

# Breastfeeding and Later Cognitive and Academic Outcomes

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**ABSTRACT.** *Objective.* This study examines the associations between duration of breastfeeding and childhood cognitive ability and academic achievement over the period from 8 to 18 years using data collected during the course of an 18-year longitudinal study of a birth cohort of >1000 New Zealand children.

*Method.* During the period from birth to age 1 year, information was collected on maternal breastfeeding practices. Over the period from 8 to 18 years, sample members were assessed on a range of measures of cognitive and academic outcomes including measures of child intelligence quotient; teacher ratings of school performance; standardized tests of reading comprehension, mathematics, and scholastic ability; pass rates in school leaving examinations; and leaving school without qualifications.

*Results.* Increasing duration of breastfeeding was associated with consistent and statistically significant increases in 1) intelligence quotient assessed at ages 8 and 9 years; 2) reading comprehension, mathematical ability, and scholastic ability assessed during the period from 10 to 13 years; 3) teacher ratings of reading and mathematics assessed at 8 and 12 years; and 4) higher levels of attainment in school leaving examinations. Children who were breastfed for  $\geq 8$  months had mean test scores that were between 0.35 and 0.59 SD units higher than children who were bottle-fed.

Mothers who elected to breastfeed tended to be older; better educated; from upper socioeconomic status families; were in a two-parent family; did not smoke during pregnancy; and experienced above average income and living standards. Additionally, rates of breastfeeding increased with increasing birth weight, and first-born children were more likely to be breastfed.

Regression adjustment for maternal and other factors associated with breastfeeding reduced the associations between breastfeeding and cognitive or educational outcomes. Nonetheless, in 10 of the 12 models, fitted duration of breastfeeding remained a significant predictor of later cognitive or educational outcomes. After adjustment for confounding factors, children who were breastfed for  $\geq 8$  months had mean test scores that were between 0.11 and 0.30 SD units higher than those not breastfed.

*Conclusions.* It is concluded that breastfeeding is associated with small but detectable increases in child cognitive ability and educational achievement. These effects are 1) pervasive, being reflected in a range of measures including standardized tests, teacher ratings, and aca-

ademic outcomes in high school; and 2) relatively long-lived, extending throughout childhood into young adulthood. *Pediatrics* 1998;101(1). URL: <http://www.pediatrics.org/cgi/content/full/101/1/e9>; *breastfeeding, cognitive ability, academic achievement, longitudinal study.*

ABBREVIATIONS. DHA, docosahexaenoic acid; WISC-R, Revised Wechsler Intelligence Scale for Children; IQ, intelligence quotient.

Over the last 2 decades, there has been an accumulation of evidence suggesting that breastfeeding may lead to small but detectable improvements in childhood cognitive ability or educational achievement. Three lines of evidence support this conclusion.

First, evidence from longitudinal studies of general child samples<sup>1-6</sup> has shown repeatedly that children who are breastfed show small increases over bottle-fed children in mean test scores on measures of intelligence and academic achievement, with these differences persisting after control for confounding factors. Typically, these studies suggest that in comparison with bottle-fed children, children who are breastfed for a minimum of 3 to 5 months have an advantage of between 0.15 and 0.25 SD units in mean test performance, even after control for confounders.<sup>1-4</sup>

Second, data from an experimental study of feeding practices among preterm infants showed that children whose mothers chose to express their own milk to feed their infant had higher developmental scores at 18 months and higher intelligence quotient (IQ) assessed at 7.5 to 8.0 years than those whose mothers chose not to do so.<sup>7,8</sup> These differences persisted after control for confounding factors, and there was evidence of dose-response relationships between the amount of breast milk supplied and developmental or cognitive gains. These children had taken part in a randomized trial of nutrition in neonatal diet. Among the children whose mothers had chosen not to express their breast milk, those randomized to donor breast milk, with low nutrient content, performed as well as those fed with nutrient supplemented preterm formula and significantly better than those fed a standard term formula.<sup>9</sup> These data raise the possibility that some components of breast milk ameliorate the effect of poor nutrition.<sup>8</sup>

Finally, neurodevelopmental research has suggested that the factors in breast milk that may be responsible for the improved cognitive abilities of breastfed children may involve long chain polyunsaturated fatty acids and, particularly, docosahexae-

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noic acid (DHA),<sup>10-12</sup> with some clinical studies in which infant formula was supplemented with DHA suggesting possible improvements in visual acuity and cognitive ability in preterm infants given the DHA-supplemented formula.<sup>13-15</sup>

Collectively, the evidence from longitudinal research, clinical trials, and neurodevelopmental research is beginning to provide a compelling case for the view that breastfeeding may have longer-term effects on individual cognitive ability and educational achievement. There are, nonetheless, a number of issues about the associations between breastfeeding and cognitive outcomes that require clarification.

