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Ambient air pollution and hypertensive disorder of pregnancy

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Abstract

Background—Ambient air pollution has been implicated in the development of hypertensive disorders of pregnancy (HDP). However, evidence of the association between air pollution and HDP is still limited, and the effects of gaseous air pollutants on HDP and their time windows of exposure have not been well studied.

Methods—We used the Florida birth registry data to investigate the associations between air pollutants (NO₂, SO₂, PM_{2.5}, O₃ and CO) and the risks of HDP in 22 041 pregnant women in Jacksonville, Florida, USA from 2004 to 2005. Further, we examined whether air pollution exposure during different time windows defined by trimesters and the entire pregnancy had different effects on HDP.

Results—The single-pollutant logistic regression model showed that exposure to four pollutants during the full pregnancy period was significantly associated with prevalence of HDP after adjusting for covariates: NO₂ (OR=1.21, 95% CI 1.09 to 1.35), PM_{2.5} (OR=1.24, 95% CI 1.08 to 1.43), SO₂ (OR=1.13, 95% CI 1.01 to 1.25) and CO (OR=1.12, 95% CI 1.03 to 1.22) per IQR increase. Similar effects were observed when first trimester exposure to NO₂, SO₂ and CO, and second trimester exposures to PM_{2.5} were examined. Consistent results were confirmed in multiple-pollutant models.

Conclusions—This study suggests that exposure to high levels of air pollution during early pregnancy and the full gestational period was associated with increased prevalence of HDP in Florida, USA.

INTRODUCTION

Women during pregnancy are susceptible to hypertensive disorders of pregnancy (HDP) including gestational hypertension, pre-eclampsia and eclampsia because changes during pregnancy lead to higher stress on the cardiovascular system.¹ HDP complicates up to 10% of all pregnancies, and can have adverse health effects on the mother and the child.² In

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Contributors XX conceived the study, participated in its design and coordination and helped to draft the manuscript. HH participated in the design of the study, performed the statistical analysis and drafted the manuscript. SH was involved in the design of the study, interpretation of results and drafting of the manuscript. JR helped interpret the results and draft the manuscript. All authors read and approved the final version of the manuscript.

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mothers, HDP is associated with maternal pitting oedema, endothelial abnormalities, liver and renal dysfunction and increased risk of cardiovascular disease, stroke and type II diabetes later in life.^{2–5} With its progression to pre-eclampsia or even eclampsia, gestational hypertension dramatically increases the risks of maternal and perinatal death.⁶ In infants, maternal HDP is associated with small for gestational age, preterm delivery, low birthweight and increased risk of hospitalisation for a wide range of neonatal diseases.^{7,8} Pre-eclampsia is the underlying cause for about 25% of all medically indicated preterm deliveries in the USA, and it is also the most frequent primary reason for preterm birth without labour, which accounts for 30–35% of total preterm deliveries.^{9,10}

Despite serious consequences, the biological mechanisms underlying HDP remain unclear. Environmental exposures such as ambient air pollution during pregnancy may play a role in the development of HDP. The association between air pollution and increased risk of hypertension in the general population has been reported by many studies.^{11–15} It is plausible that exposure to air pollution during pregnancy may increase the risk of HDP. However, evidence of the association between air pollution and HDP is still limited.^{16–19} Moreover, the effect of the time window of exposure to air pollution during pregnancy on HDP has not been well studied. In this study, we used the Florida birth registry data to investigate the association between criteria air pollutants (NO₂, SO₂, PM_{2.5}, O₃ and CO) and the risk of HDP in 22 041 pregnant women who delivered during 2004–2005 in Jacksonville, Florida, USA. Furthermore, we examined whether air pollution exposure during different time windows defined by trimesters and the entire pregnancy had different effects on HDP.

MATERIAL AND METHODS

Birth data

Birth record data were obtained from the Bureau of Vital Statistics & Office of Health Statistics and Assessment, Florida Department of Health. The data included all registered live births occurring in Jacksonville, Florida, USA between 1 January 2004 and 31 December 2005 (n=24 483). Six hundred and ninety-seven participants were excluded because of missing geographical information, or because of living too far away from monitors (see section Air pollution exposure assessment for detailed information). We further excluded infants with congenital abnormalities (n=159), as well as infants with a birthweight <400 g (n=39) or a gestational age <24 or >42 weeks (n=74). Women who had plural deliveries (n=798) or previous preterm births (n=305) were also excluded from the study because it is known that multifetal pregnancies and women with previous preterm births have higher rates of adverse pregnancy outcomes, and gestational hypertension associated with such outcomes may have a different underlying physiology.^{20,21} Additionally, women who reported having chronic hypertension (n=370) were removed from the study. Under these restrictions, a total of 22 041 births were available for analysis.

The study was conducted following a human participant's research protocol approved by the Institutional Review Board at the University of Florida and Florida Department of Health.

Outcome ascertainment

Women identified from birth records with gestational hypertension, pre-eclampsia and/or eclampsia during their pregnancy were considered as cases with HDP.

