

The Association Between Duration of Breastfeeding and Adult Intelligence

Erik Lykke Mortensen, PhD

Kim Fleischer Michaelsen, MD, ScD

Stephanie A. Sanders, PhD

June Machover Reinisch, PhD

A NUMBER OF STUDIES HAVE SUGGESTED a positive association between breastfeeding and cognitive and intellectual development in early and middle childhood.^{1,2} However, studies of correlations between childhood and adult intelligence show that intelligence is quite unstable during the first decade of life, particularly in early childhood.³ Consequently, it is possible that exclusively or predominantly bottlefed children may catch up and ultimately achieve the same intelligence level as children who were breastfed.

Few studies have examined the relationship between breastfeeding and intellectual development in older children and adolescents. One study observed significantly higher scores in breastfed children at 15 years of age on tests of nonverbal ability, mathematics, and reading ability,⁴ and another study demonstrated a positive association between breastfeeding and high school attainment at 18 years of age.⁵ The latter study also demonstrated an apparent dose-response relationship between duration of breastfeeding and scores on intelligence tests (at ages 8 and 9 years) and on standardized tests of reading and mathematics (at ages 8, 10, 12, and 13 years). These studies—and most others assessing cognitive ability in childhood—included a number of demographic, family, and perinatal factors as covariates. Despite the fact that controlling for these factors generally resulted in diminution of the

Context A number of studies suggest a positive association between breastfeeding and cognitive development in early and middle childhood. However, the only previous study that investigated the relationship between breastfeeding and intelligence in adults had several methodological shortcomings.

Objective To determine the association between duration of infant breastfeeding and intelligence in young adulthood.

Design, Setting, and Participants Prospective longitudinal birth cohort study conducted in a sample of 973 men and women and a sample of 2280 men, all of whom were born in Copenhagen, Denmark, between October 1959 and December 1961. The samples were divided into 5 categories based on duration of breastfeeding, as assessed by physician interview with mothers at a 1-year examination.

Main Outcome Measures Intelligence, assessed using the Wechsler Adult Intelligence Scale (WAIS) at a mean age of 27.2 years in the mixed-sex sample and the Børge Priens Prøve (BPP) test at a mean age of 18.7 years in the all-male sample. Thirteen potential confounders were included as covariates: parental social status and education; single mother status; mother's height, age, and weight gain during pregnancy and cigarette consumption during the third trimester; number of pregnancies; estimated gestational age; birth weight; birth length; and indexes of pregnancy and delivery complications.

Results Duration of breastfeeding was associated with significantly higher scores on the Verbal, Performance, and Full Scale WAIS IQs. With regression adjustment for potential confounding factors, the mean Full Scale WAIS IQs were 99.4, 101.7, 102.3, 106.0, and 104.0 for breastfeeding durations of less than 1 month, 2 to 3 months, 4 to 6 months, 7 to 9 months, and more than 9 months, respectively ($P = .003$ for overall F test). The corresponding mean scores on the BPP were 38.0, 39.2, 39.9, 40.1, and 40.1 ($P = .01$ for overall F test).

Conclusion Independent of a wide range of possible confounding factors, a significant positive association between duration of breastfeeding and intelligence was observed in 2 independent samples of young adults, assessed with 2 different intelligence tests.

JAMA. 2002;287:2365-2371

www.jama.com

effect, the positive association of breastfeeding with various measures of cognitive function remained significant and thus appeared robust.

There has only been one investigation of the relationship between breastfeeding and intelligence in adults.⁶ In that study, a significant association be-

Author Affiliations: Danish Epidemiology Science Center, Institute of Preventive Medicine, Copenhagen University Hospital, Denmark (Drs Mortensen and Reinisch); Department of Health Psychology, Institute of Public Health, University of Copenhagen, Denmark (Dr Mortensen); Research Department of Human Nutrition, The Royal Veterinary and Agricultural University, Frederiksberg, Denmark (Dr Michaelsen); The Kinsey Institute for Research in Sex, Gender and Reproduction (Drs Sanders and Reinisch) and Gender Studies (Dr Sanders), Indiana University, Bloomington.

Corresponding Authors: Erik Lykke Mortensen, PhD, Danish Epidemiology Science Center, Institute of Preventive Medicine, Copenhagen University Hospital, Copenhagen, Denmark (e-mail: e.l.mortensen@pubhealth.ku.dk) or June Machover Reinisch, PhD, The Kinsey Institute for Research in Sex, Gender and Reproduction, Indiana University, Bloomington (e-mail: rosenbl@downstate.edu).

Reprints: Erik Lykke Mortensen, PhD, Institute of Preventive Medicine, Kommunehospitalet, DK-1399 Copenhagen K, Denmark (e-mail: e.l.mortensen@pubhealth.ku.dk).

tween breastfeeding and scores on a computerized test of logical, verbal, and arithmetic reasoning was observed. However, when family and perinatal factors were included in a regression model, the association lost significance. This finding has been interpreted as strong evidence against a causal relationship between breastfeeding and long-term intellectual development⁷ despite the study's methodological weaknesses, which included the following: (1) feeding methods were assessed roughly in 3 categories (breastfed, bottlefed, and combined feeding, with 658 breastfed infants and only 53 bottlefed infants); (2) family information, including data on father's occupational class, was collected retrospectively from participants born between 1920 and 1930 (ie, 60-70 years later); (3) neither mean age nor variation in age at the time of intelligence testing was reported, but apparently the majority of participants were in their 60s or 70s. This means that the results may have been affected by individual differences in age-related decline in cognitive function or neurological diseases,⁸ thus weakening the possible association between breastfeeding and adult intelligence.

