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Infant breastfeeding duration and mid-childhood executive function, behavior, and social-emotional development

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Abstract

Objective—Our aim was to examine associations of breastfeeding duration and exclusivity in infancy with executive function, behavior, and social-emotional development in mid-childhood.

Methods—We studied 1037 participants in Project Viva, a pre-birth cohort that enrolled pregnant mothers from 1999-2002 and followed children to 7-10 years. Main exposures were: (1) duration of any breastfeeding in the first 12 months and (2) duration of exclusive breastfeeding in the first 6 months. Main outcomes were child executive function, behavior, and social-emotional development, assessed by (1) the Behavior Rating Inventory of Executive Function (BRIEF) and (2) the Strengths and Difficulties Questionnaire (SDQ), completed independently by parents and teachers. Higher scores indicate greater problems.

Results—In linear regression models adjusted for sociodemographics, maternal intelligence, home environment, early child care, and maternal depression, longer breastfeeding duration was not associated with substantially better executive function, behavior, or social-emotional development. For example, for each additional month of any breastfeeding, the BRIEF Global Executive Composite score (parent) was 0.10 points higher (95% CI –0.01, 0.22) and the SDQ total difficulties score was 0.06 points higher (–0.01, 0.12). Breastfeeding duration was also not associated with BRIEF or SDQ subscales, nor was exclusive breastfeeding duration associated with any of the outcomes analyzed.

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Conflicts of interest: None

Conclusion—Despite beneficial effects on general intelligence, longer duration of any breastfeeding or of exclusive breastfeeding was not associated with better executive function, behavior, or social-emotional development in mid-childhood.

Keywords

Breastfeeding; behavior; development; executive function; attention; social-emotional development

BACKGROUND

Strong evidence supports associations of more prolonged and/or exclusive breastfeeding with health benefits in infancy, including prevention of gastrointestinal infections and otitis media,¹ and with greater general intelligence and better academic performance at school age.²⁻⁴ Other aspects of children's cognitive and social-emotional development may also be influenced by breastfeeding, either by direct effects of specific nutrients in breast milk on the developing brain, or by mother-infant interactions that occur during feeding.

Most prior studies of breastfeeding and cognition have focused on intelligence quotient (IQ) or academic achievement, both of which are summary measures that reflect many underlying skills and abilities. One important domain about which these measures do not provide detailed information is executive functions, which comprise a group of processes that facilitate “purposeful, goal-directed problem-solving behavior” that reflect “guiding, directing, and managing of cognitive, emotional, and behavioral functions.”⁵ Specific abilities that fall under the umbrella of executive function include: beginning a desired task or behavior; remaining on task; shifting tasks or problem solving strategies flexibly; and controlling impulses and emotions appropriately.^{5,6} The pre-frontal region of the brain and its connections with other cortical and sub-cortical regions are implicated in executive function.⁶ Although executive function abilities emerge from infancy through early adulthood, early-life exposures such as preterm birth⁶ and iron deficiency^{7,8} are associated with executive function impairments, suggesting that infancy may be a particularly sensitive period for its development.

The ability to regulate one's thoughts and behavior – key aspects of executive function – is relevant not just to cognitive performance, but also for and social-emotional functioning⁹. In addition to a direct link between executive function and social-emotional development, factors related to breastfeeding such as differences in mother-infant interactions¹⁰, greater maternal sensitivity, and more secure attachment in infancy¹¹ all support a potential beneficial impact of early breastfeeding on infant social-emotional development that may persist into childhood.

In contrast to the large literature on breastfeeding and general intelligence, relatively few studies to date have examined aspects of childhood executive function, behavior, and social-emotional development in relation to infant feeding. A few large cohort studies have found that more prolonged breastfeeding was associated with better executive function and social competence, fewer attentional symptoms, and better overall psychosocial health¹²⁻¹⁵, but potential confounding variables such as the home environment, child care, and maternal

intelligence were not considered. A large cluster randomized, controlled trial¹⁶ of breastfeeding promotion that markedly increased the duration of breastfeeding found no effect of the intervention on child social-emotional development at 6.5 years. In that study, confounding was minimized by design, but it lacked specific measures of executive function.

