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Original Contribution

Association of Prenatal Exposure to Polybrominated Diphenyl Ethers and Infant Birth Weight

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Polybrominated diphenyl ethers (PBDEs) are a class of persistent compounds that have been used as flame retardants in vehicles, household furnishings, and consumer electronics. This study examined whether concentrations of PBDEs in maternal serum during pregnancy were associated with infant birth weight, length, head circumference, and length of gestation. Participants were pregnant women ($n = 286$) enrolled in the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) Study, a longitudinal cohort study of low-income, predominantly Mexican families living in the Salinas Valley, California. Blood samples were collected near the 26th week of pregnancy in 1999–2000, and concentrations of 10 PBDE congeners (BDE-17, -28, -47, -66, -85, -99, -100, -153, -154, and -183) were measured. Multiple linear regression models were used to investigate the association of lipid-adjusted, $\log_{10}$-transformed PBDE concentrations and birth outcome. In adjusted analyses, negative associations with birth weight were seen with BDE-47 ($\beta = -115$ g, 95% confidence interval (CI): −229, −2), BDE-99 ($\beta = -114$ g, 95% CI: −225, −4), and BDE-100 ($\beta = -122$ g, 95% CI: −235, −9). These findings were diminished slightly and were no longer statistically significant when maternal weight gain was included in the models. PBDE congeners were not associated with birth length, head circumference, or gestational duration.

birth weight; California; cohort studies; environmental exposure; halogenated diphenyl ethers; maternal exposure; maternal-fetal exchange; pregnancy

Abbreviations: CHAMACOS, Center for the Health Assessment of Mothers and Children of Salinas; CI, confidence interval; PBDE, polybrominated diphenyl ether; SD, standard deviation.

Polybrominated diphenyl ethers (PBDEs) are flame-retardant chemicals used in automobiles, airplanes, and homes. They have been used in polyurethane foam furniture and carpet padding, in textiles, and in plastic electronics housings (1). Because they are not chemically bound into products, PBDEs have the potential to leach into the home and the environment (2). PBDEs have been detected in wildlife, including fish, birds, and mammals (3), as well as in humans. Recent biomonitoring shows that 97% of Americans have detectable levels of PBDEs in their blood (4).

Several concerns have been raised about the potential health effects of PBDEs. In animal studies, they have been shown to disrupt thyroid hormone balance (5–8); to alter behavior, memory, and learning (9–12); and to affect sex hormone levels and reproductive parameters (7, 13–16). Epidemiologic studies have similarly found PBDEs to be associated with changes in thyroid hormone levels (17–20), a lower intelligence quotient (21), and lower fecundability (22).

Maternal exposure to chemical pollutants during pregnancy has been associated with low birth weight and preterm birth, major causes of infant mortality and morbidity (23). To date, 4 epidemiologic studies have examined whether PBDE exposure during pregnancy impacts birth weight. Wu et al. (24) examined 153 infants born in communities with e-waste (obsolete electrical and electronic devices) recycling facilities and control communities in China and found that infants with adverse birth outcomes (defined as preterm birth, low birth weight, or stillbirth) had significantly higher

mean levels of PBDE congeners (BDE-28, -47, -99, -153, and -183) in umbilical cord blood than controls without adverse birth outcomes; however, this study did not control for confounding. Similarly, in a population of 20 mother-infant pairs, Chao et al. (25) found that birth weight below the median (<3.05 kg) was associated with higher mean PBDE concentrations in maternal breast milk. Two other small studies have reported no association of PBDEs in maternal ($n = 12$) or cord ($n = 41$) blood with birth weight (26, 27). None of these studies controlled for gestational age at birth to examine fetal growth independent of duration of gestation.

In the current study, we measured the levels of 10 PBDE congeners in the serum samples of 286 pregnant women to determine whether PBDE exposure was associated with fetal growth or length of gestation. We used data from the Center for the Heath Assessment of Mothers and Children of Salinas (CHAMACOS), a longitudinal cohort study examining the effects of environmental exposures on the health of pregnant women and their children living in an agricultural region of northern California. We previously found that PBDE levels were associated with subclinical hyperthyroidism in mothers during pregnancy (17). Thus, we also investigated whether maternal hyperthyroidism and reduced maternal weight gain were intermediaries in the association of PBDEs and infant birth weight.

