Associations between breastfeeding and cognitive function in children from early childhood to school-age: A panel study

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Research

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Abstract

Background Despite the evident benefits of breastfeeding for preventing acute physical illnesses in infants, the evidence for the benefit of breastfeeding on long-term cognitive development is not yet convincing.

Methods The subjects of this study were 1,752 children who participated in the Panel Study on Korean Children. Breastfeeding duration was prospectively assessed by parents. The Korean Ages and Stages Questionnaire (K-ASQ) and the Korean version of the Denver II were utilized to assess early development from birth to age two (T1 to T3). Language development at age three (T4) was assessed with Receptive and Expressive Vocabulary Tests. Cognitive function at age eight (T9) was assessed using Multifactorial intelligence test.

Results Children who were breastfed for one to three months displayed significantly higher odds ratios for delayed development assessed at T2 compared to those breastfed for three to six months. Children who were breastfed for more than three months also scored significantly higher on the communication and problem-solving subscales of the K-ASQ at T2 and T3, the expressive language subscale at T4, and the vocabulary and language inference vocabulary subscales at T9 compared to children who were breastfed for less than three months.

Conclusion We found that cognitive development was improved in children that were breastfed for more than three months. Although these results are supported by previous studies, it is important to note that other factors were larger determinants of cognitive development than breastfeeding. Future studies that examine the underlying mechanism for the association between breastfeeding and cognitive development are warranted.

Background

Breastfeeding is an important component of nutrition for infants and it provides various health benefits to the child and mother [1]. Breastfeeding has clear short-term benefits for reducing morbidity and mortality from infectious disease in infants [2]. Breastfeeding provides health benefits and prevention of acute physical illnesses including gastrointestinal illnesses, otitis media, respiratory tract infections, and neonatal necrotizing enterocolitis to infants [1, 3]. Breastfeeding may also prevent infants from developing chronic diseases such as asthma, allergies, and obesity [1].

Cognitive development in children has been another effect examined in breastfeeding research. The topic was first studied by Hoefer and Hardy in 1929 and multiple other studies have since examined the associations between breastfeeding and cognitive function of children with consistently reported positive associations [4]. A meta-analysis of 11 studies reported that infants who were breastfed had higher intelligence quotients (IQ) by 5.32 points (unadjusted) and 3.16 points when adjusted for covariates [5]. In addition, the higher levels of cognitive function observed in breastfed infants were stable across successive ages. A more recent meta-analysis of 17 studies on the relationship between breastfeeding

and intelligence reported that breastfed subjects presented a higher IQ by 3.44 points or by 2.62 points when controlled for maternal IQ [6].

A randomized experiment performed with consideration of the concerns raised regarding previous observational studies also reported significantly higher verbal IQ, performance IQ, and full-scale IQ in the breastfed group by 7.5, 2.9 and 5.9 points, respectively [7]. The breastfed group also scored higher in teacher ratings of both reading and writing. Likewise, cross-population studies of British and Brazilian cohorts reported that longer breastfeeding duration was related to higher IQ scores by three to six points [8]. The cognitive benefits of breastfeeding were reported to persist into adulthood. IQ scores at age thirty were 3.76 points higher in participants who were breastfed for 12 months or more compared to those who were breastfed for less than one month [9].

Despite the evidence for the positive associations between breastfeeding and cognitive development by multiple studies within various populations, there are few studies that have employed multiple assessment tools and repetitive assessment of cognitive development at multiple points. In addition, previous studies in the Korean population, especially using prospective methods, are sparse. A study of the Korean population reported significantly higher IQ by 4.07 points in breastfed children compared to non-breastfed children assessed at age nine [10]. Kim et al. reported that breastfed Korean children had significantly higher learning quotient scores in speaking, reading, writing, spelling, and mathematical calculation than children who were never-breastfed [11]. However, these studies were based on a cross-sectional sample and retrospective information on breastfeeding, so that the causal relationship between breastfeeding and learning skills cannot be drawn and recall bias is possible in these studies. The present study aims to examine the associations between breastfeeding and cognitive development in Korean children from ages one to eight using multimodal and multi-informant assessment and a prospective study design.

Methods

Participants

The present study utilized data collected from the Panel Study on Korean Children (PSKC). The PSKC is an ongoing longitudinal panel study conducted by the Korea Institute of Child Care and Education since 2008. The participants were 2,150 children born between 2008 and 2009. Because of the challenges of longitudinal cohort studies, there was some missing data for the follow-up assessments. In our study, we analyzed data collected from 1,752 children whose assessments of breastfeeding and K-ASQ at T3 were present. The number of participating children and data in each assessment is presented in Table S1.

