Published in final edited form as:
Acta Paediatr. 2009 February ; 98(2): 286–290. doi:10.1111/j.1651-2227.2008.01111.x.

The relationship between birth weight and feeding maturation in preterm infants

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Abstract

Aim—To report changes in ingestive behaviour from 35 to 40 weeks post-conceptual age and examine the association between birth weight and feeding maturation in preterm infants.

Methods—One hundred and four preterm infants born 24 to 34 weeks gestational age were studied. Feeding maturation was assessed as the change from 35 to 40 weeks post-conceptual age in the number of sucks over 5 min, sucking bursts, sucks per burst, time between bursts and maximum pressure during a suck (Pmax). The association between birth weight and each sucking behaviour was examined after adjusting for potential confounders.

Results—Significant changes in feeding maturation occurred between 35 and 40 weeks. Birth weight was positively associated with change in Pmax and change in number of sucks per burst for extremely premature infants born 24 to <29 weeks gestational age but not for very premature infants born ≥29 to 34 weeks. The association between birth weight and change in Pmax for extremely premature infants remained significant after adjustment (adjusted beta = 0.128 mmHg increase in change in maximum sucking pressure per every 1 g of birth weight, 95% CI = 0.017, 0.239, p = 0.03).

Conclusion—Birth weight is positively associated with maturation in maximum sucking pressure among infants born extremely premature.

Keywords

Birth weight; Gestational age; Infant feeding behaviour; Preterm infant

INTRODUCTION

Birth weight is an important determinant of future nutritional status and growth patterns in infancy (1). Low birth weight has been associated with future undernutrition and growth faltering (2). An important mediator of the association between birth weight and infant growth may be feeding maturation. Infant feeding involves integrative coordination of sucking, swallowing and breathing (3), and impaired nutritive feeding may be an indicator of neurobehavioural dysfunction (4,5).

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In at-term infants, nutritive sucking frequency and maximal negative sucking pressure increase, and time between successive bursts and sucks decreases with increasing post-conceptual age (6). However, there is limited data on feeding skill development in preterm infants and potential contributing factors (7,8). Gestational age is associated with feeding maturation in preterm infants (6,9), but birth weight may be an important biological condition that may influence infant cognitive and motor development (10) that has not been sufficiently examined. Birth weight and gestational age may each have a separate influence on infant neurodevelopment (11). Additionally, extremely early born preterm infants demonstrate increased morbidity and mortality as birth weight decreases, independent of gestational age (12,13). No known study has examined the association between premature infants' feeding maturation and birth weight. Understanding developmental changes in feeding behaviour and the association between feeding maturation and birth weight could lead to interventions to improve the postnatal care of preterm infants in order to optimize future health and promote adequate growth. The purpose of this study was to assess changes in nutritive sucking parameters from 35 to 40 weeks post-conceptual age and to examine the association between birth weight and feeding maturation after adjusting for potential confounding variables in preterm infants.

METHODS AND PROCEDURES

Participants

One hundred and four preterm infants were studied. Utilizing a sample of convenience, infants were recruited from neonatal intensive care units (NICU) at two teaching hospitals once infants were medically stable. Parents of all potentially eligible preterm infants born 24–34 weeks gestational age were consecutively invited to participate. Infants were excluded if they had any congenital abnormalities that could affect feeding, if they were unable to oral feed by the age of 35 weeks or if they were still on ventilators, continuous positive airway pressure or nasal cannula oxygen at the age of 35 weeks. Approximately half of the potentially eligible infants admitted to the participating neonatal units annually chose to participate in the study.

Infants' Apgar score at 5 min after birth was used for this study as a measure of physiologic condition at birth. Intraventricular haemorrhage (IVH), bronchopulmonary dysplasia (BPD), sepsis and periventricular leukomalacia (PVL) was also documented. Length of hospitalization was recorded as the number of days infants remained in the hospital after birth. Maternal education was self-reported as high school or less, some college or college graduate or post-college. The study was approved by the Institutional Review Board at the University of Pennsylvania, Philadelphia, PA.

Feeding maturation

The Medoff-Cooper nutritive sucking apparatus (MCNSA) was used to measure infant feeding behaviour. The MCNSA is comprised of a premature nipple that has a flow-limiting device to deliver 30 ml/min at a constant 100 mmHg pressure. Silicone rubber-embedded calibrated capillary tubing is used for measuring metered nutrient flow. A second tube embedded in the silicone measures the intra-oral pressure and is connected to a pressure transducer. By ensuring viscous flow through the capillary, the instantaneous volumetric flow rate is maintained directly proportional to the pressure (14). Transducer output is recorded to a computer system and customized software was designed to capture the infant's nutritive sucking behaviours.