MATERIALS AND METHODS

Participants

Pregnant women ($n = 601$) were recruited between October 1999 and October 2000 from prenatal care clinics serving low-income residents of the Salinas Valley, California. Eligible women were less than 20 weeks' gestation, were at least 18 years of age, spoke English or Spanish, qualified for low-income health insurance (Medicaid), and were planning to deliver at the county hospital. Detailed information on the recruitment and methods of the CHAMACOS Study has been published elsewhere (28, 29). Written, informed consent was obtained from all women, and study activities were approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley.

The present analysis was limited to the 536 women who were followed through the birth of their infants. We excluded women with twins ($n = 5$), stillbirths ($n = 3$), or infants born at less than 500 g ($n = 1$), as well as women with pregnancy-induced hypertension ($n = 15$) and diabetes ($n = 26$). We further excluded women who were missing PBDE measurements during pregnancy ($n = 200$), leaving a final sample size of 286. Missing PBDE measurements were primarily due to insufficient serum volume. Women with PBDE measurements were more likely to have lived in the United States for less than 5 years (56%) compared with those without measurements (44%), but they did not differ on any other demographic factors.

Data collection

Women were interviewed at enrollment (mean: 13.4 weeks' gestation, standard deviation (SD): 5.2), at the end of the second trimester of pregnancy (mean: 25.7 weeks' gestation, SD: 2.1), and following delivery. All interviews were conducted by bilingual study interviewers using structured questionnaires. Demographic information, including maternal age, education, marital status, parity, country of birth, and number of years of residence in the United States, was gathered at the enrollment interview. Information on family income and the number of people supported by that income was collected and compared against the federal poverty thresholds. Prepregnancy body mass index was calculated by using the mother's self-reported prepregnancy weight and measured height. Information on lifestyle factors including smoking, alcohol consumption, drug use, and work status was obtained at each interview.

Prenatal and delivery medical records were abstracted by a registered nurse, including data about pregnancy and delivery complications, pregnancy weight gain, and infant birth weight, length, head circumference, and gestational age at birth. Net maternal weight gain was calculated as pregnancy weight gain minus infant birth weight.

PBDE exposure assessment

Blood samples were collected by venipuncture from the mothers close to the time of the second trimester interview (mean: 26.1 weeks' gestation, SD: 2.8). Serum was stored at −80°C until shipment to the Centers for Disease Control and Prevention, where it was analyzed for 10 PBDE congeners (BDE-17, -28, -47, -66, -85, -99, -100, -153, -154, and -183) by gas-chromatography isotope-dilution high-resolution mass spectrometry (30). Total lipids were determined by measurements of triglycerides and total cholesterol in serum by using standard enzymatic methods (Roche Chemicals, Indianapolis, Indiana) (31). A detailed description of the analytical laboratory methods has been published previously (32). Limits of detection ranged between 0.2 and 0.7 ng/g of lipids for all PBDE congeners, except for BDE-47, which ranged from 0.8 to 2.6 ng/g of lipids.

Four PBDE congeners (BDE-47, -99, -100, -153) were detected in more than 75% of the population and were analyzed as both continuous variables and categorical variables divided into quartiles. An aggregate variable (ΣPBDE) was generated by using the molar sum of these 4 congeners. Values below the limit of detection were assigned the machine-read value if a signal was detected. If no signal was detected, concentrations below the limit of detection were imputed at random by a log-normal probability distribution whose parameters were determined by maximum likelihood estimation (33).

Four additional PBDE congeners (BDE-28, -85, 154, -183) were detectable in 25%–75% of the population. These congeners were analyzed as categorical variables, defined as "no signal detected," "signal detected but at or below the limit of detection," and "above the limit of detection." PBDE congeners detected in less than 25% of the samples (BDE-17 and -66) were not included in statistical analyses.

Statistical analysis

Linear regression was used to examine the associations of PBDEs (as continuous or categorical variables) with birth

weight, length, head circumference, and gestational age (as continuous variables). The continuous PBDE variables were $\log_{10}$ transformed. Functional form was confirmed visually by overlaying locally weighted regression scatterplot smoother (LOWESS) curves on the 95% confidence intervals of the regression line.

In general, PBDE concentrations were expressed on a serum lipid basis (ng/g of lipids), which is appropriate on the basis of our assumption that lipid-adjusted serum concentrations are a marker for PBDEs in adipose tissue. However, because use of lipid-adjusted levels can result in biased estimates under other assumptions (34), we also analyzed wet-weight PBDE concentrations in sensitivity analyses (see below). Models of birth weight, length, and head circumference were adjusted for gestational age at birth by using a cubic spline. Although preliminary analyses examined low birth weight and preterm birth as dichotomous variables, the number of infants with these outcomes was too small ($n = 9$ and $n = 17$, respectively) and was not reported.

