Breastfeeding, Cognitive and Noncognitive Development in Early Childhood: A Population Study

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abstract

BACKGROUND AND OBJECTIVES: There is mixed evidence from correlational studies that breastfeeding impacts children's development. Propensity score matching with large samples can be an effective tool to remove potential bias from observed confounders in correlational studies. The aim of this study was to investigate the impact of breastfeeding on children's cognitive and noncognitive development at 3 and 5 years of age.

METHODS: Participants included ~8000 families from the Growing Up in Ireland longitudinal infant cohort, who were identified from the Child Benefit Register and randomly selected to participate. Parent and teacher reports and standardized assessments were used to collect information on children's problem behaviors, expressive vocabulary, and cognitive abilities at age 3 and 5 years. Breastfeeding information was collected via maternal report. Propensity score matching was used to compare the average treatment effects on those who were breastfed.

RESULTS: Before matching, breastfeeding was associated with better development on almost every outcome. After matching and adjustment for multiple testing, only 1 of the 13 outcomes remained statistically significant: children's hyperactivity (difference score, −0.84; 95% confidence interval, −1.33 to −0.35) at age 3 years for children who were breastfed for at least 6 months. No statistically significant differences were observed postmatching on any outcome at age 5 years.

CONCLUSIONS: Although 1 positive benefit of breastfeeding was found by using propensity score matching, the effect size was modest in practical terms. No support was found for statistically significant gains at age 5 years, suggesting that the earlier observed benefit from breastfeeding may not be maintained once children enter school.

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Dr Girard conceptualized the study, carried out the initial analyses, interpreted the data, and drafted the initial manuscript; Drs Doyle and Tremblay conceptualized the study and critically reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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WHAT'S KNOWN ON THIS SUBJECT: The medical benefits of breastfeeding for mother and child are considered numerous, yet the effect of breastfeeding on cognitive abilities remains largely debated given selection into breastfeeding. The effect on behavior is even less well understood.

WHAT THIS STUDY ADDS: In applying quasi-experimental techniques which mimic random assignment, this study supports limited positive impacts of breastfeeding for children's cognitive and noncognitive development. Although significant, the effect of breastfeeding on noncognitive development is small in practical terms.

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The medical benefits of breastfeeding for both mother and child are considered numerous and well documented.[1–5] Yet the effect of breastfeeding on general cognitive abilities has been a topic of debate for nearly a century.[6] The mechanism argued to be responsible for these effects is the nutrients found in breast milk.[7,8] Two specific types of long-chain polyunsaturated fatty acids, namely docosahexaenoic (DHA) and arachidonic acid, have been implicated in both visual and neural development and functioning through neural maturation, which is important for cognitive abilities, such as problem solving.[9–11]

The link with nutrients may also impact specific cognitive abilities like language development. For example, language abilities, such as vocabulary, are highly dependent on working and long-term memory given the consolidation and retrieval processes needed during acquisition.[12,13] In rats, deficiency of fatty acids, such as DHA, during lactation resulted in poor memory retention during learning tasks, whereas supplementation of DHA had reversal effects.[14] If the hypothesized "causal" mechanism of superior nutrition in breast milk is true, coupled with the specific impact of DHA on memory, breastfeeding should also impact language abilities. To date, ~20 studies have investigated this association and all but 1[15] examined a combined measure of language (receptive and expressive) or receptive language only. There remains debate as to whether expressive and receptive language in early childhood form distinct modalities of language,[16,17] raising the question of whether breastfeeding would be equally beneficial to each modality in the case of a 2-factor language model.

Less studied is the impact of breastfeeding on behavior. Breastfeeding may lead to reduced behavioral problems as a result of early skin-to-skin contact, which helps form a secure mother-infant bond.[18] Any effects of breastfeeding on cognitive and language development could also prevent the development of behavior problems. The absence of early behavior problems has social, economic, and medical value to society through reduced prevalence of delinquency, incarceration rates, and substance abuse,[19–21] making this an important area of research. With few exceptions, there remains a dearth of high-quality studies examining behavior,[22–25] and among them, consensus is not evident.

Without randomization of mothers to breastfeeding and formula conditions, it is challenging to confirm the causal impact of these hypotheses. One study randomized the provision of a breastfeeding intervention, modeled on the Baby-Friendly Hospital Initiative, and found that the children of mothers in the intervention group had higher intelligence scores compared with controls at age 6 years.[26] The strongest effects were for verbal intelligence. This study offers the best support to date for a causal link between breastfeeding and cognitive development. However, it is the only cluster randomized trial on human lactation.