In an effort to overcome difficulties of interpreting previous studies, we describe the association between duration of breastfeeding and adult intelligence, applying 2 different intelligence measures, in 2 nonoverlapping samples from a perinatal cohort with a wide range of potentially confounding variables collected prospectively. In both samples, intelligence was assessed in young adulthood, an age when cognitive functioning is optimal and intelligence test scores are highly stable.

METHODS

The Copenhagen Perinatal Cohort

The Copenhagen Perinatal Cohort comprises 9125 individuals born at the Copenhagen University Hospital between October 1959 and December 1961. When the cohort was established, demographic, socioeconomic, prenatal, and postnatal medical data

were recorded prospectively during pregnancy, at delivery, and at a 1-year examination.⁹ Information on duration of breastfeeding was collected by a physician who interviewed the mothers at the 1-year examination. The mothers were asked both about duration of exclusive breastfeeding and about total duration of breastfeeding, but 2 out of 3 mothers in the cohort gave the same answer to these 2 questions. It is possible that the mothers distinctly remembered when they completely stopped breastfeeding, but less clearly when they started to supplement breast milk. It was not possible therefore to make a detailed analysis of exclusive breastfeeding vs total duration of breastfeeding, but a preliminary analysis showed no significant intelligence differences between subsamples of infants who were exclusively breastfed vs partially breastfed. Consequently, unless otherwise specified, duration of breastfeeding refers to total duration of any breastfeeding.

Wechsler Adult Intelligence Scale Sample

A subsample from the Perinatal Cohort participated in an ongoing research program between 1982-1994 that focused on the developmental effects of prenatal and perinatal factors, in particular the effects of prenatal exposure to prescribed maternal medications.¹⁰ On the basis of perinatal records, 1575 potential subjects were contacted, and 1155 (73%) completed the Danish version of the Wechsler Adult Intelligence Scale (WAIS).¹¹ Information on duration of breastfeeding was available for 1001 (87%) potential subjects, but 28 twins were excluded (see below). The final sample included 973 singletons (490 males and 483 females), with a mean assessment age of 27.2 years (SD=4.4; range, 20-34 years). Of the remaining 602 contacted individuals, information on duration of breastfeeding was only available for 399 potential subjects. The distribution of duration of breastfeeding was nearly identical in these 399 subjects and in the 973 subjects included in the final sample. The

mean parental social status score of the final WAIS sample was slightly, but significantly, higher than the score of the remaining contacted subjects, but otherwise there were no significant differences with respect to the covariates included in the study (TABLE 1).

The WAIS generates 3 IQ scores: Verbal, Performance, and Full Scale IQs (in this study, derived from Danish test norms). It was individually administered by 3 psychologists who were all completely blind to the subjects' breastfeeding status and other prenatal and perinatal information.

Børge Priens Prøve Sample

As part of the same research program,¹⁰ draft records were located for 3773 male members of the cohort. With the exception of individuals with disqualifying diseases (eg, epilepsy and diabetes) and individuals who volunteer for military service at an earlier age, all Danish males are required to appear before the draft board at 18 years of age. (Only a little over 5% of Danish males do not appear.)¹²

The Danish military draft board administers an intelligence test, the Børge Priens Prøve (BPP), a 45-minute group test with 4 subtests (letter matrices, verbal analogies, number series, and geometric figures) and a total score ranging from 0 to 78. This total score has a correlation of 0.82 with the Full Scale WAIS IQ, indicating that the BPP is closely related to standard measures of general intelligence.¹³

Of the 4668 males in the Perinatal Cohort, 77% (4279) survived the first 4 weeks of life. The BPP scores were available for 3306 of these, but 501 singletons were excluded to avoid overlap with the WAIS sample; in addition, 76 twins were excluded. Information on duration of breastfeeding was available for 2280 (84%) of the remaining 2729 individuals. Thus, the final BPP sample comprised 2280 singleton males who appeared before the draft board at the mean age of 18.7 years (SD, 1.2; range, 17-26 years). The sample represents 69% of the 3306 males with BPP scores. The distribution of duration of breastfeeding was

almost identical for this sample and for the 1283 males for whom information on duration of breastfeeding was available, but who because of lack of a BPP score, overlap with the WAIS sample, or twin status were excluded. However, on several of the covariates in this study, the BPP sample differed significantly from the excluded males of the Perinatal Cohort who survived the first 4 weeks of life. The BPP sample had higher mean scores on gestational age, birth weight, and birth length and lower mean scores on parental social status and the indexes of pregnancy and delivery complications. In general, these differences were small: eg, for gestational age, 0.2 week; for birth weight, 55 g; and for birth length, 0.3 cm (Table 1).

Subject Selection

Twins were excluded because relationships between some of the covariates and adult intelligence may be different in twins and singletons (eg, associations between adult intelligence and birth weight and length) and because data for twin pairs are not statistically independent. Twin pairs only com-

prised a small fraction of the 2 samples, and when analyses were conducted on samples that included twins, the results are essentially the same as those presented in Table 3.

