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Serum Polychlorinated Biphenyls and Their Hydroxylated Metabolites are Associated with Demographic and Behavioral Factors in Children and Mothers

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Abstract

Factors contributing to the inter-individual variation in body burden of polychlorinated biphenyls (PCBs) and their hydroxylated metabolites (OH-PCBs) have not been fully elucidated. We examined associations between total serum concentrations of 209 PCBs, 64 OH-PCBs, and frequently detected individual congeners with demographic characteristics (age, gender, ethnicity and community of residence), body mass index (BMI or BMI percentile), and breastfeeding history in children and their mothers from 83 U.S. households. There was a significant positive association between age and concentrations of total PCBs and OH-PCBs in mothers. Non-Hispanics had significantly higher concentrations of total PCBs in mothers and OH-PCBs in children than Hispanics. Concentrations of total PCBs were significantly lower in mothers who had longer breastfeeding duration. Living in the Columbus Junction, Iowa community as compared to East Chicago, Indiana was associated with higher total PCBs in children, probably attributable to higher exposures at school. Lower concentrations of OH-PCBs were significantly associated with a higher BMI percentile in children. Congener-specific associations were observed for 30 PCB and 12 OH-PCB congeners and followed comparable trends. To our knowledge, this is the first study to examine factors contributing to variations in serum concentrations of total 209 PCBs and total OH-PCBs in children, as well as to examine ethnic differences in OH-PCB levels. Results from this study revealed that demographic characteristics, body mass index and

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Supporting Information

Tables of PCBs LOQ, concentration and detection frequency of PCBs, regression coefficients and P values of associations between independent variables and individual PCB and OH-PCB congeners.

breastfeeding history are factors that should be considered for human exposure and risk assessment of PCBs and OH-PCBs.

Keywords

polychlorinated biphenyls; hydroxylated polychlorinated biphenyls; risk assessment; epidemiology; body mass index; lactation

1. Introduction

Polychlorinated biphenyls (PCBs) are a group of synthetic organic compounds consisting of 209 unique congeners with varying numbers and positions of chlorine molecules on the biphenyl. Regardless of origin, PCBs are highly persistent in the environment, bioaccumulate in biota and humans, and induce adverse health effects.¹ Hydroxylated polychlorinated biphenyls (OH-PCBs) are major PCB metabolites; they appear in the human body not only because of metabolism of PCBs,² but also because of other origins such as intake of foods containing OH-PCBs, especially contaminated fish and other seafood capable of PCB metabolism,³ prenatal exposure via placental transfer,^{4–7} and possibly inhalation, as PCBs can react with OH radicals in the troposphere, leading to formation of OH-PCBs in the atmosphere.^{8, 9}

Prior studies in highly-exposed cohorts have shown that variations in the body burden of PCBs and OH-PCBs from one individual to another may be explained by demographic and behavioral factors. For example, many studies have reported that age is a determinant of human body burden of PCBs^{10–16} and OH-PCBs.^{17, 18} Gender and race/ethnicity have also been shown to be associated with serum levels of PCBs^{16, 19–22} or OH-PCBs.²³ Community of residence is another factor associated with PCBs and OH-PCBs levels such that residents living in a highly PCB-contaminated location had higher serum concentrations of PCBs and OH-PCBs than residents of a lesser contaminated community.²³ Body mass index (BMI) of adults or BMI percentile of children may also predict an individual's body burden of PCBs or OH-PCBs: several studies have found a significant association of BMI with PCB^{15, 24, 25} or OH-PCB levels in serum.²⁶ Moreover, breastfeeding history may affect body burden of PCBs or OH-PCBs; women who previously breastfed were found to have a lower body burden of PCBs^{14–16} and OH-PCBs,³ whereas children who had been breastfed during infancy were found to have significantly higher concentrations of PCBs in their serum.^{27, 28}

