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Development of Preterm Infants

Feeding Behaviors and Brazelton Neonatal Behavioral Assessment Scale at 40 and 44 Weeks' Postconceptional Age

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The purpose of this study was twofold: (1) to explore potential changes in the Brazelton Neonatal Behavioral Assessment Scale (BNBAS) from 40 to 44 weeks postconceptional age (PCA) and (2) to determine the relationship between the BNBAS scores and feeding behaviors in preterm infants at 40 and 44 weeks PCA. The BNBAS and sucking behavior measurements were completed on 104 preterm infants at 40 and 44 weeks PCA. The Orientation ($p = .001$), Motor ($p = .001$), Range of State ($p = .001$), Autonomic Regulation ($p = .01$), and Reflexes ($p = .00$) clusters were significantly more mature at 44 weeks PCA than at 40 weeks. Infants that were extremely early born ($n = 24$) had a significantly larger change in BNBAS scores over time as compared to the more mature preterm infants ($n = 77$), largely catching up with their more mature preterm counterparts. At 40 and 44 weeks PCA, the BNBAS cluster scores for orientation ($p = .02$), motor ($p = .048$), range of state ($p = .048$), and regulation of state ($p < .001$) were significantly related to the average maximum pressure, adjusted for gestational age and weeks PCA. Significant neurobehavioral maturation takes place between 40 and 44 weeks PCA in preterm infants, with the greatest changes occurring in the most preterm infants. These findings highlight the relationship between neurobehavioral maturation and feeding behaviors. **Key words:** *infant*, *neurobehavioral development*, *sucking*

THERE is evidence that early experiences affect subsequent development and maturation in profound and long-lasting ways.[1] The atypical early experiences of preterm infants are often associated with alterations in their development, thus changing, reorganizing, and redirecting their behavior.[2] Although preterm infants may have the opportunity for more and earlier experiences in their environment, the impact of their untimely birth alters and shapes their maturational process. This makes it difficult to compare and even quantify the maturation and development of their behaviors. Thus, all preterm infants at term are not developmentally equal and are also uniquely different from their full-term counterparts at birth. Understanding how preterm infants are different from full-term infants is important for predicting long-term developmental outcomes and providing appropriate intervention for these infants.

Neurological assessment of preterm infants at 40 weeks' postconceptional age (PCA) continues to be a component of most predictive models for long-term developmental outcome.[3,4] When examined at 40 weeks' PCA, preterm infants are often noted to have decreased tone, increased head lag, and weaker or delayed integration of reflexes with more asymmetries as compared with their full-term counterparts.[5-7] These differences

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are especially apparent in preterm infants born prior to 28 weeks' gestation. It has been hypothesized that environmental experiences, as well as difficulties in modulating responses, may contribute to the differences noted in motor and behavioral development at term.[8,9] However, other than the results from 1 early study of 30 infants,[10] little is known about how these high-risk infants change in their organizational skills from 40 to 44 weeks' PCA, a time in which the infants should be stabilizing and adapting to their environment.

The development of behavioral organization in an infant can be evaluated with respect to various processes, such as feeding organization, motor maturity, behavioral state, and self-regulation.[11,12] The purpose of this study was to describe changes in feeding organization and other measures of neurobehavioral development (using a feeding assessment and the Brazelton Neonatal Behavioral Assessment Scale [BNBAS]). A secondary aim was to understand the relationship between the 2 measures at 40 and 44 weeks' PCA and how gestational age at birth may influence behaviors at 40 and 44 weeks' PCA.

METHODS AND INSTRUMENTS

Sample

Infants were born at 1 of 2 inner-city academic medical centers. This convenience sample of 104 infants had a mean gestational age (GA) of 30.45 ± 2.5 weeks at birth, and a mean birth weight of 1441.7 ± 426 g ($n =$ 34 for those ≤28 weeks' GA; $n = 67$ for those >28 weeks' GA). The mean maternal age was 28.45 ± 6.8 years. Infants were hospitalized for a mean of 40.33 ± 31.429 days, with a range from 7 to 183 days. Sixty-two percent of the infants were African American, 27.9% Caucasian, 6.7% Asian, 1% Hispanic, and 2% rated as other. The infants experienced the usual range of health complications during their hospitalization (Table 1). All infants were part of a larger study of feeding behaviors and developmental outcomes over the first year of life. This study was approved by the Institutional Board of the University of Pennsylvania, Philadelphia, Pa.