The majority of studies in this field are observational, thus the causal implications of breastfeeding are questionable given the inherent difficulty in controlling for selection into breastfeeding. For example, initial associations with cognitive development are often reduced after adjustments for confounders, such as parental education/IQ (ie, from an average 5-point to 3-point difference[27]), and, in some cases, the associations are no longer statistically significant.[28] A variety of observational studies now apply quasi-experimental methods to better address the issue of selection bias, making inroads toward a better understanding of potential causal paths. The techniques used include propensity score matching (PSM), instrument variables, and sibling pair models. This study uses PSM because the sibling pair model limits the available pool of participants and instrument variables are extremely sensitive to the validity of the chosen instrumentation, which should be associated with the exposure but not with the outcome except for via the exposure.

Using a large longitudinal population sample, we applied PSM, which mimics random assignment, in an effort to investigate the potential impacts of breastfeeding on children's cognitive ability, expressive vocabulary, and behavior problems. Both breastfeeding duration and intensity were examined. Significant advantages for children who were breastfed, after matching, were expected for all outcomes. Grounded in the recommendations of the World Health Organization,[29] it was expected that larger effect sizes would be observed for children who were fully breastfed and for longer durations.

METHODS

Participants

Participants included families enrolled in the Growing Up in Ireland infant cohort. Families with infants born between December 2007 and May 2008 were identified from the Child Benefit Register and randomly selected to participate. The overall recruitment response rate was 65% (N = 11 134). A detailed description of the study design can be found elsewhere.[30] We used data collected at 9 months and 3 and 5 years of age. Only families with complete data for all confounders when children were 9 months and children who were born full term were included (N = 9854; 88.5% of the initial sample). Boys represented 50.6% (N = 4991)

TABLE 1 Family, Maternal, Infant, and Medical Characteristics: Infant Cohort at 9 Months

	Ever Breastfed (N = 5940)	Never Breastfed (N = 3914)	P
	n (%)	n (%)	
Resident spouse/partner (yes)	5469 (92.1)	3213 (82.1)	≤.001
Social class			≤.001
Professional/managerial	3486 (58.7)	1449 (37.0)	
Nonmanual/skilled manual	1533 (25.8)	1419 (36.3)	
Semiskilled/unskilled	505 (8.5)	397 (10.1)	
Unknown/never worked	416 (7.0)	649 (16.6)	
Medical card status (yes)	1336 (22.8)	1433 (36.6)	≤.001
Maternal education			≤.001
Primary level/no education	65 (1.1)	152 (3.9)	
Second level	1782 (30.0)	2269 (58.0)	
Third level	4093 (68.9)	1493 (38.1)	
Maternal working status (yes)	4828 (81.3)	2865 (73.2)	≤.001
Maternal age, y			≤.001
≤ 24	456 (7.7)	653 (16.7)	
25–29	1178 (19.8)	883 (22.6)	
30–34 y	2202 (37.1)	1240 (31.7)	
≥35 y	2104 (35.4)	1138 (29.1)	
Maternal ethnicity (Irish)	4209 (70.9)	3725 (95.2)	≤.001
Maternal depression (yes)	222 (3.7)	201 (5.3)	.001
Smoking in dwelling during pregnancy (yes)	1535 (25.8)	1646 (42.1)	≤.001
Delivery mode (cesarean)	1348 (22.7)	1063 (27.2)	≤.001
Birth weight (≥2500 g; yes)	5842 (98.4)	3810 (97.3)	≤.001
Visit to the NICU (yes)	575 (9.7)	420 (10.7)	.090
Infant sex (boy)	2944 (49.6)	2047 (52.3)	.008
Siblings living in dwelling (yes)	3248 (54.7)	2614 (66.8)	≤.001

Medical card coverage is a means-tested card issued by health services on the basis of financial need. There are 2 tiers of medical card coverage: "full coverage," which includes visits to general practitioners plus prescriptions and "general practitioner only coverage," which excludes prescriptions. Regarding the maternal education variable, primary level/no formal education is approximately equivalent to having an elementary to middle school education in the US system; second level is approximately equivalent to a high school diploma or technical trade/vocational diploma in the US system; and third level is equivalent to a college or bachelor's degree, graduate degree, or doctorate. Maternal working status refers to employment before pregnancy. Categorization of maternal depression refers to a score of ≥11 on the Center for Epidemiologic Studies Depression Scale.

