Birth Delivery Mode Modifies the Associations between Prenatal Polychlorinated Biphenyl (PCB) and Polybrominated Diphenyl Ether (PBDE) and Neonatal Thyroid Hormone Levels

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BACKGROUND: Developing infants may be especially sensitive to hormone disruption from chemicals including polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs).

OBJECTIVE: We investigated relationships between cord serum levels of PCBs and PBDEs and thyroid hormones measured in cord blood serum and neonatal blood spots.

METHODS: We measured PCBs and PBDEs, thyrotropin (TSH), thyroidoxine (T4) and free T4 (FT4) in cord blood serum from 297 infants who were delivered at the Johns Hopkins Hospital in 2004–2005. We abstracted results of total T4 (TT4) measured in blood spots collected in the hospital and at neonatal visits. We used delivery mode (augmented vaginal deliveries and nonelective cesarean deliveries) as a surrogate for intrapartum stress, which is known to alter cord blood thyroid hormones.

RESULTS: In the full study population, no compounds were associated with a change in average TSH, FT4, or TT4. BDE-100 was associated with increased odds of low cord TT4, BDE-153 with increased odds of low cord TT4 and FT4, and no compounds were associated with increased odds of high TSH. For infants born by spontaneous, vaginal, unassisted deliveries, PCBs were associated with lower cord TT4 and FT4 and lower TT4 measured in neonatal blood spots. PBDEs showed consistent but mainly nonsignificant negative associations with TT4 and FT4 measurements.

CONCLUSIONS: Prenatal PCB and PBDE exposures were associated with reduced TT4 and FT4 levels among infants born by spontaneous, unassisted vaginal delivery. Intrapartum stress associated with delivery mode may mask hormonal effects of PCBs and PBDEs.

KEY WORDS: children, cord blood, endocrine disruption, environmental health, polychlorinated biphenyls, polybrominated diphenyl ethers, thyroid hormones.

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Polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are halogenated chemicals that are persistent, have potential for bioaccumulation, and can be detected in most human and environmental samples worldwide (Burreau et al. 2006; Fonnum et al. 2006; Shen et al. 2006; Streets et al. 2006). These two groups of organohalogenes are structurally related, but PCBs have notably longer estimated half-lives in humans than do PBDEs (Ogura 2004; Thurresson et al. 2006). Commercial production of PCBs began in the 1930s (International Programme on Chemical Safety 1993) and most manufacturing, processing, and use of PCBs were banned in the United States in the 1970s. PBDEs were introduced commercially in the 1970s and have been in widespread use. Most PBDEs have been banned in Europe and were voluntarily withdrawn from the U.S. market in 2004; DecaBDE is the exception and is still in use in both Europe and North America (Eriksson et al. 2001; U.S. Environmental Protection Agency 2006).

PCBs and PBDEs have structural similarity to the thyroid hormone thyroxine (T4) (Gill et al. 2004; Ulbrich and Stahlmann 2004). Prenatal exposure to PCBs and PBDEs is of particular interest because these compounds can cross the placenta and may interfere with thyroid hormone production, receptor binding, or transport, resulting in altered hormone levels (Cheek et al. 1999; Covaci et al. 2002; Mazdai et al. 2003). Thyroid hormones are carefully regulated in utero, and lower levels of T4 are associated with impaired brain development (Howdeshell 2002; Porterfield 2000; Winneke et al. 2002). Some experimental studies conducted primarily in mice and rats have found that prenatal exposure to both PCBs and PBDEs may result in decreased plasma total T4 (TT4) levels and/or increased thyrotropin (TSH) (Brouwer 1989; Halgren et al. 2001; Morse et al. 1996). There is very little evidence relevant to the impact of prenatal PBDE exposure on human thyroid function, and studies examining the impact of prenatal PCBs exposure have been equivocal (Chevrier et al. 2007; Koopman-Esseboom et al. 1994; Longnecker et al. 2000; Pluim et al. 1992; Ribas-Fito et al. 2003; Steuerwald et al. 2000; Wang et al. 2005).

