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Breastfeeding and Mental and Motor Development at 5 ½ Years

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Abstract

Objective—Breastfeeding is associated with better child development outcomes, but uncertainty remains primarily due to the close relationship between breastfeeding and socioeconomic status. This study assesses the issue in a low socioeconomic status sample where breastfeeding was close to universal.

Methods—784 Chilean children were followed longitudinally from infancy. All but 4 were initially breastfed, 40% nursed beyond 12 months, and infant growth was normal. Child development was assessed at 5 ½ years by a cognitive, language, and motor test battery. The duration of breastfeeding as the sole milk source was analyzed as a continuous variable, adjusting for a comprehensive set of background factors.

Results—The relationship between breastfeeding and most 5 ½ -year developmental outcomes was non-linear, with poorer outcome for periods of breastfeeding as the sole milk source for < 2 months or > 8 months – statistically significant for language, motor, and one comprehensive cognitive test, with a suggestive trend for IQ.

Conclusions—The observed non-linear relationships showed that breastfeeding as the sole milk source for < 2 months or > 8 months, compared to 2–8 months, was associated with poorer development in this sample. The latter finding requires replication in other samples where long breastfeeding is common and socioeconomic status is relatively homogeneous.

Keywords

breastfeeding; mental development; motor development

INTRODUCTION

Whether or not breastfeeding is advantageous to mental and motor development has generated much interest, with over 50 relevant studies.(1–11)(see(12) for a review of 40 earlier studies)

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Many studies report a positive association between breastfeeding and better developmental outcomes as assessed in infancy, childhood, or adulthood. A recent meta-analysis concluded that a 3-point increment in cognitive function was associated with breastfeeding over formula feeding.(13) However, a number of other studies found no significant association between breastfeeding and development after adjustment for confounders.(14–23) Furthermore, many studies reporting a positive association did not control for the most influential factors—maternal intelligence and stimulation in the home.(24)

Two recent critical reviews(12;25) used methodological standards proposed by Bauchner et al.(26) to evaluate the available studies. Standards included adequate sample size, identification of target population, high quality feeding data, control of susceptibility bias, blinding, outcome based on standardized individual measures obtained when the child was ≥ 2 years old, and format of results indicating clinical significance. Of the 40 studies in the latest review,(12) only 2 met all the criteria. One of them reported a positive association between breastfeeding and cognitive development,(27) while the other did not.(23) The critical reviews concluded that pervasive methodological weaknesses warrant caution in interpreting the results of available studies.

Other limitations of the literature deserve mention. Research on this issue has been conducted almost exclusively in Europe, the United States, Australia, and New Zealand, where breastfeeding is highly confounded with socioeconomic status. Also, most studies have compared infants who were breastfed to infants fully formula fed. Since the decision to breastfeed can be closely related to socioeconomic status, the results of such comparisons may be inherently biased. As well, there is a need for more attention to motor development, which has been assessed in less than half of the previous studies.

Given the ubiquitous connection between breastfeeding and family factors, plus the mixed results of previous studies, our prediction was that there would be no relationship between breastfeeding and developmental outcomes at 5 ½ years in a socioeconomically homogeneous population where breastfeeding was universal.

METHODS

Sample

Data for this analysis were collected in the course of a study of the behavioral and developmental effects of preventing iron deficiency anemia in healthy full-term infants.(28) The infancy phase of the study was conducted between 1991 and 1996 in urban communities near Santiago, Chile. Infants were identified as potential study participants at the 4-month health maintenance visit. The entrance criteria were gestational age ≥ 37 weeks, birth weight ≥ 3.0 kg, singleton birth, and absence of major congenital anomalies, major birth or neonatal complications, Cesarean section, jaundice requiring phototherapy, hospitalization for other than an uncomplicated problem, chronic illness, or iron therapy. The 3.0 kg birth weight cutoff was used because some clinics had a preexisting program to provide iron to infants weighing < 3.0 kg.

