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Sucking Behavior of Pre-term Neonates As a Predictor of Developmental Outcomes

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Abstract

The relationship between the pattern of sucking behavior of pre-term infants during the early weeks of life and neurodevelopmental outcomes during the first year of life were evaluated. The study sample consisted of 105 pre-term infants (postmenstrual age [PMA] at birth = 30.5 ± 2.8 weeks [mean ± SD]; birth weight = 1476 ± 460 grams; mean length of hospital stay = 44.13 ± 32.6 days.) All infants received a 5-minute sucking test at 34 and at 40 weeks PMA, with outcomes evaluated at 6- and/or 12-months corrected gestational age (CGA) via the Bayley Scales of Infant Development (BSID). As expected, 6- and 12-month values for the Psychomotor Developmental Index (PDI) and Mental Development Index (MDI) of the BSID fell significantly below the normative levels established for infants delivered at term. A significant association between neonatal sucking pattern at 40 weeks PMA and developmental outcome at 12 months CGA was obtained.. Each of the three simple sucking parameters evaluated (number of sucks, mean duration of sucking bursts, and mean sucking pressure peaks), as well as a composite parameter (average of the respective parameter z-scores), was significantly related to both PMI and MDI at 12 months. Multivariable models, adjusting for PMA at birth, length of hospital stay, and other predictors, affirmed that sucking performance at 40 weeks PMA was a significant, independent predictor of developmental status 1 year later. Standardization of an instrument for neonatal sucking assessment may offer a cost-effective early screening strategy for pre-term infants at greatest risk for developmental delay.

Early identification of pre-term infants who are at risk for significant cognitive and psychomotor delays remain a major concern for pediatric care providers. It is estimated that approximately half of infants delivered prematurely (< 37 weeks postmenstrual age [PMA]) will receive, or would otherwise benefit from, remedial educational attention by the time they reach school age [1]. Neurodevelopmental delays in this population, in fact, become apparent during the first year of life. For example, pre-term infants, on average, score about one standard deviation below full-term norms for the mental and psychomotor developmental indexes (MDI and PDI) of the Bayley Scales of Infant Development (BSID) [2] . Close attention to developmental progress is indicated for the most premature infants, those with very low birth weights, and infants with salient pre-term comorbidities such as intraventricular hemorrhage [3], or bronchopulminary dysplasia [4]. Infants receiving such attention, however, represent a modest fraction of more than 500,000 pre-term infants born each year in the US [5] As a result, no early indication is available for a large number of pre-term infants with apparently 'uncomplicated' courses of care and discharge who, nevertheless, may experience significant delays in cognitive and psychomotor development. At present, there is an urgent need for a clinically useful and cost-effective instrument for stratification of developmental risk across infants born prematurely [6].

In the present study, we explore the extent to which the pattern of nutritive sucking of pre-term infants during the neonatal period can account for between-infant variability in developmental outcomes evaluated at 6 and 12 months corrected gestational age (CGA). Beginning with Wolff [7], a number of researchers have shown that the character of sucking behavior provides an indirect indicator of normal or abnormal brain function in the young infant [8-10]. Maturity of sucking organization parallels neurological development, as evaluated over the first weeks after pre-term delivery [11, 12], and across groups of infants born at different gestational ages [13]. These studies establish a clear association between sucking organization and the contemporary neurological status of preterm infants. Mizuno et al. [14] further indicated the prognostic potential of a sucking assessment. They reported a significant association between sucking performance of infants born prematurely and tested between 40 and 42 weeks PMA, and BSID measurements obtained when the same infants reached 18 months CGA. The pattern of sucking was shown to be a better predictor of developmental outcome than was perinatal cranial ultrasound and other neonatal measurements taken in the study. This precedent encourages further evaluation of the potential of a nutritive sucking assessment as part of a standardized early screen for developmental risk, and further methodological development. One limitation of the protocols used in the cited study was feeding status assignments given in categorical terms (4 levels of 'feeding maturity'), based on visual inspection of sucking pressure waveforms. In addition, the PMA range of the study sample was narrow, with the infants best described as "near-term" (mean PMA = 37.8 weeks), leaving open the relevance of the findings to those infants born more prematurely and, in the aggregate, at greater risk for developmental delays.