One important issue concerns the extent to which the benefits of breastfeeding on cognitive development persist beyond middle childhood. To date, most studies have examined these benefits in preschool children<sup>1,4-7,9,16</sup> or in children studied in the early school years.<sup>1-3,6,8,17,18</sup> Less is known about the extent to which the benefits of breastfeeding on cognitive ability extend into adolescence and young adulthood. This issue is clearly important because it is possible that the benefits of breastfeeding on cognitive development may wash out over time, with these benefits being confined to only a relatively short period of the individual's life.

A second issue concerns the assessment of educational achievement. To date, only a few studies appear to have assessed measures of academic achievement, as opposed to measures of cognitive ability,<sup>1,2,6</sup> and of these, the majority have used methods of standardized testing to assess educational achievement. Although such measures have obvious psychometric advantages reflected by their standardization, reliability, and validity data, the extent to which performance on standardized tests reflects real life academic achievement remains to be assessed. For these reasons, it would be desirable for cognitive benefits of breastfeeding to be assessed using a range of indices that could include performance on standardized tests, teacher-based evaluations of academic achievement, and levels of achievement in school examinations or in tertiary education.

To address the issues above, this paper reports on the results of an 18-year longitudinal study of the relationships between infant feeding practices and later cognitive ability and academic achievement in a birth cohort of >1000 New Zealand children studied from birth to age 18 years. The design of this study made it possible to examine 1) the extent to which benefits of breastfeeding on cognitive ability and achievement were evident throughout middle childhood, adolescence, and into young adulthood; and 2) the extent to which breastfeeding was related to a range of indices of academic achievement that included performance on standardized tests, teacher ratings of academic achievement, and levels of success in examinations on leaving school.

## METHODS

The data were gathered during the course of the Christchurch Health and Development Study. The Christchurch Health and Development Study is a longitudinal study of a birth cohort of 1265 Christchurch, New Zealand, children born in 1977. The co-

hort was an unselected population sample comprising all children born in all hospitals in the Christchurch urban region during the period from April 15, 1977 to August 5, 1977. These children have been studied at birth, at 4 months, at 1 year, at annual intervals to age 16 years, and again at age 18, using information gathered from a combination of sources including parental interview, teacher report, standardized testing and interviews with the children, and medical records.<sup>19</sup>

## Measures Used in the Study

### *Breastfeeding*

When children surveyed were 4 months and 1 year of age, mothers were questioned in detail concerning breastfeeding practices, use of milk formulas, and other aspects of infant diet. Maternal reports were supplemented by evidence on breastfeeding practices recorded in the developmental records completed by community health nurses. In addition, information was available from medical records of the mother's breastfeeding practices in the maternity unit at the time of the child's birth. Using this information, the following measures of breastfeeding were constructed. The first measure was duration in months for which the child was breastfed. For the purposes of data display, this measure has been classified into four groups: child was not breastfed; child was breastfed for <4 months; child was breastfed for 4 to 7 months; child was breastfed for  $\geq 8$ . The second measure was duration in months of exclusive breastfeeding. This was defined as the number of months, to age 4 months, that the child was reported to have been breastfed without receiving any additional cow's milk, milk formula preparation, or solid food.

Although the two measures of breastfeeding were derived independently and used different criteria, they proved to be highly correlated ( $r = 0.84$ ;  $P < .001$ ).

### **Measures of Cognitive Ability and Academic Achievement**

To describe the child's cognitive ability and academic achievement during the period from 8 to 18 years of age, the following measures were selected.

### *Measures of Cognitive Ability*

At ages 8 and 9 years, children were administered the Revised Wechsler Intelligence Scale for Children (WISC-R).<sup>20</sup> For the purposes of the present analysis, the child's total IQ scores were used. The reliabilities of these scores, assessed using split-half methods, were .93 at age 8 years and .95 at age 9 years.

