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Association Between Ambient Levels of Polycyclic Aromatic Hydrocarbons and Small for Gestational Age Hispanic Infants Born Along the United States-Mexico Border

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Abstract

Few studies have examined associations between polycyclic aromatic hydrocarbons (PAHs) and birth outcomes, and no studies have been conducted in El Paso County Texas, along the United States-Mexico border. Infants born from 2005–2007 to Hispanic mothers with a birth weight less than the 10th percentile for gestational age and sex were classified as small for gestational age (SGA). PAH exposures were estimated for the entire period of gestation and for each trimester of pregnancy using ambient air monitoring data from 2004–2007. Logistic regression was used to estimate odds ratios for the association between PAH levels and SGA infants. There was marked seasonal variation in the carcinogenic PAHs. Established risk factors for SGA were observed to be associated with SGA births in this population. No associations were detected between PAH levels and SGA births. These findings provide no evidence of an association between PAHs and SGA infants.

Keywords

Air pollution; Hispanics; Small for gestational age; Polycyclic aromatic hydrocarbons; Child health

Background

There are a limited number of epidemiological studies that have explored associations between levels of polycyclic aromatic hydrocarbons (PAHs) in ambient air and adverse birth outcomes [1–9]. PAHs are complex mixtures of chemicals that are formed during incomplete burning of organic substances. PAHs are present in air in both gas and particle phases. Ambient air sources of PAHs include vehicle exhaust, tobacco smoke, agricultural burning,

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residential wood burning, municipal and industrial waste incineration, and hazardous waste sites. Inhalation of PAHs adsorbed onto particulate matter (PM) is a major route of exposure [10].

Previous studies of PAHs and adverse birth outcomes have been conducted in Europe and in the Western or Northeastern United States [1–9, 11]. There has been no evaluation of associations between PAHs and adverse birth outcomes in vulnerable populations along the United States (U.S.)-Mexico Border. El Paso County, Texas is a unique geographic location to study associations between air pollutants and adverse birth outcomes. PAH concentrations are affected by sources within the county, such as the Newman Power Station [12], as well as sources from El Paso's sister city in Mexico, Ciudad Juarez. Those sources include maquiladoras, brick kilns, and burning of tires and wood for heating and cooking [13]. A recent study by De La Torre-Rocha and colleagues found that low molecular weight PAHs such as naphthalene are distributed evenly in soil in El Paso while concentrations of higher molecular weight PAHs like benzo[a]pyrene are found closer to industrial sources [13].

Of the six air monitoring stations measuring PAHs in Texas, only the one in El Paso County (EPA Site #: 48–141-0053) has measured PAHs above the method detection limit (MDL) [14]. PAH levels may also be elevated because of adsorption onto PM with aerodynamic diameter <10 μm (PM_{10}). PM_{10} includes both inhalable and respirable fractions of PM. The US Environmental Protection Agency (EPA) classified El Paso County as being in nonattainment for the 24-h National Ambient Air Quality Standard (NAAQS) for PM_{10} [15]. Over 2004–2007, the number of days that exceeded the 150 $\mu g/m^3$ standard were 12, 2, 6, and 3, respectively (Fig. 1) [16]. Particles <3.0 μm in aerodynamic diameter, with which airborne PAHs are associated, remain in the air for a few days and may be transported over considerable distances before deposition depending on atmospheric conditions [17].

The aim of this population-based study was to examine the association between maternal exposure to PAHs during each of the three trimesters of pregnancy and infants born small for their gestational age (SGA) to Hispanic mothers in El Paso County, Texas, where Hispanics comprise 82 % of the population in the county [18]. Pollutants examined included carcinogenic PAHs (c-PAHs), benzo[a]pyrene (a major component of c-PAHs), and naphthalene.

Methods

Study Subjects

A population-based study was conducted using birth certificate records compiled by the Texas Department of State Health Services (TX DSHS), and at our request, the TX DSHS excluded infants with birth defects because many infants with birth defects are growth restricted. Among the total number of infants born in El Paso County from 2005 to 2007 without birth defects (n = 52,347), we excluded infants if the birth records were missing geocoded maternal residence at delivery (n = 12,841) or if the maternal residence at delivery was outside of El Paso County (n = 141) by using ArcGIS Software (Version 9.3.1, ESRI, Redlands, CA). We further excluded multiple births (n = 988), infants born to non-Hispanic mothers (n = 4,262), preterm infants (<37 completed weeks of gestation) (n = 3,212), and

infants missing birth weight (n = 1) or with extreme values for gestational age and/or birth weight (n = 119). The number of live, full-term, Hispanic, and singleton infants born in 2005–2007 for this study was 30,783.

