Feeding Readiness Behaviors and Feeding Efficiency in Response to ATVV Intervention

By Rosemary C. White-Traut, DNSc, RN,*
Michael N. Nelson, PhD,† Jean M. Silvestri, MD,†
Ushanalini Vasan, MD,† Minu Patel, MSc,*
and Leticia Cardenas, BSN, RN*

Abstract

A prospective clinical random design was used to assess the effects of prefeeding auditory, tactile, visual and vestibular (ATVV) intervention on the behavioral state, frequency of feeding readiness behaviors, and oral feeding efficiency in 22 stable, premature infants. Experimental infants (group E) received 15 minutes of ATVV intervention immediately prior to their first 3 oral feedings, while the controls received normal nursery care. FRBs and behavioral states were recorded and later scored via videotape. Feeding efficiency was determined by feeding volume and feeding duration. Group E infants were more alert after the intervention ($P < .0001$) and showed more FRBS during the intervention for 5 of the 8 behaviors ($P < .05$). A trend toward decreased feeding time was noted for group E infants. The present findings support the use of ATVV intervention prior to feeding as a means of modulating behavioral states and increasing the frequency of FRBs.

It is well documented that convalescing premature infants showed disorganized behavioral state patterns and uncoordinated feeding patterns.[1,2] Nonetheless, successful oral feeding is a major determinant of readiness for discharge, because infants who show difficulty with oral feeding have longer hospital stays and higher health care costs.[3] With the initiation of oral feeding, a routine feeding schedule is often implemented. Prior to scheduled feedings, the infants are awakened during the assessment of vital signs and the associated diaper change, but frequently go without assessment of the development of feeding readiness behaviors. After this routine nursing care, nipple feeding is initiated, often while the infant is in a sleep or disorganized state. Infants who experience prefeeding alertness may also experience improved mother-infant feeding interactions. These findings have been associated with consistent weight gain, improved growth, and subsequent development.[4] By initiating feeding in an infant that is not alert, these advantages may not be fully realized. One study has identified methods to assess feeding readiness behaviors.[5] For infants who experience inefficient feeding because of difficulty organizing behavior and poor (or weak, unsustained) feeding readiness prior to nipple attempts, it is essential to identify effective interventions such as auditory, tactile, visual, and vestibular (ATVV) intervention, which may enhance the infant's ability to nipple feed.[6] The purpose of this research was to determine whether the use of ATVV intervention immediately prior to the first 3 oral feedings shifts the distribution of preterm infant behavioral state from sleep to alert states. Thus, increasing the frequency of feeding readiness behaviors and

*From the *Department of Maternal-Child Nursing University of Illinois at Chicago, College of Nursing, Chicago, IL; and †Department of Pediatrics, Rush-Children's Hospital, Chicago, IL.*

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Address reprint requests to Rosemary C. White-Traut, DNSc, RN, Department of Maternal-Child Nursing, College of Nursing, University of Illinois at Chicago, 845 South Damen Ave, Chicago, IL 60612-7350; e-mail: RWT@UIC.EDU.

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enhancing oral feeding efficiency (as measured by duration of feeding and feeding volume).

The ability to feed orally is influenced by many factors including corrected gestational age, current behavioral state, physiologic regulation, neurologic maturity, neurobehavioral organization, health status, muscle strength, and the coordination of sucking, swallowing, and breathing.[1,2,7,8] Feeding is considered the most highly organized behavior of the young infant and requires integration of both the autonomic and central nervous systems.[8,9] Feeding is effectively conducted when breathing is coordinated with the sucking and swallowing sequence of the oral pharyngeal musculature.[10] Premature infants have immature and irregular breathing patterns, which often result in problems related to oral pharyngeal musculature, including the lack of coordination of sucking and swallowing. Failure to coordinate these activities predisposes the premature infant to apneic events, which are accompanied by bradycardia and oxygen desaturation during feeding.[11] The oral pharyngeal muscular motions that are responsible for sucking and swallowing are all present before 28 weeks' gestation.[8,12] The event of sucking precedes that of swallowing and acts to inhibit respiration.[12] Initially, sucking bursts are short in duration and become longer as the premature infant matures.[12–14] During the progression of oral feeding in healthy premature infants, and as gestational age increases, there is an increased frequency in both nutritive and non-nutritive sucking patterns and a decrease in the time required for each sucking burst.[15,16] Inefficient oral feeding requires a large amount of energy expenditure by the premature infant. As a result of this inefficiency, there is often a reduction in a premature infant's ability to ingest full feedings. By 34 weeks gestation, feeding efficiency tends to improve, thus allowing the infant to maintain its strength and endurance during feeding. This related endurance results in the infant's ability to complete full oral feedings.[17]