The objective of this study was to investigate the relationship between serum cord concentrations of PCBs and PBDEs and newborn thyroid hormone function. Lipid-adjusted serum concentrations of these chemicals (nanograms per gram lipid) are reasonable surrogates for fetal and maternal exposure throughout pregnancy (Covaci et al. 2002; Mazdai et al. 2003). We hypothesized that PCBs and PBDEs alter umbilical cord blood thyroid hormone levels. Specifically, we expected that PCB and PBDE levels would be positively associated with TSH and negatively associated with TT4 and free T4 (FT4). Intrapartum stress associated with delivery can substantially change thyroid hormone levels (Copeland et al. 2002; Tehrani et al. 2003), potentially masking the effects of PCB and PBDE body burdens. We assumed that infants delivered with augmentation and/or using nonelective cesarean sections generally would have suffered more intrapartum stress than those delivered by spontaneous unassisted vaginal delivery (SUVD). To assess the...
possibility of later thyroid effects, we obtained $T_4$ data from blood spots collected at two time points after delivery by the Maryland neonatal screening program.

**Methods**

**Study design and population.** Between 26 November 2004, and 16 March 2005, we collected umbilical cord blood from women delivering at the Johns Hopkins Hospital (Apelberg et al. 2007; Herbstman et al. 2007). All women with singleton deliveries were eligible for inclusion. We obtained approval from the Maternal and Fetal Research Committee in the Department of Gynecology and Obstetrics and the Institutional Review Board at the Johns Hopkins University School of Medicine. This study required the collection of specimens that otherwise would have been discarded and information from medical records that was available to hospital personnel. Because we anonymized samples and data, the study was exempted from requirements for informed consent. The study received a HIPAA (Health Insurance Portability and Accountability Act) waiver.

Over the course of the study period, 597 singleton births occurred at the Johns Hopkins Hospital. Of the 341 cord blood specimens collected, we harvested $> 5.2$ mL serum, the required volume for analyses, in 300 of those specimens. We missed specimen collection because of complications during delivery, premature birth and/or small size of the infant resulting in a small quantity of available cord blood, and limited staffing. Infants with missed specimen collection or insufficient blood volumes, on average, had shorter gestations and/or lower birth weight and were more likely to have been firstborn or born to younger mothers. Of the 300 specimens available for laboratory analysis, 297 were successfully measured (99%). Without any knowledge of exposure and outcome status, we excluded eight infants, whose mothers had any knowledge of exposure and outcome status. We defined the limit of detection (LOD) in direct relation to the method blanks and the instrumental detection limit (Sjödin et al. 2004). In addition, we measured serum cotinine levels to verify self-reported smoking status (Bennert et al. 2000).

Concentrations of TSH, $T_T_4$, and $FT_4$ were measured in 300 cord serum samples by Quest Diagnostics (Baltimore, MD) using the ADVIA Centaur TSH assay, the Microgenics/CEDIA TT$_4$ immunoassay, and the Centaur/Competitive FT$_4$ Chemiluminescent Immunoassay.

With institutional review board approvals, we linked infant records to records in the Maryland Department of Health and Mental Hygiene (DHMH) Newborn Screening Program to obtain results of $T_T_4$ measurements from blood spots. All newborns had blood spots collected before hospital discharge (on average, at 2 days of age) and analyzed by radioimmunoassay; measurements from 265 of these infants were available. DHMH recommends a second $T_T_4$ test during a routine pediatric visit; these were collected, on average, at 18 days of age (range, 5–117 days) for 139 infants in our study.

**Data analysis.** Statistical analyses used STATA version 8.0 (StataCorp, College Station, TX). For PCB and PBDE levels below the LOD, the value was imputed using the LOD divided by the square root of 2. PCB and PBDE levels were lipid-adjusted (nanograms per gram lipid). Four individual PCB congeners—2,3',4',5'-pentaCB (CB-118), 2,2',3,4,4',5'-heptaCB/2,3,3',4,4',6-hexaCB (CB-138/CB-158, coelution), 2,2',4,4',5,5'-heptaCB (CB-153), 2,2',3,4,4',5,5'-heptaCB (CB-180)—and three individual PBDE congeners—2,2',4,4',6-pentaBDE (BDE-47), 2,2',4,4',6,6'-hexaBDE (BDE-189), and 2,2',4,4',5,5'-hexaBDE (BDE-153)—were selected for statistical analysis, based on the previous epidemiologic investigations (Hagmar 2003; Koopman-Esseboom et al. 1994; Longnecker et al. 2000; Meeker et al. 2007; Steuerwald et al. 2000), toxicological evidence (Darnaudery et al. 2007; D’Silva et al. 2004; Safe 1993), and having greater than 60% of samples with detectable concentrations (Table 1). Additionally, we used previously proposed structure- and mechanism-based PCB congener groupings (Chevrier et al. 2007; Lamb et al. 2006), restricted to PCBs detected in $> 75\%$ of the samples: 2,4,4',5-tetraCB (CB-74), 2,2',4,4',6-pentaCB (CB-99), CB-118, coeluting CB-138 and CB-158, and CB-153. Groupings consisted of PCBs that were mono-ortho (CB-74 and CB-118) and di-ortho (CB-99, coeluting CB-138 and CB-158, CB-153, and CB-180) substituted, and PCBs shown to induce microsomal enzymes (CB-99, CB-118, CB-153, and CB-180) (Chevrier et al. 2007).

