Original Contribution

Beneficial Effects of Breastfeeding on Cognition Regardless of DDT Concentrations at Birth

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The authors previously reported that intrauterine exposure to background concentrations of \( p,p' \)-dichlorodiphenyltrichloroethylene (DDT) reduces cognitive performance among preschoolers. Breastfeeding has been associated with both increased exposure to certain pollutants during infancy and better performance on cognitive tests. Thus, the authors examined the role of breastfeeding in cognitive function among preschoolers, taking prenatal DDT exposure into account. Two birth cohorts in Spain (Ribera d’Ebre and Menorca) were recruited between 1997 and 1999 (\( n = 391 \)). Infants were assessed at age 4 years using the McCarthy Scales of Children’s Abilities. Levels of organochlorine compounds were measured in umbilical cord serum. Information on type and duration of breastfeeding was obtained by questionnaire when the children were 1 year of age. Children who were breastfed for more than 20 weeks had better cognitive performance regardless of their in utero exposure to DDT. A linear dose response between breastfeeding and cognition was observed in all DDT groups (for children highly exposed to DDT, adjusted \( \beta = 0.30 \) (standard error, 0.12) per week breastfed). Despite the possibility of harm from environmental contaminants in breast milk, breastfeeding for long periods should still be recommended as the best infant feeding method.

breast feeding; child; child development; child, preschool; cognition; DDT; infant; intelligence

Abbreviations: DDE, \( p,p' \)-dichlorodiphenyldichloroethylene; DDT, \( p,p' \)-dichlorodiphenyltrichloroethylene; IQ, intelligence quotient.

Breastfeeding is the preferred and promoted mode of feeding during the first weeks of life and has been described as beneficial for children’s cognitive development (1–4). Breast milk contains all of the necessary nutrients and immunologic components that the infant needs (5). However, because of its fat composition, it accumulates and harbors persistent organohalogens, including persistent organic pollutants, heavy metals, and volatile solvents (6, 7).

Some organochlorine compounds are recognized causes of neurodevelopmental impairment and subclinical brain dysfunction. Exposure to these chemicals during early fetal development can cause brain injury at doses much lower than those affecting adult brain function (8). The role of breastfeeding in the relation between exposure to chemicals and children’s neurodevelopment has yet to be clarified.

We previously reported that the longer a child has been breastfed, the higher his or her concentrations of \( p,p' \)-dichlorodiphenyltrichloroethylene (DDT) at age 4 years (9). We also reported that intrauterine exposure to background concentrations of DDT reduces cognitive performance among preschoolers (10), while breastfeeding increases it (11). Since breastfeeding plays an important role in both
children’s exposure to environmental pollutants and children’s cognitive performance, we aimed to assess the role of breastfeeding in intelligence while taking into account exposure to DDT at birth.

MATERIALS AND METHODS

Characteristics of the study population have been published elsewhere (10, 11). Two different Spanish cohorts were included in this analysis. In Ribera d’Ebre, all healthy singleton children born in the main hospital between March 1997 and December 1999 were recruited for the cohort. A total of 102 children were enrolled, and the mothers of 76 (75 percent) provided complete outcome data for the 4-year visit. The Menorca cohort was set up in 1997 within the Asthma Multicenter Infants Cohort Study (12); all women appearing for antenatal care over a 12-month period, starting in mid-1997, were recruited. A total of 482 healthy children were subsequently enrolled, and the mothers of 402 (83 percent) provided outcome data that were complete up to the 4-year visit. Among children from both cohorts with complete data, umbilical cord serum could be obtained from 391 neonates (82 percent). Serum was obtained from 343 children at age 4 years. This study was approved by the ethics committee of the Municipal Institute of Medical Investigation (Barcelona, Spain), and all mothers provided signed informed consent.

Neuropsychological testing of the children at age 4 years (mean ages were 4.4 years in Ribera d’Ebre and 4.3 years in Menorca) was performed by three certified psychologists (one for the Ribera d’Ebre cohort and two for the Menorca cohort) (10). The staff involved in the neuropsychological testing did not know the child’s degree of exposure to organochlorine compounds or the type or duration of feeding. Cognitive development was measured with the Spanish version of the McCarthy Scales of Children’s Abilities (13), which provides information on cognitive and motor abilities.