Behavioral state represents the qualitative organization of brain function and is an important variable that affects oral feeding.[18] The behavioral state of preterm infants is less organized (less rapid eye movement and irregularity of respiration) than in term infants and varies as a function of postconceptional age.[1,19] The 7 categories of behavioral state include: active sleep, quiet sleep, drowsiness, quiet alert, active alert, crying, and indeterminant states.[20] Between 28 and 30 weeks of gestation, the infant shows minimal variation in behavioral state as measured both by electroencephalogram and behavioral state observations.[18] During 4-hour observation periods, active sleep is observed for 71.5% of the time in an infant with a postconceptional age of 30 weeks and decreases to 56.4% by 39 weeks postconceptional age.[19] Quiet sleep appears at the much later postconceptional age of approximately 36 weeks.[18] When compared to their full-term counterparts, preterm infants differ in the organization of behavioral states and the percentage of quiet sleep and quiet alert periods. The ability to organize behavioral states improves while there is a concomitant increase in quiet alert state and longer quiet sleep cycles, which evolve as a function of postconceptional age.[19] The active alert state is observed commonly before feeding in full-term infants, yet is found only 1.1% of the time during a 4-hour period in 33-week-old preterm infants.[18,19] Efforts to bring infants to an alert state prior to a feeding are associated with significantly improved feeding interactions between mother and infant as measured by the Nursing Child Assessment Feeding Scale.[4] These findings are important because improved feeding interaction promotes consistent weight gain, leading to improved growth and subsequent development.

The limited capability of the preterm infant to achieve alert behavioral states may compromise successful feeding. Successful feedings (completion of volume intake over a reasonable time limit and without physiologic distress) for preterm infants are preceded most often by behavioral states of alertness, including the active and quiet alert states.[21,22] Unfortunately, the prefeeding behavioral cues exhibited by preterm infants differ from those of the full-term infant and may not be as easily assessed.[5] Behavioral cues related to hunger in premature infants include drowsy behavioral states, alert behavioral states, or to a lesser extent crying, sucking, active movement, hand to mouth activity, rooting, and increased motor activity after a reposition or diaper change.[23,24] Vigorous sucking, rooting, and crying have been selected by practitioners as the 3 most important factors signifying hunger in preterm infants.[25]

A series of studies with homogeneous samples of preterm infants has established the safety (stable oxygen hemoglobin saturation and heart and respiratory rates within the limits of normal) of ATVV intervention and documented significant positive changes in behavioral state for infants between 33 and 36 postconceptional weeks.[26–31] Previous research has documented changes in behavioral state from sleep to quiet alert when ATVV intervention was provided 1 hour after the scheduled feeding in 35- to 36-week postconceptional age infants.[26] When ATVV intervention was administered to preterm infants (33- to 34-weeks gestational age) 1 hour before the scheduled feeding, the infants more often achieved the active alert state than the quiet alert state.[29,31] More recently, the ATVV intervention was shown to improve progression to complete nipple feeding from gavage-only feeding when administered 1 hour prior to feeding.[32] However, further data are needed to demonstrate that ATVV-

Table 1. Infant Demographics

Variables	Control (n = 10) Mean (SD)	Experimental (n = 12) Mean (SD)
Birth weight (g)	1,726 (344)	1,571 (417)
Weight at entry (g)	1,775 (185.3)	1,731 (214.6)
Birth length (cm)	40 (8)	41 (5)
Gestational age (at birth)	32 (2)	31 (3)
Gestational age (at entry)	34.6 (1.5)	33.5 (2.1)
Apgar score		
1 min	7 (2)	8 (1)
5 min	8 (1)	9 (1)
PCS score*	5.8 (2.9)	6.3 (1.9)
Gender (M/F)	5/5	6/6
Race (Black/White/Hispanic)	8/2/0	7/4/1

Abbreviations: SD, standard deviation.