Air pollution exposure assessment

Daily measurements of NO₂, SO₂, PM_{2.5}, PM₁₀, O₃ and CO were obtained from the US Environmental Protection Agency's (EPA's) Air Quality System (AQS) for 2003–2005 in

Jacksonville, Florida, USA. During the study period, there were one active NO₂ monitor, four active SO₂ monitors, two active PM_{2.5} monitors, three active PM₁₀ monitors, two active O₃ monitors and three active CO monitors. Since PM₁₀ was observed for only 180–182 days over the 3-year period (please refer to table 1), we did not include PM₁₀ in this study.

The mother's residential address at birth was geocoded at the street level using the ArcGIS V.10.1 software (ESRI, Redlands, California, USA) with a geocoding success rate of 98%. Women whose addresses could not be geocoded were excluded from further analysis (n=524). The residential addresses were then linked to the closest active monitor for each pollutant. Birth date and gestational age were used to determine the start and end dates of the trimesters and full gestational period for each infant, allowing exposures to air pollution to be calculated for each period specific to each pregnant woman. Exposures were calculated as 24 h values averaged over the corresponding periods. We used two trimester windows of exposure: 1–13 weeks and 14–26 weeks. Similar definitions have been applied elsewhere.^{22,23} Women were excluded from the study if they lived more than 20 km from all AQS monitors in the study area (n=173, please refer to online supplemental material 1).

Covariates

Census data—We extracted census-tract level median household income from the 2000 Census to control for population characteristics that may confound the effect of exposure to air pollution on HDP.²⁴ The income variable was categorised into three levels based on tertiles across all tracts in Jacksonville, Florida, USA. Tracts in the lowest tertile of socioeconomic status had a median household income under US\$35 265 and tracts in the highest tertile of socioeconomic status had a median household income over US\$45 087.

Maternal characteristics—Information on marital status, maternal age, race, education, smoking during pregnancy, season of birth and prenatal care was also obtained from birth records. Marital status was treated as a dichotomous variable (yes/no). Maternal age at delivery was categorised in 5-year increments for women between 20 and 39 years, with two additional categories for <20 and ≥40 years. Maternal race was categorised as non-Hispanic White, non-Hispanic Black and others. In addition, maternal education was categorised into three groups: <high school, high school or equivalent and >high school. Smoking during pregnancy was categorised into three groups based on the number of cigarettes smoked per day: non-smokers, smokers with <10 cigarettes smoked per day and smokers with ≥10 cigarettes smoked per day. Season of conception was categorised as two categories: warm (June–November) and cool (November–May). Year of conception was treated as a categorical variable (2003, 2004 or 2005). The trimester in which prenatal care began (first, second, third trimester or no care) was also obtained.

Statistical analysis

χ^2 Tests and t tests were applied to compare the distributions of categorical and continuous independent variables between women with HDP and those without HDP. Logistic regression models were used to evaluate the association between exposure to different air pollutants and gestational hypertension during the three trimesters and the full gestational period. Air pollutants were analysed as continuous variables in separate models with the same covariates (maternal characteristics described above). ORs and 95% CI per IQR increase in specific pollutants during a specific pregnancy period were obtained. Two-pollutant logistic models were implemented for gestational exposures to explore potential confounding by copollutants. Furthermore, multipollutant scores were calculated for each participant during different gestational periods. Participants' exposure to different air pollutants were categorised into tertiles. The multipollutant score was developed to study the

combined effects of multiple air pollutants. It is equal to the sum of air pollutants that the individuals were exposed to. Given the limited sample size of participants with a score of 5, we combined those with a score of 4 or above together. The score was then treated as a nominal categorical variable in logistic models adjusted for the same covariates as described above. All statistical analyses were conducted using SAS V.9.3 (Cary, North Carolina, USA).

RESULTS

Air pollution exposure was estimated for 22 041 women. Of the women in the study population, 4.7% had HDP (n=1037). Table 1 shows the concentrations of air pollutants and observational days by different monitors. Figure 1 shows the locations of monitors in Jacksonville, Florida, USA during the study period. Table 2 shows the distribution of exposures to each pollutant for each trimester and the entire pregnancy period.

Table 3 presents the correlation between criteria air pollutants in different gestational periods. Only a moderate negative correlation between CO and O₃ during all the gestational periods examined was observed in this study (Pearson's correlation coefficients range from -0.58 to -0.62). Weak correlations were observed among other criteria air pollutants during different gestational periods.

Table 4 shows the maternal characteristics of women by HDP status. A higher proportion of normotensive women were of a race/ethnicity other than non-Hispanic White or non-Hispanic Black (14.2% vs 9.4%), had conceived in 2003 (36.2% vs 29.5%), had begun prenatal care later and had a high socioeconomic status (33.9% vs 30.9%).