Importantly, most of the above studies did not examine all of these factors using a multivariate analysis; therefore, their findings could be explained by confounding factors; for example, associations between PCBs and ethnicity may be confounded by ethnic-specific differences in breastfeeding practice. Moreover, studies that examine factors contributing to PCBs and OH-PCBs levels in children have been very limited, despite the emerging evidence supporting the negative health impact of PCB exposure in children.^{29–32} In addition, none of the previous studies examined total PCBs concentration as the sum of concentrations of all 209 congeners; instead, focusing on common Aroclor PCB congeners. In our prior work, we demonstrated that as much as 50% of PCBs in human blood serum were PCB congeners not found in commercial mixtures.³³ This suggests that total PCBs

concentration in human serum could be underestimated by up to 50% if only based on common Aroclor PCB congeners. Furthermore, the role of individual congeners, such as mono-chlorinated PCBs and di-hydroxylated PCBs, has been overlooked in the previous literature.

This study was conducted to fill these research gaps and to investigate associations between total serum concentration of 209 PCBs (Σ_{209} PCBs), 64 OH-PCBs (Σ_{64} OH-PCBs), and frequently detected individual congeners with demographic characteristics (age, gender, ethnicity, community of residence), BMI or BMI percentile, and breastfeeding duration in children and their mothers.

2. Materials and Methods

2.1. Study locations, participants and sample collection

The present study used data from the Airborne Exposure to Semi-volatile Organic Pollutants (AESOP) Study. Detailed information related to study locations, participants, and sample collection of the AESOP study has been described elsewhere.^{33–36} Briefly, mothers and children were recruited from 86 households in East Chicago, Indiana and the rural area in and around Columbus Junction, Iowa through middle schools. Their serum samples were collected in 2010–2011 and assayed for 209 PCBs and 64 OH-PCBs. We excluded the younger child if there was more than one enrolled child from the same household. Three households were excluded because both PCBs and OH-PCBs data were not available due to poor surrogate standard recovery, giving a final sample size of 83 mother-child pairs. The AESOP study protocols were reviewed and approved by the University of Iowa Institutional Review Board. Written informed consent and assent were obtained from all participants in English or in Spanish.

2.2. Quantification of PCBs and OH-PCBs

Details for quantification and quality control of PCBs and OH-PCBs analysis were presented previously.^{33, 35} In brief, PCBs were quantified using a modified version of U.S. EPA method 1668 with gas chromatography-tandem mass spectrometry (GC-MS/MS). A total of 174 chromatographic peaks were observed, which represented all 209 PCB congeners as single or co-eluting congeners. Many of the detected PCBs were non-Aroclors.³³ The OH-PCBs selected for analysis were determined by the availability of commercial calibration standards. A total of 64 OH-PCBs were quantified as single or co-eluting MeO-PCBs in 57 chromatographic peaks.³⁵ Among the 83 households included in the present study, PCBs data were available from 82 households and OH-PCBs data were available in 74 households, respectively.

2.3. Quality control

Method blanks (1% potassium chloride, KCl), a mixture of ^{13}C -labelled PCB surrogate standards and standard reference materials were used as quality control samples. Full details of quality control results were presented in our previous studies.^{33, 35} Limit of quantification (LOQ) was determined based on the mean plus twice the standard deviation of method blanks. Each congener had its own LOQ value and samples below the LOQ value were

assigned a value of zero.^{29, 33} The list of all 209 PCB congener LOQ values is presented in Supporting Information (SI), Table S1. All 64 OH-PCB congener LOQ values were published previously.³⁵

2.4. Dependent variables

209 PCBs and 64 OH-PCBs were calculated as the sum of concentrations of 209 PCB congeners and 64 OH-PCB congeners (ng/g f.w.), respectively. Individual PCBs and OH-PCBs were selected for statistical analysis in the present study if their detection frequency was ≥ 65%. Based on this criterion, 30 PCB congeners and co-eluting congeners and 12 OH-PCB congeners and co-eluting congeners were included. Concentration and detection frequency of PCBs are available in SI, Table S2 while those for OH-PCBs were previously published.³⁵