Measurements

Demographic variables including the child’s sex, age, gestational period, birth weight, parents’ education level, and household income were assessed by paper and pencil interviews and computer-assisted

personal interviews. Breastfeeding data from T1 to T4 was prospectively collected by computer-assisted personal interviews.

Early development

To assess early cognitive development at T1, T2, and T3, the participants were assessed using the Korean Ages and Stages Questionnaires (K-ASQ) and the Korean version of the Denver II. The K-ASQ is a screening tool for the developmental progress of infants and toddlers as rated by parents [12]. The K-ASQ consists of 30 items rated on three-point Likert scales under five subdomains of communication, gross motor, fine motor, problem-solving, and personal-social [13]. Scores that were two standard deviations below average in each subdomain were coded as atypical. The Denver II is another screening tool for early development with a validated Korean version [14, 15]. The Denver II codes the development of children to the dichotomous outcomes of “normal” or “suspicious” based on the assessment scores.

Cognitive function in middle childhood and school-age

Language abilities at T4 were assessed by the Receptive and Expressive Vocabulary Test (REVT), which is comprised of 185 Korean vocabulary items and two subscales of receptive and expressive language tests [16]. The REVT results were coded as percentile scores of 1 (under 10%) to 11 (100%). The cognitive function of school-age children (T9) was assessed in terms of intelligence and academic performance. The intelligence of children was assessed using the multifactorial intelligence test (M-FIT). The M-FIT is comprised of six subdomains (vocabulary, language inference, schematization, calculation, spatial perception, and reasoning), each with 20 item tests. The scores are presented with the T-score (mean = 50; SD = 10) and percentile score (0 to 100) based on normative data. We used the T-score in our analysis.

Statistical analyses

Participants were grouped by the following breastfeeding durations: “never,” “up to 1 month,” “1 to 3 months,” “3 to 6 months,” “6 to 12 months,” “12 to 18 months” and “over 18 months.” We used logistic regression to investigate the odds ratio for delayed development of the early period (T1 to T3) assessed by the Denver II and K-ASQ. To compare the outcomes of K-ASQ as continuous variables (T1 to T3), language ability at T4, and intelligence and academic function at T9 among the groups of breastfeeding duration, analysis of variance and analysis of covariance (ANCOVA) were utilized. Finally, a linear regression analysis was performed to examine the quantitative associations between breastfeeding duration and the outcomes of K-ASQ, REVT, and M-FIT. In all analyses, the adjusted model included the children’s sex, age, gestational age, birth weight, parents’ education level, and household income as covariates. Statistical analyses were conducted using the software package SPSS 25.0 for Windows (IBM Co., Armonk, NY, USA).

Results

Demographic characteristics and prevalence of breastfeeding

The demographic characteristics of participants are presented in Table 1. Of the total participants, 893 (51%) children were male, 52 (3.0%) children were born preterm and 49 (2.8%) children were born with low-birth weights. The prevalence and duration of breastfeeding are presented in Table 2. The proportion of children who were ever-breastfed in our study was 97.4%. The proportion of never-breastfed children was 2.6% and children who were breastfed for one month or less was 15.8%. The proportion of children who continued breastfeeding after six months was 61.8%.

Odds ratios for delays in early development based on the duration of breastfeeding

The odds ratio for delayed development at T1 (age 5.5 months) to T3 (age 26.2 months) are presented in Table 3. In the six group comparison, odds ratios for delayed development assessed with K-ASQ at T2 were significantly higher in children breastfed for one to three months by 2.21 (crude) or 2.63 (adjusted) times, compared to the reference group (children breastfed for three to six months). The comparison of two groups at T3 presented significantly higher odds ratios for delayed development by 1.45-fold in children breastfed for three months or less than those breastfed for more than three months.

Comparison of cognitive function scores based on the duration of breastfeeding

The comparison of scores on each cognitive function test are presented in Table 4. The subscales of communication ($F = 17.71$; $p < 0.001$; Cohen's $d = 0.219$) and problem-solving ($F = 11.26$; $p < 0.001$; Cohen's $d = 0.175$) at T2 were significantly higher in children breastfed for more than three months compared to children breastfed for three months or less. Those breastfed for more than three months also presented significantly higher scores on the subscales of communication ($F = 6.13$; $p = 0.013$; Cohen's $d = 0.127$) and problem-solving ($F = 6.79$; $p = 0.009$; Cohen's $d = 0.134$) at T3.