A clearer understanding of the extent to which the duration and exclusivity of breastfeeding impacts childhood executive function, behavior, and social-emotional functioning could inform health policies and individual mothers' own feeding decisions, as well as our understanding of how these developmental domains are influenced by environmental factors. Our aim was to examine associations of breastfeeding duration and exclusivity with child executive function, behavior, and social-emotional development in mid-childhood. We hypothesized that breastfeeding for a longer duration is associated with better executive function and fewer behavioral and social-emotional difficulties, and that associations with exclusive breastfeeding would be stronger than for any breastfeeding.

METHODS

Participants

We studied participants in Project Viva, a prospective, longitudinal cohort study designed to examine prenatal factors, pregnancy, and child health. Project Viva enrolled pregnant women from 1999 to 2002 from 8 obstetrical offices of Atrius Health, a multi-specialty group practice in eastern Massachusetts, and included women carrying a singleton gestation, able to answer questions in English, receiving prenatal care by 22 weeks' gestation, and not planning to move away from the area prior to delivery. Details about the recruitment and follow-up of this cohort have been published.¹⁷ Follow-up in mid-childhood (median age, 7.7 years) was completed in December, 2010. The human subjects committee of Harvard Pilgrim Health Care approved this study and mothers of all participating children gave written informed consent.

Measurements

Breastfeeding duration—When the participating child was 6 months old, we asked the mother via in-person or telephone interview if she had ever breastfed her baby (by putting the baby to breast or feeding the baby breast milk), and if she was currently feeding the baby any breast milk. For breast fed infants who were weaned (no longer breastfeeding) by 6 months, we asked at what age the baby stopped breastfeeding. At 12 months, we asked mothers via mailed questionnaires if they had ever breastfed their infant; if so, whether the infant was still breastfeeding; and for weaned infants, at what age they stopped breastfeeding. Using additional questions at 6 months about timing of introduction of solid food and other liquids, we determined the duration of exclusive breastfeeding, defined as feeding breast milk but no solid foods or non-breast milk liquids (except water) to 6 months. Maternal report of breastfeeding duration is valid, particularly when recall occurs over a short period of time¹⁸ as in our study, although we are not able to quantify the volume of breast milk ingested.

Executive function—When children reached mid-childhood, parents and teachers completed the Behavioral Rating Inventory of Executive Function (BRIEF),^{5,19} a validated 86-item questionnaire designed to assess executive function behaviors in home and school environments. The BRIEF includes the following sub-scales: inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, and monitor. The sub-scales form 2 indexes: (1) the Behavioral Regulation Index, which indicates the ability of the child “to shift cognitive set and modulate emotions and behavior via appropriate inhibitory control” and (2) the Metacognition Index, which reflects the child's ability to “initiate, plan, organize, and sustain future-oriented problem-solving in working memory.” The BRIEF indices are each scaled to a mean of 50 and standard deviation of 10. The Global Executive Composite combines the 2 indices and represents a summary measure of executive function. Higher BRIEF scores represent worse executive function.

Behavior and social-emotional development—Parents and teachers completed the Strengths and Difficulties Questionnaire (SDQ), a validated 23-item questionnaire designed to assess children's social, emotional, and behavioral functioning.²⁰ The SDQ is used widely in research and clinical settings,²¹ and has five subscales (prosocial behavior, hyperactivity/inattention, emotional symptoms, conduct problems, and peer relationship problems). Possible scores range from 0-40 points. Higher scores indicate greater difficulties on all except the prosocial subscale, on which a higher score is more favorable. Normative data for the SDQ derive from a representative sample of United States children.²²

Parents and teachers completing the BRIEF and SDQ were not informed of current study hypotheses relating to breastfeeding. Further, teachers were likely to be unaware of the child's breastfeeding status.

