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Pediatrics 2011;127:e137; originally published online December 20, 2010;
DOI: 10.1542/peds.2009-3489

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American Academy of Pediatrics

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Breastfeeding Duration and Academic Achievement at 10 Years

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KEY WORDS

breastfeeding, education, child development, Raine Study

ABBREVIATIONS

WALNA—Western Australian Literacy and Numeracy Assessment
WAMSE—Western Australian Monitoring Standards in Education
CI—confidence interval

Dr Oddy contributed to the development of the hypothesis and statistical analysis, wrote the main drafts of the manuscript, and is responsible for correspondence and requests for reprints; Dr Li played a lead role in the conceptualization of the article, undertook statistical analyses, and, with Drs Whitehouse and Zubrick, contributed to the interpretation and discussion of the results and other sections of the manuscript; and Dr Malacova wrote the literature review and contributed to the initial study design, interpretation of the results, and main drafts of the manuscript.

www.pediatrics.org/cgi/doi/10.1542/peds.2009-3489

doi:10.1542/peds.2009-3489

Accepted for publication Sep 10, 2010

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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FINANCIAL DISCLOSURE: *The authors have indicated they have no financial relationships relevant to this article to disclose.*



WHAT'S KNOWN ON THIS SUBJECT: It is not clear whether the benefits of breastfeeding on cognitive development reflect nutritional or socioeconomic advantages. Some studies have revealed no differences after adjusting for socioeconomic status, environment, and maternal verbal ability, whereas others have shown benefits.



WHAT THIS STUDY ADDS: Predominant breastfeeding for ≥ 6 months was positively associated with numeracy and literacy achievement independent of maternal and demographic factors and cognitive stimulation at home. However, the effectiveness of breastfeeding differed according to gender; benefits were only evident for boys.

abstract

INTRODUCTION: The aim of this study was to examine the relationship between duration of breastfeeding and educational outcomes. We hypothesized that longer periods of breastfeeding would predict better educational outcomes in middle childhood.

METHODS: The Western Australian Pregnancy Cohort (Raine) Study used a cohort of 2900 women who were enrolled at 18 weeks' gestation; with 2868 live-born children were followed prospectively. At ~ 10 years of age, data from 1038 children were linked to standardized mathematics, reading, writing, and spelling scores. Associations between breastfeeding duration and educational outcomes were estimated by using linear models with adjustment for gender, family income, maternal factors, and early stimulation at home through reading.

RESULTS: Ten-year-old children who were predominantly breastfed for 6 months or longer in infancy had higher academic scores than children who were breastfed for less than 6 months. The effect of breastfeeding on educational outcomes differed according to gender; boys were particularly responsive (in mathematics, spelling, reading, and writing) to a longer duration of breastfeeding.

CONCLUSIONS: Predominant breastfeeding for 6 months or longer was positively associated with academic achievement in children at 10 years of age. However, the effectiveness of breastfeeding differed according to gender; the benefits were only evident for boys. *Pediatrics* 2011;127:e137–e145

Breastfeeding is promoted as beneficial to both the mother and newborn, and exclusive breastfeeding for at least 6 months is recommended.¹ Although there are many reasons to encourage breastfeeding, its benefits for cognitive ability, intelligence, and academic achievement have received increasing scientific scrutiny.²⁻⁵

Studies of the long-term effects of breastfeeding on child development are challenging. Mothers who choose to breastfeed tend to have higher socioeconomic status and higher intelligence and to be older, more educated, and nonsmokers.⁶ Breastfeeding mothers also are more likely to engage in behaviors that stimulate child development,⁷ thus contributing to the observed differences in cognitive performance between breastfed and nonbreastfed children. Therefore, it is not clear whether the apparent breastfeeding benefits on cognitive development reflect a true nutritional advantage derived from breast milk or the socioeconomic advantage associated with breastfeeding. It is not surprising that some studies^{5,8} have revealed no significant differences after adjusting for confounders including socioeconomic status, home environment, and maternal verbal ability, whereas others,⁴ including our own,⁹ have shown the benefits of breastfeeding.

In our study, we aimed to determine whether the duration of breastfeeding was associated with numeracy and literacy achievement in children at 10 years of age. We hypothesized that children who were predominantly breastfed for 6 months or longer, compared with those who were breastfed for a shorter duration, would achieve higher scores in numeracy and literacy, independent of maternal and demographic factors and early cognitive stimulation received in the home.