2.5. Independent variables

Age was calculated from the sample collection date and participant's date of birth. Body weight and height were measured by trained field staff and used for calculation of BMI. For children, age- and gender-specific BMI percentiles were calculated by comparison with the 2000 Centers for Disease Control and Prevention Growth Chart.³⁷ Breastfeeding duration in mothers was calculated as the sum of self-reported breastfeeding duration for each child that they had breastfed, whereas breastfeeding duration in children was obtained from breastfeeding duration of the enrolled child reported by his/her mother. Zero month was assigned for a mother if she had never breastfed any child, and for a child if he/she was not breastfed. In addition, ethnicity was included in the list of independent variables and coded as 0 for Hispanic or 1 for non-Hispanic. Community of residence was examined with the Columbus Junction community being coded as 0 and East Chicago as 1. Children's gender was also coded as a binary variable (0 for male and 1 for female).

2.6. Statistical analysis

SAS (version 9.3, SAS Institute, Cary, NC) was used for statistical analysis. The statistical significance level was set as 0.05. Data for mothers and children were analyzed separately. Levels of 209 PCBs and 64 OH-PCBs, as well as selected individual congeners were log-transformed to achieve normality. Pearson correlation coefficient was estimated for the relationship between log-transformed 209 PCBs and 64 OH-PCBs in 73 children and 73 mothers who had both PCB and OH-PCB data available. In multiple linear regression analyses, log-transformed 209 PCBs and 64 OH-PCBs were used as the dependent variables, whereas age, gender (for children), ethnicity, community of residence, BMI (for adults) or BMI percentile (for children), and breastfeeding duration were independent variables. Log-transformed levels of selected congeners with a detection frequency of 100% were analyzed in the same manner. For congeners that were not detected in all participants, data were analyzed using Tobit regression analysis by treating non-detected observations as left-censored values at the lowest detected concentration of that congener in the study sample. Regression coefficients with their standard errors were presented.

To determine if child selection from households with two enrolled children affected observed associations, a sensitivity analysis was conducted for 209 PCBs and 64 OH-

PCBs by including the younger child and excluding the older child. Two other sensitivity analyses were conducted in this study. First, since non-Hispanic participants were grouped as a single ethnic group due to the small number of participants from each racial group, adjusted least square mean of Σ_{209} PCBs and Σ_{64} OH-PCBs in non-Hispanic Whites and non-Hispanic African Americans were compared to determine if they were significantly different. Second, due to ethnic-specific differences in body weight status^{38, 39} and breastfeeding practice,⁴⁰ the interactions between ethnicity and BMI or BMI percentile, or the interactions between ethnicity and breastfeeding duration were included in the statistical model.

3. Results

3.1. Characteristics of participants

Of the 83 households in the present study, 46 (55.4%) were from Columbus Junction. Among children, 41 (49.4%) were male, 57 (68.7%) were Hispanic. Children's mean age was 15.1 ± 0.1 years, their BMI percentile was 71.9 ± 3.0 , and their breastfeeding duration was 3.5 ± 0.5 months. Among mothers, 53 (63.9%) were Hispanic. Mothers' mean age was 41.8 ± 0.6 years; their BMI was 31.5 ± 0.8 kg/m², and their lifetime breastfeeding duration was 11.6 ± 1.6 months. Table 1 presents these demographic data by communities of residence, generation, and ethnicity.

3.2. Correlations between Σ_{209} PCBs and Σ_{64} OH-PCBs

As shown in Figure 1, there was a modest, but significant positive correlation between serum total concentrations of Σ_{209} PCBs and Σ_{64} OH-PCBs in mothers ($r=0.38$, $P=0.001$). However, there was no significant correlation between these concentrations in children ($r=0.16$, $P=0.19$).