Several factors were identified a priori as potential confounders in the association of PBDEs and fetal growth or length of gestation on the basis of directed acyclic graphs. These included maternal age, education, marital status, parity, body mass index, country of birth, and length of residence in the United States. We also examined smoking, alcohol and drug use during pregnancy (any vs. none), family income, timing of prenatal care initiation, and infant sex. Maternal age and month of entry into prenatal care were expressed continuously; other variables were categorized as shown in Table 1. Covariates were included in multiple linear regression models if they were associated in bivariate analyses with PBDE congeners and any of the outcomes at $P < 0.2$. Maternal weight gain during pregnancy was associated with both PBDEs and birth weight in this population. Because PBDEs have been associated with maternal subclinical hyperthyroidism (17) in this population, which may in turn impact maternal weight gain, we considered that this variable might be on the causal pathway and did not include it as a covariate in the main models.

After the main models were constructed, we performed sensitivity analysis to evaluate the robustness of our results. First, we reran models after excluding outliers identified by the extreme studentized deviate many-outlier procedure at an $\alpha = 0.01$ (35). Second, we reanalyzed all the models using wet-weight PBDE concentrations (pg/g of serum) while adjusting for triglycerides and total cholesterol (expressed continuously) by including these variables in models (34). Finally, we included pregnancy weight gain and thyroid-stimulating hormone levels as covariates in the final models to determine whether they might be confounders or intermediaries in the association of PBDEs with birth outcome.

RESULTS

The study population was reflective of a low-income, primarily farm-worker community (Table 1). Mothers were almost exclusively Latina, with 84% having been born in Mexico and half having lived in the United States for less than 5 years. Mothers tended to be young (median age = 25 years),

Table 1. Demographic Characteristics of the Study Population, CHAMACOS Study, Salinas Valley, California, 1999–2000 ($n = 286$)

Characteristics	No.	%
Maternal age, years		
<20	29	10
20–24	110	39
25–29	95	33
30–34	37	13
≥35	15	5
Parity		
0	92	32
≥1	194	68
Race/ethnicity		
Non-Hispanic white	7	3
Hispanic	273	95
Other	6	2
Marital status		
Married or living as married	226	79
Unmarried	60	21
Maternal education		
Sixth grade or less	112	39
Some middle/high school	104	36
High school graduate	70	25
Family income		
Below federal poverty threshold	176	62
At federal poverty threshold or above	110	38
Country of birth		
Mexico	241	84
United States	39	14
Other	6	2
Years of residence in the United States		
≤5 years	161	56
6–10 years	56	20
≥11 years	37	13
Entire life	32	11
Body mass index, kg/m^2		
Underweight (<18.5)	2	1
Normal (18.5–24.9)	110	40
Overweight (25–29.9)	110	40
Obese (≥30)	55	20
Smoked during pregnancy		
Yes	17	6
No	269	94
Low birth weight infant		
Yes	9	3
No	277	97
Preterm infant		
Yes	17	6
No	269	94

Abbreviation: CHAMACOS, Center for the Heath Assessment of Mothers and Children of Salinas.

Table 2. Lipid-adjusted PBDE Concentrations in Sera of Pregnant Women, CHAMACOS Study, Salinas Valley, California, 1999–2000 ($n = 286$)

PBDE Congener	% >LOD	PBDE Concentrations (ng/g of Lipid) During Pregnancy			
		25th Percentile	50th Percentile	75th Percentile	95th Percentile
BDE-17	1.8	≤LOD	≤LOD	≤LOD	≤LOD
BDE-28	46.9	≤LOD	≤LOD	1.39	4.17
BDE-47	99.7	7.78	14.57	25.29	126.30
BDE-66	11.5	≤LOD	≤LOD	≤LOD	0.93
BDE-85	40.9	≤LOD	≤LOD	0.58	3.60
BDE-99	99.0	2.28	3.85	6.69	47.84
BDE-100	97.2	1.49	2.45	4.26	22.43
BDE-153	96.9	1.27	2.03	3.67	17.54
BDE-154	38.3	≤LOD	≤LOD	0.63	4.02
BDE-183	26.0	≤LOD	≤LOD	0.40	1.14

Abbreviations: BDE, brominated diphenyl ether; CHAMACOS, Center for the Heath Assessment of Mothers and Children of Salinas; >LOD, above the limit of detection; ≤LOD, at or below the limit of detection; PBDE, polybrominated diphenyl ether.

married, and with low educational attainment. Most families were living below the federal poverty threshold. Very few women smoked, drank alcohol, or used drugs during pregnancy. The proportion of low birth weight and preterm delivery was also very low.