The Institutional Review Boards for the TX DSHS and the University of Texas Health Science Center at Houston approved this study.

Classification of Small for Gestational Age (SGA)

A SGA case was an infant whose weight was below the 10th percentile for gestational age and infant sex based on the United States birth weight percentiles for gestational age and infant sex in 1999–2000 [19–21]. For most pregnancies gestational age at birth was calculated from the mother's last menstrual period (LMP). We were also able to compute gestational age using the clinical estimate (reported by the delivering physician) for all but a few births (n = 8, 0.03 %). If the absolute difference between the LMP estimate of gestational age and the clinical estimate was greater than 2 weeks, the clinical estimate of gestational age was used to determine SGA (n = 2,372, 7.71 %). The clinical estimate was also used if the gestational age calculated from LMP was missing (n = 906, 2.94 %). The first trimester was defined as LMP through 97 days (clinical estimate: weeks 1–11), second trimester as days 98 through 188 (weeks 12–24), third trimester as days 189 through 280 (weeks 25–38), and 9-month exposure as LMP through 280 days of pregnancy.

Exposure Assessment for PAHs

The main PAH variable used in the analyses was the sum of the seven carcinogenic PAHs (c-PAHs) including benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, and indeno[1,2,3-cd]pyrene. Separate analyses were also conducted for benzo[a]pyrene and naphthalene. PAH concentrations were given in units of ng/m^3 in the US EPA Air Quality System (AQS) for EPA Site #: 48–141-0053, El Paso Sun Metro, for the years 2004–2007 [13]. PAHs were captured via a high-volume sampler without a size-selective inlet on a quartz fiber filter and polyurethane foam (PUF) cartridge and analyzed by gas chromatography/mass spectrometry (GC/MS) according to US EPA Compendium Method TO-13A [22]. Air quality data over relevant periods were used to construct exposure estimates for a mother during her entire pregnancy and for each trimester of pregnancy, as defined above.

Statistical Analyses

The distribution of maternal PAH exposure metrics was examined. Crude and adjusted associations between PAH exposure (measured on a continuous scale) and the odds of SGA births were estimated using logistic regression. Models were adjusted for maternal age, education, smoking status, marital status, parity, and season of birth. Odds ratios (ORs) and 95 % confidence intervals (CI) are reported. All statistical analyses were performed using SAS (Version 9.3, SAS Institute, Inc., Cary, NC).

Results

Descriptive Statistics for PAHs

Monthly average levels (ng/m^3) of ambient c-PAHs, benzo[a]pyrene, and naphthalene from January 2004 through December 2007 are shown in Figs. 2, 3, 4. The highest concentrations of c-PAHs and benzo[a]pyrene were found during the months of January, February, November, and December. Mean trimester exposures were similar to 9-month exposure levels for PAHs (~5.5 ng/m^3 for c-PAHs, ~0.60 ng/m^3 for benzo[a]pyrene, and ~330 ng/m^3 for naphthalene), although there were two to threefold differences in the interquartile range when comparing trimester-specific metrics to metrics computed for a woman's entire pregnancy (Table 1).

Associations between PAHs and SGA

A map of maternal residences in relation to the location of the ambient air monitor is shown in Fig. 5. Demographic characteristics of the study population are provided in Table 2. Among the 30,783 Hispanic infants in this cohort, 3,420 or 11.1 % were born SGA from 2005 to 2007. Over three quarters of the population reported ''Mexican'' as their Hispanic origin. In simple logistic regression models, our results suggest greater odds of SGA for mothers who had high school education (OR 1.14, 95 % CI 1.04–1.24) and for mothers who had less than a high school education (OR 1.13, 95 % CI 1.03–1.22) compared to mothers with more than a high school education; greater odds of SGA for mothers who smoked throughout pregnancy (OR 1.60, 95 % CI 1.08–2.39) compared to non-smoking mothers, greater odds of SGA for mothers >19 years of age (OR 1.24, 95 % CI 1.12–1.37) but reduced odds of SGA for mothers 25–34 years of age (OR 0.73, 95 % CI 0.67–0.79) or 35 years of age and older (OR 0.87, 95 % CI 0.77–0.99) compared to mothers 20–24 years of age; greater odds of SGA for mothers who are nulliparous (OR 1.42, 95 % CI 1.33–1.53); and finally, greater odds of SGA for mothers who were not married compared to mothers who were married (OR 1.35, 95 % CI 1.26–1.45).