Covariates—We collected data from mothers regarding parental and child demographic, social, economic, and health information through self-administered questionnaires and interviews in pregnancy and shortly after delivery.^{17,23} To measure maternal general intelligence, we administered the Kaufman Brief Intelligence Test, 2nd edition (KBIT-II) during the mid-childhood follow-up visit. The KBIT-II is highly correlated with the Weschler Adult Intelligence Scale composite (Pearson R=0.88).²⁴ We also administered the Home Observation Measurement of the Environment short form (HOME-SF),²⁵ which assesses cognitive stimulation and emotional support in the child's environment. Possible scores range from 0 to 22. Higher scores indicate environments more supportive of child development. We assessed maternal depressive symptoms at 6 months postpartum with the Edinburgh Postnatal Depression Scale,²⁶ on which a score of 13 or higher is a highly sensitive (86%) and specific (78%) indicator of clinically diagnosed depression.

Analysis—Our main exposures were: (1) duration of any breastfeeding to 12 months; and (2) duration of exclusive breastfeeding to 6 months. Outcomes were the BRIEF indices and Global Executive Composite score, and the SDQ total difficulties and prosocial behavior scores. Using linear regression, we adjusted models for characteristics of the child (age, sex, gestational age, birth weight for gestational age z-score,²⁷ race and ethnicity, child care and attendance at 6 months); mother (age, parity, smoking status, depressive symptoms at 6 months post-partum, employment, and KBIT-II score); and family (parental education

levels, HOME-SF score). We chose these covariates because they represent factors that could potentially confound the relationship of breastfeeding duration with child neurodevelopment. We also explored sex-specific effects by performing stratified analyses, and examined our data for evidence of non-linear associations, but did not find any.

All covariates were not observed on all subjects. Most participants with missing data were missing only one or two values. To minimize loss of information and potential bias due to missing data, we used multiple imputation to generate plausible values for each missing value.²⁸ We included all exposures, outcomes and covariates from this analysis, and chose additional variables from the thousands available in Project that helped predict missing values. We generated “completed” data sets that included the observed data and one imputed value for each missing value. The analysis was replicated across completed data sets and then combined in a structured fashion that accurately reflected the true amount of information in the observed data. This method assumes that the exposures and outcomes are missing at random, given the observed variables and the imputed covariates. Using Proc MI ANALYZE in SAS version 9.3 (SAS Institute, Cary NC), we generated 50 complete data sets and combined multivariable modeling results for all 2128 live births to women originally enrolled in Project Viva.

For this analysis, we excluded 45 participants <34 weeks’ gestation because preterm infants have substantially different nutritional needs from full term infants,²⁹ and because they are at higher risk for executive function and behavioral difficulties later in life.^{30,31} We also excluded 325 infants who did not complete any part of the study assessment at 6 or 12 months, and 721 who did not complete the in-person visit in mid-childhood, and thus were missing outcome measures. Our final sample size was 1037, which was 61% of the 1708 participants considered eligible for the mid-childhood visit.¹⁷ We previously published differences in characteristics of children included and excluded in mid-childhood,² primarily that included children were of higher socioeconomic status and less likely to be of non-white race.

RESULTS

The mean (SD) duration of any breastfeeding to 12 months was 6.5 (4.6) months and of exclusive breastfeeding to 6 months was 2.4 (2.0) months. Table 1 shows Spearman correlations of continuous covariates with breastfeeding duration, as well as the mean breastfeeding duration within categories of maternal and child characteristics. Both maternal IQ (Spearman $r = 0.36$) and HOME-SF score ($r=0.13$) were directly correlated with breastfeeding duration. Mean breastfeeding duration was longer for women who did not smoke during pregnancy, were not depressed at 6 months postpartum, had attained a higher educational level, and were not working or looking for work. Child and household factors associated with longer breastfeeding duration included not being in child care, higher income, and higher education level of the father.

Table 2 shows the distributions of the BRIEF and SDQ scales. Parent- and teacher-reported scales were modestly correlated with each other, with Spearman correlation coefficients in the 0.2 to 0.4 range (Supplemental Table).