Language development at T4 assessed with REVT presented significantly higher scores on the expressive language subscale ($F = 12.85$; $p < 0.001$; Cohen's $d = 0.191$) in children breastfed for more than three months, compared to those breastfed for three months or less. However, there was no significant difference in scores on the receptive language subscale between the two groups. Children breastfed for more than three months also scored significantly higher on the vocabulary ($F = 6.78$; $p = 0.009$; Cohen's $d = 0.151$) and language inference vocabulary ($F = 5.62$; $p = 0.018$; Cohen's $d = 0.137$) subscales of the M-FIT assessment at T9.

The comparison of scores on cognitive function tests among the six groups of breastfeeding duration are presented in Table S1. The scores on the communication and problem-solving subscales of the K-ASQ at T2, expressive language subscale of REVT, and calculation subscale of M-FIT were significantly different among the six groups of breastfeeding duration.

Discussion

Prevalence of breastfeeding

The present study investigated the association between breastfeeding and cognitive function in children from 5.5 months to 8 years of age using multiple assessment tools and a prospective design. The prevalence of breastfeeding in our study is comparable to previous studies. Despite evidence of the beneficial effects of breastfeeding on the health of mother and child, the prevalence of breastfeeding was substantially different between countries, with a clear tendency of lower breastfeeding duration and prevalence in wealthier countries [17]. For instance, the proportion of children who were ever-breastfed in our study was 97.4%. The previously reported proportion of ever-breastfed children in most countries was over 90% and was especially high in low-income countries. However, some high-income countries such as France (63%), Spain (77%), Ireland (55%), and the United States (79%) had substantially lower proportions of ever-breastfed children [17]. The proportion of children who continued breastfeeding after six months was 61.8% in our study. The average proportion of children who continued breastfeeding after six months was lower than 50% in high-income countries, with especially low proportions in Denmark (13%), France (23%), Canada (30%), and the United Kingdom (34%) [17]. The previously reported proportion of breastfeeding at six months in Korea was 61%, which is consistent with the present findings [18]. The prevalence of breastfeeding in Korea is reported to have increased remarkably since the lowest prevalence in 2000, which is encouraging news for the health of children [18].

Early development

Early development of infants at T1, T2, and T3 assessed by the Denver II showed no significant differences in odds ratios for developmental delay between the groups of breastfeeding duration. These are inconsistent findings with previous studies. Barros et al. reported significantly higher suspected developmental delay at the one year assessment in children breastfed for less than one month (42.4%) compared to those breastfed for nine months or more (25.5%) [19]. Wang and Wu also reported significantly higher developmental delay in the personal-social domain of the Denver II assessed at one year of age in non-exclusively breastfed children (36%) compared to exclusively breastfed children (21%) [20].

The results of the early development assessment with the K-ASQ presented different aspects than the Denver II assessment. The odds ratios to have atypical scores in at least one subdomain of the K-ASQ at T2 was significantly higher by 2.63-fold in children breastfed for one to three months than the reference group (children breastfed for three to six months). However, there were no significant differences in odds ratios for developmental delay assessed with the K-ASQ at T1 and T3.

In the comparison of the K-ASQ score as a continuous variable among breastfeeding groups, scores on communication and problem-solving subdomains at T2 and T3 in children breastfed for more than three months were significantly higher than the children breastfed for three months or less. These are consistent with the findings of previous studies on early development using the ASQ, which have reported the benefits of breastfeeding on early development. An Irish study of 11,134 children that assessed early development with the ASQ at nine months old reported the positive effect of breastfeeding on gross motor, fine motor, problem-solving and personal-social skills [21]. A French study with 1,999 three-year-old

children also reported that ever-breastfed children scored 6.2 points higher on the ASQ than never-breastfed children [22]. The study also reported a significant positive association between exclusively breastfed infants and higher scores on the problem-solving domain of the ASQ. An Australian cohort study with 2,868 children reported that infants breastfed for four months or longer had higher scores in fine motor skills and communication assessed at age one and three years. Infants who were breastfed for less than four months were also more likely to have at least one atypical score across the subdomains compared to children breastfed for four months or longer [23].