Nutritive sucking behaviours were measured 15 min prior to a regular feeding. Feeding maturation was assessed as the change in each of the feeding variables between 35 and 40 weeks post-conceptual age. At 35 weeks, infants were assessed in the NICU and arrangements were made with the primary care nurse to schedule an assessment during a regularly scheduled feeding. At 40 weeks, mothers returned with their infants for the follow-up assessment. During

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each feeding, infants were awake and alert, and held in the arms of a nurse researcher or the mother during the feeding assessment. Feeding variables measured over 5 min at each time point included the number of sucks, number of sucking bursts, number of sucks per burst, time between bursts and maximum pressure generated during a suck (Pmax).

Analytic Plan

Most variables were skewed, as has been shown in other populations for biological variables (15) and are, therefore, described using medians, 2.5th and 97.5th percentiles. Categorical variables are reported as proportions in percentage. Characteristics for each sucking parameter at 35 weeks, 40 weeks and the change from 35 to 40 weeks were computed. Additionally, descriptive analyses were also conducted after categorizing gestational age into two groupings: extremely premature infants (24 to <29 weeks gestational age) and very premature infants (≥29–34 weeks gestational age). These cut points have previously been used to define prematurity status (16,17). Significant differences in feeding maturation from 35 to 40 weeks and between preterm infant gestational age groups were tested using repeated measures analysis of variance. Simple linear regression analyses tested unadjusted associations between birth weight and each feeding parameter change. Because of the potential association of gestational age at birth with feeding maturation, linear regression models were also used to examine associations between gestational age and change in each feeding behaviour. Then each feeding parameter change was regressed on birth weight after adjusting for potential confounding variables chosen a priori: sepsis, IVH, BPD, Apgar score, race and maternal education. Because the association between birth weight and feeding maturation among preterm infants may vary by the degree of immaturity (18), the interaction by gestational age as a quasi-continuous variable (using week intervals) on the association between birth weight and feeding maturation was also examined. All statistical tests were two-tailed and a value of $p < 0.05$ considered statistically significant. Analyses were conducted using SYSTAT version 11 (Systat Software, Inc., Richmond, CA, USA).

RESULTS

Infant demographic characteristics are provided in Table 1. There were no cases of PVL. Median infant birth weight was 1440 g. All infants were bottle-feeding at the time of testing. A sub sample of 44 infants was also breast-feeding in addition to bottle-feeding at the age of 35 weeks. Significant changes in feeding maturation status occurred between 35 and 40 weeks (Table 2). There were no statistically significant differences between extremely premature infants and very premature infants for change from 35 to 40 weeks in any of the feeding parameters.

Neither birth weight nor gestational age at birth was related to maturation of infant feeding in analyses with all preterm infants in simple linear regression. Birth weight and gestational age at birth remained unrelated to feeding maturation after adjustment for sepsis, IVH, BPD, Apgar score, race and maternal education. The interaction term of continuously expressed gestational age and birth weight was added to the adjusted models to assess the impact of birth weight by gestational age on feeding maturation. The interaction was statistically significant ($p < 0.01$) in models examining change in Pmax, which indicates that the association between birth weight and feeding maturation depends on gestational age. To explore the interaction, we conducted separate analyses by prematurity status. In regression analyses, birth weight was positively associated with change in Pmax and change in number of sucks per burst for extremely premature infants born 24 to <29 weeks gestational age but not for very premature infants born ≥29 to 34 weeks. The association between birth weight and change in Pmax for extremely premature infants remained significant after adjustment (adjusted beta = 0.128 mmHg increase in change in maximum sucking pressure per every 1 g of birth weight, 95% CI = 0.017, 0.239, p = 0.03) (Table 3).

DISCUSSION

The results of this study indicate that birth weight is positively associated with 35 to 40 week maturation in Pmax, an indicator of feeding strength/intensity, for the most premature infants after adjusting for sepsis, IVH, BPD, Apgar score, race and maternal education. This suggests that among preterm infants, low birth weight infants who are extremely preterm may be the most at risk for nutritive feeding maturation problems compared with less preterm infants. Maturational changes observed for preterm infants reflect improved neurobehavioural maturation, and can be attributed to increased maturity and experience with feeding (19).