Table 1. Incidence of health complications

Health complication	Incidence ($n = 104$)
Bronchopulmonary dysplasia	52
Hydrocephalus	6
Necrotizing enterocolitis	12
Intraventricular hemorrhage >2	10
Pneumonia	21
Meningitis	6
Seizures	7

Medoff-Cooper nutritive sucking apparatus

To conduct a feeding assessment of the infants, microanalysis of nutritive sucking behaviors was conducted during a regular feeding utilizing the Medoff-Cooper nutritive sucking apparatus.[13] The hardware of the nutritive sucking apparatus continuously measures negative pressure generated by the infant during nutritive sucking. The nutritive sucking apparatus incorporates a silicone rubber–embedded calibrated capillary for metered flow of nutrient into an otherwise ordinary nipple. A second tube embedded in the silicone measures the intraoral pressure and is connected to a Cobe pressure transducer. The volume per suck (consumption) is proportional to the pressure-time integral, or area under the pressure-time curve of the suck cycle. Flow is calibrated such that a sustained 100 mm Hg pressure yields a constant flow of 30 mL/min. All materials used in the nipple setup are nontoxic and can be easily sterilized.

The pressure signal is fed on-line to an IBM-compatible computer, which displays the pattern of sucks throughout the session and creates a sucking record for off-line data analysis. The customized software was designed to capture the infant's nutritive sucking behaviors. This software generates a set of sucking parameters, including number of sucks per session, sucking duration (interval from first to last suck in session), number of bursts in session (a 2-second pause defined a separation of 2 bursts), mean burst duration, total burst time as a percentage of bout, within-burst suck frequency, mean maximum sucking pressure (P_{max}), the coefficient of variation (SD/mean) of the within-burst intersuck interval distribution, and the coefficient of variation of the session P_{max} distribution.

Brazelton Neonatal Behavioral Assessment Scale

The Brazelton Neonatal Behavioral Assessment Scale is a means of scoring interactive behavior for both full-term and stable preterm infants. The scale consists of 27 behavioral items, each scored on a 9-point scale, and 20 elicited responses, each scored on a 3-point scale. In most cases, the infant's score is based on the best performance, not an average performance. Areas of assessment include infant state, orientation, response to stimuli in environment, alertness, motor maturity, cuddliness, consolability, activity, lability of states, and smiling. A mean test-retest stability of all items was 0.592, with a range of 0.293 to 0.967. Reliabilities for independent tests range from 0.85 to 1.00. Testers can be trained at a 0.90 level of reliability, with this level remaining for long periods of time.[14]

Protocol

All infants were part of a larger longitudinal study. Infants were assessed at 40 weeks' PCA and again at 44 weeks' PCA. Parents were asked to feed the infants before traveling to their scheduled appointments at the laboratory. The BNBAS was administered immediately upon arrival in the research laboratory. The infants were fed their prescribed formula or breast milk. The 15-minute feeding assessment was divided into three 5-minute epochs: prefeeding, feeding, and postfeeding. Infants were lightly wrapped in 1 blanket and held by the research assistant or mother throughout the protocol. After the nipple was placed in the infant's mouth, infants were not provided with any further stimulation that could increase sucking activity.

Data analysis

For each of the BNBAS and sucking variables, Student's *t* tests, linear regressions, and repeated measures analysis of covariance were used to test the hypotheses: that the scores changed over time and that this change varied by gestational age group. Gestational age was classified into 2 groups: extremely early born ($\leq$28 weeks) and more mature preterm ($>$28 weeks). The relationship between the Brazelton scores and the sucking parameters were investigated using random coefficients or "mixed" models. Transformations were explored for nonnormally distributed parameters. However, no differences were detected in the model results for each of these parameters. Therefore, the untransformed scales were used for simplicity of interpretation. A post hoc power analysis of the sample showed that the study had 80% power to detect a moderate interaction (gestational age group × weeks' PCA) effect size of 0.66, assuming a type I error (α) of 5%.

