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PAPER

Breastfeeding and trajectories of children's cognitive development

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Abstract

The aim of this study was to examine the association of breastfeeding practices with the growth trajectories of children's cognitive development. We used data from the Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID) with variables on presence and duration of breastfeeding and standardized test scores obtained during three different panel waves (N = 2681). After adjusting for covariates we found that breastfed children had higher test scores but that breastfed and non-breastfed children had similar growth trajectories in test scores over time. The results indicate that breastfeeding has an important association with test scores, and that subsequent schooling and other experiences during adolescence do not eliminate the breastfeeding gap that appears in very early childhood.

Research highlights

- Breastfeeding is associated with higher reading and math scores in very early childhood.
- The breastfeeding gap in cognitive ability persists over time throughout childhood.
- Breastfed and non-breastfed children have similar growth trajectories in test scores.
- Schooling and other experiences during adolescence do not eliminate the breastfeeding gap.

Introduction

The importance of breastfeeding on a multitude of individual outcomes has been consistently validated by health care professionals and policymakers, resulting in the inclusion of breastfeeding objectives in the *Healthy People 2020* initiative of the US Department of Health and Human Services (2011). Among the demonstrated benefits of breastfeeding, the association between breastfeeding and increased cognitive development for children is widely acknowledged. Specifically, Horwood and Fergusson (1998) observed a positive relationship between breastfeeding and a variety of beneficial educational outcomes. Oddy, Li, Whitehouse, Zubrick and Malacova (2011) found that children who were mostly breastfed for more than 6 months had higher test scores at 10 years old compared to non-breastfed children. McCrory and Layte (2011) identified a significant gap in reading and math standardized test scores between 9-year-olds who were and were not breastfed. Morrow-Tlucak, Haude and Ernhart (1988) assessed the impact of being bottle-fed, breastfed for less than 4 months, and breastfed for greater than 4 months on mental development, with mental development at 1 and 2 years of age significantly higher for breastfed children. A meta-analysis of 11 studies found that children breastfed as infants had significantly higher cognitive development scores than children who had been formula-fed as infants, even after controlling for factors such as maternal race, age, and educational attainment along with childhood experiences (Anderson, Johnstone & Remley, 1999). Although research has generally supported the benefits to cognitive development

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from breastfeeding, research conducted by Zhou, Baghurst, Gibson and Makrides (2007) and Der, Batty and Deary (2006) has found the association between breastfeeding and cognitive development to be non-significant after controlling for other factors, such as characteristics of the mother and household.

One of the shortcomings of previous research on breastfeeding and cognitive development has been the over-reliance on cross-sectional designs that are unable to delineate the temporal relationship between breastfeeding and cognitive development over time. One longitudinal design assessed duration of breastfeeding for children at 6 months of age with follow-up at 5 years of age using the Peabody Picture Vocabulary Test Revised, finding a significant increase in cognitive development for children breastfed for longer durations (Quinn, O'Callaghan, Williams, Najman, Andersen & Bor, 2001). In addition, Gómez-Sanchiz, Cañete, Rodero, Baeza and Ávila (2003) assessed mental development through the Bayley Infant Development Test for 249 children at 18 months of age, concluding that infants breastfed for longer than 4 months had significantly increased mental development.

But whether and how these differences persist over time is an important question. While it is widely agreed upon that breastfeeding is associated with cognitive benefits, the mechanism by which breastfeeding improves cognition has been debated, with researchers discussing both nutritional and psychological benefits from breastfeeding. Research suggests that increased cognitive development for breastfed infants results from long-chain polyunsaturated fatty acids (LCPFAs) that are found naturally in breast milk yet are frequently absent in formula (Anderson *et al.*, 1999; Cockburn, 2003; Drover, Hoffman, Castaneda, Morale & Birch, 2009; Farquharson, Jamieson, Abbasi, Patrick, Logan & Cockburn, 1995; Feldman & Eidelman, 2003; Horwood & Fergusson, 1998; Petryk, Harris & Jongbloed, 2007; Uauy & Dangour, 2006; Uauy & De Andraca, 1995). In particular, docosahexaenoic acid (DHA) has been cited as being necessary for neurodevelopment (Cockburn, 2003; Drover *et al.*, 2009; Uauy & De Andraca, 1995). Infants are born with a 2–3 week store of DHA, but are unable to produce sufficient levels of DHA until they are 4–6 months old (Cockburn, 2003). However, breast milk initially contains high concentrations of DHA, meaning that compared to breastfed infants, formula-fed infants are likely lacking optimal levels of DHA (Cockburn, 2003).