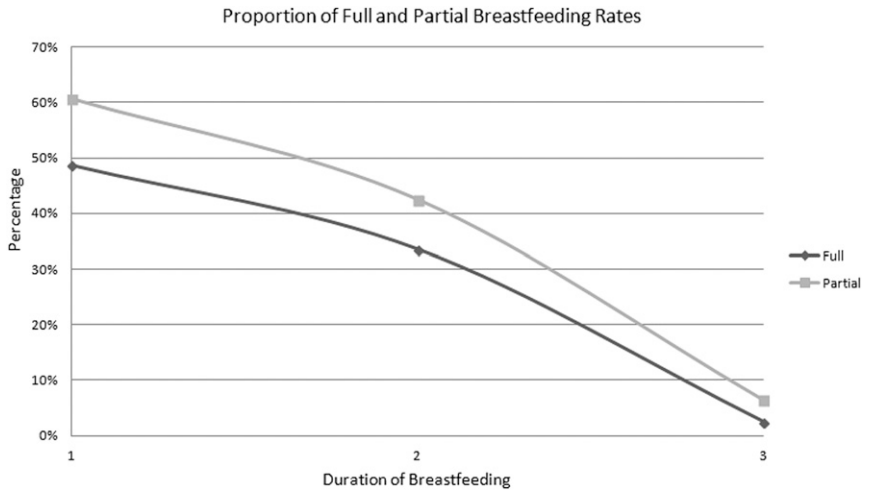

FIGURE 1
The category "1" on the x-axis represents breastfeeding up to 31 days; "2" represents between 32 and 180 days; and "3" represents ≥181 days.

of the sample. Attrition across waves reduced the sample size to 8715 children at 3 years and 8032 at 5 years. Some children had missing data on the cognitive and vocabulary scales, resulting in 8535 and 8241 children respectively at age 3 and 7972 and 7942 children respectively at age 5. Additionally, missing teacher reports for behavior at age 5 years resulted in 7478 children being included in these analyses. Demographic characteristics of the families and rates of breastfeeding engagement can be found in Table 1 and Fig 1. Ethics approval was obtained from the Research Ethics Committee, Department of Children and Youth Affairs Ireland, and written consent was collected from parents/guardians before data collection.

Measures

Children's cognitive abilities and expressive vocabulary were measured by using 2 scales from the British Abilities Scale[31]. The pictures similarities scale assessed problem-solving skills and the naming vocabulary scale assessed expressive vocabulary. The construct validity of each scale was derived by using the Wechsler Preschool and Primary Scale of Intelligence-Revised

TABLE 2 Bivariate Correlations Between Parent and Teacher SDQ Scores and Means (SDs) of Children's Outcomes at 3 and 5 Years of Age

	Conduct Problems, 5 y (Teacher)	Hyperactivity, 5 y (Teacher)	Difficulties, 5 y (Teacher)	Means (SD)	Minimum–Maximum
Conduct problems, 5 y (parent)	$r = 0.23^{***}$	$r = 0.21^{***}$	$r = 0.22^{***}$	1.44 (1.46)	0–10
Hyperactivity, 5 y (parent)	$r = 0.22^{***}$	$r = 0.35^{***}$	$r = 0.32^{***}$	3.23 (2.40)	0–10
Difficulties, 5 y (parent)	$r = 0.22^{***}$	$r = 0.29^{***}$	$r = 0.32^{***}$	7.10 (4.71)	0–32
Conduct problems, 5 y (teacher)	—	—	—	0.73 (1.33)	0–10
Hyperactivity, 5 y (teacher)	$r = 0.51^{***}$	—	—	2.96 (2.81)	0–10
Difficulties, 5 y (teacher)	$r = 0.70^{***}$	$r = 0.82^{***}$	—	5.92 (5.25)	0–32
Conduct problems, 3 y (parent)	—	—	—	2.15 (1.80)	0–10
Hyperactivity, 3 y (parent)	—	—	—	3.10 (2.14)	0–10
Difficulties, 3 y (parent)	—	—	—	7.71 (4.53)	0–32
Nonverbal reasoning, 5 y	—	—	—	58.89 (10.61)	20–80
Nonverbal reasoning, 3 y	—	—	—	53.30 (10.77)	20–80
Expressive vocabulary, 5 y	—	—	—	55.27 (12.22)	20–80
Expressive vocabulary, 3 y	—	—	—	51.16 (12.75)	20–80

*** $P \leq .001$.

(r = 0.74 and 0.83, respectively).[31] Standardized scores that adjusted for performance as compared with other children of the same age, with a mean of 50 and a SD of 10, were used. Age was adjusted in 3-month age bands.