METHODS

Study Population

The Western Australian Pregnancy Cohort (Raine) Study is an ongoing longitudinal study in which 2900 women were recruited from the public antenatal clinic at the major tertiary maternity hospital in Perth, Western Australia, and from nearby private practices. These women were randomly selected for enrollment if they were at 16 to 20 weeks' gestational age, if they had sufficient proficiency in English, if they expected to deliver at the hospital, and if they intended to remain in Western Australia for follow-up. Approximately 100 women per month were enrolled from August 1989 to April 1992.¹⁰

All children were assessed as soon as possible after each birthday at 1, 2, 3, 5, 8, and 10 years of age. Each assessment included questionnaire completion and a clinical examination by a research nurse, who provided a medical examination of the child.

Breastfeeding Duration

Infant feeding data were collected at 1, 2, and 3 years of age. A diary card was maintained in which mothers recorded important events in their child's life, including feeding. This information was transcribed by the research nurse to the questionnaire during the assessment. Although our data on breastfeeding were collected retrospectively, they were within 1 year of the breastfeeding period. In contrast, other studies have collected data as late as 5 to 11 years after the breastfeeding period.¹¹ Previous research¹² revealed that maternal recall is a valid and reliable estimate of breastfeeding initiation and duration, especially when the recall is 3 years or less after the breastfeeding period. Hence, our breastfeeding data were of adequate quality, and recall of breastfeeding duration was close enough to the time of feeding to be valid.

Information about the age at which milk other than breast milk was introduced was applied to obtain a continuous measure of predominant breastfeeding in months. These data were categorized as less than 4 vs 4 months or longer and less than 6 versus 6 months or longer. At the time of recruitment for this study, the World Health Organization and the Australian National Health and Medical Research Council recommended that all mothers breastfeed their infant for 4 to 6 months.¹ Therefore, we used the more conservative measure of 6 months in our analysis. In a similar way, information about the age at which breastfeeding stopped was used to obtain measures of any breastfeeding. Neither of our breastfeeding measures precluded the intake of solid foods. We used the definition of predominant breastfeeding because we could not meet the strict criteria for exclusive breastfeeding set by the World Health Organization.

Sociodemographic Measures

Maternal socioeconomic characteristics collected before and at birth included maternal age, maternal education, marital status of the mother, and family income. The characteristics were grouped into 3 or more categories.

Language stimulation was measured at 3 and 5 years by asking the parent (usually the mother) how often she (or someone else at home) reads a story to the child. Preliminary assessment revealed that reading at 3 and 5 years ($r = 0.448$; $P < .005$) and looking at books with the child at the age of 5 years ($r = .501$; $P < .0001$) were strongly correlated. We found that looking at books with the child at age 5 showed the strongest association between predominant breastfeeding and Western Australian Literacy and Numeracy Assessment (WALNA) scores;

therefore, we included this variable in the final models to adjust for child stimulation within the home. Given that stimulation in the home was a covariate to our research question regarding the effect of breastfeeding on educational outcomes, it did not make any substantial difference what home-stimulation variable was used.

Educational Assessment at 10 Years

The WALNA is administered annually to all students in grades 3, 5, and 7 across Western Australia (~75% of West Australian children). The assessment consists of multiple-choice, short-response, and open-response questions in 4 areas: mathematics, reading, writing, and spelling. Standardized Western Australian Monitoring Standards in Education (WAMSE) scores are derived from a raw scale, and higher scores indicate better performance. WAMSE scores refer to the scale of measurement chosen as a basis for describing achievement in the different learning areas. In much the same way as distances can be measured in centimeters or inches and temperature in Celsius or Fahrenheit, level of achievement can be represented with the use of different scales. The important thing is that the value that represents the level of achievement really is a measurement. This outcome is ensured through an iterative process of test development, analysis of student data, refinement of tests, and additional analysis. The result is that the WAMSE can be interpreted simply as a measurement of achievement. Table 1 lists the sample statistics for the WAMSE scores. Some test scores revealed negative values to enable easier interpretation and to allow monitoring of children's progress in literacy and numeracy over time within the same subject area. Linkage was undertaken by the Western Australian Data Linkage System, using a

TABLE 1 Summary Statistics of 4 Standardized Indicator WAMSE Scores of Educational Outcomes

	<i>n</i>	Minimum	Maximum	Mean	SD
Mathematics	980	-15.0	775.0	398.0	106.1
Reading	980	-47.0	702.6	385.3	104.6
Writing	980	-277.2	802.0	362.3	168.4
Spelling	980	-99.0	717.0	424.4	118.0

Negative scores were possible because scores were equated to their historical scale. Some test scores took negative values to allow for easier interpretation and monitoring of children's progress in literacy and numeracy skills over time within the same subject area.

probabilistic method of matching according to name, date of birth, gender, and address.¹³ WALNA records were linked for 1038 Raine Study children who were in grade 5 (mean age: 10 years and 5 months [SD: 2.48 months]) and attending government schools at the time of assessment.