Infants were screened at 5–6 months to prevent any with iron-deficiency anemia from entering the study. At 6 months, infants consuming ≥ 250 ml/day cow milk or formula were randomly assigned to high- or low-iron-fortified formula or unmodified cow milk plus multivitamins without iron. Infants taking < 250 ml/day, including those infants who received breast milk as the sole milk source, were randomly assigned to a liquid multivitamin with or without iron. After randomization, the infancy study entailed collection of information on feeding during weekly home visits, measurement of maternal and family factors, and developmental

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assessment of the infant at 12 months. Refusal/dropout before random assignment totaled 6.0%. Attrition after group assignment was 7.8%. There were no differences between those who did or did not complete the study in infant characteristics, family characteristics, or iron supplementation. A total of 1657 infants completed the infancy phase of the study. Full details have been previously published.(28)

The follow-up at 5 ½ years did not include the entire sample due to funding constraints. It focused on the high-iron and no-added iron conditions (n = 1252 in infancy). Developmental assessment and measurement of maternal and family factors were collected for 784 subjects (37% attrition). The sample population was highly mobile and approximately half of those not tested moved out of the area or were unable to be located. The other half declined to participate or repeatedly missed testing appointments. There were no differences between those who were or were not tested at 5 ½ years in gestational age, birth weight/length, number of children in household, single parent status, parental education, maternal IQ, depression, and age. Children not in the 5 ½ year follow-up had somewhat lower socioeconomic status ($p<.01$) and less supportive home environments ($p<.05$), but differences were small (1 point or less).

The research protocols for both the infancy and 5 ½-year phases were approved by the IRBs of the University of Michigan Medical Center, Ann Arbor, and of INTA, University of Chile, Santiago.

Developmental assessment at 5 ½ years

Developmental outcomes at 5 ½ years included the Wechsler Preschool and Primary Scales of Intelligence – Revised (WPPSI-R),(29) the Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI),(30) the Preschool Language Scale – 3rd Edition (PLS-3),(31) the Broad Cognitive Abilities – Standard Scale (BCA) of the Batería Woodcock-Muñoz-Revisada (Batería-R),(32) (the parallel Spanish version of the Woodcock-Johnson-Revised), and the short form of the Bruininks-Oseretsky Test of Motor Proficiency.(33) All evaluations were conducted by psychologists specially trained and standardized for each measurement (≥ 80% inter-tester reliability). Psychologists were unaware of the child's feeding status in infancy.

Measurement of breastfeeding in infancy

Breastfeeding data were based on maternal recall for the period before study enrollment at 4–6 months. Prior to enrollment, infants were fed according to Chilean custom at the time, which often entailed mixed breast- and bottle-feeding. All but 8 infants completing the infancy phase of the study were initially breastfed, 4 of whom were reassessed at 5 ½ years. Formula use was uncommon, and clinics distributed unmodified cow milk as part of a legally required and effective program for preventing generalized undernutrition in infancy. Fieldworkers obtained subsequent information on milk feeding concurrently at subject enrollment and weekly home visits thereafter until the infant's first birthday. Mothers were almost always the informant. The following information was obtained: method of milk feeding, date of first bottle (cow milk or formula), the average daily amount of milk or formula during the preceding week, and, if weaned by 12 months, the date of complete weaning from the breast.

Our analysis considered the period of nursing as the sole milk source (up to 12 months). We did not analyze the age of weaning from the breast, because 40% of the sample was still nursing at 12 months when the infancy phase ended and breastfeeding data were not revisited during the 5 ½-year phase. It was also not possible to consider the length of exclusive breastfeeding per WHO definitions, since systematic data on the introduction of solid foods and juice were not collected. However, previous studies in the same communities showed that families generally followed Chilean pediatric recommendations of introducing fruits and cereals at 4 months of age, meat and vegetables at 6 months, and legumes and eggs at 9 months.(34)

Background factors

Project psychologists obtained detailed family information at the 5 ½-year evaluation. Socioeconomic status was measured by the Graffar, which differentiates families at the lower end of the socioeconomic status spectrum.(35) It includes questions about household composition, parental education, work, housing ownership, and major household possessions. Maternal depressive symptomatology was measured by the Spanish-language version of the Center for Epidemiologic Studies Depression Scale (CES-D).(36) Family support for child development was assessed by the questionnaire version of the Home Observation for Measurement of the Environment-Revised (HOME).(37)

Maternal IQ was measured in infancy using a short form of the Wechsler Adult Intelligence Scale-Revised (WAIS).(38;39) Data were available for 452 subjects. Only a random 10% of subjects enrolled in the last two years of the infancy study could be assessed due to lack of funds. Because data were not missing completely at random, we used multiple imputation to impute missing IQ for the remaining 332 subjects.(40)

Data analysis

To allow for non-linear relationships between days of breastfeeding as the sole milk source and developmental outcome, we used a generalized additive model (GAM).(41) GAM makes no assumption about the form of the relationship between independent and outcome variables, in contrast to general linear models, which assume a linear association and fit a straight line to the data to describe the relationship. We used multiple generalized cross-validation for automatic selection of the smoothing parameters. The error term was assumed to be normally distributed with constant variance. The partial residuals of the GAM were plotted for the duration of breastfeeding as the sole milk source and each developmental outcome, together with their 95% confidence intervals. Partial residuals indicate the relative influence of a given explanatory variable on the prediction. Thus, the plots indicate the nature of the relationship between breastfeeding and 5 ½ year outcomes.

