Prenatal Organochlorine Exposure and Measures of Behavior in Infancy Using the Neonatal Behavioral Assessment Scale (NBAS)

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Organochlorines, including polychlorinated biphenyls (PCBs) and p,p′-dichlorodiphenyl dichloroethene (DDE), are highly persistent compounds that have been found in human serum, breast milk, and other biological media. They are known to be associated with a range of adverse health effects, including neurodevelopmental impairments. Studies have demonstrated associations between prenatal exposure to PCBs and measures of attention in early infancy, suggesting that these exposures may have long-lasting effects on neurodevelopment.

METHODS: We investigated an association between cord serum polychlorinated biphenyls (PCBs) and p,p′-dichlorodiphenyl dichloroethene (DDE) levels and measures of attention from the Neonatal Behavioral Assessment Scale (NBAS) among a cohort of 788 infants born 1993–1998 to mothers residing near a PCB-contaminated harbor and Superfund site in New Bedford, Massachusetts.

RESULTS: Medians (ranges) for the sum of four prevalent PCB congeners and DDE levels were 0.19 (0.01–4.41) and 0.30 (0.01–10.29) ng/g serum, respectively. For the 542 subjects with an NBAS exam at 2 weeks, we observed consistent inverse associations between cord serum PCB and DDE levels and NBAS measures of alertness, quality of alert responsiveness, cost of attention, and other potential attention-associated measures including self-quieting and motor maturity. For example, the decrement in quality of alert responsiveness score was –0.51 (95% confidence interval, –0.99 to –0.03) for the highest quartile of exposure to the sum of four prevalent PCB congeners compared with the lowest quartile. We found little evidence for an association with infant orientation, habituation, and regulation of state, assessed as summary cluster measures.

CONCLUSIONS: Our findings provide evidence for an association between low-level prenatal PCB and DDE exposures and poor attention in early infancy. Further analyses will focus on whether organochlorine-associated decrements in attention and attention-related skills in infancy persist in later childhood.

KEY WORDS: behavior, infant, organochlorines, p,p′-dichlorodiphenyl dichloroethene (DDE), polychlorinated biphenyls (PCBs). Environ Health Perspect 116:666–673 (2008). doi:10.1289/ehp.10553 available via http://dx.doi.org/ [Online 24 January 2008]
Laboratory measurements of exposure. Cord blood samples for organochlorine analyses were collected at the infant’s birth; the serum fraction was removed after centrifugation and stored at −20°C. All sample analyses were performed by the Harvard School of Public Health Organic Chemistry Laboratory (Boston, Massachusetts). Laboratory personnel were blinded to infant outcomes. Cord serum samples were analyzed for 51 individual PCB congeners and two chlorinated pesticides [p,p’-DDE and hexachlorobenzene (HCB)]. Laboratory analytic methods and quality control procedures are described elsewhere (Korrick et al. 2000). Briefly, liquid–liquid extraction was used according to procedures developed by the Centers for Disease Control and Prevention with modifications to conform to ultratrace-level analyses (Korrick et al. 2000). Extracts were analyzed by gas chromatography with electron capture detection on a Hewlett-Packard 5890 Series II GC (Hewlett Packard, Palo Alto, CA) with temperature and pressure programming capabilities and a split/spiltless injector. Samples with possible phthalate contamination or a coeluting substance detected in blanks were checked by confirmatory analyses on a Hewlett-Packard 6890 GC with a Micro-ECD and a capillary column of different polarity. Where results differed, the lower value—considered more accurate because it indicated separation of the PCB congener from an interfering coeluting peak—was reported (Erickson 1997).