Statistical Power

For a sample size of 980 children (estimated SD: 105), the power of a 1-tailed test to detect a difference of 16 WAMSE scores at the 5% significance level was with 99% power and to detect a difference of 8 WAMSE scores was with 90% power. Because both calculations yielded a value of more than 80%, our analyses, thus, were highly statistically powerful.

Statistical Analysis

We conducted multivariable general linear regression analyses, in which we adjusted for sociodemographic covariates. We categorized maternal education and family income to determine the effect sizes of these independent groups and control for these factors. Previous research¹⁴ has shown that these categories of maternal education and family income predict breastfeeding well. We adjusted for maternal education as a categorical variable, because these categories are much more meaningful for the Australian context than years of schooling. For the same reason, we adjusted family income as below or above \$36 000 annually. In further anal-

yses, we tested maternal education and family income in a wider range of categories (eg, maternal education in 4 categories instead 3 groups and family income in 5 categories instead of 2 groups). The results did not alter our final conclusions on the basis of the analysis in which we used a smaller range of categories. In further analysis, we tested for an interaction between breastfeeding and gender with the educational scores as the outcomes. All analyses were undertaken with SPSS 16+ software (SPSS, Chicago, IL).

Ethical Considerations

The ethics committees of King Edward Memorial Hospital and Princess Margaret Hospital in Perth approved the protocol for the study. The parent or guardian provided written consent to link the child's data at 10 years with WALNA results.

RESULTS

Table 2 lists the characteristics of the entire cohort and subcohorts. The entire cohort comprised 2868 live births; the oldest child turned 10 years old in August 2000. Of these children, 2515 were eligible for the follow-up and 2047 participated in this follow-up, and 1749 parents gave consent for their child's study data to be linked to government education databases. After the withdrawal of children from the study, nonparticipation, and eligibility, data for 1038 children who had attended government schools and provided consent were matched with WALNA records. We compared those who were eligible but not linked ($n = 1830$) to WALNA data with those who were linked ($n = 1038$) and calculated *P* values to address any bias. We found that there were significant differences between those who were and those who were not linked to WALNA. Those children who were linked to WALNA were more likely to have been breast-

TABLE 2 Comparison of Maternal Sociodemographic Characteristics Between the Entire Cohort and Children Linked and Those not Linked to the WALNA

	Entire Cohort, Valid Percent (n) (N = 2868)	Subcohorts		Pearson χ^2 P (2-Tailed Test)
		Children Linked to the WALNA, Valid Percent (n) (N = 1038)	Children not Linked to the WALNA, Valid Percent (n) (N = 1830)	
Maternal age				
Teenaged mothers	12.6 (360)	9.4 (98)	14.4 (262)	<.001
20–24 y	23.5 (674)	21.9 (227)	24.6 (447)	—
25–29 y	30.2 (867)	30.8 (320)	30.1 (547)	—
30–34 y	22.9 (657)	25.8 (268)	21.4 (389)	—
≥35 y	10.4 (299)	11.9 (124)	9.6 (175)	—
Total	2857 (99.6)	99.9 (1037)	—	—
Missing	0.4 (11)	0.1 (1)	—	—
	100.0 (2868)	100.0 (1038)	—	—
Maternal education				
Less than grade 12	51.7 (1483)	51.4 (534)	51.9 (949)	.652
Trade certification/other diploma	29.6 (848)	29.0 (301)	29.9 (547)	—
Professional or university degree	18.7 (536)	19.6 (203)	18.2 (334)	—
Total	100.0 (2867)	1038 (100.0)	—	—
Maternal marital status				
Never married/de facto	31.7 (909)	28.4 (295)	33.6 (614)	.005
Separated/divorced/widowed	3.6 (104)	3.1 (32)	3.9 (72)	—
Married	64.6 (1854)	68.5 (711)	62.5 (1143)	—
Missing	0.1 (1)	100.0 (1038)	—	—
Total	100.0 (2868)	—	—	—
Family income at 18 wk				
Adolescent/no income	5.9 (169)	4.4 (46)	6.7 (123)	.02
<\$7000	8.1 (232)	6.3 (65)	9.1 (167)	—
\$7000–11 999	8.6 (247)	7.7 (80)	9.1 (167)	—
\$12 000–23 999	24.5 (702)	25.0 (259)	24.2 (443)	—
\$24 000–35 999	23.3 (667)	25.0 (260)	22.3 (407)	—
\$≥36 000	29.6 (850)	31.6 (328)	28.5 (522)	—
Missing	0.1 (1)	100.0 (1038)	—	—
Total	100.0 (2868)	—	—	—
Any breastfeeding variables				
Breastfeeding for ≥4 mo	62.2 (1503)	61.2 (635)	60.4 (1105)	.027
Breastfeeding for <4 mo	37.8 (915)	33.2 (345)	39.6 (725)	—
Missing	450	5.6 (58)	—	—
Total	100.0 (2868)	100.0 (1038)	—	—
Breastfeeding for ≥6 mo	51.8 (1252)	50.1 (527)	50.4 (725)	.105
Breastfeeding for <6 mo	48.2 (1166)	43.6 (453)	49.6 (713)	—
Missing	450	5.6 (58)	—	—
Total	100.0 (2868)	100.0 (1038)	—	—
Duration of any breastfeeding, mean, mo		7.92	7.24	.021