Table 3 shows results of linear regression analyses using outcome measures as reported by parents. Consistent with our hypothesis, in the model adjusted only for age and sex, longer exclusive breastfeeding duration was associated with lower BRIEF metacognition scores, representing fewer metacognition problems (−0.28 points per month, 95% CI: −0.55, −0.01), but the estimate attenuated substantially after adjustment for maternal and family covariates (Model 4: −0.06 points, 95% CI −0.35, 0.23). More favorable BRIEF and SDQ outcomes were also not associated with longer breastfeeding duration in fully adjusted models, for example, for each additional month of any breastfeeding, the BRIEF Global Executive Composite score was 0.10 points higher (95% CI −0.01, 0.22) and the SDQ total difficulties score was 0.06 points higher (95% CI, −0.01, 0.12), both point estimates suggesting more problems with longer breastfeeding and thus in the direction opposite to that we hypothesized.

Table 4 shows results with outcomes reported by teachers. In models adjusted only for age and sex, longer breastfeeding duration was associated with lower BRIEF Global Executive Composite scores, indicating better executive function behaviors (−0.16 points per month of any breastfeeding, 95% CI −0.29, −0.02; and −0.51 points per month of exclusive breastfeeding, 95% CI −0.82, −0.20). Results were similar for the BRIEF Metacognition Index, and longer exclusive breastfeeding was associated with lower BRIEF Behavioral Regulation Index scores. However, adjustment for child, maternal, and household covariates led to substantial attenuation of all these estimates.

In analyses stratified by child sex, we found no evidence that longer breastfeeding duration was associated with more favorable BRIEF or SDQ scores in boys or girls (Tables 3 and 4). In fact, longer duration of any (but not exclusive) breastfeeding duration was associated with higher parent-reported BRIEF and SDQ total difficulties scores in boys, indicating more difficulties.

DISCUSSION

In this longitudinal cohort study of over 1000 mother-child pairs, we found that the duration of any breastfeeding or of exclusive breastfeeding was not associated with better executive function, behavior, or social-emotional development in mid-childhood using well-validated measures that were reported separately by parents and classroom teachers. Further, our 95% confidence intervals exclude clinically important differences. For example, we estimated that for each month of breastfeeding, the Global Executive Composite score was 0.1 points higher (less favorable), with a lower 95% confidence bound of −0.01. Thus, we can exclude a potential benefit of more prolonged breastfeeding on global executive function as large as 0.12 points for 12 months of any breastfeeding on a scale for which the standard deviation in our cohort was ~8 points. Lower 95% confidence bounds for associations with exclusive breastfeeding were slightly larger, for example for metacognition, we can exclude with 95% certainty a potential benefit as large as 2.1 points over 6 months of exclusive breastfeeding, a difference that is unlikely to be meaningful clinically, but may have relevance on a population level.³²

Although numerous studies -- including our own² in the same cohort as the current study -- have reported that longer duration of partial or exclusive breastfeeding is associated with higher global intelligence at school age, much less is known about the extent to which breastfeeding affects other aspects of child neurodevelopment. Our findings are in agreement with recently-reported results from the Infant Feeding Practices II study (n=1442), which analyzed breastfeeding duration in relation to social-emotional development, measured by the SDQ reported by the mother when the child was 6 years old.¹⁵ A major advantage of our study over that one is that we had both parent- and teacher-reported ratings of children's behavior, a strategy that is likely to be more sensitive to difficulties specific to the school setting. In contrast, the Millennium Cohort Study in the United Kingdom, which also used the SDQ (reported by a parent) when the child was 5 years old, found that full term children (n=9525) breastfed for ≥ 4 months had lower odds of conduct problems (OR 0.77, 95% CI 0.64, 0.93) and of having an abnormal total SDQ score (OR 0.67, 95% CI 0.54, 0.83) as compared with children who were never breastfed.³³ Those associations persisted after adjustment for socio-demographic variables, but they did not adjust for maternal IQ, the home environment, or early child care, as we did. Although it is difficult in observational studies to completely eliminate effects of confounding, a large (n=13,889) randomized trial of breastfeeding promotion in which confounding was eliminated by design found no differences in SDQ scores as reported by parents or teachers.¹⁶ Taken together, these findings suggest little if any beneficial impact of early breastfeeding on social-emotional development and behavior in mid-childhood, as measured by the SDQ.