Here, we apply an automated analysis of the pattern of sucking of pre-term infants (birth range: 28 – 34 weeks PMA) during separate 5-minute tests delivered at 34 and 40 weeks PMA, and evaluate the association between neonatal sucking performance and BSID outcomes evaluated at 6 and 12 months CGA. Sucking organization was characterized by three simple parameters derived from each sucking record: the number of sucks emitted (SN), the average number of sucks per burst (SBP), and the session-average of the sucking pressure peaks (Pmax). These parameters have been shown to vary consistently as a function of PMA at birth [12, 15, 16] and across other conditions of clinical interest [10, 17]. We hypothesized that these parameters taken individually, and as a composite "suck maturity index" (SMI), would be independently and positively correlated with neurodevelopmental outcomes.

Methods

Sample: The study sample consisted of 105 subjects who had developmental outcomes measured at 6 and or 12 months of age. Of these subjects, 54 had measurements taken at both 6 and 12 months; 41 had measurements only at visit one; and 10 had visits only at visit two. The infants were predominantly African-American (65.9%) (28% Caucasian, 2% Hispanic, 2% Asian, and 2% other) and half (54%) were female. The mean maternal age was 28.1± 6.9 years, with over 42% completing some college education. In contrast, 26% of the mothers had less than a high school education, with the remaining 32% having completed high school. Table 1 presents study sample characteristics, including postmenstrual age at birth (PMA), length of hospital stay (LOS), and birth weight.

Apparatus: Sucking performance was evaluated with a Nutritive Sucking Apparatus (NSA), providing a continuous record of the negative sucking pressure generated by the infant during the test session. The NSA incorporates a silicone rubber-embedded calibrated capillary for metered flow of nutrient into an otherwise ordinary nipple. The sucking signal is derived from a Cobe pressure transducer embedded in a second tube. The volume delivered 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 100mg/Hg pressure yields a constant flow of 30 ml/min. All materials used in the nipple set-up are non-toxic and easily sterilized. The pressure signal was fed on-line to an IBM compatible computer, which displayed the pattern of sucks throughout the session and stored the pressure waveform for off-line analysis. Customized software was developed to detect each sucking event and to derive the three session summary parameters selected for further analysis (below): the number of sucks per session (SN); the average number of sucks per burst (SPB) within the session (2-sec pause defined separation of 2 bursts), and the mean maximum sucking pressure (Pmax) for all recorded sucks. In addition, a composite parameter labeled the “suck maturity index” (SMI) was derived for each session (see below).

Bayley Scales of Infant Development: The Bayley Scales of Infant Development, Second Edition (BSID-II) are composed of 3 distinct scales which measure mental acuities and abilities (mental developmental index- MDI), degree of control of body coordination and fine motor skills (psychomotor developmental index- PDI), and the child's social and objective orientation to the environment (Infant Behavior Record). The Bayley scales have been used since 1958 and remain one of the most accurate and sensitive ways to measure infant development. The Bayley scales were standardized on 1262 children ranging in age from 2 to 30 months. The standardization sample was stratified to control for sex, race, socioeconomic status, and urban vs. rural home. The validity of the Bayley scales is supported by the correspondence between scores on the Bayley Mental Scale and the Stanford-Binet Intelligence Scale. Internal consistency reliability of the Bayley scales range from .68 to .93. Test-retest reliability was .76. The Bayley scales were administered by developmental experts who have been trained in the administration of these scales. The BSID-II was completed at 6 and 12 months of age.