fed longer, have older mothers, have mothers who were more likely to be married, and have families with a higher income. Of 1038 children, complete data were available on most key outcome and exposure variables for 980 (Table 3). Of 980 mothers of the children in our sample at 6 months, 54% were continuing to breastfeed, and 28% were predominantly breastfeeding.

In univariate associations between breastfeeding and the educational outcomes at 10 years, parameter estimates from linear regression revealed that continuous breastfeeding was significantly associated with an increase in scores with each additional month of breastfeeding for mathematics ($\beta = 1.21$ [95% confidence interval (CI): 0.30–2.13]; $P = .010$), reading

TABLE 3 Characteristics of the West Australian Pregnancy Cohort Study Who Had Complete Data Available for Breastfeeding, Educational Outcomes, and Confounding Factors

Variable	Valid Percent (n) (N = 980) ^a
Any breastfeeding for ≥6 mo	
Yes	53.8 (527)
No	46.2 (453)
Predominant breastfeeding for ≥6 mo	
Yes	28.0 (273)
No	72.0 (702)
Gender of child	
Female	49.7 (487)
Male	50.3 (493)
Maternal age	
<20 y	9.1 (89)
20–24 y	21.5 (211)
25–29 y	31.4 (308)
30–34 y	25.6 (251)
≥35 y	12.3 (121)
Maternal education	
≤12 y	51.0 (500)
Trade certificate/college diploma/other diploma	29.2 (286)
Professional or university degree	19.8 (194)
Family income at 18 wk	
<24 000	42.6 (417)
24 000–35 999	25.0 (245)
≥36 000	32.4 (318)
Maternal marital status	
Never married/de facto	27.6 (270)
Separated/divorced/widowed	3.2 (31)
Married	69.3 (679)
Maternal race	
Aboriginal	0.8 (8)
Caucasians	91.6 (898)
Other (mostly Asian)	7.6 (74)
Child stimulation at home	
How often do you read to your child at age 3?	
Never or once per month	11.3 (103)
2–3 times per week	30.8 (281)
Once per day	34.1 (311)
More than once per day	23.9 (218)
How often do you read to your child at age 5?	
Less than once per week	6.1 (57)
Once per week	11.4 (106)
2–3 times per week	20.3 (189)
Once per day	47.1 (438)
More than once per day	15.1 (140)
How often do you look at a book with your child at age 5?	
Less than once per week or once per week	2.6 (24)
2–3 times per week	7.3 (68)
Most days	43.0 (400)
More than once per day	47.2 (439)

The children's ages at the 10-year follow-up ranged from 9 years 4 months to 12 years 3 months (mean: 10 years 5 months; SD: 2.48 months). In the subsample used for our analysis ($n = 980$), the ages of children ranged from 9 years 4 months to 11 years 6 months (mean: 10 years 5 months; SD: 2.16 months).

^a Not all frequency distributions add to 100% because of small amounts of missing data.

($\beta = 1.68$ [95% CI: 0.78–2.58]; $P < .001$), writing ($\beta = 2.13$ [95% CI: 0.68–3.59]; $P = .004$), and spelling ($\beta = 1.46$ [95% CI: 0.44–2.48]; $P = .005$). However, these results were attenuated when adjusted for the confounding factors. With each additional month of breastfeeding, scores for reading ($\beta = 0.85$ [95% CI: –0.08 to 1.18]; $P = .073$), mathematics ($\beta = 0.64$ [95% CI: –0.30 to 1.59]; $P = .182$), spelling ($\beta = 0.66$ [95% CI: –0.34 to 1.67]; $P = .196$), and writing ($\beta = 1.29$ [95% CI: –0.22 to 2.81]; $P = .094$) increased but did not reach significance. We concluded that breastfeeding, as measured in months, was weakened in multivariate models.

Predominant breastfeeding for 6 months or longer was a significant predictor for improved academic scores in multivariable models for mathematics, reading, and spelling and approached significance for writing (Table 4). We tested for coefficients of determination for each model and found that the R^2 value of the models was 0.091 for mathematics, 0.125 for reading, 0.090 for writing, and 0.144 for spelling.