In addition to evaluating social-emotional development and behavior with the SDQ, we also assessed aspects of executive function including behavioral regulation and metacognition as well as a summary measure of executive function. Deficits in executive function are clinically relevant in that they likely underlie at least some of the neuropsychology of attention deficit hyperactivity disorder (ADHD).³⁴ Executive function is also important for academic achievement³⁵ and for the development of social competence³⁶ later in life.

We found small associations of breastfeeding duration with better executive function scores, particularly when reported by teachers, but the associations became null with adjustment for confounders. Contrary to our hypothesis, in fully adjusted models, our results indicated *worse* performance on parent-reported behavioral regulation and metacognition in relation to longer breastfeeding duration in boys but not girls. Other studies with null results include a large (n=2479) Dutch study³⁷ in which over-activity and attentional problems at ages 7, 10, and 12 years assessed on the Child Behavior Checklist were similar in breastfed vs. non-breastfed children; and a within-family analysis of data from the National Longitudinal Survey of Youth in which hyperactivity reported by mothers on the Behavior Problem Index did not differ by breastfeeding status.³⁸ In contrast, in a Spanish cohort (n=500), breastfeeding for >20 weeks vs. <2 weeks was associated with better executive function, using a mother-reported measure developed by the investigators (based on the McCarthy scales), and breastfeeding for >12 weeks was associated with fewer teacher-reported attentional symptoms at 4 years of age.¹² An Australian study of over 4000 adolescents found that breastfeeding for ≥ 4 months predicted fewer attentional problems on the Achenbach youth report, as compared with breastfeeding for a shorter duration or not at all.¹³ Given the differences in populations, ages, outcome measures, and informants

(parents, teachers, children), it is difficult to formulate a definitive conclusion about the relationship between early breastfeeding and later executive function. Our null results in combination with other rigorously controlled studies that used well-validated outcome measures^{37,38} suggest little if any benefit. It is even possible that longer breastfeeding duration leads to worse executive function in boys, although these findings may also have been spurious; replication is needed in other cohorts before making a definitive conclusion.

Whereas most prior studies assessed executive function, behavior, and social-emotional development based on parent report, our study is one of only a few to examine relationships of breastfeeding duration with these outcomes reported by both parents and teachers. A discrepancy between parent and teacher ratings of the same child may occur for difficulties that are situation-specific; having multiple raters across different settings increases the sensitivity for detecting true difficulties.³⁹ However, even despite using both parent and teacher reports, we found no differences in relation to duration of breastfeeding in infancy. Our study has several other strengths, including detailed information about exclusive and non-exclusive breastfeeding duration, and the use of well-validated screening measures of social-emotional development, behavior, and executive function. We also measured and controlled for key confounding variables, including maternal IQ, although residual confounding is still possible.

One limitation is that our cohort is of relatively high socio-economic status, potentially limiting generalizability. It is possible that in higher socioeconomic status groups, a benefit of breastfeeding is overwhelmed by other positive environmental factors, and that breastfeeding may have a greater impact on child development in lower socioeconomic groups. Additionally, we included only a subset of the original Project Viva cohort, and the children included at 7-10 years were on average of higher socioeconomic status than the children who were not included at mid-childhood. We excluded infants born <34 weeks' gestation, also potentially limiting generalizability to preterm infants. Executive functioning emerges throughout childhood at least into early adolescence,⁶ thus it is possible that our assessment at a median age of 7.7 years was too early to detect substantial effects of early feeding on executive function. Finally, we conducted many statistical tests, and it is possible that some statistically significant results (for example the association of breastfeeding duration with lower executive function) may be spurious.