Table 5 provides the crude and adjusted ORs of the single-pollutant logistic regression between HDP and gestational exposure to air pollutants during different time windows in the full gestational period. The increase in risk of HDP per IQR increase in pollutant during the full pregnancy was 21% for NO₂, 24% for PM_{2.5}, 13% for SO₂ and 12% for CO after adjusting for covariates. In addition, women with higher (per IQR increase) exposure to NO₂, SO₂ and CO during the first trimester were 14%, 14% and 19% more likely to be associated with HDP, respectively. Furthermore, women with higher exposure to PM_{2.5} during the second trimester were also associated with higher prevalence of HDP (OR=1.28, per IQR increase). All p values were <0.05.

Two-pollutant logistic models were applied for gestational exposure to pollutants exhibiting significant associations in table 5. Since no pairs of pollutants were highly correlated ($|r| > 0.7$) in this study, we analysed all pairs of pollutants (please refer to online supplemental material 2 for pollutants exhibiting insignificant associations in table 5). Figure 2 compares results with and without copollutant adjustment. Except for SO₂ during the full pregnancy and NO₂ during the first trimester, results for all other pollutants considered in the single-pollutant regression analysis are robust to copollutant adjustment and remain statistically significant. On the other hand, after adjusting for CO/SO₂, the higher level of NO₂ during the first trimester is not significantly, but still marginally, associated with HDP. Similar results were observed for SO₂ during the full gestational period after adjusting for CO and NO₂.

Figure 3 shows the adjusted ORs for risk of HDP for multi-pollutant score for participants during different gestational periods. The risks of HDP increase with the increase in the number of highly exposed pollutants for women during the first trimester or the entire pregnancy period. Such a trend was not observed during the second trimester.

DISCUSSION

This study examined the association of HDP with NO₂, PM_{2.5}, PM₁₀, SO₂, CO and O₃ exposure during both the full gestational period and different trimesters during pregnancy. When elevated air pollution exposures were assessed across the entire period of pregnancy, the increase in HDP was statistically significant for each IQR increase in NO₂, PM_{2.5}, SO₂ and CO. Similar results were observed when the first trimester exposures to NO₂, SO₂ and CO, and the second trimester exposures to PM_{2.5} were examined. The observed associations were independent of the confounding effects of maternal age, race/ethnicity, education, marital status, smoking during pregnancy, season of birth, time prenatal care began, socioeconomic status and copollutants. These results suggest that an elevated risk of HDP was associated with increased exposure earlier in pregnancy. In addition, the risk associated with increased air pollution exposure throughout the full gestational period may indicate a dose–response relationship, or only reflect the early pregnancy effects of air pollution. The results of our study add to the emerging evidence pointing to the deleterious effects of air pollution on pregnant women.

We observed that air pollution exposure at an early stage of pregnancy is associated with elevated odds of HDP. This finding may be explained by the fact that air pollution exposure at the early stage of pregnancy may change the normal pattern of blood pressure during pregnancy. In normal pregnancy, blood pressure starts to fall during the first trimester, reaching the lowest point in midpregnancy, and then gradually returns to the prepregnancy level.²⁵²⁶ However, women who develop HDP have a different pattern. Their blood pressure is stable during the first half of pregnancy and then continuously increases until delivery.²⁶ Therefore, it is plausible that exposure to air pollution may contribute to the different patterns of blood pressure change in the early stage of pregnancy between women with and without HDP. The associations we observed between air pollution exposure during the entire pregnancy period and HDP are consistent with previous studies.^{16–19} In addition, the observed association of SO₂/CO and HDP may be due to different causes. It is possible that the adverse health effects of SO₂ and CO may induce HDP; many studies have suggested that these pollutants may induce hypertension in different populations.²⁷²⁸ On the other hand, it is also possible that SO₂ and CO served as an indirect indicator of other factors, given the relatively low concentration of SO₂ and CO in this study.

Although the causal mechanisms between exposure to air pollution and HDP remain unclear, it is known that air pollution can speed the development and progression of atherosclerosis, which may potentially contribute to hypertension.^{29–31} HDP and vascular atherosclerosis may share common pathways in relation to air pollutants.³²³³ In addition, air pollution has been linked with endothelial dysfunction, which is a precursor associated with HDP.²⁰³⁴³⁵ The abnormal placentation and failed vascular remodelling due to endothelial dysfunction may trigger pre-eclampsia.³⁶

There are several strengths to this study. First, we used different models to examine the association between air pollution and HDP among pregnant women. The results from different models such as single pollutant models and multiple-pollutant models were consistent, which suggests that gaseous pollutants such as SO₂ and CO may have effects independent of particulate air pollutants on HDP. In addition, we further developed the multipollutant score to investigate the combined effects of exposure to multiple air pollutants and our findings indicate that women simultaneously exposed to high levels of several air pollutants had a greater risk of developing HDP than those exposed to one high level of air pollutant or none. These findings reinforce the fact that air pollution consists of a mixture of pollutants and that the health effects of air pollution need to consider the combined effects of all measured pollutants together. However, this approach has some

limitations. It did not consider between-pollutant correlations and that different pollutants may have different effects on the outcome since we used the same weight for each air pollutant. Thus, a potential bias may exist when evaluating the combined effects of different air pollutants.