Of interest is that the 2 key socioeconomic indicators, lower maternal education and family income, were significantly associated with decreased child academic achievement. In terms of the effect size of these control variables, we showed that maternal education of 12 years or less, or having a trade or a diploma compared with being a professional or having a university education, resulted in reduced mathematics, reading, writing, and spelling scores for both boys and girls. In relation to family income, having an annual income of \$35 999 or less compared with an annual income of \$36 000 or more was significantly related to reduced scores for all subjects, again for both boys and girls. We tested maternal education and family

TABLE 4 Multivariable Association Between Predominant Breastfeeding for ≥ 6 Months and Educational Outcomes at 10 Years of Age ($N = 980$)

	Mathematics			Reading			Writing			Spelling		
	β	95% CI	P^a	β	95% CI	P^a	β	95% CI	P	β	95% CI	P
Predominant breastfeeding ≥ 6 mo ^b	15.79	1.04–30.55	.036	18.28	3.92–32.64	.021	18.00	–5.68 to 41.67	.136	15.60	–0.0 to 31.24	.050
Child's gender												
Female	–14.74	–27.95 to –1.52	.029	10.84	–2.0 to 23.69	.098	23.28	2.08–44.48	.051	27.50	13.49–41.50	<.001
Male (reference)												
Maternal age, y												
<20	–12.31	–44.10 to 19.48	.448	–31.34	–62.26 to –0.42	.047	–19.47	–70.48 to 31.53	.454	–6.86	–40.54 to 26.82	.689
20–24	–13.20	–37.44 to 11.03	.285	–19.96	–43.53 to 6.58	.097	17.36	–21.52 to 56.24	.381	–2.58	–28.26 to 23.09	.844
25–29	–12.25	–34.11 to 9.61	.272	–12.54	–33.80 to 8.72	.247	1.30	–33.7 to 36.38	.942	–6.05	–29.21 to 17.10	.608
30–34	–23.96	–44.22 to –1.70	.055	–15.97	–37.62 to 5.68	.148	0.13	–35.5 to 35.84	.994	–0.05	–23.63 to 23.54	.997
>34 (reference) ^a			.318			.321			.541			.966
Maternal education												
≤ 12 y	–43.13	–62.33 to –23.94	<.005	–45.29	–63.84 to –26.74	<.001	–63.82	–94.42 to –33.22	<.001	–41.04	–61.25 to –20.84	<.001
Trade certificate/diploma	–30.37	–50.04 to –10.70	.003	–25.32	–44.31 to –6.32	.009	–42.00	–73.34 to –10.67	.009	–12.41	–33.11 to 8.27	.239
University degree, professional (reference) ^a			<.001			<.001			<.001			<.001
Family income												
<\$24 000	–31.24	–48.32 to –14.16	<.005	–32.29	–48.77 to –15.81	<.001	–40.86	–68.04 to –13.68	.003	–43.68	–61.64 to –25.73	<.005
\$24 000–\$35 999	–25.56	–43.34 to –7.78	.005	–30.24	–47.41 to –13.08	.001	–32.41	–60.72 to –4.09	.025	–24.32	–43.02 to –5.62	.011
\geq \$36 000 (reference) ^a			.001			<.001			.009			<.001
Marital status												
Not married	–5.96	–22.75 to 10.83	.486	12.93	–3.31 to 29.17	.108	–8.08	–34.8 to 18.70	.554	–1.87	–19.56 to 15.82	.835
Separated/divorced	7.25	–29.90 to 44.39	.702	36.65	0.41–72.90	.047	9.99	–49.8 to 69.78	.743	24.99	–14.49 to 64.47	.214
Married/(reference) ^a			.686			.060			.771			.431
Parent looks at book with child at age 5												
Once per week or less	–35.29	–77.41 to 6.83	.100	–38.25	–79.21 to 2.72	.067	–49.30	–116.87 to 18.28	.153	–54.01	–98.63 to –9.39	.018
2–3 times per week	–4.05	–30.64 to 22.54	.765	–24.54	–50.40 to 1.32	.063	–54.68	–97.33 to –12.02	.012	–23.28	–51.44 to 4.89	.105
Most days	–11.30	–25.37 to 2.77	.115	–23.82	–37.51 to –10.14	.001	–35.31	–57.88 to –12.74	.002	–22.66	–37.56 to –7.75	.003
More than once per day (reference) ^a			.215			.003			.005			.005

As well as all the variables listed in the models, additional adjustment was made for maternal country of birth, but these data are not shown because of small numbers in some groups.

^a Test of between-subject effects.