Cognitive function in middle childhood and school-age

There were significant differences in cognitive function assessed using the vocabulary test (REVT) among the groups of breastfeeding duration. There was no difference in receptive language score among the six groups of breastfeeding duration. However, when grouped by children who were breastfed for more than three months or three months or less, those breastfed for more than three months scored significantly higher on the vocabulary test. This is consistent with previous findings for language development in middle childhood based on breastfeeding duration. An Australian cohort study with 1,195 children assessed language ability with the Peabody Picture Vocabulary Test (mean=100; SD=15) and reported that children who were breastfed for over six months presented higher mean scores (3.56 points at five years and 4.04 points at ten years, respectively) than children who were never-breastfed [24].

Our results indicate an advantageous association between breastfeeding and cognitive function during school days. Scores on the M-FIT subscales of vocabulary and language inference in children breastfed for more than three months were significantly higher than children breastfed for three months or less. These findings are consistent with previous studies on the cognitive function of school-age children based on breastfeeding duration [25-27]. For instance, children born preterm who were breastfed had higher IQ scores by 7.6 points (about half a standard deviation) at eight years than never-breastfed children [25]. An Irish study with 8,226 nine-year-old school children also reported that ever-breastfed children scored significantly higher percentage points on reading and mathematics than never-breastfed children[27]. Huang et al. also reported that breastfeeding had a significant association with higher intelligence and that the association remained significant during the schooling and adolescent period [28].

Limitations

The present study has some limitations to note. First, due to the characteristics of longitudinal cohort studies, a substantial number of subjects did not participate in the follow-up assessments. Notably, some participants were excluded from the adjusted model analysis due to missing covariate data. The missing data may bias the relationship between breastfeeding and children's cognitive function. Thus, future study of a more complete dataset with covariate analysis is warranted. Second, although we tried to include important socio-demographic covariates, not all covariates could not be included. For instance, previous studies indicated that maternal IQ is a major moderating factor for the association between breastfeeding and children's intelligence, which was not included in our study [6, 29]. Despite these

limitations, the present study has the strength of using multiple tools at multiple time points to assess children's cognitive development using a prospective design.

Conclusion

The findings of our study present a generally positive association between breastfeeding and cognitive function from early childhood through to school-age. In contrast, development assessed with some tools (i.e., Denver II) and at some points (T1) revealed null findings for the association. Many previous studies support the finding that there are positive associations between breastfeeding and cognitive development. However, the mean difference (effect size) in cognitive development due to breastfeeding was only 3.44 points (about one-third of a standard deviation), which is reduced again by the adjustment for maternal IQ [6]. Considering these findings comprehensively, breastfeeding is not considered a critical factor in the cognitive development of children. Other studies have also reported that the observed advantage of breastfeeding on IQ score is actually due to genetic and socio-environmental factors. When the results are adjusted for covariates such as maternal IQ, the effect of breastfeeding on cognitive function was insignificant [30, 31]. Thus, breastfeeding should not be interpreted to have medical benefits for cognitive development. Another study on 12-year-old twins stratified by maternal education level reported a significant effect of breastfeeding on cognition in all strata of maternal education level, although much of the individual difference in cognition scores was accounted for by genetic factors (80%) [29]. Although the reported effects are not significant, it is worthwhile to continue breastfeeding for the possible beneficial effect on children's cognitive development. In addition, more research to investigate the underlying mechanism for the association between breastfeeding and cognitive development is warranted.

Abbreviations

ANCOVA, analysis of variance and analysis of covariance

ASQ, Ages and Stages Questionnaire

K-ASQ, Korean Ages and Stages Questionnaire

M-FIT, Multifactorial intelligence test

PSKC, Panel Study on Korean Children

REVT, Receptive and Expressive Vocabulary Test

Declarations

Ethics approval and consent to participate

We provided parents with information on the purpose and procedure of the study and written informed consent was obtained from parents before enrollment. This study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The study protocol was approved by the Institutional Review Board of the Korean Institute of Child Care of Education(KICCEIRB-2016-07).

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author Contributions

Conception and design of the study: KM Kim and JW Choi. Acquisition and analysis of data: KM Kim. Original draft and tables: KM Kim. Final editing of manuscript: JW Choi.