RESULTS

Brazelton Neonatal Behavioral Assessment Scale

The Brazelton results are summarized in Table 2. There were significant differences in orientation, motor organization, range of state, regulation of state, and reflexes from 40 weeks' PCA to 44 weeks' PCA. Furthermore, significant between-subject effects for gestational age group were found in the orientation ($F = 5.47$, $df = 1$, $P_b = .021$), motor organization ($F = 4.52$, $df = 1$, $P_b = .036$), range of state ($F = 7.59$, $df = 1$, $P_b = .007$), and regulation of state ($F = 5.41$, $df = 1$, $P_b = .022$) scores across the 4-week period. A significant within-subject effect for gestational age group was also found for the motor organization scores ($F = 6.86$, $df = 1$, $P_w = .010$),

Table 2. Mean scores and standard deviations for the BNBAS clusters and the sucking variables, plus results from testing for a change in each variable over the 4-week period

	40 weeks' PCA $n = 101$	**44 weeks' PCA** $n = 99$	***P***
Brazelton cluster scores			
Cluster I: Habituation*	4.67 ± 2.27	5.02 ± 2.39	.512
Cluster II: Orientation	5.39 ± 1.34	6.51 ± 1.11	.000
Cluster III: Motor organization	4.26 ± 0.73	4.83 ± 0.84	.000
Cluster IV: Range of state	4.06 ± 0.61	4.44 ± 0.51	.000
Cluster V: Regulation of state	3.83 ± 1.06	4.33 ± 1.08	.000
Cluster VI: Autonomic stability	5.57 ± 0.89	5.47 ± 1.15	.567
Cluster VII: Reflexes	5.24 ± 2.39	4.51 ± 2.33	.018
	$N = 96$	$N = 96$	
Sucking parameters			
Number of sucks	204.28 ± 93.54	238.65 ± 140.58	.028
Sucking rate	0.68 ± 0.31	0.79 ± 0.48	.037
Number of bursts	21.09 ± 9.40	21.67 ± 9.89	.451
Sucks per burst	11.02 ± 8.47	13.34 ± 11.46	.124
Average interburst width	7.72 ± 6.75	6.33 ± 3.85	.032
Average suck width	0.38 ± 0.10	0.39 ± 0.11	.476
Average intersuck width	0.41 ± 0.12	0.40 ± 0.11	.395
Average maximum pressure	103.34 ± 44.18	132.79 ± 49.10	.000

*50% at 40 weeks' PCA and 67% at 44 weeks' PCA of Cluster I not completed.

with marginally significant effects for range of state ($F = 3.025$, $df = 1$, $P = .085$) and regulation of state ($F = 3.122$, $df = 1$, $p = .080$). That is, extremely early born (EEB) infants (≤28 weeks' gestational age) had significantly lower scores at 40 weeks' PCA compared to more mature preterm infants (>28 weeks). However, EEB infants had scores that increased more over the 4 weeks, so that by 44 weeks' PCA they had similar scores to the more mature preterm infants (Fig 1).

Feeding assessment

Significant differences were found in number of sucks, sucking rate, average interburst width (time between bursts), and average maximum pressure (intensity of sucking pressures) from term to 44 weeks' PCA (see Table 2). While there was *no overall difference* between the gestational age groups for most parameters, the rate of change in number of sucks ($F = 5.38$, $df = 1$, $P_w = .023$) and suck rate ($F = 5.51$, $df = 1$, $P_w = .021$) did vary by gestational age. For these parameters, EEB infants had slightly lower scores at term but their scores increased more than the more mature preterm infants, resulting in higher scores for the EEB infants at 44 weeks' PCA (see Fig 1). The only parameter that exhibited an overall difference based on gestational age was the intensity of sucking pressures ($F = 21.24$, $df = 1$, $P_b = .000$). The more mature preterm infants had higher sucking intensities across the 4- week period.

Relationship between BNBAS scores and feeding assessment

For the Brazelton scores, it was found that motor organization, range of state, regulation of state, and orientation scores were related to the average maximum pressure, having adjusted for gestational age, weeks' PCA, and any gestational age by weeks' PCA interaction (Table 3). For each cluster, the BNBAS scores