Procedure: The 5-minute sucking assessment was completed at 34 and 40 weeks post menstrual age (PMA) approximately 30 minutes prior to a late morning scheduled feeding. Infants were picked up, swaddled and brought to a quiet alert state prior to a feeding assessment. The 34 week measurement was completed by a member of the research team. The 40 week measurement was completed at an out-patient visit. The infant’s parent was given instructions on how to hold the infant and the feeding device. Infants were swaddled and held in an upright position. Once the nipple was inserted into the infant’s mouth, no attempts were made to assist the infant sucking movements.

Data Analysis: Analyses were conducted with Stata 10.0 and SPSS, with two-sided tests of hypotheses and a p-value < 0.05 as the criterion for statistical significance. The primary variables of interest for the analysis were the sucking parameters derived from the tests delivered at 34 and 40 weeks PMA: SN, SBP, Pmax, and the SMI composite. SMI was calculated as the average of the z-scores (parameter value minus mean, divided by standard deviation) of SN, Pmax, and SBP. The primary developmental outcomes of interest were the MDI and PDI subscales of the BSID, measured at 6 and 12 months of age. The primary goal in the analysis was to identify significant correlates of increased MDI and PDI, and in particular to test if sucking scores are significant independent correlates of improved developmental outcomes. Initial analyses were descriptive and included summarizing infant demographics and BSID outcomes (Tables 1 and 2) via calculation of means, standard deviations (SDs), ranges, and 95% confidence intervals for the means. Next, (Tables 3a and 3b) means, SDs, and inter-correlations (with p-values for identification of correlations that differed significantly from zero) were computed for the sucking parameters.

Multivariate analyses were then conducted to test the hypothesis that sucking scores are significant correlates of MDI and PDI when the models are adjusted for additional covariates. We constructed generalized estimating equation (GEE) models (Tables 4 and 5) using the xtgee procedure in Stata 10.0 that considered MDI and PDI simultaneously at 6 and 12 months. Implementation of GEE for analysis of MDI and PDI was the same as conducting multivariable regression, but with one additional step to account for the fact that two measurements (MDI and PDI) were collected on each subject at each visit: This involved specifying a regression model for expected MDI and PDI, but also specifying a 2 by 2 correlation matrix to describe the association between MDI and PDI at each visit. The GEE approach could therefore be viewed as an extension of regression that adjusted for the correlation between the MDI and PDI measurements that were measured on subjects at each visit.[18] The first GEE models included SMI at 34 weeks, in addition to the variables Caucasian (that took value 1 for Caucasian subjects and 0 otherwise), male (that took value 1 for male), PMA, and length of stay in weeks. The subsequent GEE models then included SMI at 40 weeks, in addition to the variables that were just mentioned. If the regression coefficients for SMI differed significantly from zero, this would indicate that SMI was an independent predictor for MDI and PDI.

A secondary analysis considered a binary outcome that considered both MDI and PDI as simultaneous outcomes on each subject, to allow for improved power for the lowest 10% of the combined outcomes. For this analysis, a logistic GEE model was used to test the hypothesis that infants with lower SMI values at 40 weeks would be significantly more likely to be in the lowest 10% of subjects with respect to 12-month MDI and PDI. Implementation of logistic GEE was the same as conducting logistic regression, coupled with specification of a 2 by 2 correlation matrix to adjust for the correlation between MDI and PDI that were collected on subjects at each visit.***[18]***) The logistic GEE regression models considered a binary outcome on each infant that took value 1 if the infant was in the lowest 10% with respect to MDI and PDI; and took value 0 otherwise; the models included SMI as a covariate. This approach also allowed for adjustment for the correlation between the two outcomes that were measured on each subject at 12-months.

Results

Developmental Outcomes: Values for the MDI and PDI assessments at 6- and 12-month CGA are shown in Table 2. For the group as a whole, each outcome was significantly lower than the normative mean of 100 for infants delivered at term [19, 20].