3.3. Associations between demographics and Σ_{209} PCBs and Σ_{64} OH-PCBs

Table 2 presents results from multiple linear regression analyses of Σ_{209} PCBs and Σ_{64} OH-PCBs in children and their mothers. Community of residence was the only factor that was significantly associated with Σ_{209} PCBs in children ($P=0.009$): those from Columbus Junction had a significantly higher Σ_{209} PCBs concentration than children from East Chicago. By contrast, ethnicity and BMI percentile were significantly associated with Σ_{64} OH-PCBs in children ($P=0.042$ and $P=0.008$, respectively): non-Hispanic children had a significantly higher Σ_{64} OH-PCBs concentration than that of Hispanic children, and there was a negative association between concentrations of Σ_{64} OH-PCBs and children's BMI percentile.

In mothers, age was positively and significantly associated with both Σ_{209} PCBs and Σ_{64} OH-PCBs ($P=0.002$ and $P=0.001$, respectively). Ethnicity and breastfeeding duration were also associated with Σ_{209} PCBs ($P=0.018$ and $P=0.032$, respectively): non-Hispanic mothers had a higher Σ_{209} PCBs concentration than that in Hispanic mothers whereas mothers who had breastfed their children for a longer period had a significantly lower Σ_{209} PCBs concentration. Other factors examined were not associated with Σ_{209} PCBs and Σ_{64} OH-PCBs in mothers.

3.4. Associations between demographics and individual PCB and OH-PCB congeners

Table 3 presents factors that were significantly associated with selected individual PCB and OH-PCB congeners. Regression coefficients and exact P values for these associations are presented in SI, Table S3 (PCBs in children), Table S4 (PCBs in mothers), Table S5 (OH-PCBs in children) and Table S6 (OH-PCBs in mothers). As shown in Table 3, the associations between PCBs and each factor were congener-specific. However, several patterns were observed. Community of residence was the only factor that was significantly associated with lower-chlorinated PCBs (i.e., those PCBs with less than 4 chlorines, such as PCB 37) but it was rarely associated with higher-chlorinated PCBs. Higher-chlorinated PCBs (those PCBs with at least four chlorines, such as PCB 105) were often significantly associated with personal characteristics such as age, gender, ethnicity, BMI, and breastfeeding duration. Age was positively associated with most of the higher-chlorinated PCBs in mothers but not children, whereas BMI percentile was negatively associated with most of the higher-chlorinated PCBs in children but there were no significant associations between BMI and most of the higher-chlorinated PCBs in mothers. A few higher-chlorinated PCBs were associated with children's gender, showing that boys were more likely to have a higher PCB level of these congeners than girls. Ethnicity was significantly associated with most of the higher-chlorinated PCBs in both children and mothers, revealing that non-Hispanic participants tended to have higher levels than Hispanics. Some PCB congeners were also associated with breastfeeding duration: mothers who had breastfed longer had a lower PCB concentration, whereas children who were breastfed longer had higher PCB concentrations.

The associations between individual OH-PCB congeners and each of the factors examined were also congener-specific (Table 3, bottom). Age was associated with most OH-PCBs in mothers but rarely in children. With regards to gender, 4'-OH-PCB 199 was the only OH-PCB that was significantly associated with children's gender: boys tended to have a higher level of this metabolite than girls. Several higher-chlorinated OH-PCBs were associated with non-Hispanic ethnicity although this was more frequently observed in mothers than children. The community of residence was associated with very few OH-PCBs: mothers who resided in Columbus Junction were more likely to have a higher concentration of 4-OH-PCB 178, but both mothers and children from Columbus Junction had a lower concentration of 4,4'-diOH-PCB 202. The overall mean concentration of 4,4'-diOH-PCB 202 was 0.0026 (0.0005-0.0111) ng/g fresh weight. BMI or BMI percentile were inversely associated with certain OH-PCBs examined in both mothers and children; by contrast, very few OH-PCBs were associated with breastfeeding duration, with the exception that children's breastfeeding duration was positively associated with their serum level of 3'-OH-PCB 138 whereas mother's breastfeeding duration was negatively associated with their serum level of 4-OH-PCB 146, consistent with the findings for PCB congeners.