^b Reference for predominant breastfeeding for ≥ 6 months was predominant breastfeeding for < 6 months.

TABLE 5 Multivariable Association Between Predominant Breastfeeding for ≥ 6 Months and Educational Outcomes at 10 Years of Age Separately for Boys and Girls ($N = 980$)

	Mathematics			Reading			Writing			Spelling		
	β	95% CI	P^a	β	95% CI	P^a	β	95% CI	P	β	95% CI	P
Predominant breastfeeding ≥ 6 mo ^b												
Female ($n = 444$)	-5.36	-26.43 15.71	.617	10.60	-10.39 31.58	.321	-0.87	-39.61 37.87	.965	0.86	-21.71 23.43	.940
Male ($n = 448$)	34.48	13.66 55.27	.001	24.72	4.87 44.58	.015	37.41	9.43 65.40	.009	28.23	6.38 50.07	.011

The variables adjusted in these models were maternal age, maternal education, marital status, family income and looking at books with the child at five years. Further adjustment was made for maternal race: Aboriginal, Asian/other, or Caucasian, but these data are not shown due to small numbers in some groups.

^a Test of between-subjects effects.

^b Reference for predominant breastfeeding for ≥ 6 months was predominant breastfeeding for < 6 months, for boys and for girls separately.

income in a wider range of categories and did not find any differences in our final conclusions.

Reading and looking at books with the child at the ages of 3 and 5 years were associated with improved mean scores for reading and writing. Although boys achieved improved scores in mathematics compared with girls after adjustment, the opposite was true for reading, writing, and spelling; girls achieved higher scores in literacy than boys.

Table 5 lists the multivariable associations between predominant breastfeeding for 6 months or longer and educational outcomes at 10 years of age separately for boys and girls. By looking at boys and girls independently, we found that predominant breastfeeding for 6 months or longer was significantly associated with increased mathematics, reading, writing, and spelling scores for boys, but no effect of breastfeeding was apparent on the educational attainment of girls for any subject.

We found significant interactions for mathematics ($P = .007$) and spelling ($P = .047$), revealing that boys were more likely than girls to have improved academic scores if they were breastfed for a longer period (Fig 1). On average, boys had poorer numeracy and literacy scores than girls; however, the scores were improved if the child was breastfed for 6 months or longer.

DISCUSSION

Predominant breastfeeding for 6 months or longer was associated with significantly higher scores for mathematics, reading, and spelling in 10-year-old children when adjusted for the sociodemographic characteristics of the mother and family and early stimulation of the child. However, significant interaction effects were shown between gender and breastfeeding. A longer duration of breastfeeding remained predictive for academic achievement in 10-year-old boys for mathematics and spelling; there was a small but insignificant benefit for reading in girls. Our results suggest that breastfeeding duration is independently associated with better educational outcomes in middle childhood, especially for boys.

Several prospective studies have revealed that, after adjusting for confounding variables, breastfed children had a higher mean score of academic performance in adolescence and adulthood¹⁵ than those who were not breastfed. Similar results were reported for both term and preterm infants.^{3,16} Results of available meta-analyses, on the other hand, reflect a less conclusive pattern of breastfeeding effect on developmental outcomes. A meta-analysis⁷ of studies published up to 1996 revealed that breastfed children had higher cognitive scores compared with bottle-fed children, although some studies adjusted for few confounders. Another meta-

analysis¹⁷ revealed that only 2 studies met stringent criteria for inclusion, such as adequate adjustment for socioeconomic status of the family and stimulation of the child. Of these 2 studies, 1¹⁸ revealed a positive association between breastfeeding and intelligence, whereas the other¹⁹ found no benefit. The majority of previous studies have focused on the association between breastfeeding and cognitive ability, and only a few have examined academic achievement. Where academic achievement has been studied, positive associations have been observed.^{3,7,17} For example, Richards et al²⁰ found a positive impact of breastfeeding on educational attainment in midlife, independent of early background in 1739 participants from the British 1946 birth cohort. Additional analyses revealed that the association was largely accounted for by adolescent cognition and educational attainment.