Furthermore, it is also possible that breastfeeding variables serve as a proxy for other parental variables that may have a contemporaneous effect on test scores. Breastfeeding has clear nutritional benefits that affect brain development, but the nurturing and interaction with the mother that takes place during breastfeeding is also a potential positive influence on cognitive development (Jain, Concato & Leventhal, 2002; Petryk *et al.*, 2007). Specifically, in a study with 15- to 18-year-olds, adolescents who were breastfed as infants reported increased levels of parental attachment and described their mothers as being more caring than adolescents bottle-fed as infants (Fergusson & Woodward, 1999). In addition, the infant-to-mother skin contact during breastfeeding has been found to reduce infant stress and irritability while also strengthening the mother–child relationship that may improve cognitive and emotional development (Uauy & De Andraca, 1995).

This increased nurturing is also likely to persist over time and may directly affect test scores later in life (in the form of help with homework, more of an interest in student academic progress, etc.). Examining the differences or similarities in growth rates in test scores over time can aid in determining a genuine measured effect of breastfeeding rather than sustained parental nurturing that is correlated with breastfeeding and which may also influence test scores later in life. In addition, if it is primarily the nutritional benefits of breastfeeding that lead to positive outcomes, then breastfeeding is more likely to be associated with cognitive outcomes in early childhood, and may not correlate with the growth pattern of cognitive ability (unless the nutritional benefits can generate cumulative advantages). It is also possible, however, that over time, schooling and other socialization experiences occurring during adolescence can intervene and reduce or eliminate the gap between breastfed and non-breastfed children. For instance, the control of socioeconomic characteristics in the analysis tends to decrease the magnitude of the association between breastfeeding practices and cognitive development. Using propensity score matching, McCrory and Layte (2011) also found that breastfeeding had greater effects on economically disadvantaged children (who are less likely to attend high-quality schools), indicating the potential interaction between breastfeeding practices and environmental factors.

Therefore, it is important to determine the onset and trajectory of the breastfeeding effect on cognitive performance. To this end, this study examined the association between breastfeeding and the over-time growth trajectories of children's cognitive ability using longitudinal data. More specifically, the study assessed the association between breastfeeding and (1) children's reading and math score outcomes in early childhood and (2) the growth or change of children's reading and math outcomes over time. This approach provides a unique way to distinguish the potential nutritional effects of breastfeeding from other confounds.

Methods

The study objectives were examined using data from the three waves of the Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID).

Data and sample selection

The PSID is a longitudinal survey that collects demographic information and socioeconomic characteristics from a nationally representative sample of individuals and their families annually between 1968 and 1997 and biennially thereafter. Beginning in 1997, the PSID supplemented its core data with additional information from a group of children 0–12 years old (*N* = 3563) in the Child Development Supplement (CDS). The same children were interviewed three times, in 1997, 2002, and 2007, respectively, if they were still younger than age 18 at the time of each interview. The recruiting, eligibility, and attrition of the PSID-CDS have been described elsewhere (Institute for Social Research, 2010; Wright, Huston, Vandewater, Bickham, Scantlin, Kotler, Caplovits, Lee, Hofferth & Finkelstein, 2001). The CDS included measures of a broad array of child developmental outcomes, such as physical health and disability, emotional well-being, cognitive and academic achievement, and social relationships with household members and peers. The CDS collected the breastfeeding information on children in the first wave (1997) and conducted standardized achievement tests on children in all three waves.

To examine the relationship between breastfeeding and the growth of cognitive ability, PSID-CDS children who had at least one valid measure on standardized achievement tests among three waves and had valid information on breastfeeding were included (*N* = 3129). Because biological mothers are more likely to report reliable information on breastfeeding, and household dynamics could be different between children living with parents and those living with grandparents or other relatives, the study further limited subjects to children living with biological mothers and having parents (i.e. mothers, fathers, or stepfathers) in their households (*N* = 2784). Finally, the few children with missing values on variables listed in Table 1 were excluded; the final sample size was 2681.

