.337		
Behavior state			0.348	0.345		
PCA		0.596	0.355	0.352		
Consumed [*]	3, 727				53.182	.000
Feeding experience		0.374	0.140	0.139		
Number of sucks		0.411	0.169	0.167		
Behavior state		0.424	0.180	0.177		
Success [†]	3, 692				92.125	.000
Feeding experience		0.334	0.128	0.126		
Number of sucks		0.229	0.186	0.169		

^{*} Uses multiple regression analysis.[†] Uses logistic regression analysis; value expressed is χ^2 .