3.5. Sensitivity analyses

When the younger child instead of the older child from households with two enrolled children was included, a similar result was obtained for analysis of associations with total PCBs and total OH-PCBs concentrations (data not shown). The least square mean of 209 PCBs or 64 OH-PCBs did not differ significantly between non-Hispanic White and non-

Hispanic African American children, nor between non-Hispanic White and non-Hispanic African American mothers (both $P > 0.05$, data not shown), suggesting both racial groups could be combined as a single group of non-Hispanics in this study. The interactions between ethnicity and BMI (or BMI percentile), as well as the interactions between ethnicity and breastfeeding duration, were not significant in children or mothers (all $P > 0.05$, data not shown).

4. Discussion

We observed that the serum concentration of 209 PCBs was significantly and positively associated with increasing age, non-Hispanic ethnicity, and shorter breastfeeding duration in mothers. By contrast, these associations were not significant in children; however, 209 PCBs in children was significantly associated with community of residence. Congener-specific analysis showed this effect was due to lower-chlorinated and more volatile congeners. Higher concentrations of these lower-chlorinated congeners seen in the Columbus junction children were attributable to higher exposures in the schools in that community.³³ Serum concentrations of 64 OH-PCBs were significantly associated with ethnicity and BMI percentile in children but not in mothers. By contrast, age was positively associated with OH-PCBs in mothers but not their children as there was insufficient variability in the ages of children due to the study design with enrollment of subjects in middle school. Individual PCB or OH-PCB congeners were associated with some of the factors examined including demographic characteristics, body weight status and breastfeeding duration, but such associations were congener-specific. To our knowledge, this is the first study to examine factors associated with: a) total concentrations of all 209 PCBs, b) mono-chlorinated PCBs and a di-hydroxylated PCB, c) OH-PCBs in children, and d) OH-PCBs and ethnicity.

We observed a modest but significant correlation between the total concentration of PCBs and OH-PCBs in mothers. In other studies certain PCB congeners were positively associated with the total concentration of selected OH-PCBs in adults.^{3, 17, 18, 23, 29} This may be because the major source of OH-PCBs was the metabolism of PCBs in the human body. It is unclear why children's sera did not demonstrate a significant correlation between PCBs and OH-PCBs, however, our prior work has shown that their congener profiles are skewed toward the lower-chlorinated PCBs compared to their mothers^{33, 41} and these congeners are more rapidly metabolized.⁴² In addition, the limited availability of lower-chlorinated OH-PCB standards may have compromised the estimation of total OH-PCBs.

Serum concentrations of total PCBs and OH-PCBs, as well as most individual congeners were associated with maternal age after adjusting for ethnicity, community of residence, BMI and breastfeeding duration. This is consistent with previous reports for small suites of congeners and highly exposed populations.^{3, 11–18, 26, 43} Bioaccumulation of congeners is a common explanation for this observation but other factors could also cause older women to have higher levels. Older women may have higher concentrations, because they were born during a historical period of higher levels of environmental PCBs. It has been reported that PCB exposure was primarily dependent on when a person was born relative to the emission history of PCBs.⁴⁴ Interestingly, it was found that higher-chlorinated PCBs, but not lower-

chlorinated PCBs, were significantly associated with mothers' age. This might be explained by limited bioaccumulation of lower-chlorinated PCB congeners, which are more rapidly metabolized and less persistent.^{45,46}