Quantitation was based on the response factor of each individual PCB congener or pesticide relative to an internal standard. PCB concentrations were reported as individual congeners, after the amount of analyte in the procedural blank was subtracted, and as the sum of all congeners assayed (∑PCB) in units of nanograms per gram serum. Lipid content could not be determined for study subjects because of insufficient sample volume (1.5–4 mL) and was therefore measured for 12 randomly selected cord bloods from discarded, anonymous samples collected at the study recruitment site; values were reproducible (1.7 ± 0.3 g/L) and consistent with lipid content in cord blood reported elsewhere (1.8 ± 0.07 g/L) (Denkins et al. 2000). The method detection limits (MDLs) for individual PCBs ranged from 0.002 to 0.04 ng/g of serum, with most MDLs < 0.01 ng/g; respective MDLs for DDE and HCB in serum were 0.07 and 0.02 ng/g (Korrick et al. 2000). Ninety-six percent of samples had DDE levels above the MDL; from < 1% (congener 22) to 91% (congener 153) of samples had PCB congeners above the MDL (Korrick et al. 2000). Where no measurable quantity of analyte was detected, a value of zero was used in our analyses. We used quantifiable values below the detection limit to optimize statistical power and avoid biased exposure estimates associated with censoring at the MDL (Kim et al. 1995). Reproducibility of serum analyses was good; the ∑PCB within-batch coefficient of variation (CV) was 3% and the between-batch CV was 20% over the 5 years of analysis, with similar performance for pesticides.

Cord blood samples for lead measurement were analyzed at the Harvard School of Public Health Trace Metals Analysis Laboratory (Boston, Massachusetts). Samples were collected at birth in EDTA-containing Vaccum tubes for trace metal analyses. Analyses employed isootope dilution inductively coupled plasma mass spectrometry (Sciex Elan 5000; PerkinElmer, Norwalk, CT) with standard instrument operating and data collection parameters. Quality control and assurance procedures included analyses of procedural blanks, duplicates, spiked samples, and standard reference material to monitor for contamination, accuracy, and recovery rates. Recovery rates for QC and spiked samples were 90–110%, and precision was < 5%. The detection limit was 0.02 µg/dL.

Neonatal outcome assessment. Newborns were examined twice with the NBAS (Brazelton and Nugent 1995). The first assessment took place between the first and third days of life (referred to as the birth exam), and the second was administered between 5 and 22 days, 80% of which fell between 8 and 20 days, (referred to as the 2-week exam). The NBAS assesses the infant’s behavioral capacities, including his or her ability to respond to the environment, such as the ability to orient and habituate to visual or auditory stimuli, both animate and inanimate; the quality of motor tone and activity levels; and the infant’s level of state regulation (i.e., amount of crying and the infant’s capacity to regulate his or her asleep, alert, crying states). The NBAS exam takes approximately 30 min to administer and contains 28 behavioral items, 18 elicited items (including neonatal reflexes), and up to 9 supplementary items, designed to capture the quality of newborn behavioral responsiveness. Each of the NBAS behavioral items is assigned a score (ranging from 1 to 9), according to established scoring criteria, with a higher score typically indicating better performance and a lower score indicating poorer performance (there are some items in which the opposite is the case or where the midpoint is optimal). Neonatal assessments were performed by three study staff members trained in administration and scoring according to the inter-rater reliability criteria established by the NBAS manual (Brazelton and Nugent 1995). Interobserver scoring agreement was calculated before the beginning of the study and then at least biannually thereafter; inter-rater agreement was established at ≥ 90%.

The focus of the current study was infant attention, and we analyzed eight a priori selected NBAS behavioral items to identify the infant’s capacity for attention or abilities potentially associated with attention, such as state regulation and motor maturity. Table 1 lists all outcomes analyzed. The individual behavioral items analyzed for this study were alerterness, consolability, self-quieting activity, hand-to-mouth facility, irritability, elicited and spontaneous activity, and motor maturity. NBAS supplementary items were designed to evaluate the infant’s ability to cope with the examination and maintain an alert state (Brazelton and Nugent 1995). Two supplementary items measuring alertness were selected for inclusion in the analysis: a) quality

Table 1. NBAS outcome measures.