PBDE concentrations during pregnancy are shown in Table 2. Four PBDE congeners (BDE-47, -99, -100, -153) were detected in almost all women. These congeners are the primary components of the commercial mixture known as penta-BDE and are also the most commonly detected congeners in the general US population (4). Median levels of these 4 congeners were slightly lower in the study population than in the general US population (36). BDE-47 was the dominant congener with concentrations considerably higher than the others. Four other congeners (BDE-28, -85, -154, -183) were above the limit of detection for between 25% and 75% of the population.

Table 3 shows the association of the 4 most commonly detected PBDEs as continuous variables with birth outcome. In crude analyses, increasing maternal concentrations of all 4 congeners and their sum were associated with statistically significant decreases in birth weight. The magnitude of effect was slightly diminished after adjustment for covariates, and only associations with BDE-47, -99, and -100 remained statistically significant. In adjusted analyses, each 10-fold increase in maternal concentration of BDE-47 was associated with a 115-g (95% confidence interval (CI): −229, −2) decrease in birth weight. Ten-fold increases in BDE-99 ($\beta = -114$ g, 95% CI: −225, −4) and BDE-100 ($\beta = -121$ g, 95% CI: −235, −7) were associated with similar decreases in birth weight. Visual examination of the association using LOWESS plots confirmed that the log-linear link function was appropriate. No statistically significant associations were seen between maternal PBDE levels and birth length, head circumference, or length of gestation in any analyses.

Findings were similar when lipid-adjusted and wet weight concentrations of PBDEs were used and when outliers were excluded from the analyses. When maternal weight gain or maternal thyroid-stimulating hormone was included in the models, associations were reduced slightly and no longer statistically significant. Inclusion of thyroid-stimulating hormone in the model had a smaller impact on the association than inclusion of maternal weight gain; for example, the beta coefficient for BDE-47 changed from −115.3 g to −111.7 g when thyroid-stimulating hormone was included (not shown) and to −98.6 g when maternal weight gain was included (Table 3).

The 8 most commonly detected congeners were also analyzed as categorical variables. Table 4 shows that, although the highest exposure group for each congener was consistently associated with decreased birth weight, the association was not statistically significant for any congener. The strongest associations were seen with BDE-28 and -85; women in the highest category of exposure for these congeners gave birth to infants whose birth weight was 131 g and 152 g lower than those in the first quartile, respectively, but these findings did not reach statistical significance. BDEs-47, -99, and -100 were no longer significantly associated with birth weight in the categorical analysis, but this is likely due to the reduced power of collapsing of a wide range of exposures into a single, high quartile.

DISCUSSION

We found that higher concentrations of PBDEs in maternal serum during pregnancy were associated with lower birth weight in a population of low-income women living in California. Each 10-fold increase in concentrations of BDE-47, -99, and -100 was associated with an approximately 115-g decrease in birth weight. This association was relatively large; for comparison, the difference in birth weight observed between smokers and nonsmokers is between 150 and 250 g (37). When maternal weight gain or thyroid-stimulating

Table 3. Association of Lipid-adjusted PBDE Concentrations (log_{10}) During Pregnancy With Fetal Growth and Length of Gestation, CHAMACOS Study, Salinas Valley, California, 1999–2000 ($n = 286$)

