# Effect of Socioeconomic Status on Exposures to Polychlorinated Biphenyls (PCBs) and Dichlorodiphenyldichloroethylene (DDE) among Pregnant African-American Women

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**ABSTRACT. In this study, the authors investigated the associations between socioeconomic status and exposures to polychlorinated biphenyls (PCBs) and dichlorodiphenyldichloroethylene (DDE) in a cohort of inner-city African-American pregnant women. Data for this study were derived from the Columbia Presbyterian Medical Center subcohort of the National Collaborative Perinatal Project. African-American women from whom venous blood had been collected during their third trimester of pregnancy during the time period between 1960 and 1965 were included in the current study (*n* = 152). Prenatal samples were assayed for PCB and DDE concentrations. The authors used linear-regression analysis to explore the association between socioeconomic indicators and PCB and DDE concentrations. Mean concentrations of the 4 most abundant congeners (i.e., $PCB_4$) and total DDE were 3.9 μg/l and 37.2 μg/l, respectively. In adjusted analyses, income was associated significantly with an increase in serum concentrations of PCBs, whereas education was not. Neither income nor education was associated with concentrations of DDE. The authors concluded that maternal socioeconomic indicators may influence the effects of exposure to PCBs among African-American pregnant women.**
<Key words: African Americans, DDE, exposure, PCB, pregnant women, socioeconomic status>

POLYCHLORINATED BIPHENYLS (PCBs) and dichlorodiphenyltrichloroethane (DDT) were banned in the United States in the late 1970s because reproduction in wildlife sustained adverse effects. However, these chemicals are persistent in the environment, and low-level exposures continue to occur in the general population.[1] Prior to the aforementioned ban, PCBs were used in many industrial and commercial applications (e.g., rubber products, pigments, heat-transfer fluids, hydraulic lubricants, adhesives, organic diluents, pesticide extenders, plasticizers in paints and dyes[2,3]). DDT was developed to control mosquitoes that transmit malaria, and during the 1950s and 1960s it was one of the world's most extensively used pesticides.[4] Residues of DDT in blood reflect recent exposures, whereas residues of dichlorodiphenyldichloroethylene (DDE)—the major metabolite of DDT—indicate long-term historical exposure to this chemical.[4–6]

Prenatal exposure to PCBs has been associated with adverse health effects, including low birth weight, abnormal skin pigmentation, delayed developmental milestones, and decreased scores on Intelligence Quotient tests.[7–11] Results of recent studies also suggest that PCB exposures may affect early childhood behaviors.[10,11] Some data, however, suggest that positive childhood socioeconomic circumstances can mitigate these adverse effects.[12] Although there are only a few studies of the effects of DDE exposures in children, there is evidence that an association exists between DDE exposure and height attained in children (i.e., Gladen et al.[13] reported such a positive association, but an inverse association was reported by Karmaus et al.[14]). Typically, African Americans have had higher DDE levels than whites, but this racial difference has been mediated by social class.[2,5,6] Despite the relationship between socioeconomic levels and the described exposures, in no study have authors focused on the association between socioeconomic indicators and exposure to PCBs and DDEs in pregnant women. Therefore, in the current study, we considered the associations between socioeconomic indicators and exposure to PCBs and DDEs in inner-city African-American pregnant women. We hypothesized that a lower socioeconomic level, as measured by low income and limited education, would be associated with higher exposures to PCBs and DDE.

## Method

**Study population.** Data for this study derived from the Columbia Presbyterian Medical Center (CPMC) subcohort of the National Collaborative Perinatal Project (NCPP).[15] The NCPP was a prospective study in which the authors sought to relate circumstances of pregnancy, labor, and delivery to subsequent health outcomes—mainly neurodevelopmental—in infants and children (i.e., 0–7 yr of age). More than 50,000 women were recruited between the years 1959 and 1966 in 12 different centers; 2,135 women were enrolled at the CPMC. At the CPMC, the sampling frame consisted of all women who presented to the obstetric/gynecology clinic. The present analyses were limited to African-American women (a) whose offspring were followed to age 17 *and* (b) from whom 3rd-trimester venous blood samples had been obtained ($n = 152$).[16] Blood sera were obtained during pregnancy and stored at −20°C since collection (1959–1962). There have been no reported thaws of the banked sera (Mark Klebanoff, NICHD, personal communication), and organochlorine degradation under these conditions should be minimal.