The results from the crude and multiple logistic regression analyses examining associations between PAHs and SGA are shown in Table 3. No associations were found between ambient air levels of PAHs and SGA after controlling for maternal age, maternal education, maternal smoking status, marital status, parity, and season of birth.

Discussion

This is the first study to examine associations between air pollutants and an adverse birth outcome in El Paso County, Texas, a unique geographic area with a predominantly Hispanic population. We were particularly interested in examining associations between trimester-specific and 9-month levels of c-PAHs, benzo[a]pyrene, and naphthalene and SGA in Hispanic newborns. The findings of our study provide no evidence of an association between maternal exposure to ambient air levels of PAHs and SGA during any pregnancy period.

Whereas we found no evidence of an association between PAHs and SGA, Dejmek et al. [2] found an elevated association between the highest level tertile of c-PAHs (>20 ng/m^3)

and intrauterine growth restriction (IUGR), defined as birth weight below the 10th percentile by sex and gestational week, during the first gestational month (AOR 2.39, 95 % CI 1.01–5.65) in Prachatice, a district in the Czech Republic that is known to have relatively low concentrations of PM. In a sensitivity analysis, we evaluated potential effects during the 1st trimester of pregnancy among mothers in our study with the highest exposure (using the 95th percentile of c-PAHs (>17.4 ng/m^3) as the cut point for a dichotomous exposure metric) and found no association between ‘‘high’’ and ‘‘low’’ PAH levels and SGA (AOR 0.95, 95 % CI 0.81–1.12). In a study that relied on personal monitoring of PAHs during the third trimester of pregnancy among African-American and Dominican mothers in New York City [1], Choi et al. observed a twofold increase in the risk of symmetric IUGR among full-term African-American infants per a 1 natural-log (ln) increase in PAH exposure ($p < 0.05$) whereas there was no association among Dominicans. Given that the mean exposure for PAHs was similar between the two groups of mothers [1], Choi et al. attributed reduced IUGR risk in Dominicans to healthier diets and a strong social support network as compared to the African Americans [1]. While there was no information regarding social support in our study, we examined potential effect measure modification using marital status as a surrogate measure of social support as spouses tend to have greater interaction with a pregnant woman than other family members [23], and found no differences between married and not married mothers (Supplemental Materials, Table S–I).

Equivocal findings have also been reported in studies of PM and SGA. Bobak and Leon found in their Czech Republic study that IUGR (defined as <10th percentile of birth weight for gestational age and sex) was not associated with total suspended particulates (TSP) during any pregnancy period [24]. In contrast, Mannes et al. [25] found that ambient levels of PM_{10} and $PM_{2.5}$ in the second trimester of pregnancy had a small but statistically significant effect on SGA (defined as greater than two standard deviations below the mean birth weight according to gestational age) for infants born in Sydney, Australia (AOR 1.01, 95 % CI 1.00–1.04; AOR 1.03, 95 % CI 1.01–1.05, per unit increase (μg/m^3) in pollutant concentration, respectively). In a recent investigation by Le et al., the authors found a positive association in the third trimester for PM_{10} and term SGA (infants whose birth weights fell below the 10th percentile by sex and gestational week between ages 37 to 42 weeks) [AOR 1.22, 95 % CI 1.03–1.46 for the upper quartile (>35 μg/m^3) as compared to the lowest quartile (<24.3 μg/m^3)] [26].

One strength of this large, population-based study was that it was restricted to Hispanics, an understudied and susceptible population. Our crude analyses suggest that risk factors for SGA that have been established in other populations are also likely risk factors for this adverse birth outcome among Hispanic mothers. We note, however, that geocodes for maternal address at delivery were missing for nearly 25 % of the births that occurred during the study period, which could have introduced selection bias into our study. We speculate that the geocoded data were missing because mothers did not report their address at the time of delivery when completing the application for a birth certificate for their infant. Additionally, we had no information whether a mother moved during her pregnancy. Lupo et al. [27] found that changes in maternal residence during pregnancy (comparing addresses at conception and delivery among Texas mothers who participated in the National Birth Defects Prevention Study) were generally within short distances (median distance moved

was less than four miles). Regarding our focus on inhalation exposures to ambient air levels of carcinogenic PAHs, we were able to capture the considerable seasonal variation in levels of the PAHs in our assessment of trimester-specific exposures. However, a limitation of this study is that there was only a single monitoring station for the entire county measuring PAHs and this likely introduced nondifferential exposure misclassification that tends to bias results towards the null. Finally, we did not have information on dietary intake of PAHs, indoor PAH levels, or occupational PAH exposures and, thus, could not evaluate the potential for confounding due to these other sources of PAH exposure.