In summary, we found that a longer duration of exclusive or non-exclusive breastfeeding was not associated with better social-emotional development, behavior, or executive function in mid-childhood. While there are many well-established benefits of breastfeeding that justify efforts to support its initiation, continuation, and exclusivity, promoting more optimal social-emotional development or executive functioning in mid-childhood appears not to be among them.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Participant Characteristics and Associations With Breastfeeding Duration (n=1037)

Characteristic	Mean (SD)	Spearman r with breastfeeding duration	
		Mean	SD
Maternal age, years	32.3 (5.2)	0.18	
Maternal KBIT-II	107.2 (15.3)	0.36	
Gestation length, weeks	39.7 (1.4)	0.06	
Birth weight for gestational age z-score	0.2 (1.0)	0.06	
HOME-SF score	18.4 (2.2)	0.13	
	N (%)	Breastfeeding duration (months)	
		Mean	SD
Entire cohort	1037 (100)	6.5	4.6
Mother			
Nulliparous			
No	547 (52.7)	6.6	4.6
Yes	490 (47.3)	6.4	4.6
Smoking status			
Never	735 (70.9)	6.9	4.5
Former	205 (19.8)	6.5	4.5
During pregnancy	96 (9.3)	3.5	4.0
Depressed at 6 months postpartum			
No	942 (90.8)	6.6	4.6
Yes	96 (9.2)	5.3	4.7
Education level of mother			
High school diploma	89 (8.5)	3.8	4.2
Some college	221 (21.3)	4.7	4.5
Bachelor's degree	362 (34.9)	6.6	4.3
Graduate degree	365 (35.2)	8.2	4.2
Employment status 6 months postpartum			
Employed	696 (67.1)	6.1	4.5
Employed, maternity leave	68 (6.6)	8.0	4.2
Not employed, not looking	221 (21.3)	7.4	4.8
Not employed, looking	52 (5.0)	5.5	4.8
<i>Child</i>			
Sex			
Male	515 (49.7)	6.6	4.6
Female	522 (50.3)	6.4	4.6
Race/ethnicity			
Asian	157 (15.1)	5.0	4.5
Black	40 (3.9)	4.8	4.2
Hispanic	32 (3.1)	5.5	3.8
White	120 (11.6)	6.4	4.7
Other	688 (66.3)	7.0	4.5

Characteristic	Mean (SD)	Spearman r with breastfeeding duration	
Child care at 6 months			
Center	177 (17.1)	6.6	4.4
Other home	282 (27.2)	5.1	4.4
In own home	141 (13.6)	6.8	4.4
None	437 (42.2)	7.3	4.6
English as second language (7-10 years)			
No	1024 (98.7)	6.5	4.6
Yes	13 (1.3)	5.3	3.7
Family/household			
Annual income			
<\$40,000	168 (16.2)	4.4	4.6
\$40,000 to \$70,000	219 (21.1)	6.4	4.6
\$70,000	651 (62.8)	7.1	4.4
Married/cohabitating			
No	79 (7.6)	4.0	4.4
Yes	958 (92.4)	6.7	4.5
Education level of mother's partner			
High school diploma	150 (14.5)	3.9	4.3
Some college	211 (20.3)	5.3	4.5
Bachelor's degree	369 (35.6)	6.9	4.5
Graduate degree	307 (29.6)	8.2	4.1

Table 2

Measures of Executive Function, Behavior, and Social-emotional Development in Mid-childhood

	Parent	Teacher
<i>BRIEF</i>	Mean (standard deviation)	
Global Executive Composite	48.3 (7.9)	50.7 (9.6)
Behavioral Regulation Index	48.2 (8.7)	50.5 (10.1)
Metacognition Index	48.4 (8.6)	50.9 (10.8)
<i>SDQ</i>		
Total difficulties	6.5 (4.7)	6.2 (5.8)
Prosocial behavior scale	8.6 (1.6)	8.0 (2.2)

BRIEF is Behavioral Rating Inventory of Executive Function.

BRIEF scores are standardized to mean 50 and standard deviation (SD) 10, with higher scores representing greater executive function problems.

SDQ is Strengths and Difficulties Questionnaire. On the total difficulties scale, higher scores represent more difficulties (possible scores, 0-40). On the prosocial scale, higher scores represent more favorable prosocial behavior (possible scores, 0-10).