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Tables

Table 1. Demographic characteristics of participants.	
Variables	n (%)
Sex	
Male	893 (51.0)
Female	859 (49.0)
Gestational age	
< 259 day (preterm)	52 (3.0)
≥259 days (term)	1638 (93.5)
Unknown	62 (3.5)
Birth weight	
< 2,500g	49 (2.8)
≥ 2,500g	1647 (94.0)
Unknown	56 (3.2)
Household income1	
≤ 2000	432 (24.7)
2000 < and ≤ 3000	532 (30.4)
3000 < and ≤ 4000	315 (18.0)
4000 < and ≤ 5000	193 (11.0)
> 5000	111 (6.3)
Unknown	169 (9.6)
Paternal educational level (years)	
≤ 12	520 (29.7)
12 < and < 16	486 (27.7)
≥ 16 years	680 (38.8)
Unknown	66 (3.8)
Maternal educational level (years)	
≤ 12	454 (25.9)
12 < and < 16	362 (20.7)
≥ 16 years	809 (46.2)

Unknown	127 (7.2)
Age at each assessment (months; mean; SD)	
T1	5.5 (1.2)
T2	14.1 (1.0)
T3	26.2 (1.3)
T4	38.7 (1.4)
T9	99.2 (1.4)

Table 2. Proportion of participants in each breastfeeding duration category.

	n	%
Never breastfed	45	2.6
1 month or less	231	13.2
More than 1 month to 3month or less	281	16.0
More than 3 months to 6 months or less	205	11.7
More than 6 months to 12 months or less	445	25.4
More than 12 months or 18 months or less	381	21.7
More than 18 months	164	9.4
Total	1752	100.0

Table 3. Odds ratio for delayed development at T1, T2, and T3 based on the duration of breastfeeding.

breastfeeding duration (months)	0 to ≤ 1	1 < and ≤ 3	3 < and ≤ 6	6 < and ≤ 12	12 < and ≤ 18	over 18	Two group comparison[a]
Crude (n)							
Denver II at T1 (n=1429)	0.67 (0.32 to 1.44)	1.07 (0.53 to 2.15)	Referent	1.16 (0.62 to 2.19)	0.89 (0.46 to 1.73)	0.88 (0.39 to 1.99)	0.86 (0.57 to 1.30)
Denver II at T2 (n=1698)	0.85 (0.55 to 1.30)	1.04 (0.68 to 1.58)	Referent	0.88 (0.60 to 1.30)	0.98 (0.66 to 1.46)	0.91 (0.56 to 1.48)	1.00 (0.79 to 1.27)
Denver II at T3 (n=1731)	0.71 (0.39 to 1.30)	0.98 (0.56 to 1.72)	Referent	0.84 (0.49 to 1.42)	0.76 (0.44 to 1.32)	1.23 (0.66 to 2.26)	0.95 (0.68 to 1.32)
K-ASQ at T1 (n=1632)	1.01 (0.42 to 2.45)	1.41 (0.62 to 3.24)	Referent	0.88 (0.38 to 2.01)	1.28 (0.57 to 2.85)	1.14 (0.43 to 3.04)	1.14 (0.72 to 1.81)
K-ASQ at T2 (n=1704)	2.02 (0.98 to 4.15)	**2.21 (1.08 to 4.50)***	Referent	1.54 (0.77 to 3.09)	1.94 (0.97 to 3.87)	2.12 (0.97 to 4.64)	1.28 (0.92 to 1.79)
K-ASQ at T3 (n=1752)	1.73 (0.88 to 3.43)	1.51 (0.75 to 3.01)	Referent	1.26 (0.65 to 2.44)	0.99 (0.49 to 1.99)	1.17 (0.52 to 2.63)	**1.45 (1.02 to 2.07)***
Adjusted (n)							
Denver II at T1 (n=1264)	0.58 (0.26 to 1.30)	0.82 (0.39 to 1.76)	Referent	1.10 (0.56 to 2.15)	0.75 (0.37 to 1.53)	0.66 (0.26 to 1.65)	0.77 (0.49 to 1.22)
Denver II at T2 (n=1455)	1.07 (0.66 to 1.73)	1.24 (0.77 to 1.98)	Referent	1.10 (0.71 to 1.71)	1.31 (0.84 to 2.05)	1.08 (0.63 to 1.86)	1.01 (0.77 to 1.31)
Denver II at T3 (n=1472)	0.54 (0.27 to 1.09)	0.96 (0.52 to 1.79)	Referent	0.86 (0.48 to 1.54)	0.87 (0.48 to 1.57)	1.27 (0.65 to 2.49)	0.79 (0.54 to 1.16)
K-ASQ at T1 (n=1436)	1.40 (0.46 to 4.21)	2.09 (0.73 to 6.00)	Referent	1.38 (0.48 to 3.97)	1.97 (0.70 to 5.53)	1.63 (0.48	1.14 (0.67 to 1.93)