We log-transformed PCB, PBDE, and TSH levels for statistical analyses to satisfy assumptions of normality. An examination of the data using lowess curves determined that the linear models fit the data reasonably. Therefore, we used univariate and multivariate

| No. | Mean ± SD | Median | Minimum | Maximum | % < LOD | Median LOD |
|-----|-----------|--------|---------|---------|---------|----------|

Table 1. Distribution of PCB, PBDE, and thyroid hormone levels in cord blood serum.
linear regression analyses to estimate relationships between the PCBs, PBDEs, and thyroid hormone measurements. We also used multiple logistic regression analyses to compare the highest quintile (20%) of TSH (high) to the rest of the distribution (the lower 80%), and the lowest quintile (20%) of TT4 and FT4 (low) to the rest of the distribution (the highest 80%). We evaluated the associations for outliers; excluding potentially influential points from the analyses did not change the inferences.

We a priori identified gestational age, maternal age, maternal race, prepregnancy body mass index (BMI), smoking status, and number of previous live births as potential confounders and included these in all multivariate models. We derived gestational age from the best obstetric estimate. We categorized maternal race as white, Asian, or black. We categorized BMI as underweight (BMI < 18.5), normal (BMI 18.5–24.9), overweight (BMI 25.0–29.9) and obese (BMI ≥ 30.0) (Centers for Disease Control and Prevention 2005a). We determined active smoking status using a combination of recorded smoking during pregnancy and/or serum cotinine concentration > 10.0 ng/mL (Centers for Disease Control and Prevention 2005b). Parity was coded as zero versus one or more previous live births. Additional potential covariates including sex of the baby; measures of maternal socioeconomic status; history of sexually transmitted diseases (STDs), hypertension, diabetes, and anemia; and the days between delivery and blood spot collection were evaluated individually using likelihood ratio tests to determine the best-fitting models. We examined the final multivariate models for effect modification by delivery type (SUVD vs. all other deliveries) by adding an interaction term to the models.

### Table 2. Distribution of study population characteristics (n = 289).

| Characteristic                                      | No. (%)   |
|-----------------------------------------------------|-----------|
| Maternal age (years)                                |           |
| < 18                                                | 25 (8.6)  |
| 18–35                                               | 244 (84.4)|
| > 35                                                | 20 (6.9)  |
| Race                                                |           |
| White                                               | 61 (21.1) |
| Asian                                               | 21 (7.3)  |
| Black                                               | 207 (71.6)|
| Education                                           |           |
| < High school diploma                               | 86 (30.2) |
| High school diploma                                 | 95 (33.3) |
| 1–4 years college                                    | 66 (23.2) |
| ≥ 5 years college                                    | 38 (13.3) |
| BMI (kg/m²)                                         |           |
| Underweight (< 18.5)                                | 15 (5.4)  |
| Normal (18.5–24.9)                                  | 130 (46.8)|
| Overweight (25–29.9)                                | 63 (22.7) |
| Obese (≥ 30)                                        | 705 (25.1)|
| Primiparous                                         |           |
| Yes                                                 | 170 (58.8)|
| No                                                  | 119 (41.2)|
| Smoking status                                       |           |
| Active                                              | 54 (18.7) |
| Non/passive smoker                                   | 235 (81.3)|
| Infant sex                                           |           |
| Male                                                 | 160 (55.4)|
| Female                                               | 129 (44.6)|
| Type of delivery                                     |           |
| SUVD                                                 | 94 (32.5) |
| All others                                           | 195 (67.5)|
| Gestational age                                      |           |
| Preterm                                              | 37 (12.8) |
| Full term                                            | 252 (87.2)|
| Hypertension (preeclampsia, pregnancy induced, and preexisting) | | |
| Yes                                                  | 33 (11.4) |
| No                                                   | 256 (88.6)|
| Diabetes (gestational and preexisting)               |           |
| Yes                                                  | 19 (6.6)  |
| No                                                   | 270 (93.4)|
| History of STDs                                      |           |
| Yes                                                  | 40 (13.9) |
| No                                                   | 249 (86.2)|
| History of anemia                                    |           |
| Yes                                                  | 37 (12.8) |
| No                                                   | 252 (87.2)|