Univariate analyses:

Sucking parameters: Sucking performance values (mean ± SD) derived from tests delivered at 34 and 40 weeks PMA are shown in the left columns of Table 3a and 3b, respectively. The three session summary parameters are shown (total number of sucks emitted [SN], mean number of sucks per burst [SPB], and the mean pressure maximum across all recorded sucks [Pmax]), as is the composite score (SMI) given as the average z-score for the respective parameters.

Pairwise correlations among the three primary parameters were significant for both the 34- and 40-week sucking tests (Table 3). For the 40-week test, the three session summary parameters as well as SMI were each significantly associated with each BSID outcome (PDI and MDI) assessed at 12-months CGA (Table 3b). A more limited set of significant associations was obtained between 34-week sucking performance and 12-month outcomes, excepting SPB as related to MDI and Pmax as related to both MDI and PDI. By contrast, no sucking parameter was correlated with BSID outcomes from the 6-month assessment. The SMI was chosen for subsequent analyses for simplicity of presentation, and for the statistical advantages of treating a single (representative) sucking parameter in multivariable models. .

Multivariate Analyses:

A GEE models treating BSID outcomes (MDI and PDI) concurrently provide a concise account of the predictive value of SMI taken alone, and when the other predictor variables were included. The results were consistent with those of respective GEE analyses treating the two outcome variables separately (results not shown). As expected, the associations between MDI and PDI values were significant ($r^2 = 0.56$, $p < 0.0005$).

SMI at 40 weeks PMA and 12-month BSID outcomes: An initial GEE analysis evaluated the relationship between SMI and BSID outcomes, with an included term representing the interaction between SMI and subscale type (PDI, MDI). A significant association between SMI and outcomes was obtained (95% confidence interval = 5.79, 16, 60; $p < 0.0005$). The interaction term was not significant, indicating that the impact of sucking did not differ according to whether the outcome was MDI or PDI. Importantly, SMI was still significantly associated with 12-month outcomes after adjustment for additional covariates (Table 4). SMI, in fact, was the only significant correlate when all potential predictors were included. Thus, PMA and LOS, although individually correlated with 12-month MDI and with PDI values, respectively, were not uniquely associated with the outcomes in the inclusive GEE model (PMA: $p = 0.74$; LOS: $p = 0.14$)

We sought to determine whether a low sucking score significantly increased the likelihood that an infant's PDI or MDI outcome would be less than 70 (approximately at or below the 10th percentile for either). (Ten out of the 63 infants had at least one outcome that met this criterion.) The logistic GEE model yielded a significant result ($p < 0.015$; odds ratio = 0.22; 95% CI = 0.07, 0.74).

SMI at 34 weeks PMA and 12-month BSID outcomes: An initial GEE analysis showed a significant relationship between SMI and combined BSID outcomes (95% CI = 2.09, 11.11; $p < 0.005$); the interaction term [SMI X outcome type (MDI, PDI)] was not significant. The correlation between SMI and outcomes was expected given the significant univariate correlations between 34-week SMI and the respective MDI and PDI outcomes (see Table 3a). A significant overall result was obtained for the inclusive GEE model treating SMI and other neonatal variables, but no predictor was shown to be uniquely associated with the BSID outcomes in this adjusted model (Table 5). This result speaks to the high degree of intercorrelation among the three predictors (SMI, PMA and LOS) with respectively significant univariate associations with the 12-monthy MDI and PDI.