This study had several limitations. First, information on HDP was obtained from vital statistics records. It is possible that HDP may be underdiagnosed on the birth certificate since it could be asymptomatic, especially among women who do not have access to prenatal care. Second, the date of HDP diagnosis is not available in this study. However, since HDP is defined as the development of new arterial hypertension in a pregnant woman after 20 weeks' gestation, the date of an HDP diagnosis should be later than 20 weeks after conception. As we observed elevated odds of HDP associated with air pollution early in pregnancy, these results may not be biased by the unknown diagnostic date of HDP. Third, stillbirth, birth defects and preterm birth might lie on the causal pathway. Although we excluded participants with stillbirth and birth defects from this analysis, some preterm births between 24 and 37 weeks were included in this analysis and may influence our estimates. But, given that the number of preterm births was relatively small, their inclusion would not have a significant effect on our estimates. Fourth, in this study, individual air pollution exposure was estimated using the US EPA monitored data nearest to their location of residence. No direct individual measurement was performed to measure the actual exposure of pregnant women. This method of exposure assessment may suffer from misclassification because the difference between the monitored data near their address and individual air pollution exposure may be due to the fact that the individual daily mobility and behaviour patterns could substantially influence exposure to air pollution over time and in space. Moreover, information on residential mobility during pregnancy was not available. It is possible that some women in the study lived elsewhere and were exposed to different air pollution levels during a part of their pregnancy. However, the biases are likely to be non-differential, which would make the estimation more conservative and trending towards null. Furthermore, the number of air monitors available in the study area is very small. It further limits the ability of capturing spatial heterogeneity in exposure, which is especially important for assessing exposure to some air pollutants such as nitrogen dioxide. Thus, compared with other studies with substantial spatial heterogeneity in exposure,¹⁶¹⁹ the small number of air monitors available in the study area is a limitation. Fifth, the results obtained may be influenced by the fixed cohort bias, which occurs in retrospective cohorts which include all births occurring within a fixed start and end date.³⁷ This selection bias is more likely to happen when shorter pregnancies are missed at the start of the study, and longer pregnancies are missed at the end. However, since this study had the day and month of the start date just before the day and month of the end date, the potential to the bias was reduced. Finally, although we were able to control for some important covariates, other factors such as environmental tobacco smoke and individual-level socioeconomic status are unavailable on the birth certificate. Thus, we were unable to control for the confounding of these factors.

CONCLUSION

We observed a positive association between exposure to NO₂, PM_{2.5}, SO₂ and CO during the entire pregnancy period, exposure to NO₂, SO₂ and CO during the first trimester of pregnancy, and exposure to PM_{2.5} during the second trimester of pregnancy and increased prevalence of HDP among women giving birth in Jacksonville, Florida, USA between 2004 and 2005. This finding indicates that there is a need for better air pollution control in order to reduce the disease burden of HDP among pregnant women.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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What is already known on this subject

- ▶ The association between air pollution and increased risk of hypertension in the general population has been reported by many studies.
- ▶ However, evidence of the association between air pollution and hypertensive disorders of pregnancy (HDP) is still limited. Moreover, the effect of the time window of exposure to air pollution during pregnancy on HDP has not been well studied.

What this study adds

- ▶ Our findings suggest that exposure to NO₂, PM_{2.5}, SO₂ and CO during the first trimester of pregnancy is positively associated with an increased risk of hypertensive disorders of pregnancy (HDP) among women giving birth in Jacksonville, Florida, USA between 2004 and 2005. Similar findings were also observed during the entire pregnancy period.
- ▶ Our findings also suggest potentially combined effects of different air pollutants on HDP.
- ▶ These findings indicate that there is a need for a better air pollution control in order to reduce the disease burden of HDP among pregnant women.