| Individual NBAS items | Capacity measured | NBAS item |
|------------------------|------------------|-----------|
| Attention              | Alertness        |
|                        | Quality of alert responsiveness<sup>a</sup> |
|                        | Cost of attention<sup>b</sup> |
| State                  | Consolability    |
|                        | Self-quieting activity |
|                        | Hand-to-mouth facility |
|                        | Irritability     |
| Motor function         | Elicited activity |
|                        | Spontaneous activity |
|                        | Motor maturity |
| Navitas                | Average score for response to visual and auditory animate and inanimate stimuli, and alertness items |
| Habitation             | Average score for habituation to light, rattle, bell, and pin prick items |
| Regulation of state    | Average score for self-quieting and hand-to-mouth items |
| Other measures         | Never in state for assessment of orientation items<sup>c</sup> |
|                        | Recovery from birth experience<sup>d</sup> |

<sup>a</sup>Supplementary NBAS items. <sup>b</sup>Child never reached alert or awake state in which he or she was able to focus attention on stimuli. Dichotomized variable as all orientation items missing, and data on at least one orientation item. <sup>c</sup>Improved performance from birth exam to 2-week exam on individual NBAS items.
of alert responsiveness, which assesses the level of “processing” alertness as opposed to a simple awake “eyes open” state, and b) cost of attention, which measures the degree to which the motor and physiologic systems were stressed as a result of the infant’s efforts to attend to the stimuli.

As a secondary analysis we also analyzed three of six previously defined behavioral clusters (Jacobson et al. 1984b; Lester et al. 1982)

### Table 2. Distribution of baseline characteristics for mothers and term infants with an NBAS exam approximately 2 weeks after birth, New Bedford, 1993–1998 (n = 542).

| Maternal characteristics | No. (%) | Mean ± SD | Range |
|--------------------------|---------|-----------|-------|
| Age (years)              | 542     | 26.3 ± 5.5 | 17–40 |
| Age category (years)     |         |           |       |
| < 20                     | 70 (12.9)|           |       |
| 20–29                    | 311 (57.4)|           |       |
| 30–34                    | 117 (21.6)|           |       |
| ≥ 35                     | 44 (8.1) |           |       |
| Race/ethnicity (9 missing)|         |           |       |
| White                    | 419 (78.6)|           |       |
| Black                    | 26 (4.9) |           |       |
| Hispanic                 | 36 (6.8) |           |       |
| Other                    | 52 (9.8) |           |       |
| Education (9 missing)    |         |           |       |
| ≤ 11th grade             | 100 (18.8)|           |       |
| High school graduate     | 204 (38.3)|           |       |
| Some college             | 229 (43.0)|           |       |
| Annual household income (38 missing) | | | |
| < $20,000                | 192 (38.1)|           |       |
| $20–39,999               | 157 (31.2)|           |       |
| ≥ $40,000                | 155 (30.8)|           |       |
| Marital status (9 missing)|         |           |       |
| Married                  | 306 (57.4)|           |       |
| Never married/separated/divorced | 227 (42.6)|           |       |
| Parity                   |         |           |       |
| None                     | 205 (37.8)|           |       |
| One                      | 220 (40.6)|           |       |
| Two or more              | 117 (21.6)|           |       |
| Consumed local fish (9 missing) | | | |
| Yes                      | 53 (9.9) |           |       |
| No                       | 480 (90.1)|           |       |
| Smoked during pregnancy (4 missing) | | | |
| Yes                      | 172 (32.0)| 2.8 ± 5.9| 0–40 |
| No                       | 386 (68.0)|           |       |
| Alcohol consumption during pregnancy (9 missing) | | | |
| < 1 serving/month        | 481 (90.2)|           |       |
| 1–2 servings/month       | 14 (2.6) |           |       |
| > 2 servings/month       | 38 (7.1) |           |       |
| No. of servings per month|         | 0.6 ± 2.8| 0–38.4|
| Used illicit drugs before birth (12 missing) | | | |
| Yes                      | 74 (14.0)|           |       |
| No                       | 456 (86.0)|           |       |
| Born in U.S. (11 missing) |         |           |       |
| Yes                      | 422 (78.5)|           |       |
| No                       | 109 (20.5)|           |       |
| Infant characteristics   |         |           |       |
| Gestational age (weeks)  | 542     | 39.8 ± 1.1| 37–42.5|
| Birth weight (g)         | 542     | 3,401 ± 434| 1,901–5,221|
| Sex                      |         |           |       |
| Male                     | 274 (50.6)|           |       |
| Female                   | 268 (49.5)|           |       |
| Birth year               |         |           |       |
| 1993–1994                | 162 (29.3)|           |       |
| 1995–1996                | 210 (38.8)|           |       |
| 1997–1998                | 170 (31.4)|           |       |
| Breast-fed > 1 month (29 missing) | | | |
| Yes                      | 191 (37.2)|           |       |
| No                       | 322 (62.8)|           |       |
| Cord blood measures      |         |           |       |
| ΣPCB<sub>118,138,153,180</sub> (ng/g serum) | 542 | 0.25 ± 0.28 | 0.01–4.41 |
| ΣTEQ<sub>118,138,153,180</sub> (pg/g lipid) | 542 | 6.75 ± 9.73 | 0–151.49 |
| DDE (ng/g serum)         | 542     | 0.48 ± 0.95| 0–10.27|
| Pb (µg/dL) (15 missing)  | 527     | 1.45 ± 0.97| 0–9.39 |