Discussion

The present findings are consistent with the suggestion [14] that the organization of sucking behavior during the neonatal period can provide an early indicator of risk for emergent neurodevelopmental delays in infants born prematurely. Based on manual inspection of suck-pressure records and categorical ratings of feeding status, Mizuno et al. [14] demonstrated a significant association between feeding performance of infants born near-term (mean PMA at birth = 37.8 weeks PMA) and tested at 42 weeks PMA, and BSID outcomes assessed at 18 months CGA. We also report a significant relationship between neonatal sucking and BSID values, but with developmental outcomes evaluated at an earlier age than in the study of Mizuno et al. (12 vs. 18 months CGA) and, importantly, with a sample of infants that were considerably more premature at birth (range 28 – 34 weeks PMA). The replication and extension of the earlier indications are encouraging, particularly in light of the present methodological developments. Here, the subjective elements of the sucking assessment were eliminated through a fully automated analysis of the sucking pattern, yielding a simple set of summary parameters expressed in ratio scale. The two studies taken together commend further development of protocols for neonatal sucking assessment. An optimized test delivered in clinical settings may help address the largely unmet need for a simple, cost-effective screen for pre-term infants at greatest risk for delayed cognitive and psychomotor development.

A significant association between neonatal sucking performance and developmental outcomes was obtained here specifically with respect to the BSID scoring performed when the infants reached 12 months CGA. Six-month outcomes were not associated with sucking performance tested at either 34 or 40 weeks PMA. Univariate analyses revealed that SMI at each testing point was a significant predictor of the 12-month MDI and PDI subscales of the BSID, with strength of association on a par with that of PMA at birth and of length of hospital stay (LOS). There was a high degree of intercorrelation among these parameters, such that when 34-week SMI, PMA and LOS were evaluated concurrently, neither of the three stood out uniquely as a predictor of neurodevelopmental status. By contrast, when 40-week SMI was evaluated in this manner, sucking performance was shown to be a significant, independent predictor of MDI and PDI at 12-months. SMI, in fact, was the only neonatal parameter in the adjusted model significantly related to 12-month outcomes. The relatively stronger result derived from the latter sucking test may reflect sucking that is more robust on average, with stable individual-infant differences in sucking organization emerging as a function of increasing sucking experience. Alternatively, the apparent contrast may have obtained by chance, given variability in sucking performance under the present testing protocols (see below) and the study's modest sample size. Clarification of the matter, relevant to determining the optimal timing for delivery of a feeding-related screen for developmental risk, requires further study.

The indicated association between neonatal sucking performance and developmental outcomes may be noteworthy from a clinical perspective. With respect to 40-week SMI and the 12-month outcomes, a decrease of one standard deviation in the sucking score predicted a salient reduction in the BSID average below the group mean (estimated declines of 9.5 and 6.4 points, as derived from the initial and adjusted GEE models, respectively). Such a result would represent an aggravated burden when viewed in relation to average scores for pre-term infants that already fall well below the full-term norms [1, 21]. The potential clinical utility of neonatal sucking evaluation was further indicated by the GEE logistic model, where 40-week SMI was a significant predictor of whether an infant's 12-month PDI or MDI values would fall in the lowest 10% of the sample (here, with at least one subscale value below 70). Given the modest sample size and the small number of subjects falling below the cutoff, however, this result should be regarded as preliminary and in need of replication.

Further work may qualify the interpretation of the current findings. It is also possible that the present results underestimate the prognostic potential of neonatal sucking assessment. It should be emphasized, first, that each reported associations with 12-month developmental outcomes was based on a single 5-minute sucking test. The protocol was standardized such that tests were initiated as closely as possible 30 minutes before the late morning, feeding. Nevertheless, the inherent variability of infant sucking performance, arousal level and temperament (day to day and meal to meal) is well known. Such within-subject variability would have operated here to weaken the sensitivity of the method for detecting real differences between infants in sucking organization. A better estimate of an infant's maturational status may be derived from two or more tests delivered the same day and/or over consecutive days. Separately, it will be important to determine whether test sensitivity varies as a function of time of day. Protocols optimized to capture reliable differences in sucking organization between individual infants, therefore, may yield greater strength of association between neonatal sucking and developmental outcomes than that reported here. Empirical evaluation of this possibility must be provided in future studies.