New Contribution to the Literature

This is the first study looking at adverse birth outcomes and air pollution in a vulnerable population along the U.S.-Mexico Border. This study found no evidence of an association between maternal exposure to PAHs during pregnancy and SGA among infants born in El Paso County, Texas.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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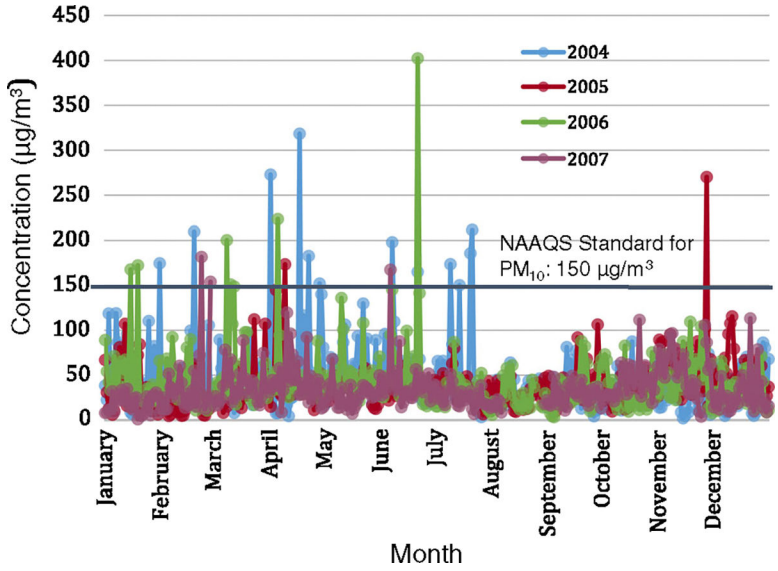

Fig. 1.

24-h average PM_{10} concentrations, El Paso County, TX, 2004–2007 (EPA Site #: 48–141–0037)

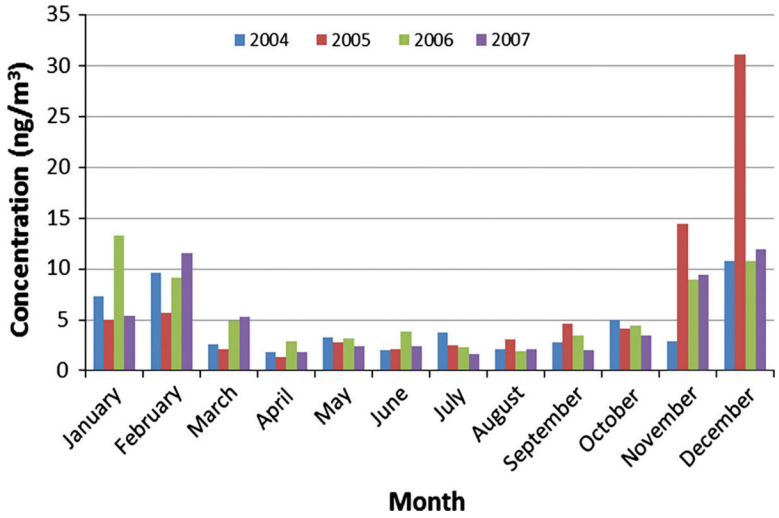

Fig. 2.
Monthly average c-PAHs concentrations (ng/m^3), El Paso County, TX, 2004–2007