The Strengths and Difficulties Questionnaire (SDQ[32]) was used to assess children's problem behaviors. The parent version was used at age 3 years and both the parent and teacher versions were used at age 5 years. The SDQ is comprised of 5 scales (emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behavior) with ratings of applicability of behaviors on a 3-point scale. A total difficulties scale is included, combining the 4 problem scales, to yield an overall difficulties score. We used the conduct problems, hyperactivity/inattention, and difficulties scales given our focus on externalizing problems. Validation of the SDQ has been extensively documented.[33] Table 2 reports the correlations between parent and teacher SDQ reports and the means and SDs for all child outcomes.

Breastfeeding information was collected retrospectively when infants were 9 months old via maternal report. Support for the reliability of recall in previous breastfeeding studies has been established.[34] However, given the lower reliability regarding the timing of the introduction of additional fluids/solids, Labbok and Krasovec's definition of full (ie, exclusive or almost exclusive) and partial breastfeeding are used.[35] Two breastfeeding variables were created to assess whether the infant was fully or partially breastfed and the duration of each. Mothers were asked 4 questions: "Was <baby> ever breastfed," "How old was <baby> when he/she completely stopped being breastfed," "Was <baby> ever exclusively breastfed," and "How old was <baby> when he/she completely stopped being exclusively breastfed?" First, infants were grouped by breastfeeding status, both full and partial (5940) and never breastfed (3914). Of those who had ever been breastfed, 4795 had full breastfeeding at some point. Next, breastfeeding duration was grouped into 3 intervals; breastfed up to 31 days, 32 to 180 days, and ≥181 days. Each category of duration was treated as mutually exclusive, dummy coded, and compared against infants who had never been breastfed for the purpose of matching.

Confounders have been suggested in part to account for the associations found between breastfeeding and child outcomes. We matched groups (breastfed, never breastfed) on 14 of the most pertinent factors. At the child level, factors included sex (boy/girl), birth weight (≥2500 g), and having neonatal intensive care (yes/no). At the maternal level, factors included age (≤24 years, 25–29 years, 30–34 years, or ≥35 years), highest level of education (primary level/no education, second level, or third level), working status before pregnancy (yes/no), ethnicity (Irish, any other white background, African or any other black background, Asian background, or other, including mixed background), depression (a score of ≥11 on the Center for Epidemiologic Studies Depression Scale), and type of delivery (vaginal or caesarean). Family-level factors included having a partner in the residence (yes/no), social class (professional/managerial, other nonmanual/skilled manual, or semiskilled/unskilled), medical card status (free medical care, free general practitioner care, or no free medical care), total number of household members who smoked during the pregnancy (none, or ≥1), and whether the cohort infant had siblings living in the household.

Statistical Analysis

PSM reduces selection bias by matching children who were breastfed to children who were not, but who had a similar probability of being breastfed based on their measured characteristics. We used PSM logit models with nearest neighbor 1:1 matching techniques. In nearest

neighbor matching, the sample is randomly ordered with matching occurring sequentially between the treatment (breastfed) and control (not breastfed) group based on participants' propensity scores. Typically, the pair is then removed from the list and the next match is created. To ensure optimal matches, we imposed a caliper so that pairs could only be matched if the propensity score was within a tenth of a SD of the other. We also allowed matching with replacement given the low rates of longer durations and full breastfeeding in this cohort. Although matching with replacement has been argued to increase variance in the data, it also arguably reduces bias in the sample by ensuring better quality of matches.[36] Balance checks in all models revealed substantial reductions of bias between matched groups on all individual confounders (ie, 0%–13.9% remaining bias in partial breastfeeding models, 0%–18.1% remaining bias in full models; data available on request). The remaining overall mean bias across models ranged from 3.2% to 8.5%. The ≤20% remaining bias has been suggested as the acceptable cutoff after matching.[37] Thus, we concluded that the analytic matching technique resulted in good matches between conditions. Matching resulted in all participants falling within the area of common support. The average treatment effect on those who were treated (ie, children who were breastfed) is reported. Adjustments were made for multiple hypothesis testing by using the Holmes-Bonferroni method. All statistical analyses for PSM were conducted by using Stata version 13 software (Stata Corp, College Station, TX).