*Sum of PCB congeners 118, 138, 153, 180. bTEF-weighted sum of mono-ortho PCB congeners 105, 118, 156, 167, and 189.
toxicologic mechanisms of action for dioxin-like versus non-dioxin-like congeners (Schantz et al. 2003). We also investigated associations with \( p,p^\prime \)-DDE. A nonlinear effect of organochlorines was investigated by dividing exposure into quartiles of the distribution.

We used linear regression analysis to estimate differences in score by level of exposure for the NBAS outcomes scored on a continuous scale; a lower score was associated with a poorer outcome. We also dichotomized 3 outcome measures: a) irritability [high (score 7–9) vs. normal (score 4–6); only 13 subjects scored < 4]; b) missing orientation data (missing data on all orientation items vs. data on one or more item); and c) failure to recover from the birth experience (failure to advance to a better score from the birth exam to the 2-week exam). Risk ratios were generated for these dichotomous outcomes with log risk models.

Data on covariates came primarily from a questionnaire administered at the 2-week exam. Questions were asked about maternal medical and reproductive histories; typical diet; alcohol, tobacco, and illicit drug use; education; race and ethnicity; occupational and exposure histories potentially relevant to exposures or outcomes of interest; and household income. Trained study personnel also reviewed hospital medical records for study mothers and their infants, at which time details of the mother’s obstetric history, labor, and delivery and of the infant’s newborn physical exam were recorded.

Covariates included \( a \) priori in the model were infant’s age at the NBAS exam, time since last feeding, NBAS examiner and infant birth year. We also evaluated confounding by infant sex and cord blood lead level, and maternal age, race/ethnicity, education, birthplace, marital status, household income, parity, obstetric (OB) risk score, breast-feeding, average cigarette smoking and alcohol consumption during pregnancy, and illicit drug use in the year before birth and diet during pregnancy, including local fish consumption and overall fish consumption, regardless of source.

The OB risk score was a modified score derived from a scoring system created by Hobel et al. (1973) used to identify pregnancies that are at high risk. The original score includes the weighted sum of 126 items that incorporate prenatal, intrapartum, and neonatal risk factors. Our score used 33 items available for the study population and for which independent covariates were not in our models, including advanced maternal age, pre-pregnancy weight, parity, VDRL serology status; history of hypertension, cystitis, diabetes, thyroid disease, anemia; among prior births: preterm delivery, cesarean section, or congenital anomalies; for the current pregnancy: eclampsia, preeclampsia, pyelonephritis, viral disease, premature rupture of membranes, precipitous labor, prolonged labor, prolonged second-stage labor, medical induction of labor, administration of pitocin, forceps or suction/vacuum delivery, meconium staining, prolapsed cord, and fetal bradycardia; and for the current infant: Apgar at 1 and 5 min, whether resuscitation was required, congenital anomalies, cardiac anomalies, respiratory abnormalities, and jaundice. Use of the summary OB risk score requires fewer parameters in the multivariable model and allowed for more precise effect estimation.