Table 1 *Characteristics of the analytic sample: PSID-CDS (1997-2007)[a], (N = 2681)*

Variables[b]	Mean (*SD*) or%
Three-wave average of test scores	
WJ-R[c] AP Score	106.7 (16.9)
WJ-R[c] LW Score	105.7 (18.2)
WJ-R[c] PC Score	104.7 (17.4)
Major independent variables	
Age in years	7.5 (2.9)
Age range	3–17
Whether children were breastfed	59.8
Duration of breastfeeding	3.4 (4.2)
Covariates	
Children's characteristics	
Race	
Black	14.4
White	64.2
Other racial groups	21.4
Gender (male)	50.0
Preterm birth (yes)	9.9
Low birth weight (yes)	2.9
Neonatal care at birth (yes)	11.0
Physical/mental limitations	4.3
Mothers' characteristics	
Age in years	33.8 (6.5)
Education in years	12.6 (3.1)
Employment status (yes)	59.5
Parental warmth	4.5 (0.5)
Emotional support to children	9.7 (2.1)
Cognitive simulation to children	9.7 (2.3)
Household level	
Household size	4.3 (1.2)
Number of children	2.4 (1.1)
Food stamp participation (yes)	18.9
AFDC[d] participation (yes)	9.3
Household income ($)	51,835.5 (54,434.0)

[a]Panel Study of Income Dynamics – Child Development Supplement
[b]All variables were measured in the 1997 PSID-CDS except for those specified in the table. [c]Woodcock-Johnson Revised [d]Aid to Families with Dependent Children

Outcome variables

The three outcome variables were children's scores on three subtests of the Woodcock-Johnson Revised (WJ-R) Tests of Achievement. As a standardized measure of a child's cognitive ability, the Woodcock-Johnson Revised (WJ-R) Tests of Achievement have been widely used and have demonstrated excellent reliability and validity (Woodcock, 1990). The PSID-CDS administered the Letter-Word Identification test (LW test) and the Applied Problems test (AP test) on children who were 3 years or older and the Passage Comprehension test (PC test) on those who were 6 years or older in all three waves. The LW and PC are two subtests on children's reading ability, and the AP is one on children's math ability. The raw scores of three tests were standardized to a 0–200 continuous variable, respectively.

Independent variables

Three major independent variables were used: children's age, a dichotomous indicator on whether children were breastfed, and a continuous variable of the duration of breastfeeding. Children's age ranged from 3 to 17.

Children who had ever been breastfed had the value '1' on the dichotomous measure of breastfeeding, and others had the value '0'. The duration of breastfeeding was measured by month and top-coded at 12 months because a very small proportion of children's breastfeeding lasted more than 12 months. It is worth noting that information on breastfeeding practice collected from maternal recall through interviews in the PSID-CDS may have measurement error, in particular for the duration measure for older children in the sample. The literature suggests that maternal recall is a valid and reliable estimate of breastfeeding, especially when it is recalled within 3 years (Li, Scanlon & Serdula, 2005). Indeed, one benefit of using a dichotomous measure in addition to the duration measure is that it is easier for women with older children to recall whether they ever breastfed their child.

Covariates

Three groups of covariates measured in 1997 were adjusted for, but for presentation purposes only the coefficients for key explanatory variables (age and breastfeeding) were reported. The first group was children's characteristics, including race (0 = White, 1 = Black, and 2 = others), gender (0 = female, 1 = male), preterm birth (1 = gestational age less than 37 weeks and 0 = others), low birth weight (1 = birth weight less than 2500 grams and 0 = others), neonatal intensive care at birth (1 = yes and 0 = no), and physical/mental limitations on childhood or school activities (1 = yes and 0 = no).

The second group was mothers' characteristics, including age, number of schooling years (1–17 years), employment status (1 = yes and 0 = no), and mothers' parenting practices. Three indicators of parenting practices were controlled for: the parental warmth scale, emotional support, and cognitive stimulation. Ranging from 1 to 5, parental warmth was a standardized scale measuring the warmth of the relationship between mothers and children, including the frequency of showing physical affection, appreciation, and so on. Emotional support and cognitive stimulation were based on observed interactions between mothers and children in the home environment by the interviewers, and most of these items were replicated from the Home Scale Short Form originally used in the National Longitudinal Survey of Youth 1979 (Institute for Social Research, 2010). Emotional support ranged from 2 to 14 and was summarized from survey items such as 'mother caressed, kissed, or hugged child at least once' and 'mother conversed with child at least twice'. Cognitive stimulation ranged from 2 to 14 and included items such as 'how many books child has read' and 'mother provided toys or interesting activities'.