A gas chromatograph with electron capture detection (Hewlett Packard 6890N GC-ECD; Hewlett Packard, Avondale, Pennsylvania) was used to quantify DDT, p,p’-dichlorodiphenyldichloroethylene (DDE), and other organochlorine compounds as described elsewhere (9). Quantification was performed using external standards, with the polychlorinated biphenyl-142 injection standard used to correct for volume. Recovery of 1,2,4,5-tetrabromobenzene and polychlorinated biphenyl-209 (75–115 percent) was used to correct results. Limits of detection for DDT and DDE were 0.02 ng/ml. A value of 0.01 ng/ml was assigned for nonquantifiable concentrations. Serum samples were stored at −40°C until analysis. All analyses were carried out in the Department of Environmental Chemistry at the Barcelona Institute of Environmental and Chemical Investigation (Barcelona, Spain).

Mothers were asked to complete interviewer-administered questionnaires for assessment of duration of exclusive breastfeeding. The questionnaires were completed twice in the Ribera d’Ebre cohort, at age 1 year and age 4 years, and three times in the Menorca cohort, at ages 6 months, 14 months, and 2 years. No significant differences were found between the surveys. Duration of breastfeeding was categorized into three groups. The reference group included all children who were not breastfed or were breastfed for less than 2 weeks. The other two groups were defined according to the median duration of breastfeeding (2–20 weeks (short-term) or >20 weeks (long-term)). Information on other covariates has been published elsewhere (10).

Neurodevelopment scores followed a normal distribution, while serum levels of organochlorine compounds were skewed to the right and were normalized by logarithmic transformation. DDT concentrations at birth were categorized into three groups (≤0.05 ng/ml, >0.05–0.20 ng/ml, and >0.20 ng/ml). The scores obtained from the McCarthy testing were examined in relation to levels of organochlorine compounds and the study variables using linear regression models.

When adjustment for an additional variable altered the breastfeeding coefficient by 10 percent or more in the models, that variable was considered a confounder. Gender, academic trimester, psychologist, age at examination (in days), maternal social class, maternal education, and maternal use of alcohol and tobacco during pregnancy were the variables that met the criteria for confounding. We checked for interaction between breastfeeding and DDT (or DDE) concentration by including an interaction term in the models. Dose-response relations were assessed using generalized additive models. All statistical analyses were conducted with Stata 8.0 statistical software (Stata Corporation, College Station, Texas).

RESULTS

The percentage of children breastfed for more than 2 weeks was 70.8 percent, with an average duration of 22.9 weeks. McCarthy scores at age 4 years and concentrations of DDT and DDE at birth are presented in table 1 according to duration of breastfeeding. Children with longer periods of breastfeeding performed better on the McCarthy cognitive scale. Concentrations of DDT and DDE at birth did not differ between breastfeeding groups. At age 4 years, DDT and DDE concentrations increased according to duration of breastfeeding. Maternal social class, educational level, and smoking during pregnancy were associated with duration of breastfeeding.

Table 2 shows the adjusted associations between breastfeeding and general cognitive, verbal, and memory McCarthy scores according to DDT exposure. Breastfeeding improved child cognitive development among all infants, and children in the lowest, medium, and highest groups of DDT exposure all had better cognitive skills after long-term breastfeeding, although the finding was statistically significant only among children with higher exposures. Long-term breastfeeding was also found to be beneficial for performance on the quantitative and perceptual-performance scales among children with high exposures (quantitative scale: β = 2.99 (standard error, 1.39) per week breastfed; perceptual-performance scale: β = 5.56 (standard error, 2.34) per week breastfed). A linear dose response between breastfeeding and cognition
was observed regardless of the child’s DDT exposure (chisquared value for nonlinearity obtained by generalized additive modeling: >0.10; for high exposure to DDT, \( \beta = 0.30 \) (standard error, 0.12) per week breastfed). DDE was not found to affect the children’s intelligence. There was no statistically significant interaction between duration of breastfeeding and DDT or DDE concentration (ng/ml) at birth or at age 4 years.