**Outcome measurements.** PCB and DDE concentrations were obtained from 3rd-trimester sera. Details of the chemical methods and quality-control methods used are presented elsewhere.[17] Similar to recent cohort studies,[8,18] we summed the 4 most abundant PCB congeners ($PCB_4$)—BZ 118, 153, 138, and 180—as a proxy for total PCB exposure. In 7 specimens, 1 of the 4 congeners could not be measured and was imputed using predicted values from a regression model. To adjust for possible variation(s) in serum concentrations of lipophilic PCBs and DDE that possibly resulted from fluctuations in serum lipids, we lipid-corrected PCB and DDE concentrations and expressed them as μg/g of serum lipids. We used an equation published by Phillips et al.[19] to compute total serum lipids used during adjustment from serum cholesterol and triglycerides determined by a commercial laboratory (Nichols Institute/Quest Diagnostics, New Jersey).

**Socioeconomic status (SES) measures.** The SES variables of interest, assessed at the time women were enrolled in the CPMC study, were education and total family income. Education was collected as a continuous variable and was defined as the highest years of schooling achieved. Total family income was also collected as a continuous measure and was defined as the total income in the household per year.

**Covariates.** Maternal age (continuous), pre- and post-pregnancy weight (kg), marital status (married vs. unmarried), and smoking status (yes/no) were considered potential confounders and were included in the analysis. In addition, we investigated pre- and post-pregnancy body mass index (BMI [kg]), breastfeeding (yes/no), and birthplace (rural vs. urban) in the analyses.

**Statistical analysis.** Descriptive statistics were obtained for each covariate in the population. Specifically, we calculated means and standard deviations for continuous variables and proportions for categorical variables. We natural-log–transformed (i.e., ln) $PCB_4$ and DDE concentrations to normalize the distribution. We calculated Spearman's correlations to assess the association between each outcome and each variable. We used linear-regression analysis to investigate the association between each socioeconomic indicator and $PCB_4$ and DDE concentrations (both before and after adjustment for potential confounders). Variables that were associated significantly with $PCB_4$ and DDE, as well as variables that have been reported as confounders in previous studies,[2,4,6,12] were considered and included in the model. Because results for which we used the lipid-corrected and -uncorrected $PCB_4$ and DDE were nearly identical, we have presented only the results for uncorrected $PCB_4$ and DDE. Two-sided $p$ values of $<0.05$ were considered statistically significant. Analyses were performed using SAS V9.1 (SAS Institute Inc., Cary, NC).

## Results

The characteristics of the study population at enrollment during the early 1960s are presented in Table 1. On average, women were in their mid-20s (mean = 25.8 yr of age), married, had less than 12 yr of education, and had a mean total family income of $4,845 (note: all monetary references herein are in U.S. dollars). Forty-one percent of the women were current smokers. The geometric mean serum $PCB_4$ and lipid-corrected $PCB_4$ were 3.6 μg/l and 0.4 μg/g, respectively. The geometric mean serum DDE and lipid-corrected DDE were 32.9 μg/l and 3.8 μg/g, respectively.