Some studies reported that males had higher PCBs levels than females.^{16, 19, 36, 47} With regards to associations between gender and OH-PCBs, two studies found no significant gender differences in certain individual OH-PCBs,^{17, 48} whereas Hovander et al. reported that men living in a highly contaminated area had significantly higher OH-PCBs than women from the same region, although such gender differences disappeared in participants from a control region.²³ In our study, gender was only associated with a few individual PCBs and 4'-OH-PCB 199 in children, with levels of these congeners being higher in boys than girls after adjusting for other factors. It is not known if this was due to gender differences in dietary exposure of these specific congeners, however, our previous analysis revealed higher consumption of meat in boys than girls in this study cohort.³⁶ Ethnicity was significantly associated with total or certain individual PCB or OH-PCB concentrations in children or their mothers. The positive regression coefficients indicated that non-Hispanics had higher levels of these congeners in serum than Hispanics. This is consistent with findings by Whitehead et al., who reported that non-Hispanic mothers, especially non-Hispanic White mothers, had greater PCBs concentrations than Hispanic mothers.¹³ Xue et al. also reported that non-Hispanic Black adults had higher PCB levels in blood than other race/ethnicity groups.²⁰ Our study further suggests that ethnicity may explain variations in individual body burden of PCBs and OH-PCBs. People of different ethnic groups have significantly different PCB metabolic pathways.^{49, 50} They also have different dietary exposures to PCB-laden foods (e.g., fish and meat). It is unknown if this difference by ethnicity contributes to the susceptibility of subjects to the adverse effects of PCBs.

Serum levels of lower-chlorinated PCBs but not higher-chlorinated PCBs differed by community of residence. This variable was infrequently associated with OH-PCBs since none of the lower-chlorinated congeners were detected in 65% or more of subjects. Children living in Columbus Junction had a significantly higher serum level of 209 PCBs than those from urban East Chicago. Previously, we reported higher PCB concentrations in indoor air of Columbus Junction schools; our inhalation exposure model estimated that about 50% of PCB inhalation exposure in children was coming from schools in our study communities.³⁶ This suggested that environmental exposure of PCBs may contribute to geographic differences in body burden of these pollutants. However, dietary habits may also modify the associations.⁵¹

Serum concentrations of many higher-chlorinated PCBs and OH-PCBs were significantly and inversely associated with BMI percentile in children in the present study. Sequestration of PCBs and OH-PCBs in adipose tissues may explain why children with a higher BMI percentile had significantly lower circulating concentrations of these congeners. Although OH-PCBs are hydrophilic, they have also been detected in human adipose tissues.^{18, 52, 53} There were significant associations between concentrations of only a few PCBs and OH-PCBs in mothers and their BMI. This may be attributed to the fact that the majority (79%) of the enrolled mothers were overweight or obese (BMI ≥ 25 kg/m²) and the number of normal weight mothers was limited.

Our study found that breastfeeding duration was positively associated with the levels of certain PCB or OH-PCB in children but negatively associated with the levels in mothers. Previous studies had also demonstrated a negative association between concentrations of PCBs or OH-PCBs in blood and cumulative lactation duration in women^{14–16, 44, 54} as well as a positive association between PCBs and breastfeeding duration in young adults or adolescents.^{27, 28} Both PCBs and OH-PCBs are detected in the breastmilk.^{55, 56} It has been suggested that body burden of PCBs in women could possibly be reduced via lactation¹⁶ while Knutsen et al. noted that childbirth also reduces body burden of PCBs.⁵⁷

Recently, toxicity of PCB 3 was studied and it was reported to form reactive intermediates which could lead to carcinogenicity in animals.⁵⁸ The present study analyzed several mono-chlorinated PCBs and a di-hydroxylated PCB that have not been examined previously for variations in humans. Unlike geographic differences in mono-chlorinated PCBs (PCB 2 and PCB 3), 4,4'-diOH-PCB 202 was the only OH-PCB that differed significantly by community of residence in both children and their mothers, with a higher level of this congener in participants from East Chicago. There are very limited data about 4,4'-diOH-PCB 202 in the literature. Campbell et al. reported that 4,4'-diOH-PCB 202 was detected from lake trout from Lake Ontario and Lake Superior⁵⁹ although Marek et al. failed to detect this congener from sediment samples from Lake Michigan.⁶⁰ The metabolic pathway of this di-hydroxylated PCB has not been fully elucidated at this stage; it is not known if dietary exposure or conversion from parent PCBs is a major source of 4,4'-diOH-PCB 202. The high detection frequency of this congener (100%) warrants understanding of its toxicity.