Total area: 918 square miles
 Total population: 778,879

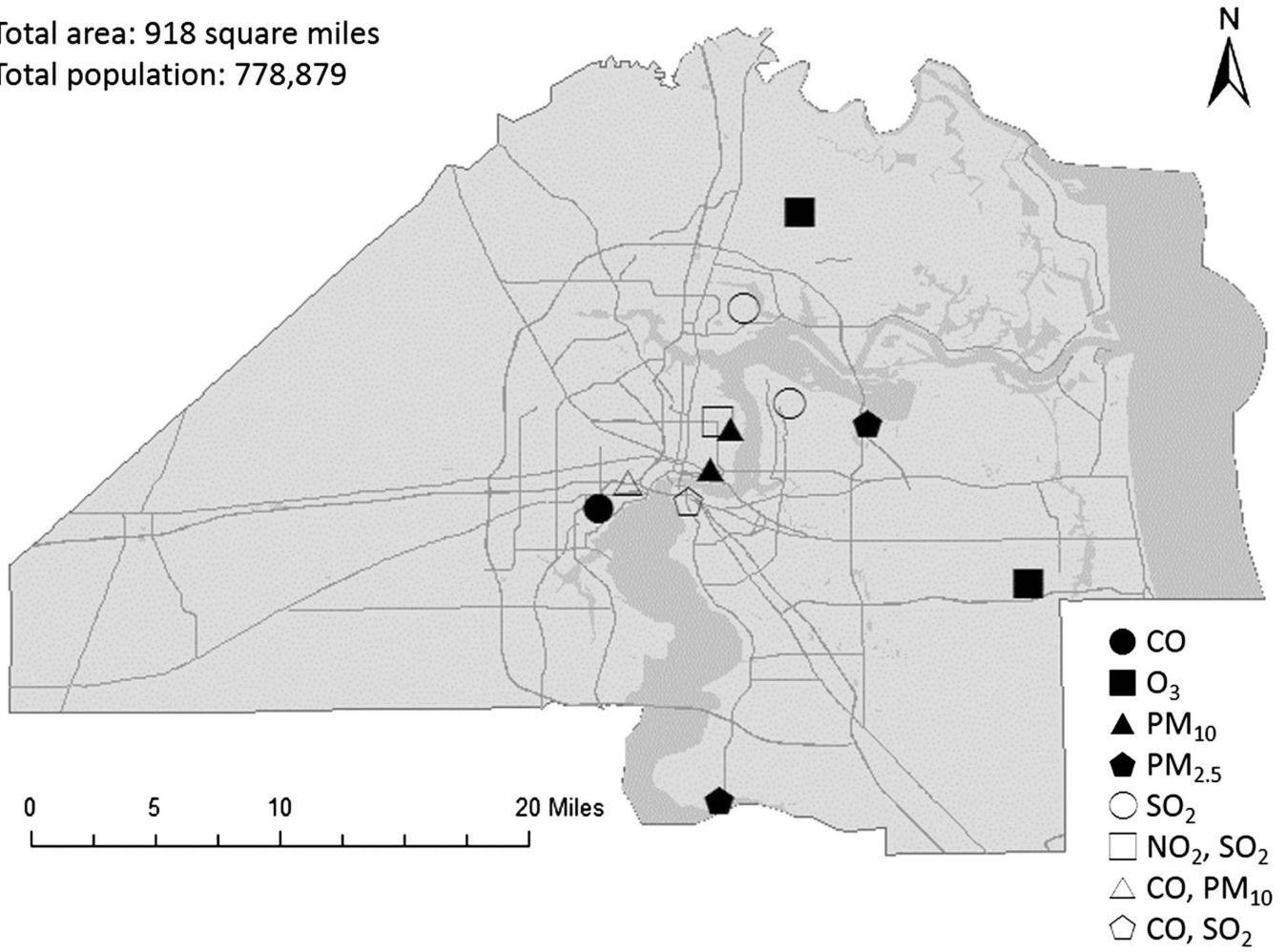


Figure 1.
 Locations of air pollution monitors during the study period in Jacksonville, Florida, USA.

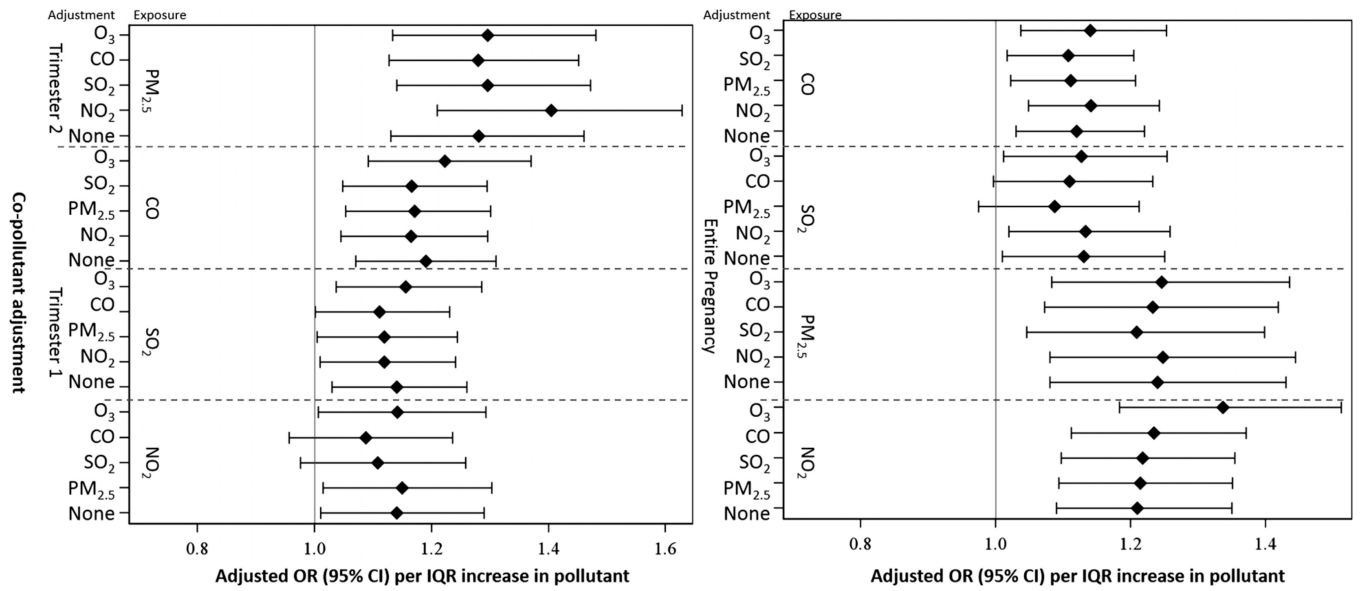


Figure 2. Adjusted OR for risk of hypertensive disorders of pregnancy per IQR increase in gestational exposure to pollutant, for single and two-pollutant models among women who gave birth from 2004 to 2005 in Jacksonville, Florida, USA. The point reflects the central estimate; the horizontal line represents the 95% CI.