Finally, five household characteristics were adjusted for: household size, number of children in households, food stamp program participation (1 = yes and 0 = no), Aid to Families with Dependent Children (AFDC) or Temporary Assistance for Needy Families (TANF) participation (1 = yes and 0 = no), homeownership (1 = yes and 0 = no), and log-transformed household income. The analyses also controlled for state fixed effects, which may serve to impart regional socialization differences on study children. All of these covariates were collected in the first wave of the PSID-CDS (1997).

Statistical analyses

In order to examine the growth trajectories of children's cognitive development, a growth curve analysis was conducted for each test score in the multilevel modeling context (Rabe-Hesketh & Skrondal, 2012). The model specification is listed below:

$$\begin{aligned} \text{Level 1}: Y_{ti} &= \beta_{0i} + \beta_{1i} * A_{ti} + \beta_2 * A_{ti}^2 + \varepsilon_{ti} \\ \text{Level 2}: \beta_{0i} &= r_{00} + r_{01} * B_i + r_{02} * X_i + u_{0i} \\ \beta_{1i} &= r_{10} + r_{11} * B_i + r_{12} * X_i + u_{1i} \end{aligned} \quad (1)$$

where Y_{ti} indicates test score of a child *i* at wave *t*; A_{ti} denotes the age of child *i* at wave *t*; B_i denotes whether children were breastfed or the duration of breastfeeding; and X_i is a vector of control variables, including all three groups of covariates discussed above. The study centered child's age to the first year when they were allowed to take specific tests (i.e. age 3 for the LW and AP tests and age 6 for the PC test). A quadratic term of children's age (A^2_{ti}) was included to model the potential nonlinearity of cognitive development. A cubic term was also added in a sensitivity test, which did not generate inconsistent results from those reported below. The intercept (β_{0i}) and the regression coefficient on children's age (β_{1i}) in the level-1 equation were allowed to be varied by children and were furthered explained by breastfeeding and other control variables in the level-2 equations. However, the regression coefficient of the quadratic term of child's age was not set as a random one. The analysis showed that the variance of this coefficient is very small if it was defined as a random coefficient. To combine the equations in two levels, the following model was obtained:

$$\begin{aligned} Y_{ti} = {} & r_{00} + r_{10} * A_{ti} + \beta_2 * A_{ti}^2 + r_{01} * B_i \\ & + r_{11}(A_{ti} * B_i) + r_{02} * X_i + r_{12}(A_{ti} * X_i) \\ & + u_{0i} + u_{1i} * A_{ti} + \varepsilon_{ti} \end{aligned} \quad (2)$$

The parameters of interest in the study are r_{01} and r_{11}. When a dichotomous measure of breastfeeding is included in the analysis, r_{01} indicates the baseline difference in test scores between children with and without breastfeeding (at age 3 for the LW and AP tests and at age 6 for the PC test), while r_{11} suggests the association between breastfeeding and the growth rate of cognitive development. Similarly, if the duration of breastfeeding is used for the analysis, r_{01} denotes the marginal effect of 1-month breastfeeding on the baseline test scores, and r_{11} is the association between the duration of breastfeeding and the growth rate of cognitive development.

Before testing the model discussed above, univariate growth curve models (i.e. without including the variable of breastfeeding and other covariates) were also conducted to examine the general growth trends of children's test scores. For all statistical analyses, weighted estimates to account for the oversampling of minority children and data attrition and standard errors were computed using Stata 12.1SE (StataCorp, 2011). This approach implements a Taylor series linearization to adjust standard errors of estimates for complex survey sampling design effects including clustered data.