Our study had several limitations. First, breastfeeding duration was self-reported and could be subject to recall bias. However, two studies have shown the reliability of breastfeeding data recalled up to 20 years after delivery of the baby.^{61, 62} Second, some mothers did not live their whole life in the communities where they currently reside so the effect of community of residence on bioaccumulating PCB congeners could reflect exposures from another community. We did ascertain how long each participant has lived in their current home and the mean values are 11.5 ± 1.4 years for residents of Columbus Junction and 5.3 ± 1.2 years for East Chicago. We have no information on exposures in their prior residences or prior communities of residence. Individual PCB congeners are often interrelated owing to the fact they may derive from common sources or may have similar physicochemical properties. This can impact the associations observed between congeners. Despite these limitations, the study addressed several novel research questions and suggests that variations in serum PCBs and OH-PCBs in children and their mothers are associated with demographic characteristics, body weight status and breastfeeding history, factors that should be considered in human risk assessments of PCBs and OH-PCBs. Our findings also demonstrate the usefulness of congener-specific analyses.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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Highlights

- Analysis of 209 serum PCBs and 64 OH-PCBs yielded significant exposure risk factors.
- PCB and OH-PCB body burdens were significantly associated with age in mothers.
- Breastfeeding lowered some PCB congeners in mothers but increased them in children.
- Non-Hispanic mothers had higher PCBs and children had higher OH-PCBs than Hispanics.
- Lower OH-PCB levels were associated with higher body mass percentile in children.

Figure 1.

Pearson correlation of log-transformed concentration of Σ_{209} PCBs and log-transformed concentration of Σ_{64} OH-PCBs in children ($r=0.16$, $p=0.19$) and mothers ($r=0.38$, $p=0.001$)

Characteristics of 83 pairs of children and mothers from the Airborne Exposure to Semi-volatile Organic Pollutants Study^a.

Table 1

	Columbus Junction				East Chicago			
	Children		Mothers		Children		Mothers	
	Hispanic (N=29)	Non-Hispanic (N=17)	Hispanic (N=25)	Non-Hispanic (N=21)	Hispanic (N=28)	Non-Hispanic (N=9)	Hispanic (N=28)	Non-Hispanic (N=9)
Gender								
<i>Male</i>	16 (55.2)	6 (35.3)	-	-	12 (54.6)	4 (50.0)	-	-
<i>Female</i>	13 (42.9)	11 (64.7)	25 (100.0)	21 (100.0)	10 (45.5)	4 (50.0)	28 (100.0)	9 (100.0)
Age (years)	15.2±0.1	15.1±0.2	41.9±0.9	45.3±0.9	14.8±0.2	15.4±0.3	39.0±1.1	42.7±2.7
Body mass index(kg/m ²)	-	-	31.0±1.5	30.1±1.4	-	-	32.8±1.3	32.3±2.6
Body mass index percentile	75.2±5.4	74.3±5.1	-	-	69.9±5.8	63.0±7.6	-	-
Breastfeeding duration (month)	3.7±0.9	4.7±1.1	14.1±3.2	13.3±3.7	3.4±1.1	0.7±0.7	11.1±2.6	2.1±2.1

^a Categorical data were presented as n (%), continuous data were presented as mean ± standard error.

Table 2

Multiple linear regression analyses of serum concentrations of Σ_{209} PCBs and Σ_{64} OH-PCBs in children and mothers.^a