**Table 1.—Population and Exposure Characteristics of Women in the African-American Subcohort: Columbia Presbyterian Medical Center, National Collaborative Perinatal Project**

| Exposure characteristic | *n* | Mean | *SD* | Percentage |
|---|---|---|---|---|
| Maternal age (yr) | 152 | 25.8 | 6.2 | |
| Prepregnancy weight (kg) | 148 | 60.5 | 11.3 | |
| Prepregnancy BMI | 143 | 22.7 | 3.8 | |
| Postpregnancy weight (kg) | 144 | 70.3 | 12.1 | |
| Postpregnancy BMI | 135 | 26.6 | 4.1 | |
| Breastfeeding (yes) | 146 | | | 15.7 |
| Marital status (married) | 152 | | | 74.0 |
| Smoking status (yes) | 152 | 11.4 | 1.9 | 41.0 |
| Education (yr) | 152 | | | |
| Income (US$)* | 142 | 4,845 | 2,358 | |
| Place of birth (rural) | 151 | | | 63.0 |
| $PCB_4$ (μg/l) | 151 | 3.9 | 1.9 | |
| Geometric mean | | 3.6 | | |
| $PCB_4$ lipid-corrected (μg/g) | 151 | 0.5 | 0.3 | |
| Geometric mean | | 0.4 | | |
| DDE (μg/l) | 151 | 37.2 | 20.0 | |
| Geometric mean | | 32.9 | | |
| DDE lipid-corrected (μg/g) | 151 | 4.4 | 2.9 | |
| Geometric mean | | 3.8 | | |

*Notes:* BMI = body mass index; *SD* = standard deviation; $PCB_4$ = the 4 most abundant polychlorinated biphenyl congeners (i.e., BZ 118, 153, 138, and 180), used as a proxy for PCB exposure; and DDE = dichlorodiphenyldichloroethylene.
*US$4,800 in the year 1960 was equivalent in buying power to US$28,000 in the year 2000 (per Consumer Price Index).

**Table 2.—Spearman's Correlation Coefficients and Respective *p* Values* for Natural-Log-Transformed Polychlorinated Biphenyls (PCBs) and Dichlorodiphenyldichloroethylene (DDE) (Uncorrected and Lipid-Corrected) and Selected Covariates**

| Characteristic | $PCB_4$ | | $PCB_4$-corrected | | DDE | | DDE-corrected | |
|---|---|---|---|---|---|---|---|---|
| | *r* | *p* | *r* | *p* | *r* | *p* | *r* | *p* |
| $PCB_4$ (μg/l) | | | | | | | | |
| $PCB_4$-corrected (μg/g) | .7726 | <0.0001 | | | | | | |
| DDE (μg/l) | .4926 | <0.0001 | .2462 | 0.002 | | | | |
| DDE-corrected (μg/g) | .4412 | <0.0001 | .5892 | <0.0001 | .7776 | < 0.0001 | | |
| Maternal age (yr) | .2116 | 0.009 | .2222 | 0.01 | .0535 | 0.51 | .1006 | 0.21 |
| Prepregnancy weight (kg) | −.081 | 0.33 | −.0431 | 0.60 | −.1562 | 0.06 | −.106 | 0.20 |
| Prepregnancy BMI | −.098 | 0.25 | −.0831 | 0.32 | −.1473 | 0.08 | −.134 | 0.11 |
| Postpregnancy weight (kg) | −.1434 | 0.09 | −.085 | 0.31 | −.1874 | 0.02 | −.123 | 0.14 |
| Postpregnancy BMI | −.1440 | 0.10 | −.1462 | 0.09 | −.2199 | 0.01 | −.225 | 0.01 |
| Breastfeeding (yes) | −.105 | 0.21 | −.048 | 0.57 | −.043 | 0.61 | −.036 | 0.67 |
| Marital status (married) | .041 | 0.62 | −.030 | 0.72 | .0482 | 0.55 | −.033 | 0.69 |
| Smoking status (yes) | −.001 | 0.99 | .034 | 0.68 | −.1262 | 0.12 | −.084 | 0.31 |
| Education (yr) | .01 | 0.95 | −.0045 | 0.96 | .0334 | 0.68 | .056 | 0.49 |
| Income (US$) | .2116 | 0.01 | .2295 | 0.01 | .029 | 0.73 | .091 | 0.28 |
| Place of birth (rural) | .095 | 0.24 | .083 | 0.31 | .2114 | 0.009 | .187 | 0.02 |

*Notes:* $PCB_4$ = polychlorinated biphenyl congeners, and BMI = body mass index.
*$p < 0.05$.