*Missing data were excluded from the calculation of percentages. The following data were missing: maternal education (4) and BMI (11).
were associated with lower TSH levels; these associations were not individually statistically significant (Figure 1A). Among babies born by SUVD, higher levels of the individual PCBs and PBDEs were associated with lower TT₄ levels. This relationship was statistically significant for BDE-100 (Figure 1B). Higher PCB (but not PBDE) levels were associated with lower FT₄ levels among SUVDs. These associations were statistically significant for CB-118, CB-153, and CB-180. Conversely, for all other deliveries, higher levels of PCBs were associated with higher FT₄ levels; these were statistically significant for CB-118 and coeluting CB-138 and CB-158 (Figure 1C). All three PCB groupings (mono-ortho substituted, di-ortho substituted, and microsomal enzyme–inducing PCBs) showed similar relationships with thyroid hormones as those for individual PCBs, with significant negative associations between PCB groupings and FT₄ among SUVDs and positive associations among all other deliveries (data not shown).

For SUVD infants, the results of multivariate logistic regression analyses examining the relationships between individual PCBs, PCB groupings, individual PBDEs, and thyroid hormones are presented in Table 3. Infants born by SUVD with higher levels of each PCB, the PCB groupings, and each PBDE had a reduced likelihood of having high TSH measurements. These results were statistically significant for BDE-47 and BDE-100 only. SUVD babies with higher levels of all PCBs, PCB groups, and PBDEs were more likely to have a low cord blood TT₄. These relationships were statistically significant for all PCB congeners and groupings and for BDE-100. SUVD babies with higher levels of PCB congeners and groups and PBDEs were more likely to have a low cord blood FT₄ levels. These relationships were statistically significant for all of the PCBs and PCB groupings but not for any of the PBDEs. Among these babies, each of the compounds was associated with increased odds of low T₄ levels in the hospital, based on the blood spot sample; however, none of these were statistically significant. Higher levels of CB-118, coeluting CB-138 and CB-158, CB-153, the mono-ortho substituted, the di-ortho substituted, the cyp-inducing PCBs, and BDE-153 were associated with an increased likelihood of having a low TT₄ measured in the subsequent neonatal blood spot. These relationships were statistically significant at p < 0.05; however, the 95% CIs for these odds ratios (ORs) are relatively large as a result of smaller sample sizes in these stratified models.

**Discussion**

In this study, we assessed the relationships between prenatal exposure to PCBs and PBDEs and thyroid hormone levels in cord blood and blood spot samples taken in the hospital and at neonatal pediatric visits. We hypothesized that organohalogen exposure levels would alter thyroid hormone levels, and specifically that higher exposures would lower T₄ and raise TSH levels. We found evidence suggesting that PCB and PBDE may be associated with lower TT₄ levels in cord blood and in the subsequent neonatal blood spot (collected, on average, at 18 days of age). Overall, umbilical cord levels of PCBs and PBDEs were not associated with higher TSH levels or with FT₄ levels.

Before this work, only a small study by Mazdai et al. (2003) examined the relationship between prenatal PBDE exposure and thyroid function. In that study, the authors found no relationship between total PBDEs in cord blood and cord blood TT₄ and FT₄.
among nine babies, but this study lacked sufficient statistical power (Mazdai et al. 2003). Several studies have examined the relationship between prenatal exposure to PCBs and thyroid hormone function. Most of these studies have been reviewed by Hagmar et al. and Kimbrough and Krouskas (Chevrier et al. 2007; Hagmar 2003; Kimbrough and Krouskas 2001; Koopman-Esseboom et al. 1994; Longnecker et al. 2000; Matsuura et al. 2001; Ribas-Fito et al. 2003; Steuerwald et al. 2000; Wang et al. 2005). Although the results have been inconsistent, differences in the exposure matrices, timing of measures of thyroid hormones, PCB congeners measured, and statistical methods make direct comparisons difficult. Additionally, none of the previous studies of prenatal PCB exposure have addressed the impact of delivery mode on the relationship between PCBs and thyroid function, a strong effect modifier in this study. The recent study by Chevrier et al. (2007) detected a positive association between TSH in newborn blood spots and the cyp-inducing PCBs. We were not able to confirm this finding either among all births or among spontaneous vaginal unassisted deliveries alone. However, important differences in study design may explain these discrepancies. We did not measure all of the same PCB congeners as Chevrier et al. (2007). Additionally, because neonatal thyroid hormones are dynamic, the difference in the timing of the TSH measurement—ours in cord blood at birth and theirs in bloodspots of newborns collected a few days after birth—may have important implications.