To note, although PSM is advantageous in mimicking random assignment, a drawback is the challenge in evaluating a linear dose-response association, which has previously been found. Structural equation modeling (SEM) offers an alternative approach to examining this dose-response association. Additionally, SEM uses the full sample and has greater power. Thus, the data were also modeled by using SEM, where confounders were treated as correlated exogenous variables, the duration of breastfeeding was treated as a continuous mediating variable, and child outcomes were treated as correlated, which could be influenced by both breastfeeding and confounders. These results can be found in the Supplemental Material.

RESULTS

Postmatching results for children fully breastfed up to 31 days revealed no statistically significant differences between groups on any outcome at age 3 or 5 years (Table 3). Similarly, for children who were fully breastfed between 32 and 180 days, no statistically significant differences were found for any outcomes at either age postmatching (Table 4). Finally, for children who were fully breastfed for ≥6, statistically significant differences were found postmatching for only 2 outcomes, problem solving and hyperactivity at age 3 years. Children who were fully breastfed scored 2.95 (SE = 1.39, $P = .048$) points higher on the problem-solving scale compared with children who were never breastfed and −0.84 (SE = 0.25, $P \leq .001$) points lower on the hyperactivity scale. After adjustment for multiple testing, cognition was no longer statistically significant. However, children who were fully breastfed had slightly lower parent-rated hyperactivity compared with controls, and this remained statistically significant after adjustment (Table 5). Of note, results of the partial breastfeeding models were similar to the full models, however, after adjustment for multiple testing, neither cognitive ability nor hyperactivity at age 3 years remained statistically significant. These results can be found in the Supplemental Material.

DISCUSSION

Without randomized controlled trials, the issue of causality will necessarily remain open, however the present results contribute important insights to the long-standing debate of potential "causal effects" versus artifacts of confounding that are not properly accounted for. This study also provides new perspectives on breastfeeding and children's externalizing behavior. To the best of our knowledge, this is among the first studies to examine expressive vocabulary as an individual outcome and to consider externalizing behavior. It should be noted that our results apply only to infants born full term.

After adjustment for multiple testing, the initial support found for breastfeeding and better problem solving at age 3 years if the child was breastfed for a minimum of 6 months was no longer statistically significant. In addition, no statistically significant effects were found for cognitive ability at age 5 years. These results are in contrast to some studies that have used PSM techniques to examine the effects of breastfeeding and general cognitive abilities.[38–40] However, differences in both analytical choices of the PSM approach used (eg, replacement, calipers) and differing selection of covariates may help to explain these differences across studies. Nonetheless, our findings were surprising in the context of the nutrients in breast milk being responsible for increased cognitive development. Regarding expressive vocabulary, no statistically significant advantages were observed for children who were breastfed at either age 3 or age 5.

The limited research on breastfeeding and behavior problems is inconsistent, despite the relatively consistent reliance on the SDQ. Of interest, studies that have dichotomized the SDQ scales into abnormal scores (ie, at the 85th or 90th percentile) have not found

TABLE 3 Full Breastfeeding up to 31 Days and Child Outcomes at 3 and 5 Years of Age: Pre- and Postmatching

	Prematching				Postmatching			
	T	C	Difference	SE	T	C	Difference	SE
Problem solving, 3 y	53.75	52.52	1.23***	0.35	53.75	53.05	0.70	0.79
Problem solving, 5 y	59.30	58.06	1.24***	0.35	59.30	58.03	1.26	0.83
Vocabulary, 3 y	52.22	50.34	1.88***	0.40	52.22	50.91	1.30	0.95
Vocabulary, 5 y	56.09	55.40	0.69†	0.39	56.09	56.51	−0.41	0.89
Conduct, 3 y	2.11	2.31	−0.20***	0.05	2.11	2.14	−0.03	0.14
Conduct, 5 y	1.43	1.56	−0.13**	0.05	1.43	1.39	0.04	0.11
Hyperactivity, 3 y	3.07	3.27	−0.19**	0.07	3.07	3.04	0.03	0.16
Hyperactivity, 5 y	3.31	3.43	−0.11	0.08	3.31	3.01	0.29	0.18
Difficulties, 3 y	7.63	8.11	−0.47**	0.14	7.63	7.50	0.13	0.35
Difficulties, 5 y	7.15	7.49	−0.33*	0.16	7.15	6.54	0.60	0.36
Conduct, 5 y (teacher)	0.73	0.74	−0.01	0.04	0.73	0.67	0.06	0.10
Hyperactivity, 5 y (teacher)	2.95	3.12	−0.16†	0.09	2.95	3.03	−0.07	0.21
Difficulties, 5 y (teacher)	5.77	6.21	−0.44*	0.18	5.77	5.94	−0.16	0.40