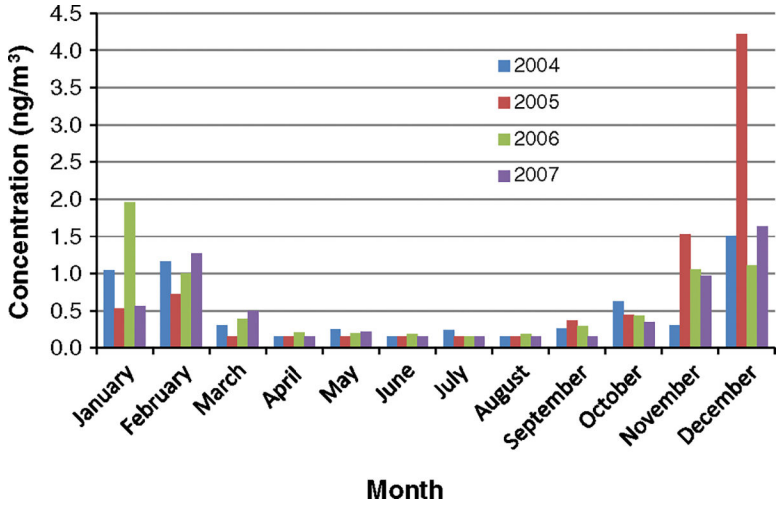

Fig. 3.

Monthly average benzo[a]pyrene concentrations (ng/m^3), El Paso County, TX, 2004–2007

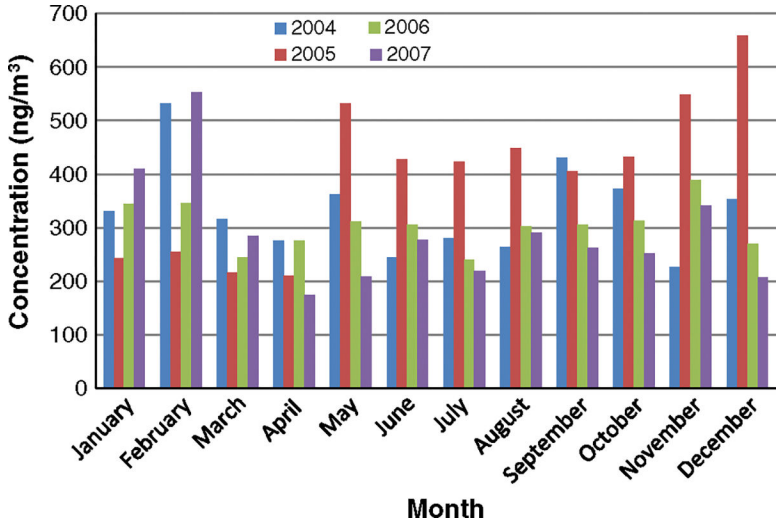

Fig. 4.

Monthly average naphthalene concentrations (ng/m^3), El Paso County, TX, 2004–2007

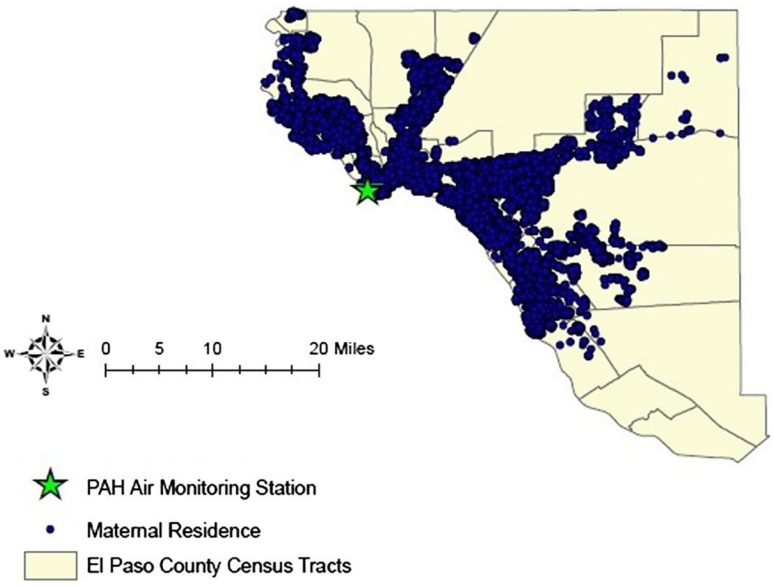

Fig. 5.

Distribution of maternal residences at delivery and PAH air monitoring station (EPA Site #: 48–141-0053) in El Paso County Texas, 2005–2007 (n = 30,783)