### *Teacher Ratings of School Performance*

When children were 8 and 12 years of age, teacher ratings of the child's performance in reading and mathematics were obtained. Teachers were asked to rate the child's performance in each area relative to other children of the same age, and ratings were made on a five-point scale ranging from 1 = very poor to 5 = very good.

### *Standardized Tests of Achievement*

During the period from 10 to 13 years of age, children were administered a series of standardized tests of achievement including 1) tests of reading comprehension based on the Progressive Achievement Test of Reading Comprehension,<sup>21</sup> administered at ages 10 and 12 years; 2) tests of mathematical reasoning based on the Progressive Achievement Test of Mathematics,<sup>22</sup> administered at age 11 years; and 3) tests of Scholastic Abilities,<sup>23</sup> administered at age 13 years. The Test of Scholastic Abilities is a broad-based measure designed to assess those verbal and numerical reasoning abilities deemed to be requisite for success in academic aspects of the school curriculum.<sup>23</sup> The reliabilities of these measures, assessed using coefficient  $\alpha$ , ranged from .83 for the measures of reading comprehension to .87 for the measure of mathematical reasoning and .95 for the measure of scholastic ability.

### *High School Outcomes*

At 18 years of age, study participants were assessed on the following two measures of high school success. The first was the number of passing grades achieved in School Certificate examinations. School Certificate is a national series of examinations that

New Zealand children may attempt at the end of their third year of high school. School Certificate examinations are the first of a series of public examinations that provide young people with the eligibility requirements to enter universities. Students typically undergo School Certificate at 15 or 16 years of age and attempt examinations in between four and six subjects. The results of School Certificate examinations are graded from A to E, with grades A, B, and C considered passing grades. The second measure was leaving school without qualifications. Students who had left school by age 18 without at least one passing grade in School Certificate were classified as having left school without qualifications.

### Confounding Factors

To control for potentially confounding and selection factors associated with breastfeeding, a range of measures of social, family, and other factors was selected from the database of the study. These measures were chosen on the basis of being known to be associated with the mother's breastfeeding history and/or with the cognitive and academic outcomes.

### Measures of Social and Family History

Maternal age at the time of the survey child's birth and maternal education at the time of the child's birth were the first two measures of social and family circumstances. Education was coded on a three-point scale reflecting the highest level of qualification obtained, with 1 = no formal qualifications, 2 = high school qualifications, and 3 = tertiary level qualifications. The third measure was family socioeconomic status at the time of the child's birth. This was assessed using the Elley/Irving scale of socioeconomic status for New Zealand.<sup>24</sup> This scale categorizes families into six classes on the basis of paternal occupation. The fourth measure was the child's family placement at birth. This was a binary measure reflecting whether the child entered a single-parent family or a two-parent family at birth. The fifth measure was maternal smoking during pregnancy. This was a binary measure reflecting whether the mother smoked during pregnancy.

The sixth measure was family living standards (0 to 5 years). Each year until survey children were 5 years of age, survey interviewers were asked to rate the family's living standards on a five-point scale ranging from 1 = very good to 5 = very poor. These ratings were summed and then averaged over the 5-year period to provide a global measure of the general quality of living standards experienced by each family during this period. The seventh measure was averaged family income (0 to 5 years). Each year, estimates of the family's gross annual income were obtained from parental report. To provide a measure of the average level of income available to each family for the period from the child's birth to age 5 years, the income estimates for each year were first

recoded into decile categories and the resulting measures then averaged over the 5-year period to produce a measure of the family's averaged income decile rank.

### Measures of Perinatal Outcome

These were measures of gender, the child's birth weight in grams, the child's estimated gestation in weeks, and the child's birth order in the family.

### Sample Sizes

Although this study is based on a birth cohort of 1265 children, the sample sizes studied in this paper are smaller, ranging from 772 to 1064. There were three reasons for these variations in sample size. First, during the study period, there was attrition in the sample attributable to the combined effects of subject refusal, outmigration from New Zealand, and death. The result of this attrition was that by age 18, the number of cohort subjects had been reduced to 1025 subjects, with these subjects representing 81.0% of the original sample and 92.3% of the sample still in New Zealand. Second, for standardized testing, sample size was reduced further because of logistic reasons that made it necessary to confine standardized tests to the sample of children resident in the Canterbury region. Canterbury residents represented ~80% of the cohort in any year. Finally, there were small amounts of missing data for some measures. The sample sizes studied for each outcome measure are shown in Table 1.