*Postnatal Complications Score: possible range, 0–10 (highest possible = 10)

related alertness directly facilitates improved feeding efficiency.

The major premise of this study was that, when introduced immediately prior to feeding, the multisensory intervention would improve behavioral state organization and feeding efficiency by promoting behavioral state alertness. In light of pilot findings on brain-injured infants that noted improved oral feeding progression in response to ATVV intervention administered 1 hour prior to feeding, we hypothesized that the intervention would facilitate feeding by increasing the number of prefeeding behaviors and improving feeding efficiency if administered immediately prior to feeding.[32]

Methods

Subjects

This study took place in the intermediate care nursery of 2 level-III centers and 1 level-II center in the Midwest. A convenience sample of 22 preterm infants between 29 to 33 weeks' gestational age at birth were randomly assigned to a control (group C) or an experimental group (group E). Infants were clinically stable, not receiving oxygen therapy or continuous intravenous therapy, and had no obvious physical anomalies such as a cleft lip/palate, Down syndrome, or other chromosomal abnormalities. Infants were entered into the study between 33 and 35 weeks corrected-gestational age (Table 1). Corrected-gestational age was calculated by dates using the mother's last menstrual period and/or antenatal ultrasound assessments. In the event of a discrepancy, the attending neonatologists' admission assessment note was determinative. The Manual for Postnatal Complications was used to verify equivalency of the 2 groups before the intervention.[33] The Postnatal Complications Score (PCS) was selected to obtain information relating to the infants' health status during the initial neonatal period (respiratory distress, infection, ventilatory assistance, noninfectious anomaly, metabolic disturbance, seizure, hyperbilirubinemia or exchange transfusion, temperature disturbance, feeding within 24 hours after birth, and surgery). Interrater reliability was $>$ 95% agreement between 2 raters.

Intervention

Infants assigned to group C received routine nursery care including transition from gavage to nipple feeding when the infant reached 1500 g or 32 weeks postconceptional age, whichever came first. Progression from an every 3- to an every 4-hour feeding schedule occurred when all oral feedings within a 24-hour period were orally ingested. In addition to routine nursery care, group E received ATVV intervention for 15 minutes before the initiation of the first nipple feeding and again immediately before the next 2 subsequent feedings. Although great effort was made to administer the intervention on the first day of transition from gavage to nipple feeding, there were few instances in which the intervention was administered on the day after the first oral feeding.

ATVV intervention provides infant-directed talk via a soothing female voice (auditory stimulation) as the researcher massages the infant for 10 minutes (tactile stimulation), followed by 5 minutes of rocking (vestibular stimulation). Throughout the 15-minute period, the researcher attempts to engage in eye-to-eye contact with the infant (visual stimulation). Findings from previous studies have documented the behavioral responses of the premature infant to the described experimental intervention.[26,28–31] The infant's responses to the intervention are used to modify the stimulation. For example, if an infant exhibits negative disengagement cues, such as hiccuping, finger splay, crying, fussing, or spitting/vomiting, that particular part of the intervention is discontinued and the next portion of the technique is attempted.[6] Yawning was not considered a negative cue, rather it is a sign of state transition (ie, from sleep to alert or alert to sleep).

ATVV intervention was chosen for the present study in light of the positive behavioral and physiologic findings noted by earlier research, and because ATVV intervention focuses on sensory systems that are well developed even in the preterm infant.[26–31] In addition, previous research has documented a faster progression from total gavage to complete nipple feeding in brain-injured infants when ATVV intervention was administered 1 hour prior to scheduled feedings.[32] Thus, ATVV intervention may facilitate continued behavioral state development and may reinforce support for evolving sensory pathways.