Gender Differences

Only 1 previous study²¹ has examined gender differences in the association between breastfeeding and child development. Breastfeeding was associated with improved clarity of speech in boys and girls but significantly more so in boys, and better speech was associated with improved reading ability. The effect of breastfeeding on the development of speech and reading in boys was reported in a later follow-up, which suggests that breastfeeding accelerates the rate of maturation of boys.^{21,22} In the Dun-

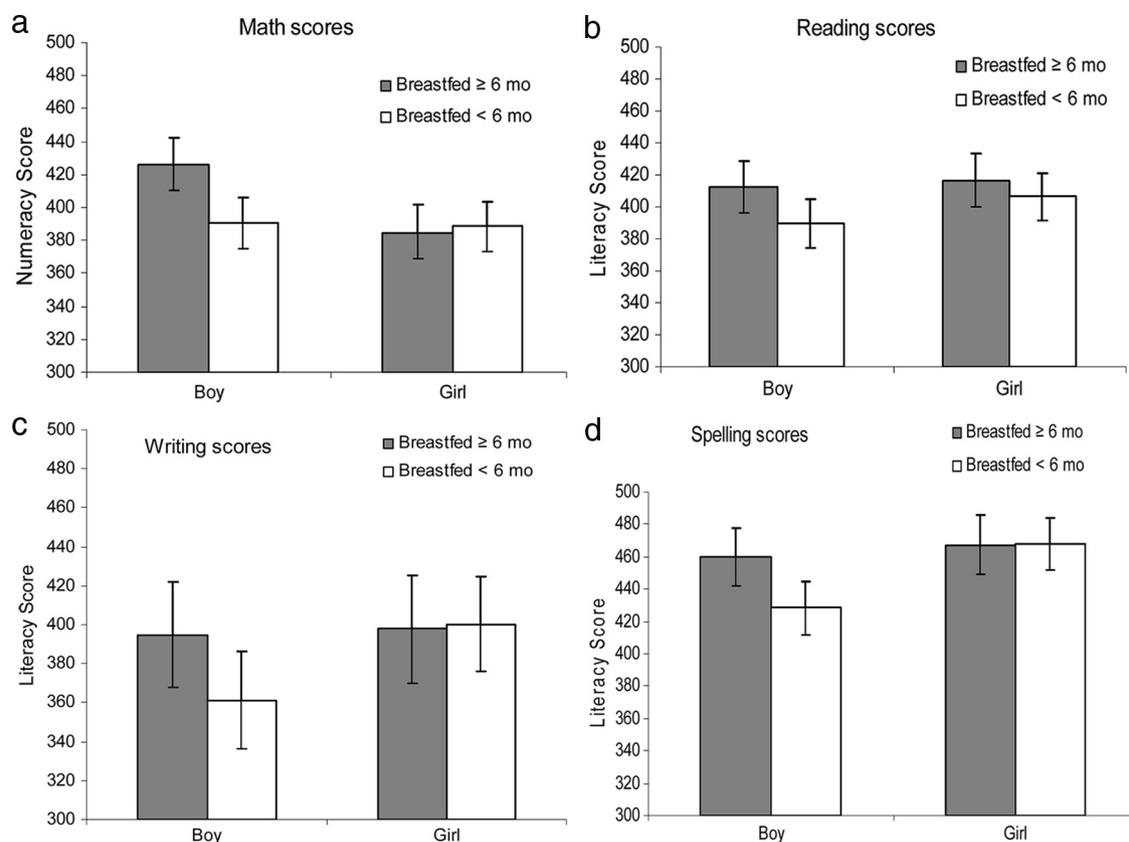


FIGURE 1

Interaction effects for boys and girls breastfed for ≥ 6 months compared with those breastfed for < 6 months for educational outcomes. Shown are interaction effects for boys and girls breastfed for 6 months or longer compared with those breastfed for less than 6 months for mathematics ($P = .007$), reading ($P = .353$), writing ($P = .108$), and spelling ($P = .047$) scores, after adjustment for maternal age, maternal education, maternal race, marital status, family income, and looking at books with the child at the age of 5 years. Error bars represent 1 SE of the mean.

edin Multidisciplinary Child Development Study,²³ girls performed higher on language and Peabody Picture Vocabulary Test scores, which is consistent with other studies that showed that girls scored higher than boys on most tests, but there were no significant gender differences, a necessary condition for establishing an interaction effect. Significant gender differences were observed in the association between breastfeeding and educational outcomes in our study; therefore, in addition to multivariate analysis, we analyzed our data according to boys and girls separately.

The findings of our study suggest that gender should be considered in explanations of the link between breastfeeding and neurocognitive development. Male children are known to be more vulnerable to adversity during critical

periods than female children.²⁴ The reasons for this vulnerability may relate to the neuroprotective effect of estradiols,²⁵ which typically are at higher concentrations in female children. From this perspective, any neuroprotective role of breast milk, and the downstream consequences for language development, would have greater benefits for male children. Another possibility is that breastfeeding exerts an influence on both genders but in different ways. Research with nonhuman primates has found that male fetuses exposed to prenatal maternal stress show a decrease in the size of the corpus callosum, whereas female fetuses show an opposite reaction.^{26,27} A similar effect may exist with the neuroactive role of breastfeeding.