Results

Table 1 reports the distributions of outcome and independent variables and demographic characteristics of the analytic sample. The mean scores of the AP, LW, and PC tests were 106.7 (SD = 16.9), 105.7 (SD = 18.2), and 104.7 (SD = 17.4), respectively, in the sample. The PSIC-CDS children, on average, were 7.5 years old in 1997. About 60% of the sampled children were breastfed, and the average duration of breastfeeding was 3.4 months. More than 60% of subjects were White children, and half of the children were male. The mean age of their mothers was 34 in 1997, and the mean schooling years for mothers was 13. Less than 60% of mothers were employed in 1997. On average, children lived in a household with four members (including two children) and reported an average income of about $52,000.

Figure 1 presents the average scores of three tests by child's age. The range of the y-axis is roughly about two standard deviations around the mean test score. For the AP, LW, and PC tests, the mean scores at different ages were connected using the dashed line, the solid line, and the dotted line, respectively. The figure shows that, overall, the mean score was about 5 points above or below 100. There was a slight upward trend in early childhood, and a slight downward trend was noticed in late childhood.

Table 2 reports results of three univariate growth curve models and three models using the dichotomous

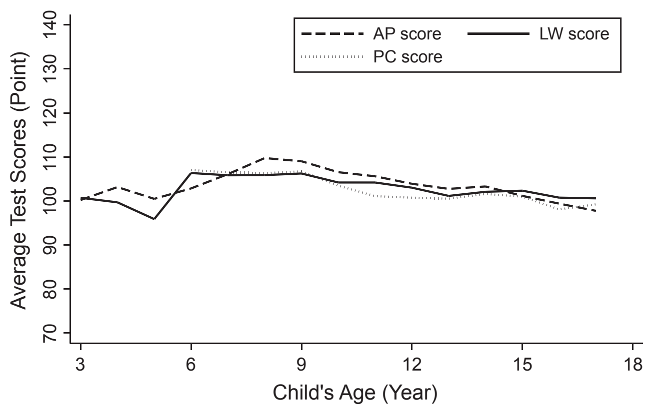

Figure 1 *Average test scores by child's age.*

measure of breastfeeding to predict the growth trajectories of children's test scores. First, except for the analysis on the PC score, the univariate growth curve models had a positive regression coefficient on the age variable (r_{10} = 1.88; 95% CI: .99, 2.77; $p < .001$ for the AP score; and r_{10} = 1.72; 95% CI: .92, 2.51; $p < .001$ for the LW score) and had a negative coefficient on the age-squared variable ($\beta_2 = -.16$; 95% CI: −.21, −.10; $p < .001$ for the AP score; and $\beta_2 = -.15$; 95% CI: −.20, −.09; $p < .001$ for the LW score). The coefficients of child's age and age squared were only significant at the .1 level in the analysis of the PC score. Consistent with the findings in Figure 1, these findings suggest that age had a diminishing return on children's test scores.

Second, the dichotomous measure of breastfeeding had statistically positive associations with three test scores in the baseline. Breastfeeding increased children's AP score by 3.6 points at age 3 (95% CI: 1.40, 5.76; $p < .001$), raised the LW score by 3.2 points at age 3 (95% CI: .82, 5.52; $p < .001$), and increased the PC score by 3.5 points at age 6 (95% CI: 1.54, 5.38; $p < .001$). Third, the interaction term between breastfeeding and child's age did not have a statistically significant coefficient across the three models, and the magnitude of this coefficient was relatively small. That is, breastfeeding had a positive association with children's cognitive ability in early childhood, but did not correlate with the growth rate of cognitive ability.

Results on the duration of breastfeeding presented in Table 3 are consistent with those in Table 2. One month increase in the duration of breastfeeding raised the AP score, the LW score, and the PC score, respectively, by .4 points (95% CI: .10, .69; $p < .01$), .4 points (95% CI:. 12, .72; $p < .01$), and .2 points (95% CI: −.03, .46; $p < .10$). Since the mean duration of breastfeeding was 3.4, these estimations suggest a weaker association between breastfeeding and test scores compared to those reported in

Table 2 *Growth-curve models with a dichotomous measure of breastfeeding*[a]