PBDE Congener	Birth Weight, g[a]		Length, cm[a]		Head Circumference, cm[a]		Gestational Age	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Crude								
BDE-47	−133.5*	−243.8, −23.2	−0.42	−1.00, 0.17	−0.23	−0.60, 0.14	0.10	−0.30, 0.50
BDE-99	−133.6*	−242.5, −24.6	−0.33	−0.91, 0.25	−0.29	−0.65, 0.07	0.10	−0.30, 0.50
BDE-100	−144.2*	−253.8, −34.6	−0.44	−1.02, 0.14	−0.26	−0.63, 0.11	0.09	−0.31, 0.49
BDE-153	−132.6*	−247.7, −17.5	−0.48	−1.09, 0.13	−0.32	−0.70, 0.06	−0.05	−0.47, 0.37
Sum PBDEs	−140.2*	−254.1, −26.3	−0.43	−1.04, 0.17	−0.29	−0.67, 0.09	0.10	−0.31, 0.51
Adjusted[b]								
BDE-47	−115.4*	−229.0, −1.7	−0.23	−0.84, 0.38	−0.20	−0.57, 0.18	0.24	−0.19, 0.67
BDE-99	−114.4*	−224.6, −4.2	−0.17	−0.76, 0.42	−0.26	−0.62, 0.10	0.22	−0.20, 0.63
BDE-100	−121.5*	−234.5, −8.5	−0.25	−0.86, 0.36	−0.21	−0.59, 0.16	0.24	−0.19, 0.66
BDE-153	−92.4	−213.2, 28.5	−0.23	−0.87, 0.42	−0.24	−0.64, 0.15	0.08	−0.38, 0.54
Sum PBDEs	−116.8	−234.3, 0.6	−0.22	−0.86, 0.41	−0.25	−0.63, 0.14	0.25	−0.19, 0.69
Adjusted[c]								
BDE-47	−98.6	−211.8, 14.7	−0.19	−0.81, 0.42	−0.16	−0.54, 0.22	0.26	−0.17, 0.69
BDE-99	−100.2	−209.8, 9.5	−0.14	−0.74, 0.46	−0.23	−0.59, 0.13	0.23	−0.19, 0.65
BDE-100	−104.8	−217.5, 7.8	−0.21	−0.83, 0.40	−0.17	−0.55, 0.20	0.25	−0.18, 0.69
BDE-153	−71.5	−192.2, 49.2	−0.18	−0.84, 0.47	−0.20	−0.59, 0.20	0.10	−0.36, 0.57
Sum PBDEs	−98.7	−215.9, 18.5	−0.18	−0.82, 0.45	−0.20	−0.59, 0.19	0.27	−0.18, 0.72

Abbreviations: BDE, brominated diphenyl ether; CHAMACOS, Center for the Heath Assessment of Mothers and Children of Salinas; CI, confidence interval; PBDE, polybrominated diphenyl ether.

* $P < 0.05$; all P values are 2 sided.

[a] All models of birth weight, birth length, and head circumference adjust for gestational age by using a cubic spline.

[b] Adjusted models included maternal age, marital status, parity, body mass index, country of birth (United States vs. other), family income, and sex of infant.

[c] Adjusted for maternal age, marital status, parity, body mass index, country of birth (United States vs. other), family income, and sex of infant plus net weight gain.

hormone levels were added to the models, the association of PBDEs and birth weight was slightly reduced and no longer statistically significant. No statistically significant associations were seen with birth length and head circumference, although the direction of the association was consistently negative.

Our findings of an association of PBDEs and birth weight are consistent with those of some recent studies. For example, Wu et al. (24) found that levels of BDE-28, -47, -99, -153, and -183 were higher in the cord blood of infants with adverse birth outcomes, and Chao et al. (25) found that BDE-47, -99, -100, and -209 were higher in breast milk of mothers delivering lower birth weight infants. However, both of these studies were case-control studies with a very small number of low-birth-weight cases ($n = 25$ and 10, respectively). Two other small human studies have found no association of PBDE exposure during pregnancy and fetal growth (26, 27). Median PBDE concentrations in all 4 previous studies were comparable to or lower than what we observed. The present study, with its sample size of 286 infants, is the first prospective study to examine this question and is the largest study to date.

Although animal studies have not found PBDEs to be associated with birth weight, studies have found decreased weight gain of offspring in the early postnatal period, which is comparable to the third trimester of development in humans. Kodavanti et al. (5) found that exposing pregnant rats to 10 and 30 mg/kg/day of DE-71, a commercial penta-BDE mixture, was associated with lower weight gain and smaller body weights in female (but not male) offspring by postnatal day 29. Kim et al. (38) found lower pregnancy weight gain in pregnant rats dosed with BDE-209 and lower weight gain in male (but not female) offspring by postnatal day 28. However, it is difficult to tell whether the doses that caused body weight effects in rats are environmentally relevant in humans. Other animal studies found no associations of maternal PBDE exposure with offspring's birth weight or body weight gain (13, 39, 40).