						to 5.54)	
K-ASQ at T2 (n=1461)	1.95 (0.86 to 4.42)	**2.63 (1.20 to 5.77)***	Referent	1.63 (0.75 to 3.53)	2.03 (0.94 to 4.38)	**2.54 (1.09 to 5.90)***	1.30 (0.90 to 1.88)
K-ASQ at T3 (n=1491)	1.64 (0.76 to 3.52)	1.61 (0.75 to 3.45)	Referent	1.40 (0.67 to 2.93)	1.20 (0.56 to 2.56)	1.10 (0.44 to 2.77)	1.33 (0.89 to 1.99)

a: Odds ratio for development delay in children breastfed for three months or less compared to children breastfed for more than three months.

The adjusted model included children's sex, age, gestational age, birth weight, parents' education level and household income as covariates.

* $p < 0.05$

Table 4. Comparison of scores on intellectual function tests between children grouped based on breastfeeding duration.

Breastfeeding duration	3 months or less	more than 3 months	Crude		Adjusted		Cohen's da
			F	p	F	p	
K-ASQ at T1 (n=1632)							
Comunication	53.7 (8.9)	53.8 (8.8)	0.03	0.855	0.01	0.922	
Fine motor	54.3 (9.0)	54.9 (8.6)	2.15	0.143	1.32	0.252	
Gross motor	57.3 (6.6)	57.5 (6.2)	0.23	0.632	0.14	0.707	
Personal-social	54.2 (8.2)	54.9 (8.1)	2.11	0.147	0.44	0.506	
Problem solving	55.9 (7.3)	56.1 (7.4)	0.29	0.591	0.00	0.978	
K-ASQ at T2 (n=1704)							
Comunication	47.7 (11.9)	50.2 (10.7)	17.71	**<0.001****	8.75	**0.003****	0.219
Fine motor	47.0 (12.1)	48.1 (11.7)	3.17	0.075	2.13	0.145	
Gross motor	56.4 (9.2)	56.5 (8.7)	0.12	0.726	0.06	0.811	
Personal-social	52.1 (11.1)	52.6 (10.9)	1.01	0.315	1.73	0.189	
Problem solving	48.1 (13.3)	50.2 (11.3)	11.26	**<0.001****	13.18	**<0.001****	0.175
K-ASQ at T3 (n=1752)							
Comunication	51.9 (11.3)	53.3 (10.8)	6.13	**0.013***	4.75	**0.029***	0.127
Fine motor	52.6 (9.8)	53.6 (8.4)	4.17	0.041	2.54	0.111	
Gross motor	57.2 (6.7)	57.3 (5.6)	0.12	0.727	0.12	0.731	
Personal-social	54.3 (9.5)	55.1 (8.5)	2.52	0.113	0.28	0.597	
Problem solving	53.4 (8.2)	54.4 (7.6)	6.79	**0.009****	4.18	**0.041***	0.134
REVT at T4 (n=1630)							
Expressive	4.4 (3.1)	5.00 (3.2)	12.85	**<0.001****	5.55	**0.019***	0.191
Receptive	6.5 (3.6)	6.4 (3.6)	0.00	0.983	0.11	0.737	

M-FIT at T9 (n=1398)							
Vocabulary	55.4 (10.5)	57 (10.6)	6.78	**0.009****	1.91	0.167	0.151
Language inference	56.4 (9.8)	57.7 (9.3)	5.62	**0.018***	1.24	0.266	0.137
Schematization	53.6 (9.8)	54.7 (9.3)	3.73	0.054	0.56	0.453	
Calculation	53.4 (9.8)	54.1 (9.7)	1.43	0.232	0.28	0.600	
Spatial perception	56.4 (10.2)	57.1 (10.7)	1.48	0.223	0.32	0.572	
Reasoning	55.6 (10.8)	56.1 (11.1)	0.58	0.447	0.41	0.523	

a: Cohen's *d* was calculated by the crude model without consideration of covariates.

The number of samples corresponds to the crude model.

The adjusted model included children's sex, age, gestational age, birth weight, parents' education level, and household income as covariates.

* $p < 0.05$; ** $p < 0.01$

Additional File 1

Title of data: Table S1. Comparison of scores on intellectual function tests among the six groups of breastfeeding duration.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementtable.docx