Postmatching results have been adjusted for multiple hypothesis testing. *N*s at age 3 years for the treatment group varied between 1262 and 1337 and between 3335 and 3419 for the control group. *N*s at age 5 for the treatment group varied between 1229 and 1243 (teacher outcomes, 1154) and between 3078 and 3105 (teacher outcomes 2887) for the control group. C, control (not breastfed); Diff, difference in scores between groups; T, treatment (breastfed).

*** $P \leq .001$.

** $P \leq .01$.

* $P \leq .05$.

† $P \leq .10$.

TABLE 4 Full Breastfeeding 32 to 180 Days and Child Outcomes at 3 and 5 Years of Age: Results Pre- and Postmatching

	Prematching				Postmatching			
	T	C	Difference	SE	T	C	Difference	SE
Problem solving, 3 y	54.26	52.52	1.73***	0.27	54.26	52.91	1.34	1.02
Problem solving, 5 y	59.72	58.06	1.66***	0.28	59.72	58.81	0.91	1.03
Vocabulary, 3 y	52.17	50.34	1.83***	0.33	52.17	50.72	1.44	1.24
Vocabulary, 5 y	55.34	55.40	−0.05	0.32	55.34	56.41	−1.06	1.11
Conduct, 3 y	2.02	2.31	−0.29***	0.04	2.02	2.09	−0.06	0.16
Conduct, 5 y	1.32	1.56	−0.24***	0.03	1.32	1.35	−0.02	0.13
Hyperactivity, 3 y	2.92	3.27	−0.34***	0.05	2.92	3.17	−0.24	0.19
Hyperactivity, 5 y	2.94	3.43	−0.48***	0.06	2.94	2.93	0.01	0.22
Difficulties, 3 y	7.30	8.11	−0.81***	0.11	7.30	7.37	−0.07	0.41
Difficulties, 5 y	6.56	7.49	−0.93***	0.12	6.56	6.47	0.08	0.45
Conduct, 5 y (teacher)	0.68	0.74	−0.06†	0.03	0.68	0.69	−0.01	0.12
Hyperactivity, 5 y (teacher)	2.75	3.12	−0.36***	0.07	2.75	3.01	−0.26	0.27
Difficulties 5 y, teacher	5.56	6.21	−0.65***	0.14	5.56	6.06	−0.49	0.52

Postmatching results have been adjusted for multiple hypothesis testing. *N*s at age 3 years for the treatment group varied between 2524 and 2742 and between 3335 and 3419 for the control group. *N*s at age 5 years for the treatment group varied between 2514 and 2548 (teacher outcomes, 2402) between 3077 and 3105 for the control group (teacher outcomes 2877). C, control (not breastfed); Diff, difference in scores between groups; T, treatment (breastfed).

*** $P \leq .001$.

† $P \leq .10$.

statistically significant differences,[23–25] suggesting that breastfeeding is not likely to be a contributor to behavioral problems at clinical levels. When the SDQ scales are treated as continuous, small effects under certain conditions have been found.[22] In this study, we treated all 3 scales as continuous and found that children who were fully breastfed for ≥6 months had lower parent-rated scores on the hyperactivity scale at age 3 years only. This result remained statistically significant after adjustment for multiple testing. Our results suggest that longer durations of breastfeeding might help to reduce hyperactive behaviors for children who display mild to moderate levels in the short term, but that these benefits are not maintained even in the medium term. This result would seemingly support the recommendation of the World Health Organization, suggesting that breastfeeding for at least 6 months is necessary for early gains to be observed.