Given the present lack of clinical guidelines for early identification of pre-term infants at greatest risk for developmental delays, and the scale of the present “screening gap”, it is important that all potentially useful approaches – analysis of neonatal feeding organization among them – be further explored. For example, comprehensive neurobehavioral assessment regimes, such as the Neurobehavioral Assessment of the Preterm Infant [NAPI][22], the Neonatal Intensive Care Unit Network Neurobehavioral Scale [NNNS][23], and others, have been shown to discriminate outcomes across groups of pre-term infants with different risk profiles (e.g., between infants of very- versus extremely-low birth weights; between pre-term infants with or without prenatal exposure to cocaine or methamphetamine [24, 25]). Further work may indicate the (added) value of such protocols for stratifying developmental risk across infants within particular at-risk groups, such as otherwise healthy pre-term infants born within a given PMA range. Assessments of brain morphology and function may reach points of development suitable for discriminating between-infant differences in developmental risk. At present, however, only between-group (e.g., pre-term vs. control) sensitivities have been demonstrated [26, 27]. Another direction comes from work on the organization of sleep patterns, where profiles were shown to differ between pre-term and full-term neonates [28, 29] and to vary as a function of PMA at birth and over time in pre-term infants [30, 31]. Importantly, parameters related to sleep state organization of pre-term neonates have been associated with individual differences in developmental outcomes assessed later in infancy [32, 33]. The different approaches have yet to be compared and contrasted systematically, and it may be determined that the strongest prognostic models incorporate metrics derived from a combination of tests. Although future clinical research may yield encouraging results, the 'cost factor' will be a significant obstacle for widespread deployment of assessments, such as those noted, that involve elaborate or expensive equipment and/or personnel with specialized training. Therein lies a particular practical advantage of neonatal feeding assessment as part of a screening instrument for developmental risk in pre-term infants. With further evidence supporting its predictive value, cost concerns may be mitigated by a recording device that should be inexpensive at scale, and by an automated measurement and analysis system that would minimize the need for specialized training in test delivery and interpretation [9].

In conclusion, evaluation of the sucking organization of pre-term infants during the neonatal period offers a potentially useful and cost-effective approach to developmental risk assessment. The link between early sucking performance and risk for emergent developmental days is not likely a direct one; i.e., with significant delays arising as a consequence of weak or poor quality feeds early in life. Rather, poor sucking performance and elevated developmental risk would appear to be epiphenomena of immature or compromised neurobehavioral function in pre-term neonates. Further work is needed to verify and extend the present findings, and to develop protocols with greater sensitivity for detection of stable and reliable individual differences in neonatal sucking organization.

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Table 1: Infant Demographics

Study Sample	**N = 105**
Birth weight (mean ± SD)	1476.1 ± 459.6 grams (mean ± SD)
Gestational age at birth	30.5 ± 2.8 weeks (range 28 – 34 weeks)
Male	46.1%
White	28.6%
Maternal age	28.1 ± 6.9 weeks
Length of stay	41.6 ± 31.4 days
IVH *	11% (n = 16; n = 3 with grade III or III-IV)
BPD *	13% (none requiring O_2 supplementation at time of hospital discharge)

- **= Diagnosed at birth**
- **IVH- Intraventricular Hemorrhage**
- **BPD Bronchopulmonary Displasia**

Table 2: Bayley Sclaes of Infant Development Scales: PDI and MDI Subscales

Bayley Subscales	**Mean ± SD**	**95% Confidence Interval**
6-Month Assessment (N = 95)		
MDI	89.4 ± 10.7	87.4, 91.5
PDI	84.7 ± 17.8	81.3, 88.2
12-Month Assessment (N = 63)		
MDI	91.2 ± 13.2	88.1, 94.3
PDI	88.7± 17.0	84.7, 92.7

MDI- Mental Developmental Index
PDI- Psychomotor Developmental Index

Table 3a: 34-Week Sucking Parameters: Inter-correlations and Relation to 6- and 12-Month Developmental Outcomes