PCB and DDE exposures were correlated positively with one another (Table 2). $PCB_4$—whether uncorrected or lipid-corrected—was associated positively with maternal age ($r = .21$) and total income ($r = .21$). DDE uncorrected and lipid-corrected were associated negatively with postpregnancy BMI (both with $r = -.22$), while uncorrected DDE was associated negatively with postpregnancy weight ($r = -.19$). Uncorrected and lipid-corrected DDE were associated with being born in a rural area ($r = .21$ and .19 for uncorrected and lipid-corrected, respectively). Total family income was associated positively with years of education ($r = .36$, data not shown).

In the regression analyses, total family income was associated significantly with $PCB_4$ (Table 3), whereas education was not. For every $1,000 increase in total family income, ln $PCB_4$ increased by 0.03 μg/l. These

Table 3.—Regression Analyses for Polychlorinated Biphenyl Congeners ($PCB_4$ [Uncorrected] [ln Sum of Congeners 118, 138, 153, and 180]) as a Function of Maternal Education and Income at Registration ($n = 142$)

| | Regression coefficients | | | | | |
|---|---|---|---|---|---|---|
| | Unadjusted | | | Adjusted | | |
| Characteristic | Coefficient | 95% CI | *p* | Coefficient | 95% CI | *p* |
| Maternal education | −0.005 | −0.04–0.03 | 0.71 | −0.01 | −0.05–0.02 | 0.47 |
| Income at registration | 0.03 | 0.003–0.06 | 0.03 | 0.03 | 0.002–0.06 | 0.03 |

*Notes:* CI = confidence interval. The income coefficient was adjusted for maternal age, prepregnancy maternal weight, and education. The education coefficient was adjusted for maternal age, prepregnancy maternal weight, and income at the time of registration.
$^*p < 0.05$.

Table 4.—Regression Analyses for Dichlorodiphenyldichloroethylene (ln) as a Function of Maternal Education and Income at the Time of Registration ($n = 142$)

| | Regression coefficients | | | | | |
|---|---|---|---|---|---|---|
| | Unadjusted | | | Adjusted | | |
| Characteristic | Coefficient | 95% CI | *p* | Coefficient | 95% CI | *p* |
| Maternal education | −0.003 | −0.04–0.04 | 0.88 | 0.003 | −0.04–0.05 | 0.89 |
| Income at registration | 0.003 | −0.03–0.04 | 0.84 | 0.002 | −0.03–0.04 | 0.88 |

*Notes:* CI = confidence interval. The income coefficient was adjusted for maternal age, prepregnancy maternal weight, and education. The education coefficient was adjusted for maternal age, prepregnancy maternal weight, and income at the time of registration.
$^*p < 0.05$.

findings persisted even after we adjusted for maternal age and prepregnancy weight. We repeated the analyses and included postpregnancy weight and pre- or post-pregnancy BMI instead of prepregnancy weight, and the results were nearly identical to the ones presented in Table 3. We also investigated the effect of breastfeeding, and the results remained essentially similar to those presented in Table 3. We investigated education (<12 yr vs. ≥12 yr of schooling) and income (<$5,000 vs. ≥$5,000, using the median) as dichotomous variables, and the results remained the same as those reported here. Neither income nor education was associated with DDE (Table 4). Given the possibility of environmental exposures, we stratified our analyses for both PCBs and DDE by birthplace. However, for neither rural nor urban place of birth was the effect of income or education statistically significant with respect to PCB or DDE levels.

## Discussion

Total family income at registration was associated positively with prenatal PCB levels in an inner-city African-American subcohort of pregnant women from the CPMC cohort of the NCPP study. This finding remained mostly unchanged, even after adjustment for potential confounders. There was no association between socioeconomic indicators and DDE levels.