Variables	AP Score b (95% CI)		LW Score b (95% CI)		PC Score[b] b (95% CI)	
	Univariate	Multivariate	Univariate	Multivariate	Univariate	Multivariate
Intercept (r_{00})	100.99*** (97.86, 104.11)	50.26*** (31.99, 68.53)	100.09*** (97.28, 102.89)	72.37*** (53.72, 91.02)	104.82*** (102.33, 107.31)	72.41 (55.80, 89.02)
Age (r_{10})	1.88*** (.99, 2.77)	4.48*** (2.53, 6.43)	1.72*** (.92, 2.51)	2.16* (.18, 4.14)	.13 (−1.00, 1.26)	2.15$^{\Psi}$ (−.32, 4.62)
Age squared (β_2)	−.16*** (−.21, −.10)	−.16*** (−.21, −.10)	−.15*** (−.20, −.09)	−.15*** (−.20, −.09)	−.11$^{\Psi}$ (−.21, .00)	−.10$^{\Psi}$ (−.21, .00)
Breastfeeding (Yes; r_{01})		3.58*** (1.40, 5.76)		3.17** (.82, 5.52)		3.46*** (1.54, 5.38)
Breastfeeding*Age (r_{11})		−.05 (−.28, .18)		−.02 (−.27, .23)		−.12 (−.42, .17)
Num. of children	2,681		2,681		2,613	
Num. of observations	5,219		5,219		4,657	

$^{\Psi}p < .1$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. [a]All multivariate models are adjusted for the following covariates: (1) children's race, gender, preterm birth, low birth weight, neonatal intensive care, and physical/mental limitation; (2) mother's age, education, employment status, parental warmth, emotional support, and cognitive stimulation; and (3) household's size, number of children, food stamp participation, Aid to Families with Dependent Children or Temporary Assistance for Needy Families participation, homeownership, household income, and state fixed effects. [b]The analysis on the PC score has a smaller sample size since only children aged 6 or older can take this test.

Table 2. For instance, according to Table 3, children who were breastfed for 3.4 months would have an AP score only 1.4 points higher at age 3 than those who were not.

Figures 2-4 compare the fitted averaged test scores based on results in Table 2 for children who were breastfed and those who were not. These figures indicate that, in general, the growth trajectories of cognitive ability for the two groups of children were similar. The gap in test scores between the two groups appeared in early childhood and was maintained throughout childhood.

Discussion

Our results show, even after controlling for an extensive array of confounds, that the breastfeeding gap appears at a very early age and persists over time. Breastfeeding increases the AP and LW test score by about 3–3.5 points at age 3, and the PC score by 3.5 points at age 6. The adjusted mean differences in test scores between breast-fed children and their counterparts without breastfeeding in this study are similar to that estimated in previous studies; for instance, a meta-analysis (Anderson *et al.*, 1999) suggests that adjusted mean difference in standardized cognitive tests between breast-fed and formula-fed children is nearly 3 points in 28 studies.

Although our study cannot show whether the breastfeeding gap in test scores is set at the time of breastfeeding, these results are consistent with previous research by Jedrychowski *et al.* (Jedrychowski, Perera, Jankowski, Butscher, Mroz, Flak, Kaim, Lisowska-Miszczyk, Skarupa & Sowa, 2012), who found cognitive gains even at age 1 and further at age 7 for children exclusively breastfed over children not exclusively breastfed. In addition, the gap between the breastfed and non-breastfed that was found in our sample does not change over time throughout childhood. This indicates that the effect of breastfeeding observed in the literature may reflect the 'true' effect of breastfeeding practices, rather than serving as a proxy for parental characteristics or other environmental factors. A consistent but weaker association between the duration of breastfeeding and test scores has been estimated in the study as well, which may suggest that the measure of duration is less accurate than the dichotomous measure of breastfeeding due to the greater difficulty of recalling duration.

The study makes unique contributions to this topic by examining the association of breastfeeding practices with the growth trajectories of children's cognitive development. Despite the assets of the present study, several limitations bear mentioning. Similar to other nationally representative longitudinal studies, the PSID relies on

Table 3 *Growth-curve models with the duration of breastfeeding*[a,b]