Dependent Measures

Behavioral state. Behavioral state was assessed with the Thoman state scoring system.[20] The scale is acceptable in terms of both inter-rater reliability and test-retest reliability when used with preterm infants.[19] For this study, 7 categories of infant state were assessed: active sleep, quiet sleep, drowsy, active alert, quiet alert, crying, and the indeterminant state. The individual judging behavioral state was blind to the infant's group assignment. To assess reliability, 25% of the observations of infant state were independently judged by 2 research assistants. Inter-rater reliability, which was maintained at a level of .91, was calculated via a Kappa statistic.[34]

Feeding readiness behaviors. Prefeeding periods were videotaped to record feeding readiness behaviors and corresponding behavioral state. The videotapes were reviewed by using the Cagan Videotape Coding System for Orally Directed Behaviors, which evaluates the occurrence of prefeeding behaviors including mouthing, hand to mouth, hand swipes at mouth, sucking on hand, tonguing, empty sucking, rooting, and yawning.[5] Two research assistants were trained by Cagan to establish inter-rater reliability prior to initiation of the study. A research assistant blind to the purpose of the study and the infant's group assignment scored the videotapes. To assure inter-rater reliability, 25% of the videotape recordings were independently scored by two research assistants and compared. Inter-rater reliability was 95.4%.

Feeding efficiency. Feeding efficiency was measured as duration of feeding time and feeding volume. Feeding duration was recorded from the start to the completion of the feeding and was indicated by foot switch marks on recording paper. Completion of feeding was indicated by complete ingestion of formula or a cessation of sucking. In addition, the research assistant verified the duration of feeding with a stopwatch. The Neonatal Nurse Practitioner (NNP) or physician order prescribed the total possible volume per feeding. This prescribed amount was poured into the bottle. Feeding volume was measured by the amount of formula (or breast milk) orally ingested. Formula that leaked from the infant's mouth was collected on a preweighed pad, which was then weighed after the feeding, and subtracted from the total amount extracted from the feeding container. If the infant did not ingest the prescribed amount, the remainder was given via the indwelling nasogastric tube.

Procedure

After informed consent was obtained from the infant's parents, the infant was randomly assigned to group C or E. Before each study session, baseline vital signs were assessed and the infant was weighed. The study proceeded if the infant's heart rate was greater than 100 and less than 180, respiratory rate was between 30 and 60, and the infant's skin temperature was between 97.6 (F) and 99.6 (F). All group E infants received ATVV intervention prior to 3 consecutive nipple feedings over the course of 1 day (between 5 a.m. and 3 p.m.). ATVV intervention was initiated when the infant was in a sleep state and approximately 20 minutes before the next scheduled feeding.

The infant remained in the incubator or the open crib throughout the procedure. The video equipment was set to continuously record the infant. Control group infants remained side-lying in the incubator (or open crib) during the observation period and were covered with a blanket. Group E infants received 10 minutes of auditory and tactile stimuli followed by 5 minutes of vestibular stimuli, as described above. Visual stimulation was provided during all alert states. As in our previous research, the primary investigator provided the tactile component of ATVV intervention around or over the electrocardiogram leads.

Behavioral state was judged at different intervals over the course of the 4 phases of the intervention session: every minute for 5 minutes prior to the initiation of the intervention (baseline), every 2.5 minutes during the intervention (intervention), every 15 seconds for 1 minute after completion of the experimental protocol (1-minute immediate postintervention), and every minute for 3 minutes after completion of the experimental protocol (3-minute extended postintervention). Behavioral state was judged at different time intervals during the ATVV intervention because we wanted to maintain blind dependent measures. This required that we did not frequently interrupt the administration of the ATVV.

To maintain blindness to group assignments during the intervention, the research assistant verbally informed the primary investigator of all upcoming state readings, thus allowing a 10-second interval before each behavioral state observation. During this 10-second interval, the group E infants were placed in the side-lying position and covered with a blanket in the same manner as the group C infants. After behavioral state was observed, the primary investigator resumed administration of the intervention. The research assistant wore a soundproof headset and was visually obscured by a screen from the primary investigator and the infant except during each scheduled pause in the intervention, at which time behavioral state was judged. Feeding readiness behaviors and behavioral state were videotaped during the 5-minute baseline phase, during the intervention, and through the 3-minute extended post-intervention period (a total of 24 minutes). When the videotaping was completed, the infant was bottlefed. A stopwatch and the use of a foot pedal on a recorder monitored initiation and termination of feeding. At the completion of the feeding, the infant was returned to the incubator or open crib in a side-lying position and the pad weighed for unconsumed formula (or breast milk).