To our knowledge, this is the first study in which the associations between SES indicators and PCB and DDE levels in pregnant women have been evaluated. However, in several studies investigators have assessed the relationships between PCB levels and women's occupations and socioeconomic levels among families.[2,4,6] For example, Rogan et al.[6] found that women in high-income, high-education–level occupations (e.g., professionals, paraprofessionals) exhibited higher mean PCB concentrations than their counterparts in occupations associated with low education and low incomes (e.g., laborers/farmers, factory/household workers). James et al.,[2] however, did not find such a relationship between occupation and PCB levels. Jacobson et al.[4] conducted a study in which an aggregate measure of family socioeconomic level was significantly positively associated with SES and PCB levels; however, the effect on PCBs disappeared after adjustment was made for breastfeeding. In other studies, investigators have included socioeconomic indicators as covariates in the analysis without presenting or discussing their effect on mean PCB concentration.[12,20] With respect to DDE, the results of some studies have suggested that there is a racial difference in DDE levels, with the highest levels being among African Americans.[5,6] However, in one study, such a racial difference was explained by social class.[5] In addition, similar to the aforementioned PCB concentrations, DDE levels were highest among professional and white-collar workers.[2,5]

Although our findings of a positive association between income and PCB concentrations did not support our hypothesis, the results of previous studies have documented an increase in serum PCB concentrations as family income increases. It has been suggested that high-income families in the 1960s were more likely to have consumed contaminated fish.[21–23] In addition, in previous studies investigators have found that there was no association between 4-year PCB serum level and SES after adjusting for breastfeeding.[4] Perhaps some high-income women in our sample were less likely to have breastfed during the 1960s, and therefore were less likely to have eliminated high PCB levels. Although breastfeeding occurred after the assessment of both exposure and SES indicators, the majority of women in our sample were not primiparous and, therefore, breastfeeding could have contributed to lowering their body burdens of PCBs and DDE. We examined the effect of breastfeeding as a confounder; however, the results remained essentially similar to the ones presented here, which ruled out the possibility of confounding by breastfeeding. It is also worth noting that the available NCPP data on breastfeeding are for the *current* pregnancy only.

We also note that our findings were contrary to the inverse association observed between income and exposure to environmental lead,[24–27] thus confirming that the modes of exposure to lead and PCBs usually differ. For example, low-income children tend to live in older housing, which may lead to opportunities for exposure to lead-based paint[24]; whereas in the case of PCBs, low-income families are less likely to consume fish and to have access to pesticides from the fish and from other sources.[21,23] Our null finding for DDE exposures could have resulted from the lack of heterogeneity in exposure levels in our sample, as well as from the use of a single racial group. In addition, given that DDT remained in use at the time the samples were collected, the observed levels of DDE could have reflected both recent and past exposures.

The small sample size of our study limited our ability to detect significant differences and associations, as well as our ability to test interactions between socioeconomic indicators and other covariates included in our model. However, because we focused on SES in a single racial group, the results of this study afforded us the opportunity to rule out the possibility of residual confounding. There is evidence that income and education have different meanings for individual racial/ethnic memberships.[28,29] For example, whites tend to earn higher incomes than African Americans, after accounting for age and education. Therefore, studying a single racial group allowed us to ascertain the effects of income and education without the possibility of potential confounders resulting from incommensurability across racial groups of socioeconomic indicators.[30] Finally, although our sample was small, our mean values for PCB and DDE concentrations were consistent with the values reported in other studies in which the entire NCPP sample, or a larger subsample of the NCPP sample, was used.[17,20]

In summary, our findings suggest that income is associated with PCB values. Nonetheless, the results of our study underscored the number of questions that remain unanswered with respect to the association of income and education with health outcomes and health-related risk factors. Additional research, a larger sample size, and examination of multiple racial and ethnic groups are needed if investigators are to identify the effect(s) of maternal socioeconomic indicators on exposure to PCBs and DDE. Specifically, researchers should focus their attention on the interaction between race/ethnicity and SES indicators and exposures to PCBs and DDE.

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