Variables	AP score b (95% CI)	LW score b (95% CI)	PC score[c] b (95% CI)
Intercept (r_{00})	51.29*** (32.71, 69.86)	72.37*** (53.72, 91.02)	71.08 (54.33, 87.82)
Age (r_{10})	4.30*** (2.33, 6.27)	2.02* (.02, 4.02)	2.20$^{\Psi}$ (−.29, 4.70)
Age squared (β_2)	−.16*** (−.21, −.10)	−.15*** (−.20, −.09)	−.11$^{\Psi}$ (−.21, .00)
Duration of breastfeeding (Month; r_{01})	.39** (.10, .69)	.42** (.12, .72)	.22$^{\Psi}$ (−.03, .46)
Duration of breastfeeding*Age (r_{11})	−.05 (−.28, .18)	−.01 (−.04, .02)	.01 (−.03, .04)
Number of children	2,636	2,636	2,569
Number of observations	5,135	5,135	4,588

$^{\Psi}p < .1$; $*p < .05$; $**p < .01$; $***p < .001$. [a]All three models are adjusted for the following covariates: (1) children's race, gender, preterm birth, low birth weight, neonatal intensive care, and physical/mental limitation; (2) mother's age, education, employment status, parental warmth, emotional support, and cognitive stimulation; and (3) household's size, number of children, food stamp participation, Aid to Families with Dependent Children or Temporary Assistance for Needy Families participation, homeownership, household income, and state fixed effects. [b]Due to the missing information on the duration of breastfeeding, the analyses in this table have samples sizes smaller than those in Table 2. [c]The analysis on the PC score has a smaller sample size since only children aged 6 or older can take this test.