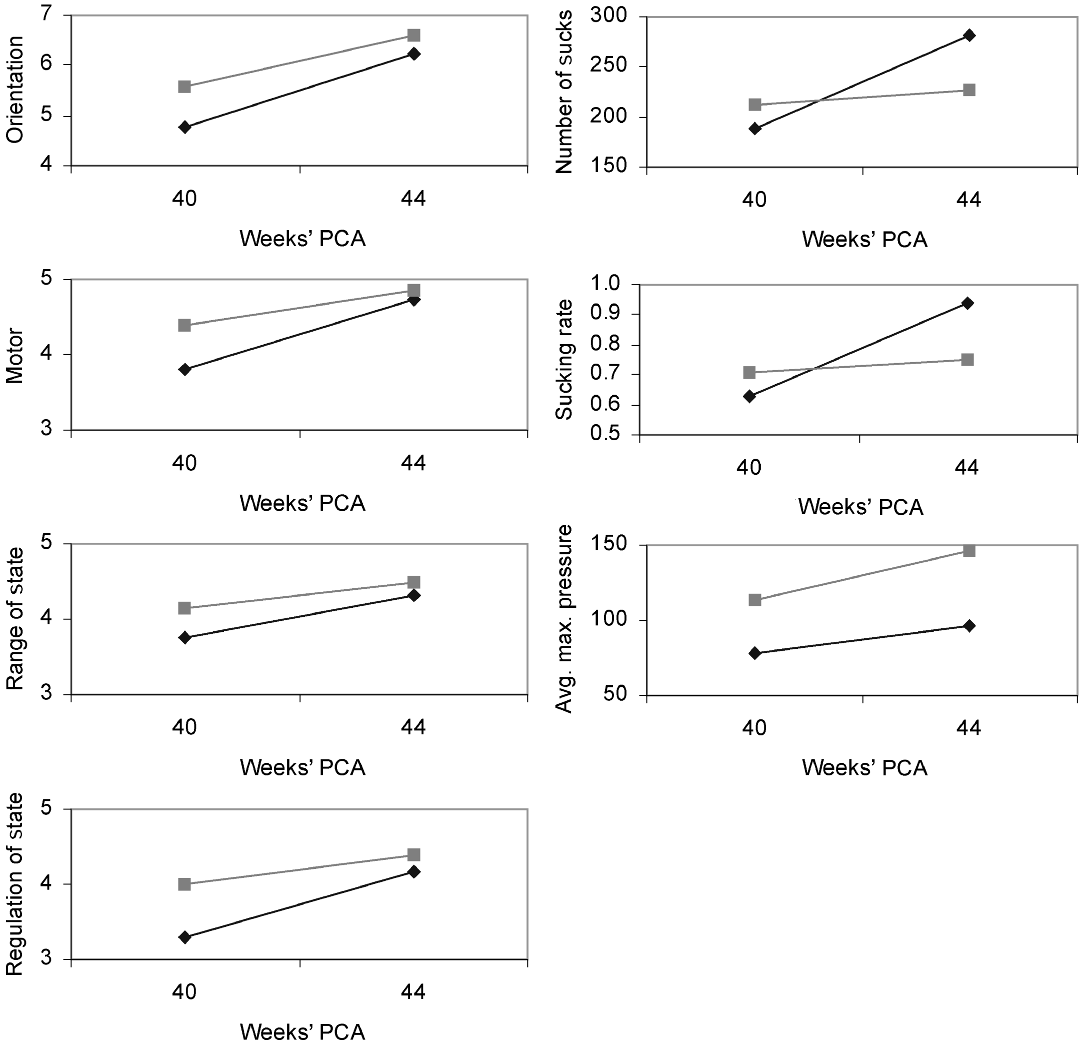

Figure 1. Average scores for each gestational age category at 40 and 44 weeks' PCA: ♦, extremely early born (≤28 weeks' GA); ■, more mature preterms (>28 weeks' GA).

increase as the pressure increases. None of the other sucking parameters were found to have a significant effect on any of the Brazelton scores across the 4-week period.

DISCUSSION

This study represents one of the first analyses of preterm infant neurobehavioral maturation from 40 to 44 weeks' PCA. Most studies using the BNBAS as a measure of infant neurologic and behavioral functions have had small sample sizes and have not been longitudinal in design.[15] In addition, there are no published normative values for either preterm or full-term infants. Rather, individual study means and standard deviations have been published for sample sizes ranging from 10 to 40 infants. According to the findings in the literature, preterm infants at term appear to be less organized, as assessed on the BNBAS, than full-term infants.[16] However, little is known about how the preterm infant neurobehavioral functions change over time or how these functions are related to other measures of maturity.