Congener	Age		Gender		Ethnicity		Community		BMI ^b		Breastfeeding duration	
	$\beta \pm SE$	P	$\beta \pm SE$	P	$\beta \pm SE$	P	$\beta \pm SE$	P	$\beta \pm SE$	P	$\beta \pm SE$	P
<i>Children</i>												
Σ_{209} PCBs	0.0342 $\pm$ 0.111	0.76	-0.263 $\pm$ 0.220	0.24	0.117 $\pm$ 0.237	0.62	-0.611 $\pm$ 0.227	0.009	-0.0063 $\pm$ 0.0041	0.13	0.0081 $\pm$ 0.0229	0.72
Σ_{64} OH-PCBs	-0.0155 $\pm$ 0.0624	0.80	-0.069 $\pm$ 0.121	0.57	0.276 $\pm$ 0.126	0.034	0.112 $\pm$ 0.123	0.37	-0.0063 $\pm$ 0.0022	0.006	0.0077 $\pm$ 0.0124	0.54
<i>Mothers</i>												
Σ_{209} PCBs	0.0479 $\pm$ 0.0150	0.002	–	–	0.419 $\pm$ 0.173	0.018	-0.186 $\pm$ 0.166	0.265	-0.0150 $\pm$ 0.0112	0.186	-0.0115 $\pm$ 0.0052	0.032
Σ_{64} OH-PCBs	0.0406 $\pm$ 0.0118	0.001	–	–	0.246 $\pm$ 0.136	0.074	0.109 $\pm$ 0.132	0.413	-0.0151 $\pm$ 0.0091	0.101	-0.0014 $\pm$ 0.0042	0.744

^a Age, body mass index (BMI), breastfeeding duration were continuous variables; gender, ethnicity, and community of residence were categorical variables with males, Hispanics, Columbus Junction coded as 0, whereas females, non-Hispanics, East Chicago coded as 1. Regression coefficients (β) and their standard errors (SE) were presented. Significant associations were shown in bold.

^b BMI percentile was used in the analyses of children's data.

Table 3

Tobit regression analyses of individual congeners detected in serum samples from at least 65% of subjects and selected factors in children and mothers^a.

Congener(s)	Age		Gender	Ethnicity		Community of residence		BMI ^b		Breastfeeding duration	
	C	M		C	M	C	M	C	M	C	M
PCBs											
2						—	—				
3						—	—				
14						—					
15						—	—				
20+28						—	—				
37						—					
105		+						—			
114		+			+			—			
118		+						—			
128+166		+									—
129+138+163		+		+				—			—
130		+						—			
133		+			+						—
137		+		+	+			—			—
146		+	—	+				—			—
153+168 ^c		+		+	+			—		+	—
156+157				+	+			—		+	
158		+									
167		+						—			—
170		+		+	+			—		+	
177		+		+				—			
180+193		+	—	+	+			—	—	+	—
183		+		+	+			—			
187		+	—	+				—		+	
196		+		+	+			—			
198+199		+		+	+			—			
202		+		+	+			—			
203		+	—	+	+			—			
206		+		+	+			—			
209		+	—		+	—		—			
OH-PCBs											
4-OH-PCB 107		+						—			
4'-OH-PCB 208					+						

Congener(s)	Age		Gender		Ethnicity		Community of residence		BMI ^b		Breastfeeding duration	
	C	M	C		C	M	C	M	C	M	C	M
4'-OH-PCB 199			–		+							
5-OH-PCB 183 + 4-OH-PCB 187		+			+	+			–			
4-OH-PCB 202		+			+				–	–		
3'-OH-PCB 138		+			+				–		+	
4'-OH-PCB 101		+										
4'-OH-PCB 172		+			+				–	–		
4-OH-PCB 163		+			+				–	–		
4-OH-PCB 178		+			+			+				
4-OH-PCB 146 ^c		+			+	+			–	–		–
4,4'-diOH-PCB 202 ^c	+						–	–				

^a Age, body mass index (BMI), breastfeeding duration were continuous variables; gender, ethnicity, and community of residence were categorical variables with males, Hispanics, Columbus Junction coded as 0, whereas females, non-Hispanics, East Chicago coded as 1. Data from Children (C) and mothers (M) were analyzed separately. The sign (+, –) denotes a significant positive or negative association between the factor and the congener (P<0.05).

^b BMI percentile was used in the analyses of children's data.

^c These congeners were detected in all samples; their data were analyzed by multiple linear regression instead of Tobit regression analyses with the same list of explanatory variables.