The variations in sample size raise the possibility that the results reported here could have been influenced by the effects of nonrandom sample attrition. However, whereas previous analyses of educational outcomes for this cohort suggest a slight bias in the samples available for analysis toward underrepresentation of children from more disadvantaged family backgrounds, analyses that incorporate statistical corrections for such bias produce conclusions essentially identical to those that do not incorporate such correction.<sup>25,26</sup> These findings suggest that sample loss processes are unlikely to influence the conclusions drawn from the analyses reported here.

## RESULTS

### Associations Between Duration of Breastfeeding and Measures of Cognitive Ability and School Achievement

Table 1 presents the relationships between the duration of breastfeeding classified into four groups (not breastfed, breastfed <4 months, breastfed 4 to 7 months, breastfed ≥8 months) and mean scores on a series of measures of cognitive ability and school

**TABLE 1.** Associations Between Duration of Breastfeeding and Measures of Cognitive Ability, Teacher Ratings of School Performance, Standardized Tests of Achievement, and High School Success

Measure	N	Duration of Breastfeeding				r	P
		Not Breastfed	<4 Months	4-7 Months	≥8 Months		
Mean cognitive ability scores*							
WISC-R total IQ, 8 years	869	97.46	98.89	102.16	102.83	0.22	<.0001
9 years	799	97.78	98.55	102.39	102.80	0.21	<.0001
Mean teacher ratings of achievement†							
Reading, 8 years	1064	2.85	2.94	3.08	3.20	0.14	<.0001
12 years	988	2.76	2.92	3.18	3.27	0.20	<.0001
Mathematics, 8 years	1064	2.89	2.88	3.04	3.25	0.14	<.0001
12 years	981	2.73	2.97	3.12	3.27	0.20	<.0001
Mean standardized achievement test scores*							
Reading comprehension, 10 years	834	97.86	98.94	101.77	103.06	0.21	<.0001
12 years	791	98.05	98.82	100.87	103.49	0.20	<.0001
Mathematics, 11 years	818	98.16	98.81	101.19	102.90	0.18	<.0001
Scholastic ability, 13 years	772	97.78	99.00	101.45	103.05	0.21	<.0001
High school attainment							
Mean number of School Certificate passes‡	999	2.66	3.04	3.75	3.99	0.24	<.0001
Leaving school without qualifications (%)	999	25.3	25.5	10.8	9.7	-0.18	<.0001
Percentage of sample in each breast feeding group		31.1%	26.6%	18.4%	23.9%		

\* Measures of cognitive ability and standardized tests of achievement have been scaled to have a mean of 100 and an SD unit of 10.

† Teacher ratings have been scaled to have a mean of 3 and an SD unit of 1.

‡ The sample SD for the number of School Certificate passes was 2.27.

achievement including the WISC-R IQ test; teacher ratings of performance in reading and mathematics; standardized tests of reading comprehension, mathematics, and scholastic ability; and success in School Certificate examinations. Table 1 also shows the percentage of children in each group who left school without qualifications. For ease of comparison, all standardized tests have been scaled to a mean of 100 and an SD unit of 10, and teacher ratings have been scaled to a mean of 3 and an SD unit of 1. Each comparison is tested for statistical significance, with continuously distributed measures being tested by one-way analysis of variance and the dichotomous measure by the  $\chi^2$  test of independence. The strength of association between duration of breastfeeding and each outcome is described by the product moment correlation.

Table 1 shows clear and highly significant ( $P < .0001$ ) tendencies for increasing duration of breastfeeding to be associated with higher scores on measures of cognitive ability, teacher ratings of performance, standardized tests of achievement, better grades in School Certificate examinations, and lower percentages of children leaving school without qualifications. On average, children who were breastfed for  $\geq 8$  months 1) scored between 0.35 and 0.59 SD units higher on standardized tests of ability or achievement and teacher ratings of school performance than children who were not breastfed, and 2) were considerably less likely than nonbreastfed children to leave school without qualifications (relative risk = 0.38; 95% CI: 0.25, 0.59).