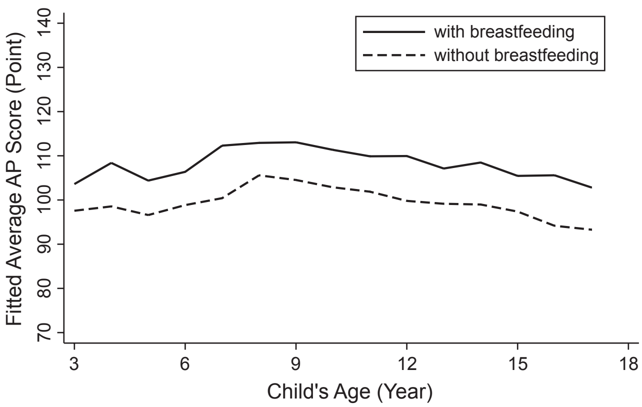

Figure 2 *Fitted average AP scores by breastfeeding status.*

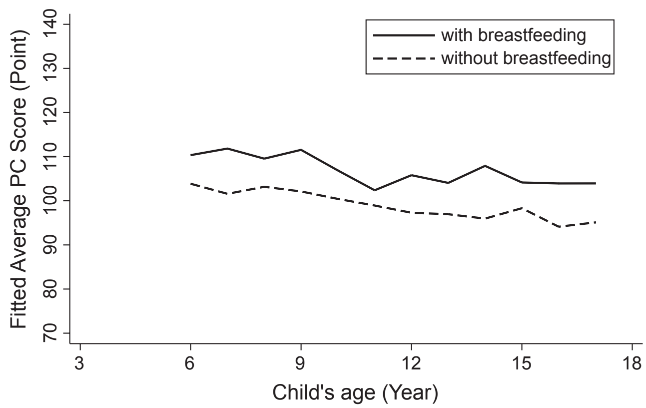

Figure 4 *Fitted average PC scores by breastfeeding status.*

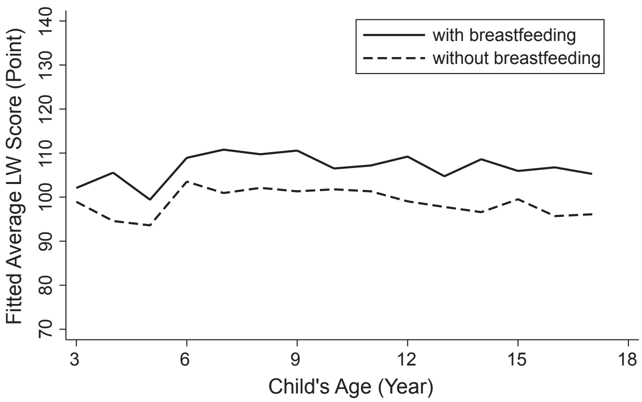

Figure 3 *Fitted average LW scores by breastfeeding status.*

parental reports of breastfeeding and other behaviors that are subject to the possibility of over-reporting due to social desirability response bias. As discussed above, the breastfeeding information reported by mothers may have measurement error, especially for older children in the sample. The measure of breastfeeding also does not take into consideration frequency or intensity, or whether the child was fully or partially breastfed. The dichotomous measure is less prone to measurement error, but is less fine-grained than the duration measure. However, there is no reason why the pattern observed here would stem from systematic over-reporting. Another limitation is the relatively wide age range of the children in the study (3–12 in 1997). Children in this age range were at different developmental stages when their test scores were measured. Because the age distribution was similar for breastfed and non-breastfed children this should not affect our main conclusions. Finally, although several parental confounds, such as warmth and cognitive stimulation, were controlled for, there may also be other unobserved parental characteristics or behaviors that are more likely to occur among mothers who breastfeed. In particular, maternal factors including smoking history (Julvez, Ribas-Fitó, Torrent, Forns, Garcia-Esteban &

Sunyer, 2007), intelligence (Der *et al*., 2006), and depression (Grace, Evandar & Stewart, 2003) have all been linked as contributors to cognitive development in children in the literature, and should be addressed in future studies.

Public policy implications

An important public policy question is how the effect of breastfeeding on test scores compares with other policy interventions aimed at improving test scores and school performance. Although federal and state policies designed to increase test scores are abundant, many of these educational interventions initiated within the United States have failed to generate large, if any, improvements in test scores. Specifically, an evaluation of the Reading First Program, initiated as a result of No Child Left Behind, found no participant improvements in reading comprehension (Gamse, Bloom, Kemple & Jacob, 2008). In addition, Hakel, Koenig and Elliott (2008) assessed the impact on standardized test scores of students being taught by board-certified teachers, with results showing a small increase in test scores. In Florida, for example, students taught by a board-certified teacher had increased standardized test scores in reading with an effect of 2–4%; math scores, however, were not significantly different between the two groups. Furthermore, Zief, Lauver and Maynard (2006) reviewed the impact of after-school programs on academic outcomes and found no statistically significant difference in standardized test scores for program participants versus non-participants.

Our results suggest that one early intervention – encouraging breastfeeding – is likely to improve test scores and has none of the potential negative unintended consequences associated with other education interventions (South, Haynie & Bose, 2007). Indeed, breastfeeding has several other positive public health benefits, such as increased immunity and decreased risk of developing asthma and becoming obese (US Department of Health and Human Services, 2011). Breastfeeding also has significant economic benefits for parents that choose to breastfeed. The Surgeon General's *Call to Action to Support Breastfeeding* reported that parents can save \$1200–\$1500 by breastfeeding rather than buying formula in one year alone (US Department of Health and Human Services, 2011). Despite the costs associated with primary prevention campaigns designed to encourage low prevalence breastfeeding populations such as Black mothers to breastfeed, breastfeeding is likely to compare favorably in terms of cost–benefit analysis to the expensive education policy interventions aforementioned. In addition to education campaigns, it is likely that laws regarding parental leave, breaks at work to allow for the pumping of breast milk, and other public policies might need to be altered to facilitate breastfeeding. While systematic analysis will need to be conducted, the certainty of such a payoff may justify the expenses associated with changing laws and regulations and redoubling efforts to encourage mothers to breastfeed.

Clinical implications

In the meantime, pediatricians, primary care doctors, and other medical practitioners can continue to encourage mothers to breastfeed their children. Though at least 6 months of exclusive breastfeeding may be ideal, this may not be practical for all mothers, many of whom must return to work well before 6 months and may have difficulty pumping breast milk at work depending on their job. Thus, stressing the important benefits of even a few weeks of exclusive breastfeeding (while encouraging more, of course) is important. Our results show that even 1 month or less of breastfeeding produces positive results.

Conclusion

How breastfeeding influences children's cognitive development is an important question. Our study provides additional evidence of the importance of breastfeeding. We also show that the effects of breastfeeding are apparent in very early childhood and do not increase or dissipate over time. This indicates that we can be fairly certain that a genuine breastfeeding effect exists, rather than breastfeeding being an indicator of unobserved variables (such as maternal nurturing) that have a contemporaneous effect on breastfeeding. Future research should further consider the mechanisms by which breastfeeding influences cognitive development, and the amount of time that breastfeeding is necessary to maximize the cognitive benefits.

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