### TABLE 1. Median crude scores on the McCarthy Scales of Children’s Abilities at age 4 years and concentrations of DDT* and DDE* measured in umbilical cord serum at birth, according to duration of breastfeeding, Ribera d’Ebre and Menorca, Spain, 1997–2001

<table>
<thead>
<tr>
<th>Duration of breastfeeding (weeks)</th>
<th>McCarthy score</th>
<th>DDT or DDE concentration (ng/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General cognitive scale</td>
<td>At birth</td>
</tr>
<tr>
<td></td>
<td>Verbal scale</td>
<td>DDT</td>
</tr>
<tr>
<td>&lt;2 (n = 77)</td>
<td>104 (93–118)†</td>
<td>0.07 (0.04–0.27)</td>
</tr>
<tr>
<td>2–20 (n = 162)</td>
<td>106 (92–118)</td>
<td>0.07 (0.04–0.23)</td>
</tr>
<tr>
<td>&gt;20 (n = 152)</td>
<td>110 (101–126)</td>
<td>0.06 (0.03–0.14)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DDT or DDE concentration (ng/ml)</th>
<th>At birth</th>
<th>At age 4 years‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT</td>
<td>0.07 (0.04–0.27)</td>
<td>0.02 (0.01–0.04)</td>
</tr>
<tr>
<td>DDE</td>
<td>0.94 (0.49–1.94)</td>
<td>0.04 (0.01–0.08)</td>
</tr>
</tbody>
</table>

* DDT, \( p,p' \)-dichlorodiphenyltrichloroethane; DDE, \( p,p' \)-dichlorodiphenyldichloroethylene.
† Numbers in parentheses, interquartile range.
‡ Numbers of subjects were 68, 138, and 137, respectively.

### TABLE 2. Adjusted† change in score on three McCarthy scales according to duration of breastfeeding and level of DDT‡ exposure at birth, Ribera d’Ebre and Menorca, Spain, 1997–2001

<table>
<thead>
<tr>
<th>Scale and duration of breastfeeding</th>
<th>Total population (n = 391)</th>
<th>DDT exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (&lt;0.05 ng/ml)</td>
<td>Medium (0.05–0.20 ng/ml)</td>
</tr>
<tr>
<td></td>
<td>(n = 162)</td>
<td>(n = 138)</td>
</tr>
<tr>
<td>General cognitive scale</td>
<td>Reference group§</td>
<td>103.98</td>
</tr>
<tr>
<td>Short-term (2–20 weeks)</td>
<td>1.90 (2.57¶)</td>
<td>2.11 (4.21)</td>
</tr>
<tr>
<td>Long-term (&gt;20 weeks)</td>
<td>7.66 (2.66)*</td>
<td>5.69 (4.53)</td>
</tr>
<tr>
<td>Verbal scale</td>
<td>Reference group§</td>
<td>48.26</td>
</tr>
<tr>
<td>Short-term (2–20 weeks)</td>
<td>0.28 (1.54)</td>
<td>0.48 (2.54)</td>
</tr>
<tr>
<td>Long-term (&gt;20 weeks)</td>
<td>3.10 (1.60)</td>
<td>2.21 (2.74)</td>
</tr>
<tr>
<td>Memory scale</td>
<td>Reference group§</td>
<td>21.26</td>
</tr>
<tr>
<td>Short-term (2–20 weeks)</td>
<td>0.37 (1.01)</td>
<td>0.87 (1.63)</td>
</tr>
<tr>
<td>Long-term (&gt;20 weeks)</td>
<td>2.03 (1.05)</td>
<td>0.85 (1.75)</td>
</tr>
</tbody>
</table>

* \( p < 0.05 \).
† Adjusted for gender, academic trimester at examination, psychologist, maternal social class, maternal education, and maternal use of alcohol and tobacco during pregnancy.
‡ DDT, \( p,p' \)-dichlorodiphenyltrichloroethane.
§ Infants who were breastfed for less than 2 weeks.
¶ Numbers in parentheses, standard error.
breastfeeding and prenatal exposure to DDT \((p = 0.14)\). The benefits of breastfeeding were significant in both genders. No association was found between DDT \((p = 0.65)\) or DDE \((p = 0.46)\) at age 4 years and child cognitive score.

**DISCUSSION**

In this study, breastfeeding was associated with an increase in preschoolers’ cognitive performance, while DDT exposure was associated with lower performance on the McCarthy Scales of Children’s Abilities. The beneficial effect of breastfeeding on child cognition was present regardless of the child’s DDT exposure.