Table 3. Results for parameter estimates evaluated via random coefficient models

BNBAS score (dependent variable)	Mean maximum pressure	
	β (estimate)	***P***
Cluster II: Orientation	0.0050	.0176
Cluster III: Motor organization	0.0028	.0483
Cluster IV: Range of state	0.0020	.0476
Cluster V: Regulation of state	0.0072	.0002

The Brazelton scale is an instrument that elicits and evaluates the full range of newborn behaviors.[17] We have found the instrument useful in documenting changes in behavior. Preterm infants in our study appear to show maturation in 5 of the 7 cluster scores. At 44 weeks' PCA, the preterm infants were assessed to be more oriented, to have increased their motor skills, and to demonstrate a more stable range of states, as well as a more robust alert state. The reflex items, which were included to provide information about neurologic status as well as to allow the tester to produce a change in state,[18] do not provide further data on neurobehavioral maturation.

It was interesting to note that the habituation cluster could not be scored in 50% of the infants at 40 weeks' PCA and 67% of infants at 44 weeks' PCA. Habituation, a decrease in response to repeated disturbing stimuli (such as a light or a bell ringing), is state-related.[19] The expectation is that infants will lower their behavioral state with repeated stimulation. In fact, many of the infants remained in active alert states with little, if any, habituation noted during the assessment period. We hypothesize that in these preterm infants, who were now between 10 and 20 weeks' chronologic age, habituation may be difficult to assess. These infants were already in a wide-awake alert state, ready to interact with their environment rather than ignore it.

For the most part, little attention has been paid to sucking patterns, a basic behavioral function, as a clinically appropriate method of appraising brain function[20] or maturation. Nutritive sucking is characterized by repetitive mouthing on a nursing nipple associated with negative intraoral pressure sufficient to deliver liquid from the nipple.[21] Compared with nonnutritive sucking, it requires greater coordination between suck, swallow, and respiratory effort. It is organized as a continuous stream, rather than an alternation of bursts and rest periods, with a slower mean rate per second, about half that of nonnutritive sucking.[22] Although nonnutritive sucking also has definite patterns, nutritive sucking provides the infant with reinforcement that is more likely to motivate a steady level of behavior.[23] In this study, we have demonstrated maturational changes in sucking patterns between 40 and 44 weeks' PCA in 4 of the 8 parameters. Although the changes in the parameters were relatively small, they do mirror the patterns that we have found when examining differences in sucking patterns across gestational ages[24] and between preterm and full-term infants at term.[11] The infants increased the number of sucks, the sucking rate, and the mean maximum pressure they were able to generate with each suck. They also significantly decreased the time they needed to generate a new burst (average interburst width) as their PCA increased. These changes over time all demonstrate increasing maturation in their sucking patterns, which can be attributed to both increased maturity and increased feeding experience.[11]

We were very interested in how the BNBAS and feeding behaviors, both indices of neurobehavioral maturation, were related. Only the mean maximum pressure was found to be significantly related to motor organization, range of states, regulation of state, and orientation. It is not surprising that the mean maximum pressure per suck, an indicator of strength and coordination, was significantly related to the motor skills, state, range of state, and orientation clusters of the BNBAS, all of which are sensitive to the maturity of the infant.[25–28]

It appears that except for sucking strength, little if any relationship exists between sucking patterns and the BNBAS clusters. We hypothesize that, even though both assessments reflect maturation of brain function, for the most part the BNBAS items and feeding organization are tapping into different areas of the nervous system. Volpe[29] suggests that orientation and alertness are most likely related to activating the system of reticular gray matter present in diencephalons, midbrain, or upper pons. Although basic sucking responses are attributed to brain stem function, the organization of the sucking patterns and the coordination of suck-swallow-breath mechanism are thought to be regulated by cerebral functions. Disturbances in sucking organization may also be related to defects in the nuclear, nerve, or neuromuscular centers. This all supports our notion that sucking behaviors and the BNBAS items may indeed represent different functions within the maturational process.

In conclusion, it should be noted that significant neurobehavioral maturation takes place between 40 and 44 weeks' PCA in preterm infants, with the greatest changes occurring in the most preterm infants. However, the maturational process noted in both feeding behaviors and the BNBAS appear to be relatively independent of each other.

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