Feeding Parameter mean ± SD	SN (p)	SPB (p)	Pmax (p)	PDI6 (p)	MDI6 (p)	PDI12 (p)	MDI12 (p)
SN 115.8 ± 78.1	1.00			0.17 (0.11)	0.05 (0.60)	0.32 (0.01)	0.28 (0.03)
SPB 6.85 ± 6.07	0.75 (0.00)	1.00		0.11 (0.31)	0.07 (0.47)	0.26 (0.04)	0.16 (0.22)
Pmax 61.30 ± 33.4	0.26 (0.003)	0.26 (0.013)	1.00	-0.04 (0.67)	-0.02 (0.86)	0.05 (0.72)	0.05 (0.70)
SMI **0.029 ± 0.79**	0.87 (*)	0.85 (*)	0.64 (*)	-0.09 (**0.38**)	-0.10 **(0.35)**	0.42 (**0.000**)	0.37 **(0.002)**

*** = <0.0005**

Table 3b: 40-Week Sucking Parameters: Inter-correlations and Relation to 6- and 12-Month Developmental Outcomes

Feeding Parameter mean ± SD	SN (p)	SPB (p)	Pmax (p)	PDI6 (p)	MDI6 (p)	PDI12 (p)	MDI12 (p)
SN 241.3 ± 76.8	1.00			-0.06 (0.57)	-0.09 (0.39)	0.29 (0.02)	0.25 (0.05)
SPB 13.9 ± 13.0	0.49 (0.0000)	1.00		-0.11 (0.29)	-0.17 (0.11)	0.43 (0.001)	0.38 (0.002)
Pmax 117.5 ± 41.3	0.23 (0.03)	0.24 (0.02)	1.0000	-0.02 (0.85)	0.06 (0.54)	0.30 (0.017)	0.28 (0.028)
SMI **[-0.05 ± 0.63]**	0.78 (*)	0.78 (*)	0.60 (*)	-0.09 **(0.29)**	-0.19 **(0.35)**	0.42 **(0.001)**	0.38 **(0.002)**

- **= <0.0005**

- **SN Suck Number**
- **SPB Sucks Per Burst**
- **PMax Mean Maximum Pressure**
- **SMI Sucking Maturity Index**

Table 4: *Generalized Estimating Equations* Analysis of 34 Week Sucking Maturity Index at 12 Months

Outcome	Coefficient	Std. Error	z	P >|z|	[95% Conf. Interval]
SMI 34	3.367693	2.036807	1.65	0.098	-.6243762, 7.359762
Gestational Age	-.2121059	1.105186	-0.19	0.848	-2.37823, 1.954018
Male	-1.680172	3.0252	-0.56	0.579	-7.609455, 4.249111
LOS week	-1.291921	.7140157	-1.81	0.070	-2.691366, .1075243
White	.8120479	3.211843	0.25	0.800	-5.48305, 7.107145
Cons	104.1657	37.26191	2.80	0.005	31.13369, 177.1977

SMI 34 Sucking Maturity Index at 34 Weeks Post Menstrual Age
LOS Length of Stay

Table 5: *Generalized Estimating Equations* Analysis with 40 Week Sucking Maturity Index at 12 Months

Outcome	Coefficient	Std. Error	z	P >|z|	[95% Conf. Interval]
SMI 40	6.444341	2.988561	2.16	0.031	.5868694, 12.30181
Gestational Age	-.904588	1.156309	-0.34	0.736	-2.656782, 1.875864
Male	-4.106641	3.113005	-1.32	0.187	-10.20802, 1.994736
LOS week	-1.088891	.7439668	-1.46	0.143	-2.547039, .3692573
White	.3595041	3.273896	0.11	0.913	-6.057214, 6.776223
Cons	110.2118	38.80872	2.84	0.005	34.14812, 186.2755

SMI 40 Sucking Maturity Index at 40 Weeks Post Menstrual Age
LOS Length of Stay