The research assistant viewed the videotapes, scored the number of feeding readiness behaviors, and judged behavioral state. These independent ratings of feeding readiness behaviors and corresponding behavioral state were made in addition to the behavioral state judgments obtained during the ATVV intervention as a means of verifying the reliability of the behavioral state readings.

Infants assigned to group C were scored on the dependent variables at identical time intervals as the group E infants. The given time points were selected to evaluate the feeding-related variables that are present prior to, throughout, and after the completion of the ATVV intervention. Concurrent videotape recordings allowed the investigators to identify all of the behavioral responses to the intervention, which may have been related to the ATVV intervention, rather than to focus only on the more limited time-dependent observations. The phases of the intervention that were used for data analysis reflect the infant's behavioral responses prior to (baseline), during (intervention), and after the intervention (immediate post-intervention, extended postintervention) for both groups of infants.

Data Analyses

Analysis of variance (ANOVA) was used to analyze the equivalency of postnatal complications, birth weight, gestational age at birth, and corrected gestational age at time of entry into the study for the two groups. Chi-square analyses were computed to determine whether the categorical infant demographic variables of gender, race, and type of delivery were equivalent between the two groups. Chi-squares were also used to detect group differences in the proportion of each behavioral state documented across the 4 phases of the intervention session (baseline, intervention, 1-minute immediate postintervention, and 3-minute extended postintervention).

The total frequency of the feeding readiness behaviors was tabulated for each behavior. Repeated measures ANOVAs were conducted to detect significant differences between the groups in the number of feeding readiness behaviors counted over each of the 3 feeding/intervention sessions.

Although the behavioral state analysis was conducted by using the 4 phases of the intervention session, the immediate post- and extended postintervention phases were combined into 1 phase (postintervention) for the analysis of the feeding readiness behavior data. This merge was performed to account for the few, yet potentially significant, feeding readiness behaviors that were recorded within the short, 1-minute post-intervention period. For data management and scoring purposes, each 24-minute session was divided into 30-second intervals and the frequency of each feeding readiness behavior was tallied within each 30-second interval. The 30-second tallies were later summed within each intervention phase for each baby, yielding phase-specific frequencies of each feeding readiness behavior. To compare group differences in the frequency of feeding readiness behaviors over the 3 phases of the intervention session (ie, baseline, intervention, post-intervention), repeated measures ANOVAs were conducted. When significant differences were noted, these group differences were further investigated by running post-hoc Dunnett analyses on the frequencies of each behavior during the 15-minute intervention phase only.

Finally, the duration of feeding and feeding volume was analyzed via one-way ANOVA for each of the 3 feedings. Group differences for feeding duration and feeding volume were also assessed for the 3 feedings simultaneously via repeated measures ANOVA.

Results

Demographics

No differences between groups C and E infants were noted via one-way ANOVA and chi-square analysis for birth weight, weight at entry into the study, birth length, gestational age at birth, gestational age at entry into the study, Apgar scores at birth, PCS scores, gender, or race (Table 1). The mean gestational age at birth ranged from 31 to 32 weeks, and 33 to 34 weeks at entry into the study. Infants were clinically stable as indicated by their Apgar scores at birth, with means ranging from 7 to 9.