Table 3

Adjusted^a Associations of Breastfeeding Duration With Executive Function, Behavior, and Social-emotional Development in Mid-childhood, as Reported by the Parent, Overall (n=1037) and Separately in Boys and Girls

	Model 1	Model 2	Model 3	Model 4	Model 4 (boys)	Model 4 (girls)
Any breastfeeding						
<i>BRIEF</i>			β (95% CI), points per month of breastfeeding			
Global Executive Composite	-0.02 (-0.13, 0.09)	0.01 (-0.10, 0.12)	0.09 (-0.02, 0.21)	0.10 (-0.01, 0.22)	0.25 (0.07, 0.43)	-0.06 (-0.22, 0.09)
Behavioral Regulation Index	0.01 (-0.11, 0.12)	0.04 (-0.08, 0.16)	0.12 (-0.01, 0.25)	0.13 (0.00, 0.26)	0.22 (0.02, 0.42)	0.01 (-0.16, 0.18)
Metacognition Index	-0.04 (-0.16, 0.07)	-0.02 (-0.14, 0.10)	0.06 (-0.07, 0.19)	0.08 (-0.05, 0.21)	0.28 (0.08, 0.48)	-0.14 (-0.30, 0.02)
<i>SDQ</i>						
Total difficulties	-0.06 (-0.13, 0.00)	-0.03 (-0.09, 0.03)	0.04 (-0.02, 0.11)	0.06 (-0.01, 0.12)	0.13 (0.03, 0.23)	-0.03 (-0.12, 0.06)
Prosocial scale	-0.02 (-0.04, 0.01)	-0.02 (-0.04, 0.00)	-0.03 (-0.05, 0.00)	-0.02 (-0.05, 0.00)	-0.03 (-0.07, 0.01)	-0.02 (-0.05, 0.02)
Exclusive breastfeeding						
<i>BRIEF</i>						
Global Executive Composite	-0.15 (-0.39, 0.10)	-0.08 (-0.33, 0.17)	0.06 (-0.20, 0.32)	0.08 (-0.19, 0.34)	0.36 (-0.06, 0.78)	-0.21 (-0.54, 0.13)
Behavioral Regulation Index	-0.02 (-0.30, 0.25)	0.07 (-0.21, 0.34)	0.20 (-0.09, 0.49)	0.21 (-0.09, 0.50)	0.43 (-0.04, 0.89)	-0.01 (-0.39, 0.36)
Metacognition Index	-0.28 (-0.55, -0.01)	-0.22 (-0.50, 0.05)	-0.08 (-0.36, 0.21)	-0.06 (-0.35, 0.23)	0.30 (-0.16, 0.76)	-0.40 (-0.76, -0.04)
<i>SDQ</i>						
Total difficulties	-0.18 (-0.32, -0.03)	-0.09 (-0.23, 0.06)	0.04 (-0.11, 0.20)	0.05 (-0.10, 0.21)	0.22 (-0.02, 0.45)	-0.11 (-0.32, 0.10)
Prosocial scale	-0.02 (-0.07, 0.03)	-0.03 (-0.08, 0.02)	-0.03 (-0.09, 0.03)	-0.03 (-0.08, 0.03)	-0.02 (-0.11, 0.07)	-0.03 (-0.10, 0.04)

BRIEF is Behavioral Rating Inventory of Executive Function. BRIEF scores are standardized to mean 50 and standard deviation (SD) 10, with higher scores representing greater executive function problems.

SDQ is Strengths and Difficulties Questionnaire. On the total difficulties scale, higher scores represent more difficulties (possible scores, 0-40). On the prosocial scale, higher scores represent more favorable prosocial behavior (possible scores, 0-10).