We included covariates that improved the fit of the model, demonstrated by a statistically significant partial \( F \)-test \((\alpha < 0.10)\) and investigated whether inclusion of these variables in the model had a meaningful impact on the exposure effect estimate. Individual NBAS items fell into three broad domains: a) measures of attention (alertness, quality of alert responsiveness and cost of attention), b) measures of state (consolability, self-quieting activity, hand-to-mouth facility, irritability and never in state to do orientation items), and c) measures of motor function (elicited and spontaneous activity, and motor maturity). For consistency, the set of covariates included within each domain were kept constant. Estimates of effect and 95% confidence intervals across quartiles of exposure were generated with multivariable models. We computed \( p \)-for-trend to assess monotonic linear trends in the data using the median exposure score for each quartile.

The study protocol was reviewed and approved by the human subjects committees of Harvard School of Public Health and Brigham and Women’s Hospital in Boston and of St. Luke’s Hospital, the New Bedford site of Southcoast Hospitals Group, New Bedford. Written informed consent was obtained from all participating families before study evaluation.

Results
Among the 788 infants included in the initial study population, we excluded 6 twins, 24 singleton preterm births, and 36 infants without serum organochlorine measures. Of the remaining 722 infants, 539 had measures for the birth NBAS assessment, 542 for the 2-week assessment, and 408 infants were administered both exams. Table 2 shows characteristics for the 542 mother–infant pairs with the 2-week exam. Mothers were mostly white, > 80% graduated from high school, more than a third were low income (household income < $20,000 per year), a little more than half were married, and almost a third smoked during their pregnancy. The mean gestational age at birth and mean birth weight were 39.8 weeks and 3,401 g, respectively, and 37% of infants were breast-fed for at least 1 month. The median cord serum level for subjects included in this analysis was 0.19 ng/g (range, 0.01–4.41 ng/g serum) for the sum of four prevalent PCB congeners and 0.30 ng/g (range, 0.01–10.27 ng/g serum) for DDE.

Figure 1 shows inverse associations for the two PCB congener groups as well as DDE and measures of attention, including alertness, quality of alert responsiveness, and cost of attention.
quality of alert responsiveness, and cost of attention. Though the $p$-for-trend was statistically significant for just one-third of these associations, most of the graphs show a consistent decline in attention-related scores with increasing quartile of exposure.

There were less consistent associations between cord serum organochlorines and state-related items, including consolability, self-quieting activity, and hand-to-mouth facility (Figure 2). We observed inverse associations between only a few organochlorines and state-associated outcomes, and predominantly for self-quieting activity. Irritability was associated with the sum of mono-ortho TEF-weighted PCB congeners (TEQ) and DDE (Figure 3), as shown by increasing risk ratios for high versus normal irritability across quartiles of cord serum levels and significant or near significant $p$-values for trend. There was less evidence for increased risk of never being in the appropriate state to respond to orientation (missing data for all orientation items) across quartiles of cord serum PCBs, TEQ, and DDE.

Less consistent associations were also found for motor outcomes, though motor maturity did appear to decline with increasing cord serum PCB, TEQ, and DDE levels (Figure 4). There appeared to be a positive association between cord serum organochlorines and spontaneous activity. There were no consistent associations between organochlorines and any of the three cluster measures (orientation, habituation, and regulation of state; data not shown).

The general pattern of these findings was unchanged when a narrower window of time (10–17 days after birth) was used for the 2-week exam. Findings also remained unchanged when more recent TEF weights were applied (Van den Berg et al. 2006).

Subjects had to have data for both the birth and the 2-week exams to be included in the failure-to-recover analysis. Depending on the item, between 59 and 358 subjects were included. There were no consistent patterns found for PCBs, TEQ, or DDE and failure to recover for any of the NBAS outcomes.

**Discussion**

Our approach to analyzing the NBAS in the current study was different than previous studies that used the traditional seven summary cluster measures developed by Lester et al. (1982) and later revised by Jacobson et al. (1984b). These previous studies found associations between organochlorines (primarily PCBs) and increased number of abnormal reflexes, decreased autonomic maturity and habituation, and, less commonly, range of state (Jacobson et al. 1984a; Lonky et al. 1996; Rogan et al. 1986; Stewart et al. 1990).