Behavioral State

During the baseline period, prior to the first feeding, the frequency distribution of behavioral states did not differ between the two groups, nor did the data analysis detect any group differences during the baseline periods of the second or third feedings. During the ATVV intervention period, however, significant differences in the proportional distribution of behavioral states between the 2 groups were identified ($P < .0001$). These significant differences persisted across the 1-minute immediate postintervention ($P < .0001$) and 3-minute extended postintervention periods ($P < .0001$). Observations of group E infants doc-

Table 2. Total Frequency of Feeding Readiness Behaviors for the 3 Feedings by Group

	Control Group				Experimental Group			
	Feeding Number				Feeding Number			
Variables	**1**	**2**	**3**	**Sum**	**1**	**2**	**3**	**Sum**
Mouthing	58	19	73	(150)	67	60	82	(209)
Hand to mouth	59	18	38	(115)	116	68	120	(304)
Swipes at mouth	20	17	21	(58)	46	26	31	(103)
Sucking on hand	138	14	13	(165)	30	24	52	(106)
Tonguing	187	40	173	(400)	226	205	236	(667)
Sucking on tongue	21	10	5	(36)	17	6	22	(45)
Rooting	46	24	93	(163)	75	35	57	(167)
Yawning	12	19	11	(42)	17	30	47	(94)
Grand total	541	161	427	1129	594	454	647	1,695

umented sleep states 51% of the time during baseline and 39% of the time during the administration of the ATVV intervention. This contrasted with the group C infants, who were observed as asleep 68% of the time during the baseline period and 77% of the time during the period that the experimental infants received the ATVV intervention. The ATVV intervention resulted in a progressive increase in infant alertness from 23% of the time during the baseline period, 36% during the ATVV intervention, 39% during the 1-minute immediate post-intervention, and 40% during the 3-minute extended post-intervention period. Within group C, the percentage of time spent in alert states was less than 10% during the baseline, intervention, and the 1-minute postintervention periods. Although this percentage increased to 28% by the end of the 3-minute extended postintervention period, it is of note that this percentage was still less than that of the experimental group. During the intervention period, when only the experimental infants received the ATVV intervention, drowsiness accounted for 20% for group E infants as compared to only 7% for group C infants.

Feeding Readiness Behaviors

The frequency of each feeding readiness behavior was consistently higher for the experimental group across the 3 feeding/intervention sessions (Table 2). Repeated measures ANOVA identified significant differences between the groups for the number of feeding readiness behaviors observed across the 3 phases of the intervention for mouthing ($P < .001$), hand to mouth ($P < .001$), swiping at mouth ($P < .01$), tonguing ($P < .001$), rooting ($P < .001$), and yawning ($P < .001$) behaviors (Table 3). Descriptive statistics revealed that these differences were in the direction of a greater number of each of these behaviors for the group E infants. Although group E was also

Table 3. Average Number of Each Feeding Readiness Behavior per Infant by Phase of the Intervention Session

Variables	**Control Group Mean (SD)***			**Experimental Group Mean (SD)***			**Repeated Measures ANOVA**
	Baseline	**Intervention**	**Post**	**Baseline**	**Intervention**	**Post**	***P* value**
Mouthing	1.5 (2.5)	2.8 (5.4)	.73 (1.4)	.91 (1.4)	4.4 (4.7)	1.0 (1.5)	< .001
Hand to mouth	.80 (1.5)	2.3 (3.7)	.70 (1.5)	1.7 (2.2)	6.0 (6.9)	1.5 (2.5)	< .001
Swiping at mouth	.53 (1.3)	.97 (2.1)	.43 (1.2)	.67 (2.3)	2.0 (3.3)	.45 (1.0)	.011
Sucking on hand	1.3 (5.0)	4.0 (16.1)	.27 (.69)	.45 (.71)	2.1 (3.0)	.67 (1.6)	.175
Tonguing	3.4 (7.6)	6.9 (13.7)	3.0 (7.5)	2.0 (3.9)	14.6 (13.9)	3.6 (6.2)	< .001
Sucking on Tongue	.47 (1.3)	.43 (1.4)	.30 (1.3)	.21 (1.1)	1.0 (2.3)	.12 (.42)	.149
Rooting	1.3 (4.3)	3.4 (8.8)	.73 (1.4)	.85 (1.9)	3.3 (3.8)	.94 (1.9)	.001
Yawning	.50 (1.0)	.87 (1.2)	.03 (.18)	.52 (.80)	2.0 (2.4)	.33 (.74)	< .001

Note. Phases of the intervention session not equal in length (Baseline = 5 minutes; Intervention = 15 minutes; Post Intervention = 4 minutes).