Table 1

Distribution of maternal exposure estimates (ng/m^3) during pregnancy to ambient levels of c-PAHs, benzo[a]pyrene, and naphthalene, El Paso County, TX, March 2004-December 2007 (n = 30,783)

	c-PAHs				Benzo[a]pyrene				Naphthalene			
	Trimester 1	**Trimester 2**	**Trimester 3**	**9-months**	**Trimester 1**	**Trimester 2**	**Trimester 3**	**9-months**	**Trimester 1**	**Trimester 2**	**Trimester 3**	**9-months**
Minimum	1.98	1.80	1.80	3.06	0.15	0.15	0.15	0.26	207.89	206.07	206.07	235.06
5th percentile	2.30	1.99	1.99	3.47	0.15	0.15	0.15	0.31	235.28	221.94	223.60	272.24
25th percentile	2.95	2.73	2.61	4.07	0.19	0.18	0.18	0.42	281.80	273.05	267.12	299.02
Median	3.80	3.59	3.75	4.84	0.38	0.37	0.35	0.50	312.83	311.10	303.65	318.32
75th percentile	7.02	6.86	6.94	6.06	0.82	0.80	0.82	0.62	387.61	397.07	398.23	365.29
95th percentile	17.40	16.73	16.42	9.50	2.29	2.10	2.10	1.11	512.92	498.06	498.06	449.46
Maximum	19.60	19.86	19.86	9.70	2.51	2.60	2.60	1.13	550.31	564.89	564.89	469.42
IQR	4.07	4.13	4.33	1.98	0.63	0.62	0.64	0.20	105.82	124.02	131.11	66.27
Mean	5.73	5.49	5.53	5.64	0.61	0.59	0.59	0.60	339.33	334.33	331.04	336.01
SD	4.17	4.22	4.20	2.06	0.58	0.58	0.58	0.27	78.91	83.61	85.41	53.17

Table 2

Crude odd ratios (ORs) (95 % CI) for the associations between demographic characteristics of Hispanic infants born in El Paso County, TX and SGA, 2005–2007 (n = 30,783)

Characteristics	Full-term singleton infants (%) n = 30,783	SGA term infants (%) n = 3,420	OR (95 % CI)
Infant sex			
Female	49.52	48.51	Reference
Male	50.48	51.49	1.05 (0.98–1.12)
Maternal education			
More than high school	39.36	36.78	Reference
High school	26.48	27.75	1.14 (1.04–1.24)
Less than high school	34.16	35.44	1.13 (1.03–1.22)
Maternal smoking			
Non-smoker	97.43	97.22	Reference
Smoked prior, stopped early[a]	1.67	1.49	0.88 (0.66–1.18)
Smoked through pregnancy	0.57	0.85	1.60 (1.08–2.39)
Maternal age			
20–24 years	30.11	32.89	Reference
≤19 years	16.63	21.87	1.24 (1.12–1.37)
25–34 years	43.32	35.61	0.73 (0.67–0.79)
≥35 years	9.94	9.62	0.87 (0.77–0.99)
Parity			
1 or more	63.41	55.91	Reference
Nulliparous	36.58	44.09	1.42 (1.33–1.53)
Marital status			
Married	57.28	50.64	Reference
Not married	42.72	49.36	1.35 (1.26–1.45)
Season of birth			
Warm (April-September)	50.78	50.61	Reference
Cool (October-March)	49.22	49.39	1.01 (0.94–1.08)

[a]Smoked in the first, second, or both first and second trimester of pregnancy

Table 3

Crude and adjusted odds ratios (ORs) (95 % CI) for the associations between SGA and PAHs by gestational period, El Paso County, TX, 2005–2007 (n = 30,783)

	OR	95 % CI	AOR[d]	95 % CI
c-PAHs[a]				
First trimester	0.98	0.93–1.02	0.97	0.92–1.02
Second trimester	0.96	0.92–1.01	0.96	0.92–1.01
Third trimester	1.01	0.97–1.06	1.02	0.97–1.07
9-months	0.94	0.86–1.02	0.94	0.86–1.02
Benzo[a]pyrene[b]				
First trimester	0.96	0.91–1.03	0.96	0.88–1.03
Second trimester	0.95	0.89–1.01	0.95	0.89–1.02
Third trimester	1.02	0.96–1.09	1.03	0.96–1.11
9-months	0.91	0.80–1.04	0.91	0.79–1.05
Naphthalene[c]				
First trimester	0.97	0.93–1.02	0.97	0.92–1.02
Second trimester	0.98	0.94–1.02	0.98	0.94–1.02
Third trimester	1.01	0.97–1.05	1.01	0.97–1.06
9-months	0.97	0.91–1.04	0.97	0.91–1.04

[a] per 5 ng/m^3 increase

[b] per 1 ng/m^3 increase

[c] per 100 ng/m^3 increase

[d] Adjusted for maternal age, maternal education, maternal smoking status, marital status, parity, and season of birth