For this analysis we hypothesized an association between PCBs and attention-associated behaviors in infancy. Previous literature suggests that prenatal PCB exposures affect attention later in childhood (Grandjean et al. 2001; Jacobson and Jacobson 1996, 2003; Peper et al. 2005; Vreugdenhil et al. 2004). A study of children born to Lake Michigan fish
consumers reported associations between prenatal PCB exposure and poorer performance on a Digit Cancellation task, which indicates difficulty with focused attention and concentration, among 11-year-old children who had not been breast-fed (Jacobson and Jacobson 2003). Associations were also reported among these same children between PCBs and poorer freedom from distractibility, a subscale of the Wechsler Intelligence Scales for Children (Jacobson and Jacobson 1996). Associations were not detected, however, between PCBs and measures of sustained attention among children in this study at 11 years of age, or at an earlier assessment made at 4 years of age (Jacobson and Jacobson 2003; Jacobson et al. 1992). The Faroe Islands study found associations between PCBs and attention measured by a continuous performance test among children 7 years of age only in the context of high mercury exposure, suggesting a potential interaction between these contaminants (Grandjean et al. 2001). A Dutch study found associations between PCBs and sustained attention among 9-year-olds, measured by a continuous performance test (Vreugdenhil et al. 2004). Another study among adults exposed to PCBs from a contaminated building found associations with attention as well as distractibility (Peper et al. 2005).

The present analysis was designed to investigate whether an association between organochlorines and attention could be detected in early infancy. We therefore focused on a priori selected individual NBAS items, including supplementary items (Brazelton and Nugent 1995), as well as cluster measure outcomes that we believe reflect attention-associated skills. In addition, there is substantial overlap between childhood attention disorders [for example, the diagnosis of attention deficit hyperactivity disorder (ADHD)] and the diagnosis of motor impairment as occurs, for example, in developmental coordination disorder (Gillberg 1998; Kadesjo and Gillberg 1998). Independent of co-morbidities, children with ADHD may also have poor movement ability (Gillberg 2003; Pitcher et al. 2003), so NBAS measures of motor function were included in our analyses.

Our results show consistent inverse associations between PCB, TEQ, and DDE cord serum levels and attention-related NBAS outcomes, including alertness, quality of alert responsiveness, and cost of attention (Figure 1). The NBAS supplementary items analyzed (quality of alert responsiveness, cost of attention) were designed to capture qualitative aspects of the infant’s ability to attend to visual and auditory stimuli. For example, quality of alert responsiveness is designed to measure “‘processing’ alertness, not just simple awake, eyes-open states. Given this specified purpose, it is notable that the association with cord serum PCBs and TEQ was particularly strong for supplementary items (Figure 1). These supplementary items were not included in the NBAS manual until 1995, well after most previous studies of PCBs and NBAS had been conducted, thereby affording an opportunity to assess a more inclusive set of attention measures in this analysis than had been possible previously.

Inverse associations were less pronounced for state- and motor-associated outcomes (Figures 2 and 4). We found little evidence for an association with the three cluster outcomes analyzed, which did not corroborate results of the previous studies conducted in Oswego, New York, and in North Carolina that found associations between PCBs and the habituation cluster (Rogan et al. 1986; Stewart et al. 2000).

The positive association observed between organochlorines and spontaneous activity is consistent with hyperactivity–impulsivity observed in experimental animal models of early-life PCB exposure (Berger et al. 2001; Holene et al. 1998; Rice 2000). Impulsive responding has been reported among humans exposed to PCBs. A study designed to dissociate response inhibition from attention found associations between PCBs and impulsive responding among children 8 and 9.5 years of age but not with sustained attention (Stewart et al. 2005). These results are consistent with earlier studies of this cohort in which an association between PCBs and response inhibition was reported at 4.5 years of age (Stewart et al. 2003). The Michigan study also found associations between PCBs and impulsivity among 11-year-olds who had not been breast-fed (Jacobson and Jacobson 2003).