A potential implication for the positive association between birth weight and change in Pmax in the most preterm infants is that expectations of feeding maturation in the NICU could be adjusted based on birth weight and birth status. Extremely premature infants of low birth weight may take longer to feed because of greater difficulty controlling nutritive flow, putting them at risk for greater ongoing nutritional and feeding difficulties beyond their time in the NICU. There are also clinical implications related to future child health outcomes. For the most preterm infants, around full term, they may still have difficulties in their neurological maturation compared with preterm infants who were born older (19). The fact that the association between birth weight and maximum sucking pressure remained significant for the most premature infants compared with less premature infants even after adjusting for sepsis, IVH and BPD, suggests that the explanation for the slower neurological development of the most preterm infants may be the result of more severe prematurity and not just greater medical complications. This is consistent with the fact that extremely premature infants are at increased risk for poorer neurodevelopmental outcomes later in childhood (20,21).

Additional clinical considerations include potential intervention strategies to prevent future morbidity associated with low birth weight. For example, low birth weight for post-conceptual age is a risk factor for cardiovascular disease and diabetes in adulthood (22). On the one hand, vigorous feeding in infancy in order to accelerate growth and improve nutritional status could help reduce infant morbidity and mortality in low birth weight infants. However, recent studies suggest that catch-up growth and rapid postnatal weight gain may be associated with the development of chronic adult diseases such as obesity, cardiovascular disease and type 2 diabetes (23,26). Unfortunately, data on follow-up weight to assess the role of feeding maturation on future weight gain were not collected in this study. Future research is needed to determine if a more intense infant feeding style is associated with early rapid weight gain and with overweight in childhood, and if it is the most preterm infants that have the greatest risk. If this is the case, then strategies to modify accelerated growth will need to weigh the benefits of improved nutritional status with the potential costs of future chronic disease (2).

This is the first known study to characterize feeding maturation from 35 to 40 weeks post-conceptual age and to examine the association of changes in feeding parameters with birth weight. Feeding maturation was precisely measured and a number of important covariates were included in the regression models. There are however several limitations of this study. There may be additional potential confounding variables of the association between birth weight and feeding maturation not measured in this study. For example, mother's affect and feeding behaviour influence the rate of weight gain and motor development in premature infants (27, 28), and were not assessed in this study. More importantly, gestational age is correlated with infant birth weight and this could potentially confound the association between birth weight and feeding maturation. We attempted to address this by using gestational age as a quasi-continuous variable using week intervals, with an interaction term of continuously expressed gestational age and birth weight used to assess the impact of birth weight differences within gestational ages. Additionally, our sample was comprised of 9 infants with birth weight <10th percentile, typically defined as SGA and therefore not adequately powered to examine differences between SGA and AGA infants. Additional research is needed to clarify the independent contributions of birth weight and gestational age on feeding maturation in preterm infants, and to investigate the physiologic mechanisms for these relationships. A second limitation is that infant weight gain was not assessed. Therefore, it is not possible to determine the relationship between feeding maturation and rate of growth. However, this study provides support for future hypotheses that examine the role of feeding maturation in early rapid weight gain. Third, only the change in mean maximum pressure (Pmax) was found to be significantly associated with birth weight in adjusted analyses. Because in animal studies poor intrauterine nutrition may be associated with a lower number of muscle fibers (29), and theoretically muscle strength, it is plausible that birth weight is associated with Pmax, an indicator of feeding strength/intensity, while the other feeding parameters are not. Finally, the reported sucking mechanisms relate to bottle-fed infants and the findings may not apply to infants not yet able to bottle-feed or with neurological or congenital conditions that influence bottle-feeding.

In conclusion, this study provides preliminary information on feeding maturation in infants born preterm and indicates that significant neurobehavioural maturation occurs between 35 and 40 weeks post-conceptual age. Birth weight may be an important biological indicator of changes in feeding strength in the most preterm infants. Additional research is needed to determine if feeding maturation is associated with the rate of early weight gain and health problems later in life.

ACKNOWLEDGEMENTS

The present study was supported by the Nutrition Center of The Children's Hospital of Philadelphia and by NIH/NINR funding, Grant No NINR R01-NR02093.