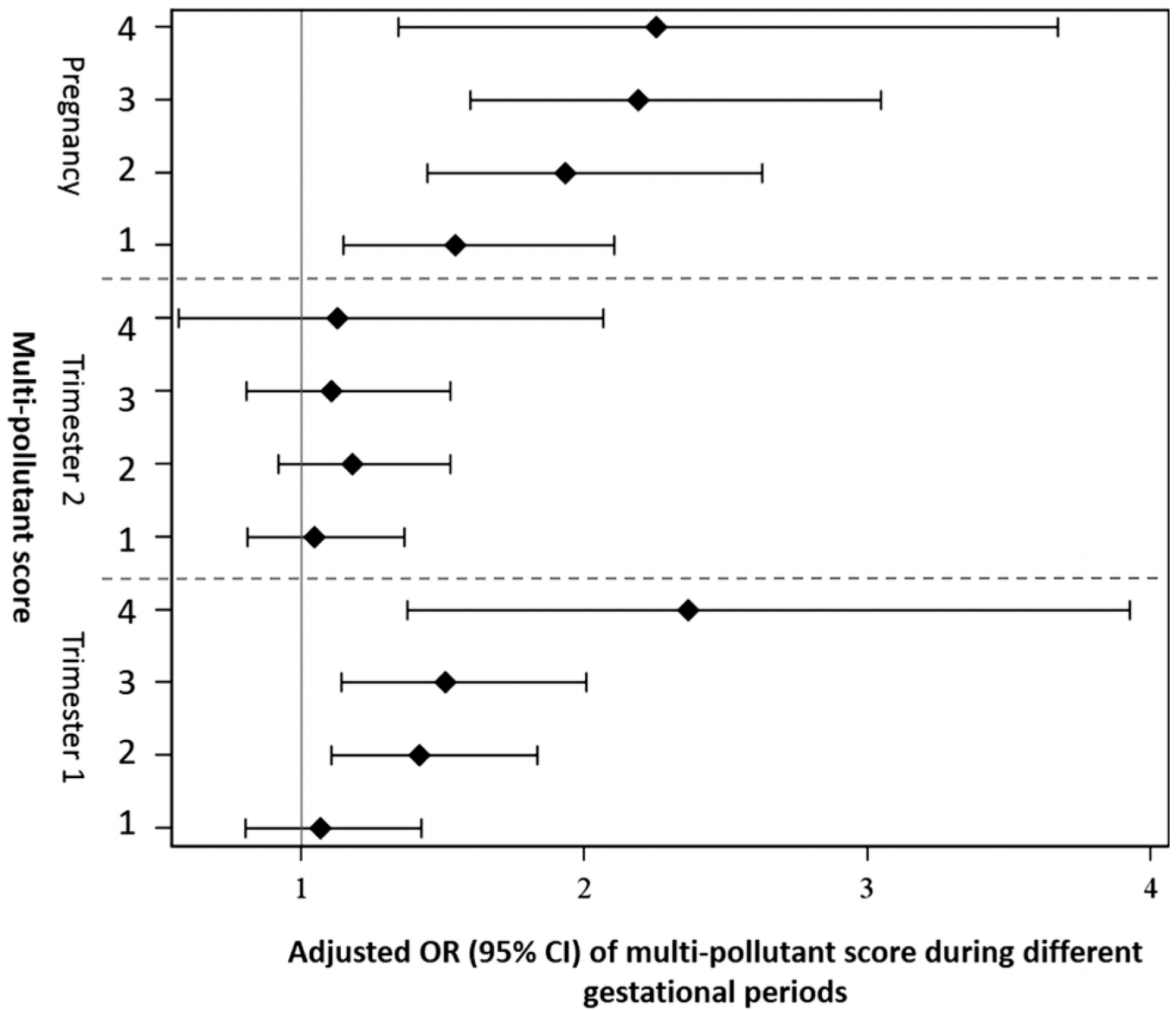


Figure 3. Adjusted ORs for risk of hypertensive disorders of pregnancy for multipollutant score during different gestational periods among women who gave birth from 2004 to 2005 in Jacksonville, Florida, USA. The point reflects the central estimate; the horizontal line represents the 95% CI.