Prior reports have indicated that complications of labor and delivery can alter thyroid hormone function in mothers and infants at the time of delivery (Chan et al. 2001a, 2003). Several studies have demonstrated associations between mode of delivery and measures of stress-related hormones measured in maternal and umbilical cord blood (Gitau et al. 2001; Mears et al. 2004; Vogl et al. 2006). In response to stress, the production of hormones including epinephrine, norepinephrine, and cortisol is increased. These increases alter the hypothalamic–pituitary–adrenal axis, which is also involved in thyroid hormone production (Charmandari et al. 2005). Although we had no direct measure of intrapartum stress, the medical charts clearly indicated the delivery mode (i.e., vaginal or cesarean section), whether labor was spontaneous or augmented, and whether the delivery required assistance or intervention (i.e., forceps, vacuum, etc.). We had hypothesized a priori, based on the published literature, that spontaneous, unassisted, and vaginal deliveries would be less likely to involve intrapartum stress than other deliveries [augmented vaginal deliveries and emergency (nonselective) cesarean deliveries]; hence, we expected that relationships between PCBs, PBDEs, and thyroid hormone levels might be more easily detectable among such births (Chan et al. 2001a, 2001b; Lao and Lee 2002; Miyamoto et al. 1991). However, the extent of effect modification we observed was unexpected.

The biologic mechanism explaining the difference in effect between the spontaneous vaginal deliveries and other deliveries is unknown. Delivery stress is associated with elevated cord TSH levels (Lao and Panesar 1989; Tehrani et al. 2003). Possibly, the increased TSH triggers the production of T4. Alternatively, elevated TSH levels may be a response to low circulating T4 among babies with delivery-induced stress. In either case, if vaginal deliveries requiring augmentation and cesarean sections after attempted labor are stressful for the infant, this may initiate a cascade of hormonal responses that may mask subtle thyroid perturbations in association with prenatal PCB and/or PBDE levels. We explored the possibility of analyzing infants delivered by elective cesarean as a separate group that would be expected to have very little stress as a result of delivery, but there are only 26 elective cesareans in this population—too few for analyses. Moreover, these elective cesarean sections include mothers and babies with preexisting medical conditions that also may be associated with stress.

In this study, the observed relationships between PCB and PBDE serum levels and specific thyroid hormone measures generally were consistent in the same direction, even when they were not individually statistically significant. Such consistency of association supports the hypothesis that there are true associations between prenatal PCB and PBDE exposure and thyroid hormone levels. Alternatively, this consistency may be attributable to positive correlations among PCB and PBDE congeners. However, PCB levels are not correlated with PBDE levels in this population (Herbstman et al. 2007). Given the large number of individual models, the consistency of associations across the individual PCB and PBDE congeners and PCB groupings is reassuring.

It is difficult to extrapolate between associations at the lower exposure levels observed in this population and the much higher levels observed in animal studies. The difference in exposure levels may elicit different effects, given the possibility of nonmonotonic dose–response relationships that have been observed previously for endocrine effects (Rice and Barone 2000). Despite compelling evidence from animal models, it is possible that humans and animals respond differently to these organohalogen exposures (Kimbrough and Krouskas 2001). For example, it has been suggested that the principal thyroid transport protein in humans is Tg-binding globulin compared with transthyretin, which is the main thyroid hormone transporter in rodents (Check et al. 1999; Kimbrough and Krouskas 2001). Therefore, if PCBs and/or PBDEs are competitively binding with the transthyretin protein in rodents, the pattern of responses for humans could be different.