Tests of linearity applied to the associations in Table 1 suggested that in all cases, the association between duration of breastfeeding and the outcome measure was well approximated by a linear model. The product moment correlations between duration of breastfeeding and the outcome measures were generally similar across all outcomes, ranging from 0.14 to 0.24, with a median value of 0.20, suggesting that from middle childhood to the point of leaving school, there were moderate but consistent tendencies for increasing duration of breastfeeding to be associated with increasing levels of cognitive ability and academic success.

The pervasive associations found between breastfeeding and measures of cognitive ability and aca-

ademic achievement were, in part, explained by the fact that the outcomes described in Table 1 were all significantly correlated. Correlations between different measures ranged from as high as 0.88 to as low as 0.32, with the median intercorrelation between measures being 0.61. Given the correlations between cognitive ability and academic achievement throughout childhood and into young adulthood, it is evident that if breastfeeding is associated with one of these outcomes, it is likely to be associated with others.

### Associations Between Duration of Breastfeeding and Social, Family, and Perinatal Factors

Table 2 shows the relationships between duration of breastfeeding and the potentially confounding social, family, and perinatal factors described in the "Methods." For ease of data display, measures of family factors and social background have been expressed as dichotomous variables. The rules for constructing these dichotomies are reported in Table 2. The significance of the associations between the duration of breastfeeding and the variables in Table 2 was tested using the  $\chi^2$  test of independence for dichotomous measures and one-way analysis of variance for continuously distributed variables (ie, birth weight, gestation).

Table 2 shows clear tendencies for increasing duration of breastfeeding to be associated with decreasing levels of social and family disadvantage and improved child perinatal outcomes. In particular, there were detectable tendencies for women who did not breastfeed to be younger ( $P < .001$ ), to have poorer educational qualifications ( $P < .001$ ), to have smoked during pregnancy ( $P < .001$ ), to be more likely to come from families of lower socioeconomic status ( $P < .001$ ), families with below-average living standards ( $P < .001$ ), or families with low income ( $P < .001$ ); and to have been a single parent at the time of the survey child's birth ( $P < .001$ ). In addition, women who did not breastfeed were more likely to have had infants of lower birth weight ( $P < .001$ ) and to be primiparous ( $P < .001$ ). However, the duration of breastfeeding appeared to be unrelated to the child's gender ( $P > .30$ ) or gestation ( $P > .20$ ).

**TABLE 2.** Associations Between Duration of Breastfeeding and Social, Family, and Perinatal Factors

Measure	Duration of Breastfeeding				P
	Not Breastfed	<4 Months	4-7 Months	$\geq 8$ Months	
Social/family factors (%)					
Mother age <25 years at birth of child	40.3	51.3	35.5	30.9	<.001
Mother lacked formal educational qualifications	64.6	60.2	40.6	29.4	<.001
Family of semiskilled/unskilled socioeconomic status	32.4	31.9	21.7	15.6	<.001
Child entered single-parent family at birth	10.9	9.9	4.2	1.4	<.001
Mother smoked during pregnancy	43.9	42.7	28.6	12.8	<.001
Below average living standards (0-5 years)	24.3	22.3	13.4	10.6	<.001
In lowest quartile on averaged family income (0-5 years)	27.4	31.8	16.7	18.9	<.001
Perinatal factors					
Male (%)	46.6	52.2	48.4	52.1	>.30
Mean birth weight (g)	3281	3353	3394	3445	<.001
Mean gestation (weeks)	39.5	39.7	39.7	39.6	>.20
First born in family (%)	29.7	46.5	39.6	37.6	<.001

### Associations Between Duration of Breastfeeding and Cognitive Outcomes After Adjustment for Confounding

To examine the associations between duration of breastfeeding and cognitive and educational outcomes after adjustment for the social, family, and perinatal factors presented in Table 2, the data were reanalyzed by fitting multiple regression models in which each outcome measure was modelled as a function of the duration of breastfeeding and the potentially confounding or selection factors. For continuously scored outcomes, multiple linear regression models were fitted, whereas for the dichotomous outcome, multiple logistic regression methods were used. In fitting these models, the social and family factors were not scaled as dichotomies as shown in Table 2, but rather were scored as described in "Methods."