The models included the following covariates identified *a priori* as important in the breastfeeding and child development literature:(7;12;13;24;25;42) gender, birth weight, child's age at testing, maternal education, IQ, depression, age, number of children, father absence, paternal education, HOME score, and socioeconomic status. Since maternal age and number of children (average 2.4) were substantially correlated ($r = 0.51$, $p<.0001$), we excluded number of children. We also controlled for three other important factors: overall nutritional status (weight-for-height *z*-scores at 12 months), iron deficiency anemia at 12 months, and iron supplementation group in the infancy study.(28)

We also wanted to facilitate comparisons with previous studies. Therefore, we conducted additional analyses of breastfeeding as a categorical variable to allow calculation of effect sizes. We converted breastfeeding data (in days) to months using 30.4 days per month (365 days per year/12 months). We categorized the duration of breastfeeding as the sole milk source into 3 groups: 0–61 days, "< 2 months" (n = 275; 35%); 62–243 days, "2–8 months" (n = 421; 54%); and > 243 days, "> 8 months" (n = 88; 11%). Groups were based on the inflection points from the results of the continuous analyses for the BCA, PLS-3, and IQ (WPPSI-R). Effect sizes for each 5 ½-year outcome were calculated by determining the difference in means between groups, divided by the sample standard deviation. Assessing the magnitude of effects also offset the risk that our relatively large sample size might result in statistically significant differences that would not be clinically meaningful. To identify background differences related to early or late introduction of cow milk/formula, we examined the variables in Table 1 by breastfeeding groups using ANOVA.

All analysis were carried out with SAS version 9.1 (SAS Institute Inc, Cary, NC), R version 2.1.1,(43) and the mgcv package version 1.3-7.(44) An alpha level of 0.05 was defined for tests of statistical significance.

RESULTS

Characteristics of the 5 ½-year sample are shown in Table 1. Fathers were absent from 19% of households. Both parents averaged slightly more than 9 years of schooling. Maternal depressive symptoms were common, as is often the case in mothers of young children in economically stressed environments.(45) Maternal IQ averaged in the mid 80's, similar to that of U.S. women of lower socioeconomic groups with less than a high school education.(46; 47)

Figure 1 shows the relationship between breastfeeding as the sole milk source as a continuous variable (in days) and developmental outcomes at 5 ½ years. The relationship is shown after adjusting for the comprehensive set of covariates mentioned above. A significant non-linear effect was found for 3 of 5 outcomes: Broad Cognitive Abilities – Standard Scale of the Batería Woodcock-Muñoz-Revisada (χ^2=8.20, p<.01), Preschool Language Scale-3rd Edition (χ^2=10.53, p<.01), and the Bruininks-Oseretsky Test of Motor Proficiency (χ^2=4.29, p<.05). For the Wechsler Preschool and Primary Scales of Intelligence-Revised, the non-linear effect showed a suggestive trend (χ^2=3.17, p=.07). Neither the linear nor non-linear effect was statistically significant for the Visual-Motor Integration Test. Poorer outcomes on the cognitive and language assessments (Figure 1a, 1b, 1d) were found for both the short and long extremes of breastfeeding as the sole milk source. Poorer outcome on the motor test was found for the long extreme only (Figure 1c).

Among the covariates in the models, HOME score was the strongest predictor for the cognitive and language outcomes, followed by maternal IQ for the cognitive outcomes and paternal education for the language outcome. For the motor outcome, gender was the strongest predictor, followed by HOME score.

Table 2 shows the results of categorical analyses comparing developmental outcomes in groups based on the duration of breastfeeding as the sole milk source (0–61 days, "< 2 months"; 62–243 days, "2–8 months"; and > 243 days, "> 8 months"). There was a significant non-linear effect for the same 3 outcomes in the continuous variable analysis: BCA, PLS-3, and the Bruininks-Oseretsky Test of Motor Proficiency. Children in the middle group (2–8 months) averaged 0.14 and 0.17 SD units higher on the BCA and PLS-3, respectively, than the < 2 months group and 0.22 SD units higher than the > 8 months group. On the motor test, there was no difference in scores between the < 2 and 2–8 months groups; the > 8 months group scored 0.39 SD units lower than the rest of the sample. Although the non-linear relationship for VMI was not statistically significant, the magnitude of effects comparing the 2–8 months group and > 8 months group was 0.20 SD units, which falls within the range found for statistically significant outcomes.