Exclusive breastfeeding beyond 6 months may be associated with nutrient deficiencies and suboptimal growth.¹⁴ In a preliminary analysis, we investigated this potential risk to intellectual development. In the WAIS and BPP samples, the 40 and 83 subjects who were exclusively breastfed for 7 months or longer obtained essentially the same adjusted mean test scores as the 87 and 180 subjects who were partially breastfed for 7 months or longer. Consequently, we decided to include subjects who were exclusively breastfed for 7 months or longer in the analyses presented here.

Data Analysis

Duration of breastfeeding was originally recorded on a 1- to 11-point scale (from ≤ 1 -2 weeks to > 12 months). On the basis of this scale, the subjects in both samples were classified into 5 categories according to duration of breastfeed-

ing: (1) 1 month or less (in the 2 samples, 67% and 72% of this category were originally coded ≤ 1 -2 weeks); (2) 2 to 3 months; (3) 4 to 6 months; (4) 7 to 9 months; and (5) more than 9 months. It was not possible to include a separate category for children who were never breastfed since they were coded as 1 to 2 weeks or less. For both samples, the number of subjects in each breastfeeding category is shown in TABLE 2. Unadjusted and adjusted mean differences in intelligence test scores among the 5 breastfeeding categories were analyzed statistically for both samples, using the SPSS linear regression and analysis of variance routines (SPSS Inc, Chicago, Ill, version 10.0). The level of significance was set at .05.

Based on preliminary regression analyses, the following variables were considered potential confounders and included as covariates in analyses of both the 3 WAIS IQs and the BPP scores: (1) marital status; (2) social status; (3) breadwinner's education; (4) mother's height; (5) mother's age; (6) mother's weight gain during pregnancy; (7) mother's cigarette consumption during the third tri-

Table 1. Comparison of Participating/Included and Nonparticipating/Excluded Subjects*

	Wechsler Adult Intelligence Scale†			Borge Priens Prøve‡		
	Participants (n = 973)	Nonparticipants (n = 602)	P Value§	Included (n = 2280)	Excluded (n = 1999)	P Value§
Duration of breastfeeding (1- to 11-point scale)	4.2 (2.5)	4.0 (2.5)	.28	3.8 (2.6)	3.7 (2.5)	.27
Parental characteristics						
Maternal height, cm	163.3 (5.4)	163.4 (5.3)	.84	162.8 (5.5)	163.0 (5.6)	.33
Mother's age, y	28.3 (6.6)	28.1 (6.6)	.47	25.5 (6.5)	26.4 (6.6)	<.001
Social status (1- to 8-point scale)	4.6 (1.9)	4.4 (1.8)	.006	3.9 (1.8)	4.2 (1.9)	<.001
Breadwinner's education (1- to 4-point scale)	2.6 (0.8)	2.5 (0.7)	.14	2.4 (0.7)	2.5 (0.8)	<.001
Single mother, %	23	25	.47	39	36	.047
No. of pregnancies	2.0 (1.2)	2.0 (1.3)	.18	1.9 (1.2)	1.9 (1.2)	.10
Smokers, %	46	46	.96	52	51	.36
Cigarette consumption, No. per day	3.7 (5.2)	3.8 (5.6)	.65	4.5 (5.9)	4.4 (5.8)	.44
Weight increase during pregnancy, kg	11.4 (3.5)	11.8 (3.5)	.10	11.5 (3.6)	11.7 (3.6)	.11
Pregnancy complications (range, 10-291)	70.6 (37.6)	70.4 (34.2)	.90	54.7 (33.1)	61.3 (35.4)	<.001
Delivery complications (range, 20-249)	71.6 (40.5)	71.6 (39.7)	.99	67.6 (41.6)	70.7 (41.5)	.02
Infant characteristics						
Gestational age, wk	39.2 (2.0)	39.3 (2.1)	.49	39.1 (2.7)	38.9 (2.7)	.02
Birth weight, g	3251 (562)	3243 (590)	.79	3288 (631)	3233 (660)	.005
Birth length, cm	51.1 (2.6)	51.1 (2.8)	.75	51.4 (3.1)	51.1 (3.2)	.004

*The original 11-point coding of duration of breastfeeding was analyzed for this table; for all variables, subjects with missing data were excluded from the analysis. Data are expressed as mean (SD) unless otherwise indicated.

†The Wechsler Adult Intelligence Scale group includes a mixed-sex sample of 973 participating subjects and 602 contacted but nonparticipating subjects.

‡The Borge Priens Prøve test group includes an all-male sample of 2280 and the remaining 1999 males who survived the first 4 weeks of life.