Several prior epidemiology studies also have reported on populations with thyroid hormone levels within the clinically normal range (Koopman-Esseboom et al. 1994; Longnecker et al. 2000; Matsuura et al. 2001;}

### Table 3. Adjusted ORs (95% CIs) for thyroid hormone levels in response to organohalogen exposure among babies born by SUVD, n = 92.

| PCB          | High vs. lowest 80% | Low vs. highest 80% |
|--------------|---------------------|---------------------|
| PCB-118      | 0.35 (0.12—1.05)    | 2.91 (1.17—7.20)*   |
| PCB-138      | 0.53 (0.22—1.27)    | 2.44 (1.08—5.48)*   |
| PCB-153      | 0.52 (0.20—1.33)    | 2.37 (1.05—5.33)*   |
| PCB-180      | 0.43 (0.18—1.03)    | 2.22 (0.76—5.62)    |
| Mono-ortho   | 0.44 (0.14—1.40)    | 3.02 (1.08—8.53)*   |
| Di-ortho     | 0.45 (0.17—1.26)    | 2.62 (0.89—7.99)*   |
| Cyp-inducers | 0.43 (0.12—1.72)    | 2.70 (1.16—6.36)*   |
| BDE-47       | 0.39 (0.19—0.78)*   | 1.46 (0.82—2.59)    |
| BDE-100      | 0.36 (0.16—0.82)*   | 2.14 (1.01—4.18)    |
| BDE-153      | 0.56 (0.26—1.17)    | 1.30 (0.71—2.39)    |

*All models adjusted for baby’s sex, gestational age, maternal age, maternal prepregnancy BMI, smoking status. *TSH also adjusted for history of STDs and parity. *TT4 also adjusted for reported hypertension, diabetes, and anemia. *Both blood spot measurements were also adjusted for time since birth blood spot was collected (in days). High: being in the highest quintile. Low: being in the lowest quintile. *Models where the 95% CIs around the OR do not include 1.0.
Ribas-Fito et al. 2003; Steuerwald et al. 2000; Wang et al. 2005). Comparison of dose among epidemiology studies is also challenging. For PCB levels, a study by Hagmar proposed a relative body burden (RBB) measure for comparing studies with different analytic methods, different congeners measured, different biological matrices, and with and without adjustment for lipid composition (Hagmar 2003). By this method, the geometric mean total RBB for PCBs in this study is 26.9 ng/g lipid compared with 1,120 ng/g lipid reported in the Faroese population (Steuerwald et al. 2000). Steuerwald et al. observed that higher total PCBs were weakly associated with lower TSH levels, perhaps consistent with our findings, even though our RBB levels were much lower.

Timing of exposure in early development likely is critical. It would be interesting to assess thyroid hormone expression earlier in pregnancy and before the timing of the development of an intact hypothalamic–pituitary axis, which can compensate for small perturbations. It may be possible to investigate this hypothesis by studying hormone levels in amniotic fluid, which was not available in this study population. We were able to assess thyroid hormone levels at three points in time (birth, approximately 2 days after delivery, and at a subsequent time, generally within 1 month). In our study, among babies born by SUVD, PCBs are associated with lower TTF1 levels at all three time points and with FT4 levels in cord blood. Weaker evidence suggests a similar relationship between PBDEs and TTF1 in cord blood. These differences indicate that despite apparent structural similarities between PCBs and PBDEs, these chemicals may be eliciting different endocrine effects in humans or that PBDEs are less potent than PCBs in this regard. Further studies may want to investigate this relationship more thoroughly, because it is clear that even small perturbations in thyroid hormone levels at critical exposure windows may have long-lasting health impacts (Branchi et al. 2003).

There is also the possibility that other unmeasured factors may affect the relationship between PCBs, PBDEs, and thyroid function. For example, we did not measure iodine status in this population. Iodine is known to be related to thyroid hormone synthesis and regulation and may also be related to PCB and PBDE exposure through the diet, because both iodine and PCBs may be found in fish (Boyages 1993).

Despite the limitations of this study, we saw patterns indicating that among babies born by SUVD, PCBs are associated with lower TTF1 levels at all three time points and with FT4 levels in cord blood. Weaker evidence suggests a similar relationship between PBDEs and TTF1 in cord blood. These differences indicate that despite apparent structural similarities between PCBs and PBDEs, these chemicals may be eliciting different endocrine effects in humans or that PBDEs are less potent than PCBs in this regard. Future studies may want to investigate this relationship more thoroughly, because it is clear that even small perturbations in thyroid hormone levels at critical exposure windows may have long-lasting health impacts (Branchi et al. 2003).
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