Regarding background differences that related to breastfeeding group, early introduction of milk/formula was associated with more father absence (p<.01) and higher maternal depressive symptoms (p<.01). Children with later introduction had greater weight-for-height *z*-scores at 12 months (p<.01) and were 1 week younger for the 5 ½-year follow-up (p<.05).

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DISCUSSION

We found a non-linear relationship between the duration of breastfeeding as the sole milk source and most developmental outcomes at 5 ½ years. The highest scores were observed among the children who received breast milk as the sole milk source for 2–8 months. Our finding that breastfeeding as the sole milk source past 2 months resulted in better cognitive and language outcomes than those breastfed < 2 months resembles numerous studies that report a positive association between breastfeeding and developmental outcome. The effect sizes we observed, though small, are similar to effect sizes reported in the literature (see(12) for a review of reported effect sizes). While the association between a short duration of breastfeeding as the sole milk source and higher maternal depression and more father absence points to background factors in our sample that may adversely affect breastfeeding early on, poorer 5 ½ year outcomes remained statistically significant controlling for these and other background factors.

Our findings regarding the short duration of breastfeeding as the sole milk source seem to support the biological and interactional effects of breastfeeding considered in most previous studies. Breast milk components not previously found in formula, such as long-chain polyunsaturated fatty acids, are thought to promote development. Another reason is interactional, i.e., nursing itself may foster the mother-child relationship, stimulating the breastfed infant and enhancing development. Our < 2 months group had the shortest window to receive these biological and interactional benefits. In addition, the use of unmodified powdered cow milk may have been detrimental to development.

In contrast to the short duration findings, our observation of poorer outcome at the longest duration of breastfeeding as the sole milk source (> 8 months) is distinct from most previous studies. It is also puzzling, given the many known benefits of breastfeeding. Compared to children receiving breast milk as the sole milk source for 2–8 months, children who received no other milk for > 8 months had lower cognitive and language test scores, like the short breastfeeding group. They also had the lowest motor scores of all groups, scoring 0.39 SD units in mean test performance below those who received some milk or formula before 8 months.

These findings clearly need to be replicated in other samples where many infants are breast fed into the second half of the first year of life and socioeconomic status is relatively homogeneous. Indeed, there is little basis for direct comparisons with previous studies, and caution is warranted in terms of generalizing these results. We found only 2 studies analyzing the duration of breastfeeding that reported a proportion of infants with long breastfeeding (> 8 months) similar to our sample.(4;48) The majority of other studies either contrasted children who received at least some breastfeeding with those who never breast fed, unlike our study where breastfeeding was virtually universal and extensive, or did not look at breastfeeding into later infancy.

That said, a very early study(49) reported that infants breastfed ≥ 10 months scored lower on cognitive measures than those breastfed shorter durations or not at all. However, there were also important background differences. A recent study on breastfeeding duration(4) reported a positive dose-response relationship for Verbal, Performance, and Full Scale IQ among adult males who were breastfed as infants up to 9 months but lower mean scores for those breastfed > 9 months. Lower scores in the long extreme were not discussed, perhaps because the differences in adjusted means between groups breastfed 7–9 months and > 9 months were not statistically significant nor were tests for a non-linear relationship. Using published data for that study, we calculated the magnitude of effects between the 7–9 months and > 9 months groups. The effect size was 0.13 SD units—similar to differences interpreted as meaningful in the breastfeeding and development literature. While small, it is important to note, as did Rogan and Gladen,(42) that even a small change in mean IQ can affect both the number of children falling below any given cutoff of concern and the number considered high functioning. Despite differences in definitions of breastfeeding and statistical analysis, these 2 studies and ours highlight the need for a closer look at breastfeeding in later infancy.