We examined whether organochlorines impaired the infant’s ability to recover from the birth experience by assessing changes in performance between the birth exam and the 2-week exam. Recovery is informative of an infant’s ability to cope and adapt to the extrauterine environment, and was an originally intended application of the NBAS (Brazelton and Nugent 1995). Our findings for recovery were limited in power, however, because data were missing for either exam (both were required).

PCBs are a heterogeneous mixture of congeners, potentially with different toxicologic modes of action. A considerable strength of this study was our ability to measure up to 51 different PCB congeners. Though not presented in the results, effect sizes for the sum of 51 congeners were similar, though slightly attenuated, compared with the sum of 4 PCBs; these 4 congeners are more prevalent and likely measured with more accuracy than the sum of 51 congeners, which may explain the more attenuated effects found for the sum of 51 congeners. The correlation between the sum of 51 and the sum of 4 congeners was also quite high (0.91), and we therefore presented only the sum of the 4 congeners, which we believe adequately represents the sum of all congeners.

To take advantage of congener-specific information, we grouped congeners into structurally related classes—dioxin-like PCBs

| ΣPCB | Elicited activity | Spontaneous activity | Motor maturity |
|------|------------------|----------------------|---------------|
|      | Difference in score (95% CI) | Difference in score (95% CI) | Difference in score (95% CI) |
| P for trend | P for trend | P for trend |
| Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 0.30 | 0.10 | 0.00 | 0.10 | 0.30 | 0.10 | 0.00 | 0.10 | 0.30 | 0.10 | 0.00 | 0.10 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Figure 4. Associations and 95% confidence intervals (CIs) between cord serum levels of the sum of four PCB congeners (118, 138, 153, 180), the sum of mono-ortho TEF-weighted PCB congeners (TEQ), and DDE, and 2-week NBAS measures of motor function (elicited activity, spontaneous activity, and motor maturity), adjusted for infant sex, age at exam, birth year, time since last feeding, NBAS examiner, and maternal birthplace, breast-feeding, and OB risk score for term infants born in New Bedford, 1993–1998.
that infant attention is predictive of intelligence in childhood and adolescence (Sigman et al. 1986, 1997). A study of temperament in infancy (5–6 months) and toddlerhood reported significant prediction of impulsivity and inattention among 8-year-old children (Olson et al. 2002). Other studies did not find infant temperament alone to be predictive, but rather that the combination of infant temperament with parental attitude or perception was predictive of behavioral problems later in childhood (Cameron 1978; Oberklaid et al. 1993; Wasserman et al. 1990). These studies suggest that infant temperament and the interaction between the infant and his or her environment are important determinants of later behavioral outcomes.

How well the NBAS predicts attention later in childhood is also uncertain. Some studies report poor correlation between NBAS and behavioral outcomes later in childhood (Risholm-Morthander 1989; Sameroff et al. 1978), whereas another study found behavioral and reflex clusters to be good predictors of later developmental disabilities among a high-risk population (Ohgi et al. 2003). An important area for future study will be to examine whether these PCB-associated decrements in attention-related skills in infancy are transient or predict attention-related problems later in childhood.

We did not assess maternal IQ at birth, though we did measure maternal IQ with the Kaufman Brief Intelligence Test (Kaufman and Kaufman 1990) on a subset of the children that were available for testing at 8 years old. When we included maternal IQ as a covariate the exposure–outcome effect was slightly stronger, although the precision was reduced because of the smaller number of children on whom maternal IQ was available. In addition, maternal IQ was not predictive of any of the analyzed NBAS items. Final estimates are therefore reported without adjustment for maternal IQ.

This analysis was limited to subjects who were administered an NBAS exam (539 had an exam around the time of birth, 542 had an exam 1–3 weeks after birth, and 408 had both exams). This process resulted in reduced study power, particularly for the recovery analysis, which required both exams. However, we do not expect that it resulted in bias as organochlorine exposure, which was measured in sera from umbilical cord blood, is associated with cognitive function and ADHD symptoms in healthy preschoolers. Clin Endocrinol (Oxf) 66(6):990–998.

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