From the parameters of the fitted regression models, estimates of the dose-response functions between the duration of breastfeeding and the outcome measures adjusted for confounding factors were obtained. These adjusted associations are given in Table 3, which shows for each outcome 1) the covariate adjusted mean scores or percentages for each level of the breastfeeding factor; 2) the test of significance of the breastfeeding factor based on the ratio of the regression coefficient for the breastfeeding measure to its SE; and 3) the confounding covariates that were found to be significant in each equation. The adjusted mean scores and percentages were obtained using the methods described by Lee (1981).<sup>27</sup> The adjusted means and percentages give estimates of the mean test scores and percentages that would have been observed had all subjects been exposed to comparable levels of the confounding covariates in shown for each equation.

Examination of Table 3 leads to the following conclusions:

1. In all cases, control for confounding factors reduced the strength of association between the du-

ration of breastfeeding and later outcomes. This result suggests, in part, that the apparently superior performance of children exposed to lengthy duration of breastfeeding reflected the presence of confounding factors and/or selection processes that were associated with both breastfeeding and later cognitive achievement. Inspection of the significant covariate factors suggests that these confounding factors included both measures of social/family advantage (maternal age, education, family socioeconomic status, family income, and living standards) and measures of perinatal outcome (birth weight, birth order, gender).

2. Of the 12 comparisons made, however, 10 show statistically significant ( $P < .05$ ) associations between duration of breastfeeding and later outcomes, one comparison is marginally significant ( $P < .10$ ), and one clearly nonsignificant ( $P > .15$ ). Of particular note is the fact that both the individual's levels of success in School Certificate examinations and his/her risk of leaving school without qualifications were significantly related to duration of breastfeeding even when allowance was made for confounding factors.

3. In general, the results suggest that after adjustment for confounding, there were small but consistent tendencies for increasing duration of breastfeeding to be associated with increased IQ, increased performance on standardized tests, higher teacher ratings of classroom performance, and better high school achievement. The size of this influence can be seen by comparing the adjusted mean test scores of children who were not breastfed with those of children who were breastfed for  $\geq 8$  months. These comparisons show that children who were breastfed for  $\geq 8$  months had mean scores that were between 0.11 and 0.30 SD units higher than the scores for those who were not breastfed. Similarly, children breastfed for  $\geq 8$  months were only two thirds as likely as non-

**TABLE 3.** Associations Between Duration of Breastfeeding and Measures of Cognitive Ability, Teacher Ratings of School Performance, Standardized Tests of Achievement, and High School Success After Adjustment for Covariates

Measure	Duration of Breastfeeding				P	Significant Covariates*
	Not Breastfed	<4 Months	4-7 Months	$\geq 8$ Months		
Mean cognitive ability scores						
WISC-R total IQ, 8 years	98.70	99.65	100.59	101.54	<.005	1-3, 5, 8, 9
9 years	98.96	99.78	100.60	101.42	<.01	1-3, 5, 8, 9
Mean teacher ratings of achievement						
Reading, 8 years	2.95	2.99	3.02	3.06	>.15	1, 2, 5, 7-9
12 years	2.93	2.98	3.03	3.08	<.10	1, 2, 4, 7-9
Mathematics, 8 years	2.89	2.97	3.06	3.14	<.005	1-3, 5, 7-9
12 years	2.87	2.97	3.07	3.17	<.001	1, 2, 5, 7-9
Mean standardized achievement test scores						
Reading comprehension, 10 years	98.86	99.76	100.66	101.56	<.005	2-4, 7
12 years	98.91	99.75	100.59	101.43	<.01	2-4, 7, 9
Mathematics, 11 years	99.06	99.77	100.49	101.21	<.05	1-3, 5, 7-9
Scholastic ability, 13 years	99.13	99.81	100.50	101.18	<.05	2, 3, 5, 7-9
High School Attainment						
Mean number of School Certificate passes	3.05	3.22	3.40	3.57	<.005	1-9
Leaving school without qualifications (%)	22.2	19.2	16.4	14.0	<.05	1-4, 6-8

\* Covariates: 1 indicates maternal age; 2, maternal education; 3, family socioeconomic status; 4, averaged standard of living (0-5 years); 5, averaged family income (0-5 years); 6, maternal smoking during pregnancy; 7, gender; 8, birth order; 9, birth weight.

breastfed children to have left school without qualifications.

### Supplementary Analyses

To examine the robustness of study conclusions to changes in analytic approaches, the following supplementary analyses were conducted.