§The P values for the percentages of single mothers and smokers refer to χ^2 tests of differences between participating and nonparticipating subjects. For the remaining variables, P values refer to F tests of differences between the 2 categories.

mester; (8) number of pregnancies; (9) estimated gestational age; (10) birth weight; (11) birth length; (12) a previously described index of pregnancy complications¹⁵; and (13) a previously described index of delivery complications.¹⁵

Table 2. Relation Between Covariates and Duration of Breastfeeding*

	N	Duration of Breastfeeding, mo					P Value†
		≤1	2-3	4-6	7-9	>9	
No. of subjects							
WAIS sample	973	272	305	269	104	23	...
BPP sample	2280	784	736	497	190	73	...
Parental characteristics							
Maternal height, cm							
WAIS sample	971	163.4	163.2	163.3	163.1	165.3	.50
BPP sample	2252	162.5	162.9	162.8	163.6	162.9	.23
Mother's age, y							
WAIS sample	970	28.6	27.2	29.0	28.9	30.7	.004
BPP sample	2265	25.4	24.8	25.9	26.8	27.7	<.001
Social status (1- to 8-point scale)							
WAIS sample	918	4.2	4.5	4.9	5.4	4.6	<.001
BPP sample	1987	3.6	3.7	4.2	4.8	3.9	<.001
Breadwinner's education (1- to 4-point scale)							
WAIS sample	903	2.4	2.5	2.7	2.9	2.5	<.001
BPP sample	1959	2.3	2.3	2.5	2.7	2.4	<.001
Single mother, %							
WAIS sample	971	33	28	13	10	9	<.001
BPP sample	2272	45	42	34	23	38	<.001
No. of pregnancies (including current pregnancy)							
WAIS sample	973	2.2	1.8	2.0	1.8	1.9	.001
BPP sample	2276	2.0	1.8	1.8	1.8	2.0	<.001
Smokers, %							
WAIS sample	950	55	47	41	38	35	.005
BPP sample	2228	56	54	51	35	38	<.001
Cigarette consumption, No. per day							
WAIS sample	963	4.8	3.7	3.1	2.7	2.6	<.001
BPP sample	2243	5.2	4.7	4.1	3.0	3.1	<.001
Weight increase during pregnancy, kg							
WAIS sample	747	11.1	11.4	11.7	11.6	11.5	.53
BPP sample	1286	11.1	11.7	11.8	12.0	10.8	.03
Pregnancy complications (range, 10-291)							
WAIS sample	973	76.4	68.4	68.9	67.3	66.5	.06
BPP sample	2280	56.4	53.5	56.3	48.6	52.4	.03
Delivery complications (range, 20-249)							
WAIS sample	973	74.1	71.1	70.3	70.7	67.2	.80
BPP sample	2280	69.2	65.8	68.5	66.8	64.8	.54
Infant characteristics							
Gestational age, wk							
WAIS sample	875	38.9	39.4	39.2	39.3	39.4	.07
BPP sample	1792	38.7	39.3	39.3	39.5	39.3	<.001
Birth weight, g							
WAIS sample	973	3160	3243	3304	3367	3278	.007
BPP sample	2279	3157	3338	3341	3450	3416	<.001
Birth length, cm							
WAIS sample	971	50.7	51.2	51.3	51.7	51.2	.01
BPP sample	2278	50.8	51.5	51.6	52.3	51.6	<.001

*WAIS indicates Wechsler Adult Intelligence Scale; BPP, Børge Priens Prøve.

†The P values for the percentages of single mothers and smokers refer to χ^2 test of differences between breastfeeding categories. For the remaining variables, P values refer to the overall F tests of mean differences between breastfeeding categories (1-way analysis of variance).

Preliminary analyses of both the BPP and the WAIS samples showed no significant 2-factor interaction between any covariate and duration of breastfeeding. Thus, analyses of the WAIS sample showed no significant interactions between sex and duration of breastfeeding. Consequently, the analysis of the WAIS sample only included the main effect of sex. The WAIS sample consisted of 433 subjects who were prenatally exposed to maternal medication and 540 control subjects. (Among the exposed subjects, 106 were exposed to hormones and 323 were exposed to barbiturates.) There were no significant interactions between duration of breastfeeding and being either a medication-exposed or a control subject, but the main effect of being exposed to medication was significant and this factor was included as a covariate. Control subjects obtained significantly higher WAIS IQs than subjects exposed to maternal medication, and this finding was not unexpected since we have previously observed effects of prenatal exposure to phenobarbital on adult intelligence.¹⁶

Preliminary analyses revealed significant nonlinear associations between some of the intelligence test scores and mother's height, mother's age, and delivery complications. To reflect possible nonlinearity, the final regression models included squared deviations from the mean for these 3 variables.

For most covariates, the missing data rate was less than 1%, but the missing data rates for maternal weight gain, gestational age, social status, and breadwinner's education were 23%, 10%, 6%, and 7%, respectively, in the WAIS sample, and 44%, 21%, 13%, and 14%, respectively, in the BPP sample. Since about 38% and 63% of the 2 samples had missing data on 1 or more predictor variables, we decided to present analyses based on overall mean substitution for missing values and to include dummy variables for missing data on weight increase in pregnancy, gestational age, social status, and breadwinner's education.¹⁷ (Essentially the same results were obtained with alternative methods of im-

puting missing values.) Univariate analyses showed that missing data were not significantly related to WAIS scores, but that missing data on maternal weight gain were significantly associated with lower BPP scores. In the regression analyses with all covariates included, missing data on maternal weight gain, gestational age, social status, and breadwinner's education were not significantly associated with any intelligence test score.

In general, correlations between the included covariates were low (<0.20), but a few covariates showed relatively high intercorrelations. In the BPP sample, the largest squared multiple correlations between an individual covariate and all other variables in the regression model were 0.71 (for both birth weight and length) while they were 0.64 for these 2 variables in the WAIS sample (here the squared multiple correlation for social status was 0.69). The purpose of the study was not to estimate effects associated with the individual covariates, but to obtain unbiased estimates of the effects associated with duration of breastfeeding. Consequently, collinearity among the covariates was not considered a serious problem.