Table 1

Concentrations of air pollutants and observational days by monitor from 2003 to 2005 in Jacksonville, Florida, USA

Monitor ID	Observational days	Daily mean	The 5th centile	The 25th centile	Median	The 75th centile	The 95th centile
NO₂ (ppb)							
12-031-0032	937	27.95	12.00	20.00	26.00	34.00	48.00
PM₁₀ (µg/m³)							
12-031-0053	180	21.98	11.50	16.00	21.00	25.50	36.00
12-031-0084	182	26.17	13.00	20.00	25.00	31.00	41.00
12-031-0089	182	22.29	11.00	16.00	22.00	26.00	38.00
PM_{2.5} (µg/m³)							
12-031-0098	1005	10.01	3.70	6.50	9.00	12.30	19.40
12-031-0099	1095	10.44	4.00	6.80	9.50	12.60	20.40
SO₂ (ppb)							
12-031-0032	1034	6.74	0.00	2.00	4.00	8.00	23.00
12-031-0080	986	4.69	0.00	1.00	2.00	6.00	18.00
12-031-0081	1002	8.72	0.00	1.00	3.00	8.00	41.00
12-031-0097	976	7.12	0.00	2.00	4.00	8.00	28.00
CO (ppm)							
12-031-0080	990	0.50	0.50	0.30	0.40	0.60	1.10
12-031-0083	917	0.60	0.30	0.40	0.50	0.70	1.20
12-031-0084	1012	0.85	0.30	0.50	0.80	1.10	1.70
O₃ (ppm)							
12-031-0077	982	0.038	0.019	0.029	0.037	0.047	0.062
12-031-0100	1017	0.042	0.021	0.032	0.040	0.051	0.067

Table 2
Exposure information concerning NO₂, PM_{2.5}, SO₂, CO and O₃ by gestational hypertension (GH) status

	Trimester 1			Trimester 2			Full gestational period					
	GH (n=1037)	No GH (n=21 004)	Total (n=22 041)	p Value	GH (n=1037)	No GH (n=21 004)	Total (n=22 041)	p Value	GH (n=1037)	No GH (n=21 004)	Total (n=22 041)	p Value
NO ₂ (ppb)												
Mean (SD)	28.54 (3.68)	27.95 (3.73)	27.98 (3.73)	<0.01	27.97 (3.76)	27.89 (3.77)	27.90 (3.77)	0.55	28.12 (1.70)	27.83 (1.52)	27.84 (1.53)	<0.01
Median	28.74	28.27	28.28		28.44	28.23	28.24		28.08	27.76	27.77	
IQR	4.71	5.34	5.39		6.19	6.44	6.43		1.79	1.64	1.65	
PM _{2.5} (µg/m ³)												
Mean (SD)	10.18 (0.85)	10.11 (0.92)	10.12 (0.91)	0.02	10.39 (0.75)	10.16 (0.85)	10.17 (0.85)	<0.01	10.38 (0.38)	10.28 (0.44)	10.29 (0.44)	<0.01
Median	10.22	10.21	10.21		10.39	10.12	10.13		10.40	10.33	10.33	
IQR	1.20	1.18	1.18		1.15	1.26	1.25		0.54	0.67	0.67	
SO ₂ (ppb)												
Mean (SD)	6.33 (2.67)	5.96 (2.79)	5.98 (2.79)	<0.01	5.99 (2.73)	6.08 (2.72)	6.07 (2.72)	0.29	6.15 (1.78)	6.08 (1.72)	6.08 (1.72)	0.17
Median	6.31	5.84	5.85		5.86	5.89	5.89		5.91	5.74	5.75	
IQR	3.69	3.72	3.73		3.77	3.70	3.70		2.70	2.54	2.55	
CO (ppm)												
Mean (SD)	0.65 (0.23)	0.63 (0.21)	0.63 (0.21)	<0.01	0.60 (0.22)	0.61 (0.22)	0.61 (0.22)	0.13	0.60 (0.17)	0.60 (0.17)	0.60 (0.17)	0.68
Median	0.59	0.56	0.57		0.52	0.55	0.55		0.55	0.57	0.57	
IQR	0.29	0.24	0.24		0.25	0.25	0.25		0.16	0.15	0.15	
O ₃ (ppm)												
Mean (SD)	0.041 (0.006)	0.040 (0.006)	0.040 (0.006)	0.40	0.041 (0.006)	0.041 (0.005)	0.041 (0.005)	0.13	0.041 (0.003)	0.040 (0.003)	0.040 (0.003)	<0.01
Median	0.041	0.040	0.040		0.042	0.041	0.041		0.041	0.041	0.041	
IQR	0.011	0.009	0.010		0.008	0.009	0.009		0.003	0.003	0.003	

Table 3

Correlation between criteria air pollutants in different gestational periods

	NO ₂	PM _{2.5}	SO ₂	CO	O ₃
Trimester 1					
NO ₂	1.00	0.02*	0.15*	0.01	0.35*
PM _{2.5}	-	1.00	0.20*	0.03*	0.02*
SO ₂	-	-	1.00	0.29*	-0.36*
CO	-	-	-	1.00	-0.61*
Trimester 2					
NO ₂	1.00	-0.18*	0.08*	0.09*	0.29*
PM _{2.5}	-	1.00	0.13*	0.04*	-0.14*
SO ₂	-	-	1.00	0.25*	-0.39*
CO	-	-	-	1.00	-0.62*
Full gestational period					
NO ₂	1.00	-0.04*	0.06*	0.08*	0.22*
PM _{2.5}	-	1.00	0.10*	-0.15*	0.36*
SO ₂	-	-	1.00	0.18*	-0.28*
CO	-	-	-	1.00	-0.62*

* p<0.05.