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Table 1

Infant demographic information

All infants, n = 104 unless otherwise noted	Median or proportion	2.5th–97.5th percentile
Gestational age (weeks)	31.0	24.1–34.0
Birth weight (g)	1440.0	632.4–2215.3
Sex, (% female)	51%	NA
Apgar score (5 min), (n = 101)	8	6–9
Length of hospitalization (days), (n = 102)	34.5	9.1–117.4
Sepsis, n	47	NA
Bronchopulmonary dysplasia, n	12	NA
Intraventricular haemorrhage, n	Grade 1: 7	NA
	Grade 2: 2	
	Grade 3: 3	
	Grade 4: 0	
Extremely premature infants (24 to <29 weeks gestational age, n = 29)		
Gestational age (weeks)	27.0	24.0–28.0
Birth weight (g)	952.0	596.9–1431.0
Sex, (% female)	41%	NA
Apgar score (5 min)	8	2.1–9
Length of hospitalization (days)	71.0	54.0–123.3
Sepsis, n	16	NA
Bronchopulmonary dysplasia, n	11	NA
Intraventricular haemorrhage, n	Grade 1: 2	NA
	Grade 2: 2	
	Grade 3: 3	
	Grade 4: 0	
Very premature infants (≥29 to 34 weeks gestational age, n = 75 unless otherwise noted)		
Gestational age (weeks)	32.0	29.0–34.0
Birth weight (g)	1560.0	936.3–2262.6
Sex, (% female)	55%	NA
Apgar score (5 min), (n = 72)	8	6–9
Length of hospitalization (days), (n = 73)	25.0	9.0–60.1
Sepsis, n	31	NA
Bronchopulmonary dysplasia, n	1	NA
Intraventricular haemorrhage, n	Grade 1: 5	NA
	Grade 2: 0	
	Grade 3: 0	
	Grade 4: 0	

Table 2

Feeding behaviours for all infants, extremely premature infants and very premature infants for 35 weeks, 40 weeks and change from 35 to 40 weeks post-conceptual age, mean (SD)

	All Infants (n = 104)		
	35 weeks	**40 weeks**	**Change 35–40 weeks**
Maximum pressure (mmHg)	59.52 (27.4)	104.31 (37.5)	44.79 (37.4)**
# Sucks	148.14 (65.1)	207.05 (83.2)	58.90 (94.7)**
# Bursts	20.83 (8.1)	22.78 (9.1)	1.95 (11.6)
Suck/burst	8.02 (6.6)	10.58 (8.0)	2.56 (8.4)**
Interburst width (sec)	8.33 (3.6)	7.11 (6.1)	−1.22 (6.9)
	Extremely premature infants (24 to <29 weeks gestational age, n = 29)		
Maximum pressure (mmHg)	51.41 (25.0)	88.81 (40.3)	37.41 (43.5)**
# Sucks	129.45 (62.3)	195.69 (97.3)	66.24 (113.2)*
# Bursts	21.86 (9.0)	24.10 (8.6)	2.24 (11.3)
Suck/burst	6.44 (4.5)	10.27 (10.7)	3.82 (10.3)
Interburst width (sec)	9.70 (4.7)	6.79 (3.1)	−2.91 (5.5)*
	Very premature infants (≥29 to 34 weeks gestational age, n = 75)		
Maximum pressure (mmHg)	62.66 (27.8)	110.30 (34.8)	47.64 (34.7)**
# Sucks	155.37 (65.1)	211.44 (77.33)	56.07 (87.3)**
# Bursts	20.43 (7.7)	22.27 (9.3)	1.84 (11.8)
Suck/burst	8.63 (7.2)	10.70 (6.8)	2.07 (7.6)*
Interburst width (sec)	7.80 (3.0)	7.23 (6.9)	−0.56 (7.3)

* $p < 0.05$;

** $p < 0.001$.

Table 3

Association between birth weight and feeding maturation for extremely premature infants (24 to <29 weeks gestational age)

Dependent variable	Unadjusted (n = 29)	p-value	Adjusted* (n = 23)	p value
Change in maximum pressure (mm Hg)	B = 0.088 (0.023,0.154)	0.01	B = 0.128 (0.017,0.239)	0.03
Change in # Sucks	B = 0.110 (−0.078,0.298)	0.24	B = 0.082 (−0.222,0.386)	0.57
Change in # Bursts	B = −0.017 (−0.035,0.001)	0.06	B = −0.013 (−0.044,0.018)	0.38
Change in suck/burst	B = 0.018 (0.001,0.034)	0.03	B = 0.012 (−0.014,0.038)	0.35
Change in interburst width (sec)	B = 0.001 (−0.008,0.011)	0.77	B = 0.000 (−0.018,0.018)	1.00

B = Beta estimate (95% CI).

*Adjusted for sepsis, bronchopulmonary dysplasia, intraventricular haemorrhage, Apgar score, race and maternal education.