In summary, the BPP means are adjusted for marital status, social status, breadwinner's education, mother's height, mother's age, mother's weight gain during pregnancy, mother's cigarette consumption during the third trimester, number of pregnancies, estimated gestational age, birth weight, birth length, an index of pregnancy complications, and an index of delivery complications. The adjusted WAIS means are also adjusted for effects of sex and medication exposure, and for both samples, the linear regression model included variables coding possible nonlinear effects of mother's height, mother's age, and delivery complications and missing data for maternal weight gain, gestational age, social status, and breadwinner's education.

Contrasts were calculated to evaluate the significance of differences between pairs of means, in particular the differences between the 7- to 9-months and the more than 9-months breast-

Table 3. Observed and Adjusted Means for Intelligence Test Scores in Relation to Duration of Breastfeeding*

	Duration of Breastfeeding, mo					P Value
	≤1	2-3	4-6	7-9	>9	
WAIS Verbal IQ						
Unadjusted mean (SD)	98.2 (16.0)	101.7 (14.9)	104.0 (15.7)	108.2 (13.3)	102.3 (15.2)	<.001
Adjusted mean	99.7	102.3	102.7	105.7	103.0	.007
WAIS Performance IQ						
Unadjusted mean (SD)	98.5 (15.8)	100.5 (15.2)	101.8 (15.6)	106.3 (13.9)	102.6 (14.9)	<.001
Adjusted mean	99.1	100.6	101.3	105.1	104.4	.02
WAIS Full Scale IQ						
Unadjusted mean (SD)	98.1 (15.9)	101.3 (15.2)	103.3 (15.7)	108.2 (13.1)	102.8 (14.4)	<.001
Adjusted mean	99.4	101.7	102.3	106.0	104.0	.003
BPP						
Unadjusted mean (SD)	36.9 (11.3)	39.0 (11.1)	40.8 (11.2)	43.1 (11.0)	40.2 (12.3)	<.001
Adjusted mean	38.0	39.2	39.9	40.1	40.1	.01

*The significance levels for both the unadjusted and adjusted means refer to the overall F tests of significance of mean differences between the 5 breastfeeding categories. The adjusted means for the Børge Priens Prøve (BPP) test are adjusted for marital status, social status, breadwinner's education, mother's height, mother's age, mother's weight gain during pregnancy, mother's cigarette consumption during the third trimester, number of pregnancies, estimated gestational age, birth weight, birth length, an index of pregnancy complications, and an index of delivery complications. The adjusted means for the Wechsler Adult Intelligence Scale (WAIS) are also adjusted for effects of sex and medication exposure.

feeding categories. For tests of trend, interval midpoints were used to code duration of breastfeeding (0.5, 2.5, 5.0, 8.0, and 11.0 months) and power polynomials were calculated.¹⁷ Tests of trend using the original 1- to 11-point scale essentially showed the same results as those reported for the 5-category classification.

The study was approved by the institutional review board of the Institute of Preventive Medicine and the Danish Public Scientific Ethics Committee. Informed consent was obtained for the WAIS sample, but according to Danish rules, was not necessary for the BPP sample, which is purely register-based.

RESULTS

Table 2 shows the relation between the covariates and breastfeeding categories. Duration of breastfeeding was positively associated with mother's age, social status, education, birth weight, birth length, and negatively associated with single mother status and cigarette consumption. In addition, further significant associations with breastfeeding categories were observed in the BPP sample for gestational age, weight in-

crease during pregnancy, and pregnancy complications.

In both samples, the positive association between duration of breastfeeding and parental demographic characteristics (social status and education) and between breastfeeding and physical development at birth (birth weight and length) was observed in 4 of the 5 breastfeeding categories. However, breastfeeding for more than 9 months was associated with lower means than those of the 7- to 9-months category, and thus the association with duration of breastfeeding appears to be nonlinear.

TABLE 3 shows significant differences among breastfeeding categories for all 3 WAIS IQs. Both the unadjusted and adjusted IQ means showed a dose-response relationship with duration of breastfeeding up to 9 months, but a lower mean IQ in the more than 9-months category. However, the differences between the 7- to 9-months category and the more than 9-months category were not significant for any WAIS IQ, and with covariate adjustment, tests of linear and quadratic trend showed only a significant linear trend ($P=.001$ for the Verbal and Performance IQs and $P<.001$ for the Full Scale IQ). Although covariate ad-

justment somewhat reduced the effects associated with duration of breastfeeding, the differences between the less than 1 month and the 7- to 9-months categories remained substantial. The unadjusted and adjusted differences in mean Full Scale IQ between these 2 breastfeeding categories were 10.1 and 6.6, respectively. Since the theoretical SD is 15, the unadjusted difference corresponds to about two thirds of the theoretical SD, while the adjusted difference is approaching half an SD. The patterns of differences for the Verbal and Performance IQs were strikingly similar, as the adjusted difference between the less than 1 month and the 7- to 9-months categories was 6.0 for both IQs.