Possible explanations for the poorer outcomes we found with longer breastfeeding as the sole milk source include nutritional limitations, behavioral factors, harmful exposures, and unmeasured background factors. Perhaps breastfeeding no longer fully meets infants' nutritional needs in the second half of the first year of life. Although iron deficiency anemia did not differ between groups and was covaried in our analyses, there could have been other micronutrient deficiencies, such as zinc. The children in the > 8 months group had the highest weight-for-height *z*-scores at 12 months, which argues against zinc deficiency, but some other unidentified nutrient might have been inadequate given the rapid growth. The sample's rapid growth could also suggest that, from an evolutionary standpoint, breast milk may have been able to fully meet the needs of infants in the past who were not growing so quickly but could not do so in our population of large infants.

Behavioral factors are another possibility. Infants who receive breast milk as the sole milk source into the second 6 months of life might miss the developmental window for easily accepting other foods and thus develop nutrient deficiencies. Alternatively, long breastfeeding could reflect a limited repertoire of maternal response to infant distress. Harmful substances might be another factor. If environmental contaminants are found in breast milk, children with long breastfeeding as the sole milk source might have higher levels of toxic substances and be at greater risk for associated developmental ill effects.

There were no statistically significant differences in the study's comprehensive set of maternal or familial characteristics that might explain the lower test scores in the > 8 months group. However, mothers providing breast milk as the sole milk source for a long time might have differed in unmeasured ways. Maternal characteristics such as dominance, insecurity, self-esteem, etc. were not assessed. These and other unmeasured background factors might explain the findings. It should also be noted that our sample was of quite low socioeconomic status, and the results may not apply to populations with higher socioeconomic status.

In sum, this study found a non-linear relationship between the duration of breastfeeding as the sole milk source and 3 of 5 developmental outcomes at 5 ½ years, before and after adjustment for important confounders, with a suggestive trend for a 4th outcome. The observed non-linear relationships showed that breastfeeding as the sole milk source for < 2 months or > 8 months in this sample was associated with poorer development than breastfeeding as the sole milk source for 2–8 months. Our results regarding the short duration of breastfeeding agree with numerous prior studies. Our findings regarding the long duration of breastfeeding as the sole milk source are uncommon in the breastfeeding and child development literature, but there are few comparable studies. The latter findings should not detract from the well-known benefits of breastfeeding. Rather, they should invite replication in other samples where breastfeeding is extensive and socioeconomic status is relatively homogeneous.

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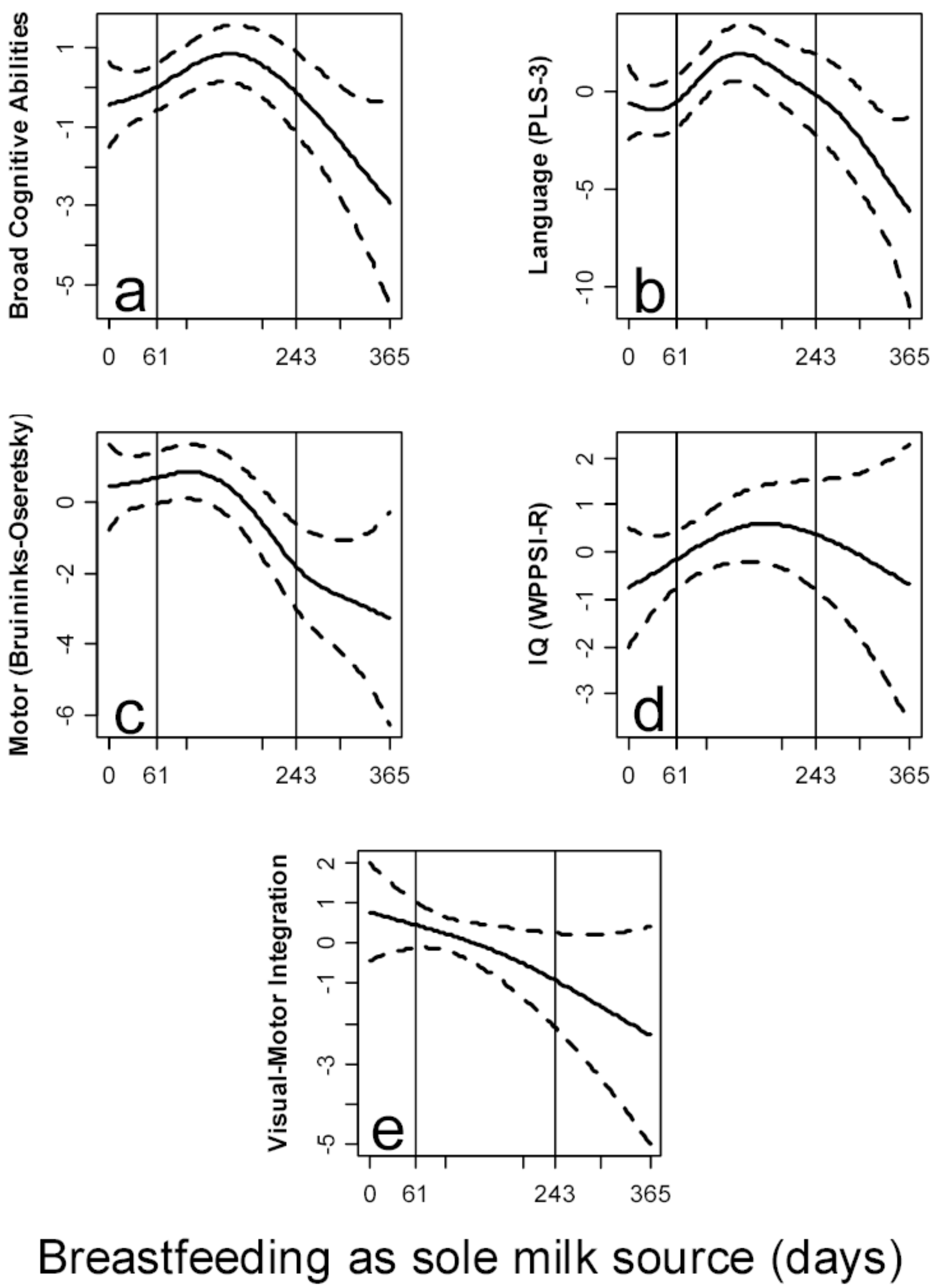