Table 4

Maternal characteristics of women by hypertensive disorders of pregnancy (HDP) status among women who gave birth from 2004 to 2005 in Jacksonville, Florida, USA

	HDP (n=1037)	No HDP (n=21 004)	
	n (%)	n (%)	p Value
Maternal age (years)			
<20	117 (11.3)	2549 (12.1)	0.50
20–24	309 (29.8)	6322 (30.1)	
25–29	266 (25.7)	5588 (26.6)	
30–34	212 (20.4)	4257 (20.3)	
35–39	108 (10.4)	1852 (8.8)	
40	25 (2.4)	435 (2.1)	
Race			
Non-Hispanic White	536 (51.7)	10 787 (51.4)	<0.01
Non-Hispanic Black	404 (39.0)	7233 (34.4)	
Others	97 (9.4)	2984 (14.2)	
Maternal education			
<High school	155 (15.2)	3676 (17.7)	0.06
High school or equivalent	341 (33.4)	7085 (34.1)	
>High school	526 (51.5)	10 043 (48.3)	
Marital status			
Married	611 (59.0)	11 986 (57.1)	0.24
Not married	426 (41.1)	9017 (42.9)	
Smoked during pregnancy			
No	954 (93.4)	18 919 (91.6)	0.11
Yes, and <10 cigarettes/day	28 (2.7)	781 (3.8)	
Yes, and ≥10 cigarettes/day	39 (3.8)	947 (4.6)	
Season of conception			
Warm	509 (49.1)	10 032 (47.8)	0.41
Cool	528 (50.9)	10 972 (52.2)	
Year of conception			
2003	306 (29.5)	7593 (36.2)	<0.01
2004	563 (54.3)	10 499 (50.0)	
2005	168 (16.2)	2912 (13.9)	
Prenatal care began			
No care	8 (1.0)	230 (1.6)	0.04
First trimester	602 (77.2)	10 792 (73.8)	
Second trimester	149 (19.1)	2963 (20.3)	
Third trimester	21 (2.7)	641 (4.4)	
Tract median household income			
Low	340 (32.8)	6899 (32.9)	0.07
Moderate	377 (36.4)	6996 (33.3)	

	HDP (n=1037)	No HDP (n=21 004)	
	n (%)	n (%)	p Value
High	320 (30.9)	7109 (33.9)	

Table 5

ORs for risk of hypertensive disorders of pregnancy for an IQR increase in air pollution (NO₂, PM₁₀, PM_{2.5}, SO₂, CO and O₃) exposure by air pollutants and pregnancy period of exposure among women who gave birth from 2004 to 2005 in Jacksonville, Florida, USA

	Unadjusted OR (95% CI)	Adjusted OR [†] (95% CI)
NO ₂		
Trimester 1	1.25 (1.15 to 1.37)*	1.14 (1.01 to 1.29)*
Trimester 2	1.03 (0.93 to 1.15)	0.98 (0.83 to 1.15)
Pregnancy	1.21 (1.14 to 1.29)*	1.21 (1.09 to 1.35)*
PM _{2.5}		
Trimester 1	1.09 (1.01 to 1.19)*	1.10 (0.99 to 1.23)
Trimester 2	1.51 (1.38 to 1.67)*	1.28 (1.13 to 1.46)*
Pregnancy	1.40 (1.27 to 1.55)*	1.24 (1.08 to 1.43)*
SO ₂		
Trimester 1	1.19 (1.10 to 1.29)*	1.14 (1.03 to 1.26)*
Trimester 2	0.96 (0.88 to 1.04)	1.00 (0.89 to 1.11)
Pregnancy	1.07 (0.97 to 1.17)	1.13 (1.01 to 1.25)*
CO		
Trimester 1	1.12 (1.04 to 1.19)*	1.19 (1.07 to 1.31)*
Trimester 2	0.95 (0.88 to 1.02)	1.06 (0.95 to 1.18)
Pregnancy	0.99 (0.93 to 1.05)	1.12 (1.03 to 1.22)*
O ₃		
Trimester 1	1.05 (0.95 to 1.16)	1.00 (0.84 to 1.19)
Trimester 2	1.08 (0.98 to 1.19)	0.94 (0.82 to 1.07)
Pregnancy	1.21 (1.12 to 1.31)*	0.98 (0.87 to 1.11)

* p<0.05.

[†] Adjusted for maternal age, race, education, marital status, smoking during pregnancy, season of conception, year of conception, prenatal care began and tract median household income.