The inherent strengths of this study include the use of a particularly large longitudinal developmental dataset, the use of a quasi-experimental

TABLE 5 Full Breastfeeding ≥181 Days and Child Outcomes at 3 and 5 Years of Age: Results Pre- and Postmatching

	Prematching				Postmatching			
	T	C	Difference	SE	T	C	Difference	SE
Problem solving, 3 y	54.43	52.52	1.90*	0.77	54.43	51.48	2.95	1.39
Problem solving, 5 y	59.54	58.06	1.47†	0.79	59.54	58.30	1.24	1.48
Vocabulary, 3 y	50.85	50.34	0.51	0.90	50.85	49.42	1.42	1.80
Vocabulary, 5 y	53.29	55.40	−2.10**	0.85	53.29	52.14	1.15	1.80
Conduct, 3 y	1.88	2.31	−0.42***	0.12	1.88	1.95	−0.06	0.22
Conduct, 5 y	1.20	1.56	−0.35**	0.11	1.20	1.43	−0.22	0.16
Hyperactivity, 3 y	2.52	3.27	−0.74***	0.15	2.52	3.37	−0.84***	0.25
Hyperactivity, 5 y	2.69	3.43	−0.74***	0.17	2.69	2.87	−0.18	0.27
Difficulties, 3 y	6.73	8.11	−1.37***	0.32	6.73	7.67	−0.93	0.57
Difficulties, 5 y	6.07	7.49	−1.42***	0.36	6.07	6.41	−0.34	0.56
Conduct, 5 y (teacher)	0.64	0.74	−0.09	0.10	0.64	0.52	0.11	0.15
Hyperactivity, 5 y (teacher)	2.61	3.12	−0.50*	0.21	2.61	2.82	−0.21	0.36
Difficulties, 5 y (teacher)	5.39	6.21	−0.82*	0.40	5.39	5.56	−0.16	0.66

Postmatching results have been adjusted for multiple hypothesis testing. *N*s at age 3 years for the treatment group varied between 195 and 220 and between 3335 and 3419 for the control group. *N*s at age 5 years for the treatment group varied between 211 and 213 (teacher outcomes, 185) and between 3306 and 3337 (teacher outcomes 2877) for the control group. C, control (not breastfed); Diff, difference in scores between groups; T, treatment (breastfed).

*** $P \leq .001$.

** $P \leq .01$.

* $P \leq .05$.

† $P \leq .10$.

statistical approach, the use of a repeated measures design, the use of multiple informants and simultaneous standardized assessments thereby limiting potential shared method variance, the comparatively large number of confounders controlled (ie, 14) in contrast to previous studies (ie, an average of 7.7 ± 3.4 in higher-quality studies[28];), and assessments in both cognitive and noncognitive domains of child development. Despite these strengths, some limitations must be noted. First, information on breastfeeding was collected retrospectively. Although the reliability of recall has been established,[34] it must be acknowledged that recall bias may nevertheless be present, particularly regarding the duration of full breastfeeding. Second, only parent-reported SDQs were collected when children were 3 years of age. Studies have found that parents typically rate their children as having higher levels of problem behaviors as compared with teacher reports, with weak associations between these 2 types of informants, [24] as was found in the current study for behavior ratings at age 5 years between parents and teachers. Having access to child care staff reports at age 3 years would have increased the reliability of the maternal-rated hyperactivity finding. Third, no information pertaining to direct breastfeeding versus expressed breast milk feeding was collected. Thus, it is not possible to investigate whether the association with reduced hyperactivity at age 3 years was the result of skin-to-skin contact or due to the nutrients in breast milk. This is an important direction for future studies examining behavioral outcomes. Fourth, although maternal education was included as a confounder, maternal IQ was not collected in this cohort. In the few studies that controlled for maternal IQ, the findings suggested that it accounted for a large part of the association between breastfeeding and cognitive outcomes.[39,41] Thus, the inclusion of maternal IQ in future studies that employ PSM is warranted. Finally, PSM does not address selection on unobservables. Causal estimates may only be estimated by using PSM if selection is on observable characteristics or, in cases where unobservable factors influence selection into breastfeeding, the balancing on observables also balances on these unobservables. Despite these limitations, the results of this study add to the growing literature by showing that some statistically significant positive noncognitive benefits may result from longer durations of breastfeeding. Yet, beyond the statistical implications, the practical implications appear minimal and short lived. It is important to note, however, that these findings do not contradict the many medical benefits afforded to both mother and child as a result of breastfeeding.

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ABBREVIATIONS

DHA: docosahexaenoic
PSM: propensity score matching
SDQ: strengths and difficulties questionnaire
SEM: structural equation modeling

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