FIGURE 1. Relationship between duration of breastfeeding and developmental outcomes at 5 ½ years

The partial residuals (—) of the generalized additive model (GAM) are plotted for each developmental outcome, together with their 95% confidence intervals (- -). Confidence intervals are wider at the beginning and end (0 and 365 days) due to lower numbers of subjects. Results are shown after adjustment for all background factors listed in Table 1.

Table 1

Sample characteristics (n = 784)

	Values*
Child	
Child's age at testing, months	66.1 ± 0.0
Gender, % male	53 (415/784)
Birth weight, grams	3555 ± 13.2
12-month weight-for-height (z-score)	0.5 ± 0.0
Family	
Maternal age, years	26.7 ± 0.2
Father absent, %	19 (151/783)
Paternal education, years	9.7 ± 0.1
Maternal education, years	9.8 ± 0.1
Maternal IQ	84.3 ± 0.4
Maternal depressive symptoms (CES-D)	19.8 ± 0.5
Home environment (HOME)	34.8 ± 0.2
Socioeconomic index (Graffar)†	36.3 ± 0.3

*Values are means ± SE for continuous variables and percentages and n's for the categorical variables.

†The Graffar is a scale designed specifically to differentiate families at the lower end of the socioeconomic spectrum. A score of 36 falls in the medium range of the lower class spectrum.

Table 2

Categorical analyses results showing developmental outcomes and effect sizes by breastfeeding group*

	Breastfeeding group						
	< 2 months *n* = 275	2–8 months *n* = 421	> 8 months *n* = 88	t - statistic	Non-linear *P*†	Effect size < 2 v. 2–8	Effect size 2–8 v. >8
Broad Cognitive Abilities (BCA)	461.7 ± 0.5	462.8 ± 0.4	461.1 ± 0.8	−2.27	.02	.14	.22
Preschool Language Scale-3rd Edition	89.8 ± 0.7	91.8 ± 0.6	89.2 ± 1.3	−2.46	.01	.17	.22
Bruininks-Oseretsky Test of Motor Proficiency	52.7 ± 0.5	52.7 ± 0.4	49.6 ± 0.9	−2.42	.02	0	.39
IQ (WPPSI-R)	87.1 ± 0.6	88.4 ± .05	88.1 ± 1.2	−.97	.33	.12	.03
Visual-Motor Integration Test	97.8 ± 0.7	97.3 ± 0.6	95.0 ± 1.3	−.92	.36	.05	.20

*A total of 718 children had breastfeeding data, developmental outcomes, and covariates.

†Significance levels are shown for adjusted means and refer to tests of non-linear effects between breastfeeding groups and developmental outcomes. Values are means ± SE and are adjusted for gender, birth weight, age of child at testing, father absence, paternal education, maternal education, IQ, depression and age, HOME score, socioeconomic status, weight-for-height *z*-score at 12 months, iron deficiency anemia, and iron supplementation group.