The observed percentages of subjects with Full Scale IQ scores below 90 were 28, 20, 18, 9, and 4 in the 5 breastfeeding categories, respectively. A χ^2 test showed that these percentages were significantly different among the 5 breastfeeding categories ($P < .001$), and they remained significant when a logistic regression model was used to adjust for all covariates included in the linear regression analyses of IQ ($P < .001$).

Table 3 shows a similar pattern of mean test scores for the BPP sample. Thus, analyses of the BPP sample also revealed a positive dose-response relationship for the first 4 breastfeeding categories. While the unadjusted difference between the BPP mean for the 7- to 9-months and the more than 9-months categories approached significance, the adjusted means were identical, and for the model with covariates, tests of linear and quadratic trend only showed significant linear trend ($P = .002$). However, the effect associated with breastfeeding appeared smaller for the BPP than for the WAIS, as the difference between the lowest and the highest adjusted means was 2.1 BPP points, which is less than one fifth of an SD.

COMMENT

The current study demonstrates a robust association between the duration of breastfeeding and adult intelligence in 2 nonoverlapping samples assessed with 2 different measures of intelli-

gence. The results suggest larger effects associated with breastfeeding for the WAIS sample. A likely explanation is that the WAIS is a more sensitive measure than the BPP because the 11 subtests of the WAIS assess a broader range of cognitive functions than the 4 subtests of the BPP. In addition, the WAIS was administered individually by trained psychologists, while the BPP is a group test administered as part of the military preinduction procedures.

The unadjusted test scores were lower for individuals who were breastfed for more than 9 months compared with those breastfed for 7 to 9 months. However, the adjusted means for the 2 categories were not significantly different for any of the test scores. Thus, the overall pattern of results suggests that no additional positive effects are associated with breastfeeding after 9 months.

Three types of explanations may be considered for the observed positive association between breastfeeding and cognitive development⁴: (1) differences between human milk and infant formula or other complementary foods (ie, breast milk may contain nutrients that stimulate brain development); (2) factors associated with the feeding situation, ie, physical and psychological contact between mother and child; and (3) unidentified factors that correlate with both infant feeding methods and development of cognitive and intellectual ability, or relevant and identified factors that cannot be fully controlled in statistical analyses (residual confounding). The first 2 types of explanations consider the association with intellectual development as a direct effect of breastfeeding, whereas the third type of explanation focuses on factors that are associated with the choice of feeding method.

Most studies in industrialized countries have found a positive association between breastfeeding and parental education as well as social class.¹⁸ This was also the case in our samples since duration of breastfeeding was associated with a number of demographic factors (mother's age, single mother status, social status, and education).

Although we were able to statistically control these and other social and perinatal factors, the question remains whether duration of breastfeeding in our samples was associated with unregistered factors that correlate with offspring intellectual development.

The most obvious factor is maternal intelligence, since studies have observed either nonsignificant or much smaller effects of breastfeeding on offspring intellectual development when maternal intelligence was included as a covariate.^{19,20} However, in a recent study, the association between duration of breastfeeding and intelligence at 5 years persisted after controlling for maternal intelligence.²¹ In our study, the multiple correlations between parental education and social status (both of which are highly correlated with IQ) and the 4 offspring IQs were high (0.43, 0.46, 0.28, and 0.41, for the BPP and the WAIS Verbal, Performance, and Full Scale IQs, respectively). It is likely that correlations between education, social status, and parental IQs would be even higher. Consequently, including parental education and social status as covariates in the current study removed a substantial part of the variance in offspring IQ associated with parental IQ (the average correlation between parent IQ and offspring IQ has been reported to be 0.42).²² In addition, the current study does not focus on bottlefeeding vs breastfeeding, but on the relationship between duration of breastfeeding and offspring intelligence. Consequently, maternal intelligence could only explain our results if it correlated systematically with duration of breastfeeding even within educational and social classes (since the latter variables were controlled as covariates). It is possible that general awareness of potential benefits from breastfeeding was less prevalent and more strongly associated with maternal intelligence among low social status mothers than among high social status mothers. Counter to this hypothesis, when the 2 samples were split into low social status (codes 1-5) and high social status subsamples (codes 6-8), the patterns of mean test scores for the 5

breastfeeding categories were remarkably similar in the 2 social status subsamples, and formal statistical tests showed no interaction between duration of breastfeeding and social status.

The extra mother-child physical and psychological contact associated with duration of breastfeeding may affect the intellectual development of the child during the first year of life, but seems an unlikely explanation of long-term effects of breastfeeding on intellectual development into adulthood. Perhaps a more viable hypothesis is to consider duration of breastfeeding as an indicator of the interest, time, and energy that the mother is able to invest in the child during the whole upbringing period. Behavior predicts behavior, and even within each different social class and educational level, it may be that mothers who spend more time breastfeeding during the first year of life also spend more time later interacting with the child. The influence of family environment on long-term intellectual development has, however, been questioned by some twin studies,²² and it is an open question whether associations between duration of breastfeeding and particular aspects of parental behavior can explain the effects.