The findings of this study are limited primarily to the components of the penta-BDE mixture. Because these congeners are highly correlated in our population (36), we are limited in our ability to distinguish which specific congeners may be causally associated with birth weight. An additional limitation of this study is that we were unable to measure BDE-209, the main constituent of the deca-BDE mixture. Thus, this study cannot provide any information on the association of the deca mixture with birth outcomes.

Table 4. Adjusted[a] Association of Lipid-adjusted PBDE Concentrations (Categorical Variables) With Birth Weight, CHAMACOS Study, Salinas Valley, California, 1999–2000 ($n = 286$)

PBDE Congener	No.	Birth Weight, g	
		β	95% CI
BDE-28			
ND	152	1.0	Referent
≤LOD	77	40.4	−75.9, 156.6
>LOD	57	−130.8	−267.0, 5.4
BDE-47			
Q1	72	1.0	Referent
Q2	71	46.9	−93.9, 187.7
Q3	72	14.5	−126.1, 155.1
Q4	71	−95.0	−241.6, 51.7
BDE-85			
ND	169	1.0	Referent
≤LOD	80	−29.8	−143.7, 84.2
>LOD	37	−151.9	−307.4, 3.5
BDE-99			
Q1	72	1.0	Referent
Q2	71	−5.6	−145.6, 134.3
Q3	72	15.2	−125.0, 155.5
Q4	71	−107.3	−251.2, 36.6
BDE-100			
Q1	72	1.0	Referent
Q2	71	−7.8	−146.7, 131.0
Q3	72	86.3	−53.5, 226.1
Q4	71	−119.3	−265.8, 27.3
BDE-153			
Q1	72	1.0	Referent
Q2	71	−103.9	−243.8, 35.9
Q3	72	−47.5	−188.9, 93.8
Q4	71	−101.6	−249.0, 45.8
BDE-154			
ND	179	1.0	Referent
≤LOD	72	6.5	−112.0, 125.1
>LOD	37	−71.8	−228.5, 84.8
BDE-183			
ND	211	1.0	Referent
≤LOD	47	−75.5	−213.3, 62.2
>LOD	27	−65.6	−237.4, 106.2

Abbreviations: BDE, brominated diphenyl ether; CHAMACOS, Center for the Heath Assessment of Mothers and Children of Salinas; CI, confidence interval; ≤LOD, at or below the limit of detection; >LOD, above the limit of detection; ND, not detected; PBDE, polybrominated diphenyl ether; Q, quartile.

* $P < 0.05$; P values are 2 sided.

[a] Adjusted models included maternal age, marital status, parity, body mass index, country of birth (United States vs. other), family income, sex of infant, and cubic spline for gestational age.

A large number of women in the study population had insufficient serum volume for analysis of PBDEs, which may result in selection bias. The women who were not included in the analysis had lived in the United States for slightly more years on average than those who were included. Years of residence in the United States is positively correlated with PBDE concentrations in this population, so it is possible that we excluded women with higher PBDE levels. Although birth in the United States was associated with lower birth weight in this population, total years living in the United States among immigrants was not. However, it is possible that the results may have been different if the entire population had been included.

An additional limitation is that, because PBDEs were measured in blood collected during pregnancy, pregnancy- and weight gain-related pharmacokinetics could influence exposure measurements. We considered that pregnancy weight gain might be on the causal pathway and did not include it in our main models. However, weight gain could also be a confounder if increased weight diluted PBDE measurements on a lipid basis. Controlling for maternal weight gain in our analysis diminished the magnitude of the effect on birth weight, but the negative association remained (P values ranging from 0.07 to 0.09 for BDE-47, -99, -100, and ΣPBDEs).

Despite these limitations, this study benefits from a strong prospective design, with PBDE concentrations measured in maternal serum collected at a relevant exposure time point (near the start of the third trimester of pregnancy), and information on birth outcomes collected by hospital staff blinded to PBDE exposure status. The study population is relatively homogeneous with regard to race, socioeconomic status, and time residing in the United States, but we were also able to control for several potential confounders.

The study population comprised mainly low-income, Mexican immigrant women living in an agricultural region of California. As such, the results may not be generalizable to the US population. Mexican immigrant women in the United States have been shown to have very low rates of low birth weight (41), and this was reflected in our study population (the proportion of low birth weight births in the United States was 8% in 2000 compared with 3% in this study). It should be noted that levels of PBDEs in our study were also lower than those in the general US population. It is possible that, among women with higher PBDE exposures and greater risk of low birth weight, the impact of PBDEs would be of greater clinical significance.

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