1. The data were reanalyzed using a classification of breastfeeding based on the number of months for which the child was exclusively breastfed. This analysis produced conclusions that were consistent with those drawn above: increasing duration of exclusive breastfeeding was associated with increasing levels of cognitive ability and academic achievement, and adjustment for confounding tended to reduce the size of these associations but, even after adjustment, significant ( $P < .05$ ) associations remained between the duration of exclusive breastfeeding and 9 of the 12 outcomes studied. In particular, there were significant adjusted associations between duration of exclusive breastfeeding and high school outcomes measured at age 18.
2. To examine whether the effects of breastfeeding varied for boys and girls, the analyses were extended to include tests of interactions between gender and measures of breastfeeding in their effects on cognitive and educational outcomes. However, in no instance was there any detectable evidence to suggest that the association of breastfeeding with the outcome measures varied with the child's gender.
3. Exploration of additional possible confounding factors was conducted by examining the extent to which such factors as maternal work force participation patterns explained the associations. There was no evidence to suggest that the associations between breastfeeding and academic achievement or cognitive ability could be explained further by the inclusion of such confounding factors into the models.

### DISCUSSION

This study has examined the statistical linkages between duration of breastfeeding and later cognitive outcomes in a birth cohort of New Zealand-born children studied to 18 years of age. The findings of this study may be summarized as follows.

Increasing duration of breastfeeding was associated with small, detectable, and generally consistent increases in childhood cognitive outcomes from the age of 8 to the age of 18. Breastfed children had higher mean scores on tests of cognitive ability; performed better on standardized tests of reading, mathematics, and scholastic ability; were rated as performing better in reading and mathematics by their class teachers; had higher levels of achievement in school-leaving examinations; and less often left school without educational qualifications. There seems to be little doubt on the basis of this evidence that patterns of infant feeding were consistently related to levels of educational attainment from middle childhood to the point of young adulthood.

Subsequent analysis revealed that, in part, the cognitive and academic superiority of breastfed children was explained by the fact that they tended to be born into socially advantaged families characterized by having older, better educated mothers, who did not smoke during pregnancy, higher socioeconomic status, better living standards, and higher family income. However, even after control for confounding and selection factors associated with infant feeding practices, increasing duration of breastfeeding was associated with small but significant increases in scores on standardized tests of ability and achievement, teacher ratings of classroom performance, and greater success at high school. The size of this effect may be illustrated by comparing the mean test scores of those who were breastfed for  $\geq 8$  months with those who were not breastfed. This comparison showed that even after statistical adjustment, children exposed to  $\geq 8$  months of breastfeeding had mean test scores that were between 0.11 to 0.30 SD units higher than those not breastfed. These effect sizes appear to be very similar to the effects found in other studies of general child samples.<sup>1-4</sup> Similarly, after adjustment for confounding factors, children who were breastfed for  $\geq 8$  months had only an approximate two-thirds risk of leaving school without qualifications compared with children who were not breastfed. These results were found to be resilient to a change to an alternative measure of the duration of breastfeeding based on the number of months of exclusive breastfeeding.

Although the results above suggest that associations between duration of breastfeeding and later outcomes persisted when allowance was made for a range of confounders, the possibility remains that the association between breastfeeding and longer-term outcomes found in this study is noncausal and arises from the effects of confounding factors that have not been controlled adequately in the analysis. Nonetheless, when taken in conjunction with the existing literature on this topic,<sup>1-11,16-18</sup> the weight of the evidence clearly favors the view that exposure to breastfeeding is associated with small but detectable increases in childhood cognitive ability and educational achievement, with it being likely that these increases reflect the effects of long chain polyunsaturated fatty acid levels and, particularly, DHA levels on early neurodevelopment.<sup>10-12</sup> The present study extends these conclusions by showing that the effects of breastfeeding are 1) pervasive and reflected in a range of measures including standardized tests, teacher ratings, and success in high school examinations; and 2) relatively long-lived, extending throughout childhood into young adulthood.

### Clinical Implications

These findings add to a growing body of evidence that has suggested breastfeeding may have multiple health and other benefits for children.<sup>12,28</sup> The particular significance of the present findings is that they show the cognitive benefits that are associated with breastfeeding are unlikely to be short-lived and appear to persist until at least young adulthood. These findings underwrite the need to encourage breast-

feeding and/or to continue to develop improved infant formulas with properties more similar to those of human breast milk that may lead to improved developmental outcomes in children.<sup>11-13</sup>

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*Pediatrics* 1998;101:e9

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