A randomized trial demonstrated that early diet may affect childhood intelligence,²³ and the hypothesis that breast milk contains nutrients that stimulate brain development was supported by a study comparing developmental scores at the age of 18 months of infants fed solely standard formula and infants fed donor breast milk.²⁴ A possible explanation of the influence of breastfeeding on cognitive development is an effect of long-chain polyunsaturated fatty acids, especially docosahexaenoic acid (DHA), which is present in human milk but not in infant formula or cow's milk. Docosahexaenoic acid is a main constituent of cell membranes in the central nervous system, including the retina, and it has been suggested that it has a role in signal transmission both within and between neurons.²⁵ Randomized controlled trials in both preterm and term

infants have demonstrated improved visual and mental development in those receiving a formula supplemented with DHA.²⁵⁻²⁷ To some degree, DHA may be converted from the precursor alpha-linolenic acid (ALA), and the content of ALA in modern infant formula is high compared with the content in cow's milk and infant formula used in the early 1960s. According to the DHA hypothesis, the effect of breastfeeding would therefore be expected to be somewhat larger in a cohort born in the early 1960s compared with cohorts of infants receiving modern infant formula.

In conclusion, we observed a positive significant association between duration of breastfeeding and intelligence in young adults in 2 independent samples assessed with 2 different intelligence tests. These results indicate that breastfeeding may have long-term positive effects on cognitive and intellectual development. The nutrients in breast milk, behavioral factors, and factors associated with choice of feeding method may all contribute to the positive association.

Author Contributions: *Study concept and design:* Mortensen, Sanders, Reinisch.

Acquisition of data: Mortensen, Sanders, Reinisch. *Analysis and interpretation of data:* Mortensen, Michaelsen, Sanders, Reinisch.

Drafting of the manuscript: Mortensen.

Critical revision of the manuscript for important intellectual content: Mortensen, Michaelsen, Sanders, Reinisch.

Statistical expertise: Mortensen.

Obtained funding: Mortensen, Sanders, Reinisch.

Administrative, technical, or material support: Mortensen, Sanders, Reinisch.

Study supervision: Reinisch.

Funding/Support: This study was supported by United States Public Health Service (USPHS) grants HD17655 and HD20263 from the National Institute of Child Health and Human Development to Dr Reinisch, USPHS grant DA05056 from the National Institute on Drug Abuse to Drs Reinisch and Sanders, and grant 9700093 from The Danish Research Councils as well as grant 1400/2-4-1997 from the Danish National Board of Health to Dr Mortensen.

Acknowledgment: We thank Vibeke Munk, BA, for help with the manuscript and critical comments.

REFERENCES

- Anderson JW, Johnstone BM, Remley DT. Breastfeeding and cognitive development: a meta-analysis. *Am J Clin Nutr.* 1999;70:525-535.
- Golding J, Rogers IS, Emmett PM. Association between breastfeeding, child development and behaviour. *Early Hum Dev.* 1997;49(suppl):177-184.
- Schuerger JM, Witt AC. The temporal stability of individually tested intelligence. *J Clin Psychol.* 1989;45:294-302.

4. Rodgers B. Feeding in infancy and later ability and attainment: a longitudinal study. *Develop Med Child Neurol.* 1978;20:421-426.

5. Horwood LJ, Fergusson DM. Breastfeeding and later cognitive and academic outcomes. *Pediatrics.* 1998;101:1-7.

6. Gale CR, Martyn CN. Breastfeeding, dummy use, and adult intelligence. *Lancet.* 1996;347:1072-1075.

7. Feldman W, Feldman ME. The intelligence on infant feeding. *Lancet.* 1996;347:1057.

8. Mortensen EL, Hogh P. A gender difference in the association between APOE genotype and age-related cognitive decline. *Neurology.* 2001;57:89-95.

9. Zachau-Christiansen B, Ross EM. *Babies: Human Development During the First Year.* New York, NY: John Wiley & Sons; 1975.

10. Reinisch JM, Mortensen EL, Sanders SA. The prenatal development project. *Acta Psychiatr Scand.* 1993;(suppl)370:54-61.

11. Wechsler D. *The Measurement and Appraisal of Adult Intelligence.* Baltimore, Md: Williams & Wilkins; 1958.

12. Teasdale TW, Owen DR. National secular trends in intelligence and education. *Nature.* 1987;325:119-121.

13. Mortensen EL, Reinisch JM, Teasdale TW. Intelligence as measured by the WAIS and a military draft board group test. *Scand J Psychol.* 1989;30:315-318.

14. Rogers IS, Emmett PM, Golding J. The growth and nutritional status of the breast-fed child. *Early Hum Dev.* 1997;49(suppl):157-174.

15. Baker RL, Mednick BR. *Influences on Development: A Longitudinal Study.* Boston, Mass: Kluwer Academic Publishers; 1984:3-16.

16. Reinisch JM, Sanders SA, Mortensen EL, Rubin DB. In utero exposure to phenobarbital and intelligence deficits in adult men. *JAMA.* 1995;274:1518-1525.

17. Cohen J, Cohen P. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences.* Hillsdale, NJ: Lawrence A. Erlbaum Associates; 1983.

18. Rogers IS, Emmett PM, Golding J. The incidence and duration of breastfeeding. *Early Hum Dev.* 1997;49(suppl):45-74.

19. Jacobson SW, Jacobson JL. Breastfeeding and intelligence. *Lancet.* 1992;339:926.

20. Fergusson DM, Beautrais AL, Silva PA. Breastfeeding and cognitive development in the first seven years of life. *Soc Sci Med.* 1982;16:1705-1708.

21. Angelsen NK, Vik T, Jacobsen G, Bakkeiteig LS. Breast feeding and cognitive development at age 1 and 5 years. *Arch Dis Child.* 2001;85:183-188.