A third proposal is that breastfeeding has a positive effect on the mother-child relationship and thereby facilitates bonding, interaction, and, indirectly, cognitive growth. A number of studies have revealed that male infants are more reliant than female infants on maternal attention and encouragement for the acquisition of cognitive and language skills.^{28,29} If breastfeeding facilitates mother-child interactions, then we would expect the positive effects of this bond to be greater in male children compared with female children, as we observed.

Biological Mechanisms

An early study³⁰ revealed small but significant increases in later ability and attainment between breastfed and formula-fed infants. Fergusson et al²³

combined male and female children and tested for differences in intelligence, comprehension, expression, and articulation and found significantly increased scores for intelligence and comprehension at 3, 5, and 7 years and expression at 3 and 5 years in infants who were breastfed for 4 months or longer. Quinn et al³¹ speculated that the observed cognitive differences between breastfed and formula-fed infants observed in their birth cohort of 3880 infants followed to 5 years were a result of the unique constituents of breast milk.

Breastfeeding may influence children's academic achievement through brain development and general health. Nutrients in breast milk that are essential for optimum brain growth, such as long-chain polyunsaturated fatty acids, may not be in formula milk.³² Long-chain polyunsaturated fatty acids are structural elements of cell membranes and essential in the formation of new tissue, including neurons. Makrides et al³³ noted increased docosahexaenoic acid (22:6*n*-3) content of the brain cortex with breastfeeding. Breastfed infants had a greater proportion of docosahexaenoic acid in their erythrocytes and brain cortex and scored better on visual and developmental tests than did formula-fed infants. Crawford³⁴ highlighted arachidonic acid (20:4*n*-6) and docosahexaenoic acid as vital components of breast milk that support development of the newborn brain, and the results of extensive research have supported these findings.³⁵⁻³⁷

Strengths and Limitations

Our study had a number of strengths, including the use of prospective pregnancy data and educational data collected at 10 years. The study design and large community sample, which generated adequate statistical power to measure the association between

breastfeeding and educational outcomes, were clear strengths of our study. Breastfeeding data were collected close to the period of breastfeeding cessation, and a diary card was maintained to improve this collection. Those children who had their educational data linked to the Raine cohort were likely to be more advantaged, and, although the loss of more disadvantaged participants may have affected the results of our study, the original cohort overrepresented socially disadvantaged women.¹⁴ Therefore, this pattern of attrition may have increased the extent to which our findings can be generalized. Computer simulations in which data from the Avon Longitudinal Study of Parents and Children were used have revealed that selective dropout of cohort studies only marginally affects regression coefficients, if participant selection occurs according to the predictor variable.³⁸ Ours is one of the few studies that have shown that breastfeeding has an independent effect on academic achievement.

We acknowledge that a limitation of our study was that we could not directly adjust for maternal intelligence. However, regardless of maternal IQ, the effect of nutrition on later child development is plausible, and after adjustment for a range of factors the breastfeeding effect remained. Two other limitations of our study included a lack of information on children who attended nongovernment schools, as well as academic achievement in numeracy and literacy at other time points, especially after grade 5. Children who attended nongovernment schools may have had higher WALNA scores and been more likely to have been breastfed than children who were attending government schools, but we cannot make these assumptions. We did not adjust for all possible factors that may affect breastfeeding

duration, such as length of maternity leave or partner support; however, we did adjust for a range of socioeconomic covariates as well as early stimulation of the child at home. It is important that future studies fill these gaps.

CONCLUSIONS

The positive effect of predominant breastfeeding for 6 months or longer on academic achievement can be viewed as shifting the mean population score upward, particularly for boys. Our study adds to growing evidence that breastfeeding for at least 6 months has beneficial effects on optimal child development. Mothers should be encouraged to breastfeed for 6 months and beyond.

ACKNOWLEDGMENTS

The Western Australian Pregnancy Cohort Study is funded by project and program grants from the Raine Medical Research Foundation, the National Health and Medical Research Council of Australia, Western Australian Health Promotion Foundation, and the Australian Rotary Health Research Fund. Dr Oddy was supported by a National Health and Medical Research Council Population Health Career Development Award, Dr Li was supported by a Curtin University of Technology Research Fellowship Award, and Dr Malacova was supported by an Australian Postgraduate Award Industry scholarship, provided through an Australian Research Council Linkage Project grant (LP0455417).

We acknowledge the study investigators and staff responsible for the collection of the data presented here, the Raine Medical Research Foundation at the University of Western Australia, and the Telethon Institute for Child Health Research. Sincere thanks are extended to all study families, without whose participation this research could not have been conducted. We thank Peter Jacoby for statistical advice.

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Pediatrics 2011;127:e137; originally published online December 20, 2010;

DOI: 10.1542/peds.2009-3489

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