*Means and Standard Deviations of each feeding readiness behavior by phase of the intervention session.

more likely to show the sucking on tongue behavior, the difference was not statistically significant. Post-hoc Dunnett analyses revealed a greater number of mouthing, hand to mouth, swiping at mouth, tonguing, and yawning behaviors in group E during the 15-minute intervention phase as compared to that of group C ($P < .05$; Table 3).

Feeding Efficiency

The feeding volume and duration of feeding were compared to determine differences between the 2 groups in feeding efficiency. No significant differences in feeding volume and duration of feeding were found between the groups via repeated measures ANOVA, for all 3 feedings, or one-way ANOVA, for each feeding separately. Despite lack of significance, the duration of feeding increased over the 3 feedings by almost 4 minutes for the group C infants. Initially the mean duration of feeding for group C infants was 9.3 minutes, which increased to 10.6 minutes and 13.1 minutes for the second and third feedings, respectively. In contrast, group E infants showed a nearly 1-minute decreased duration of feeding, which occurred over the course of the 3 feedings. The duration of feeding for the experimental infants varied from a mean of 13.3 minutes for the first feeding to 14.4 minutes and 12.6 minutes for the second and third feedings, respectively.

Discussion

In this study, ATVV intervention significantly shifted the distribution of observed behavioral state from sleep to alert states for infants in group E, while group C infants were more often observed in sleep states. Both group E and group C infants experienced the greatest increase in alertness during the last three minutes of observation, most likely due to natural arousal out of hunger. Nonetheless, during the last 3-minute observation period (extended postintervention), significant differences persisted between the 2 groups with group E experiencing the greatest increase in alertness. The data derived from this study document the ability of the ATVV intervention to increase alertness when these preterm infants receive it immediately prior to feeding. Additionally, these data are the first to document that alertness continues to increase during the first 3 minutes after completion of the ATVV intervention. Continued ATVV intervention with subsequent feedings appeared to further enhance the infant's alert state, eliciting a trend toward improved feeding efficiency. These findings are similar to previous research that documented the importance of alertness prior to feeding and compared two methods for changing behavioral state prior to feeding.[4,21,22] Our research differs in that it sought to evaluate the effect of behavioral state modulation on subsequent feeding efficiency.

Group differences in the frequency of 6 feeding readiness behaviors were noted when the two groups were compared by the frequency of each feeding readiness behavior across the three phases of the intervention session (Table 3). Post-hoc Dunnett analyses further revealed that there were significantly more feeding readiness behaviors in group E during the administration of the intervention for 5 of 6 of these behaviors. These findings suggest that infants who receive at least 3 ATVV intervention sessions show significantly more feeding readiness behaviors than those who do not receive the intervention sessions. This finding, coupled with the aforementioned increase in alertness, may have modified group E's feeding efficiency. Indeed, a trend that documented the reduced duration for an identical volume of feeding was noted for the group E infants.

Conclusion

Our findings support the use of the ATVV intervention prior to feeding as a means of increasing the frequency of feeding readiness behaviors and modulating prefeeding behavioral state. In light of the trends noted in the present paper concerning improved feeding efficiency, future research should evaluate whether increased alertness after ATVV intervention is related to improved caloric intake at lower energy costs and *significant* increases in measures of feeding efficiency. If greater feeding efficiency is documented for infant's receiving the ATVV intervention as compared to that of control infants, it may be worth considering the incorporation of the ATVV intervention into the standard of clinical practice for these at-risk infants. Further research investigating the long-term effects of ATVV intervention on the time required to transition from gavage to full oral feeding, length of hospital stay, and parent-infant interaction is warranted for both severely premature and central nervous system injured infants. Central nervous system injured infants are particularly at-risk for having difficulty transitioning to oral feeding as well as organizing behavioral state. Thus, these infants might benefit greatly from ATVV intervention. Future research should be conducted to evaluate the physiologic, feeding-related, and behavioral indicators of central nervous system integration in infants in whom the ATVV intervention is administered. Subsequently, extending this research to central nervous system injured infants may significantly add to our knowledge of neural plasticity of the developing and/or injured brain.

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