22. McGue M, Bouchard TJ Jr, Iacono WG, Lykke DT. Behavioral genetics of cognitive ability: a life-span perspective, I. In: Plomin R, McClearn GE, eds. *Nature, Nurture and Psychology.* Washington, DC: American Psychological Association; 1993:59-76.

23. Lucas A, Morley R, Cole TJ. Randomised trial of early diet in preterm babies and later intelligence quotient. *BMJ.* 1998;317:1481-1487.

24. Lucas A, Morley R, Cole TJ, Gore SM. A randomised multicentre study of human milk versus formula and later development in preterm infants. *Arch Dis Child Fetal Neonatal Ed.* 1994;70:F141-F146.

25. Lauritzen L, Hansen SH, Jørgensen MH, Michaelsen KF. The essentiality of long chain n-3 fatty acids in relation to development and function of the brain and retina. *Prog Lipid Res.* 2001;40:1-94.

26. SanGiovanni JP, Parra-Cabrera S, Colditz GA, Berkley CS, Dwyer JT. Meta-analysis of dietary essential fatty acids and long-chain polyunsaturated fatty acids as they relate to visual resolution acuity in healthy preterm infants. *Pediatrics.* 2000;105:1292-1298.

27. Birch EE, Garfield S, Hoffman DR, Uauy R, Birch DG. A randomized controlled trial of early dietary supply of long-chain polyunsaturated fatty acids and mental development in term infants. *Dev Med Child Neurol.* 2000;42:174-181.

agreements in the categorization of a restaurant were settled through discussion.

Results. All 16 hospitals responded to the survey. Six of the 16 (38%) hospitals had regional or national fast food franchises on the grounds of their main medical centers, with 4 facilities contracting with 2 chains simultaneously. One of the hospitals without a fast food franchise had closed a fast food franchise in 1999, but later opened a hospital-owned restaurant serving a similar menu. Another center had a fast food franchise located in one of its associated hospitals. None of the centers with fast food franchises described unique dietary options available at their restaurants.

Comment. Among 16 of the nation's top hospitals, we found that fast food franchises are present in more than one third of facilities surveyed. Although these hospitals are clearly not representative of all hospitals in the United States, they do include several of the most widely recognized and influential medical centers in the world.

Hospitals play an important role in promoting healthy lifestyles among their patients, visitors, and employees. However, hospitals are also businesses that need to address important economic issues such as customer satisfaction, employee retention, and financial viability. These roles unfortunately can occasionally lead to conflicting institutional goals. During the 1980s, for example, hospitals struggled with whether to let visitors or employees smoke cigarettes within their facilities. Ultimately, hospitals decided that the benefit of allowing individuals the freedom to smoke was outweighed by their responsibility for advocating health promotion.⁷

Of course, fast food restaurants are not solely responsible for the rising incidence of obesity in the United States. How-

ever, their ubiquitous presence undoubtedly contributes to the proliferation of high-fat and high-calorie diets among Americans.⁸ Hospitals may wish to revisit the idea of serving high-calorie fast food in the very place where they also care for the most seriously ill.

Peter Cram, MD
Brahmjee K. Nallamotheu, MD, MPH
A. Mark Fendrick, MD
Sanjay Saint, MD, MPH
Department of Internal Medicine
University of Michigan Medical School
Ann Arbor

1. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The spread of the obesity epidemic in the United States, 1991-1998. *JAMA*. 1999; 282:1519-1522.
2. Koplan JP, Dietz WH. Caloric imbalance and public health policy. *JAMA*. 1999; 282:1579-1581.
3. Markel H. Diagnosis: supersize. *New York Times*. March 24, 2002:sect 4.
4. America's best hospitals. *US News & World Report*. July 23, 2001.
5. Chen J, Radford MJ, Wang Y, Marciniak TA, Krumholz HM. Do "America's best hospitals" perform better for acute myocardial infarction? *N Engl J Med*. 1999; 340:286-292.
6. Green J, Wintfeld N, Krasner M, Wells C. In search of America's best hospitals: the promise and reality of quality assessment. *JAMA*. 1997;277:1152-1155.
7. Ho AM. Reducing smoking in hospitals: a time for action. *JAMA*. 1985;253: 2999-3000.
8. Schlosser E. *Fast Food Nation: The Dark Side of the All-American Meal*. Boston, Mass: Houghton Mifflin Co; 2001.

CORRECTION

Incorrect E-mail Address: An incorrect e-mail address was given in the Original Contribution entitled "The Association Between Duration of Breastfeeding and Adult Intelligence" published in the May 8, 2002, issue of the *THE JOURNAL* (2002;287: 2365-2371). On page 2365, in the "Corresponding Authors" footnote, the correct e-mail address for Dr Reinisch is rosenbl@downstate.edu.

CME ANNOUNCEMENT

CME Hiatus: July Through December 2002

CME from *JAMA/Archives Journals* will be suspended between July and December 2002. Beginning in early 2003, we will offer a new *online* CME program that will provide many enhancements:

- Article-specific questions
- Hypertext links from questions to the relevant content
- Online CME questionnaire
- Printable CME certificates and ability to access total CME credits

We apologize for the interruption in CME and hope that you will enjoy the improved online features that will be available in early 2003.