Multiple studies have found that breastfeeding alone is beneficial for children’s neurodevelopment \((1-4)\). Children who were formula-fed or breastfed for less than 2 weeks performed worst in the cognitive areas. This difference might be due to breast milk’s containing superior nutrients than formula milk \((14-16)\) or to the frequency of physical and psychological contact between mothers and their infants during breastfeeding \((17)\). Alternatively, it has been suggested that variables such as maternal education, intelligence, or income might mediate much of the observed association between breastfeeding and cognition \((18)\).

The role of breastfeeding in children’s health has become a controversial issue because of the possibility of harm from environmental contaminants in breast milk \((19)\). Children who are breastfed have more continuous exposure to a contaminant than children who are formula-fed, and concentrations of DDT and DDE at age 4 years are much higher among children who are breastfed longer \((9)\). It is difficult to disentangle the negative role of breastfeeding (the contaminants) from its positive role (the nutrients). One study found that despite the high levels of polychlorinated biphenyls and dioxin transferred via breast milk, breastfeeding seemed to have a beneficial effect on neurologic status in comparison with formula feeding \((20, 21)\). Walkowiak et al. \((22)\) found that mental and motor development between 7 and 42 months of age had a significant negative association with the concentration of polychlorinated biphenyls in human milk. In a previous study of children from the Ribera d’Ebre cohort, we found that long-term breastfeeding was beneficial to neurodevelopment at age 1 year, potentially counterbalancing the impact of exposure to these chemicals through breast milk \((23)\). In the current study, we found that long-term breastfeeding was also beneficial for child development when children were 4 years of age, regardless of the concentration of DDT in umbilical cord serum.

These results suggest that breastfeeding does not increase neurotoxicologic risk through potential DDT exposure via breast milk. One explanation could be that the nutrients in breast milk counterbalance the negative effect of DDT. Another could be related to the kinetics of these contaminants in colostrum, transitional milk, or mature milk. Unfortunately, we did not collect colostrum or mature milk from mother-infant pairs to better understand patterns of exposure. In any case, concentrations of DDT at age 4 years were not associated with a decrease in cognitive skills, and the prenatal exposures were the only ones associated with a potentially harmful effect on neurodevelopment.

A potential limitation of the present study is the nonresponse rate \((17\,\%\) ). However, in most cases, subjects were excluded \((n = 77)\) because of the small quantities of umbilical cord serum in their repository aliquots. We eliminated geographic differences between Menorca and Ribera d’Ebre by analyzing the data by cohort. The results obtained using the Menorca cohort alone showed no differences from the two-cohort analyses, and the results obtained from the Ribera d’Ebre cohort alone pointed in the same direction but were not statistically significant \((10)\). This lack of significance could be explained by the small size of the cohort. The possibility of recall bias cannot be discounted, since information was obtained retrospectively. However, one study found more than 98 percent agreement between responses obtained at age 3 years and data recorded prospectively by nurses \((24)\). Information for this study was obtained at age 6 or 12 months. Information on duration of breastfeeding was obtained through questionnaires, so reporting bias must also be considered. The results could be biased if better-educated mothers reported their breastfeeding behaviors more accurately. We are unaware of any literature that has documented a connection between breastfeeding recall and education. Education was included in all models.

The possibility of residual confounding cannot be discounted, since inclusion of social class and educational level in the models might not have removed part of the variance in parental intelligence quotient \((IQ)\) associated with children’s IQs \((25)\). Unfortunately, parental IQ could not be measured in the Menorca cohort. In the Ribera d’Ebre cohort, maternal IQ was not associated with child neurodevelopment. We did not assess the home environment with a standardized tool such as the HOME Inventory \((26)\), because of cross-cultural differences.

More information regarding DDT and other pollutants in breast milk and their effect on infant development is needed to provide recommendations for clinical practice and to promote environmental and public health policies that reduce human exposure to dangerous pollutants \((27)\). Overall, despite the possibility of harm from environmental contaminants in breast milk, breastfeeding for long periods should still be recommended as the best infant feeding method, even in developing countries where DDT spraying is currently being undertaken and population exposure is much higher.

**ACKNOWLEDGMENTS**

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Conflict of interest: none declared.
REFERENCES