^aModel 1 is adjusted in linear regression for child age and sex. Model 2 is adjusted for covariates in Model 1 and gestation length, birth weight z-score, and child race/ethnicity. Model 3 is adjusted for covariates in Model 2 and for maternal age, parity, smoking in pregnancy, IQ, education levels of both parents, and HOME-SF score. Model 4 is additionally adjusted for maternal depression, employment status, and child care status at 6 months

Table 4

Adjusted^a associations of breastfeeding duration with executive function, behavior, and social-emotional development in mid-childhood, as reported by the teacher, overall (n=1037) and separately in boys and girls

	Model 1	Model 2	Model 3	Model 4	Model 4 (boys)	Model 4 (girls)
Any breastfeeding						
<i>BRIEF</i>			β (95% CI), points per month of breastfeeding			
Global Executive Composite	-0.16 (-0.29, -0.02)	-0.09 (-0.22, 0.04)	0.01 (-0.13, 0.15)	0.05 (-0.10, 0.19)	0.11 (-0.08, 0.31)	-0.04 (-0.26, 0.17)
Behavioral Regulation Index	-0.10 (-0.25, 0.05)	-0.02 (-0.17, 0.13)	0.05 (-0.10, 0.21)	0.10 (-0.06, 0.26)	0.14 (-0.07, 0.34)	0.03 (-0.21, 0.27)
Metacognition Index	-0.22 (-0.37, -0.07)	-0.16 (-0.31, -0.01)	-0.03 (-0.19, 0.13)	0.00 (-0.17, 0.16)	0.09 (-0.14, 0.32)	-0.12 (-0.36, 0.12)
<i>SDQ</i>						
Total difficulties	-0.05 (-0.13, 0.04)	-0.01 (-0.10, 0.07)	0.05 (-0.04, 0.13)	0.06 (-0.03, 0.15)	0.09 (-0.04, 0.22)	0.01 (-0.11, 0.13)
Prosocial scale	-0.01 (-0.04, 0.02)	-0.02 (-0.05, 0.02)	-0.02 (-0.06, 0.01)	-0.03 (-0.06, 0.01)	-0.02 (-0.07, 0.04)	-0.04 (-0.09, 0.01)
Exclusive breastfeeding						
<i>BRIEF</i>						
Global Executive Composite	-0.51 (-0.82, -0.20)	-0.33 (-0.64, -0.03)	-0.15 (-0.47, 0.17)	-0.10 (-0.43, 0.22)	0.10 (-0.36, 0.57)	-0.30 (-0.78, 0.17)
Behavioral Regulation Index	-0.38 (-0.72, -0.04)	-0.18 (-0.51, 0.15)	-0.07 (-0.41, 0.28)	0.00 (-0.35, 0.36)	0.22 (-0.26, 0.70)	-0.21 (-0.73, 0.31)
Metacognition Index	-0.63 (-0.98, -0.29)	-0.49 (-0.83, -0.14)	-0.24 (-0.60, 0.12)	-0.21 (-0.58, 0.16)	-0.01 (-0.54, 0.52)	-0.40 (-0.93, 0.13)
<i>SDQ</i>						
Total difficulties	-0.19 (-0.37, 0.00)	-0.10 (-0.29, 0.08)	0.00 (-0.20, 0.19)	0.01 (-0.18, 0.21)	0.10 (-0.20, 0.40)	-0.08 (-0.34, 0.18)
Prosocial scale	-0.01 (-0.08, 0.06)	-0.02 (-0.10, 0.05)	-0.03 (-0.10, 0.05)	-0.03 (-0.11, 0.04)	-0.01 (-0.13, 0.11)	-0.05 (-0.16, 0.05)

BRIEF is Behavioral Rating Inventory of Executive Function. BRIEF scores are standardized to mean 50 and standard deviation (SD) 10, with higher scores representing greater executive function problems.

SDQ is Strengths and Difficulties Questionnaire. On the total difficulties scale, higher scores represent more difficulties (possible scores, 0-40). On the prosocial scale, higher scores represent more favorable prosocial behavior (possible scores, 0-10).

^aModel 1 is adjusted in linear regression for child age and sex. Model 2 is adjusted for covariates in Model 1 and gestation length, birth weight z-score, and child race/ethnicity. Model 3 is adjusted for covariates in Model 2 and for maternal age, parity, smoking in pregnancy, IQ, education levels of both parents, and HOME-SF score. Model 4 is additionally adjusted for maternal depression, employment status, and child care status at 6 months