Published in final edited form as:

Spat Spatiotemporal Epidemiol. 2019 June ; 29: 43–50. doi:10.1016/j.sste.2019.03.002.

A Bayesian Spatio-temporal Analysis on Racial Disparities in Hypertensive Disorders of Pregnancy in Florida, 2005-2014

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Abstract

Disparities in hypertensive disorders of pregnancy (HDP) exist among racial and ethnic groups in the US. However, little is known about spatio-temporal variations in HDP disparities. We used a Bayesian hierarchical regression approach to investigate spatio-temporal variations in HDP disparities from 2005 to 2014. County-level variation was firstly examined, followed by census tract-level variation assessment in counties where high HDP disparities were observed. A significant disadvantage in HDP was revealed for African Americans in Florida overall (Odds Ratio: 1.27, 95% Confidence Interval: 1.25, 1.29), with significant spatial variations. The greatest HDP disparities between African Americans and non-African Americans occurred in North Central Florida counties (the Big Bend region of Florida), with consistent patterns from 2005 to 2014. Analyses at census tract-level further revealed significant neighborhood disparities within these counties. Findings from this study provide important information for public health agencies and policymakers to reduce HDP disparities at the population level.

Keywords

Hypertensive disorders of pregnancy; Racial disparities; Bayesian; Spatio-temporal analysis

Introduction

Hypertensive disorders of pregnancy (HDP) are common pregnancy complications, characterized by high blood pressure, usually after 20 weeks of gestation when the change in blood volume leads to higher stress on the cardiovascular system (Yoder, Thornburg, & Bisognano, 2009). HDP have been linked to increased neonatal and maternal morbidity and mortality (Allen, Joseph, Murphy, Magee, & Ohlsson, 2004; Bauer & Cleary, 2009; Bellamy, Casas, Hingorani, & Williams, 2007; Duley, 2009; Lo, Mission, & Caughey, 2013;

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Competing financial interests: The authors disclose that they have no actual or potential competing financial interests.

Wang et al., 2012; Wu et al., 2009). Despite serious consequences, the biological mechanisms underlying HDP have not been fully elucidated. Known risk factors for HDP include maternal factors such as new paternity, obesity, age of 35 years or older, adolescent pregnancy, insulin resistance, pre-pregnancy hypertension or diabetes mellitus, pregnancy-related factors such as multiple gestation, placental abnormalities, weight gain, and gestational diabetes mellitus (GDM), family history of pre-eclampsia (Wolf et al., 2004). In addition, it is recently revealed that environmental factors may also play an important role in HDP (Alpérovitch et al., 2009; Brook et al., 2004; Brook et al., 2010; Dong et al., 2013; Houston, 2007; Hu et al., 2014; Osorio-Yañez et al., 2016; Strand, Barnett, & Tong, 2011; Tran et al., 2015; Vinikoor-Imler, Gray, Edwards, & Miranda, 2012).

The burden of HDP falls disproportionately on African Americans (Tanaka, Jaamaa, Kaiser, & Hills, 2007). A 10-year longitudinal study in New York State reported that 8.5% of African American women had HDP during pregnancy, compared with 5.5% and 6.2% in White and Hispanic women, respectively (Tanaka et al., 2007). More importantly, Tanaka et al. found an increasing trend of racial disparities in HDP that appear to be independent of the influences of other risk factors such as new paternity, multiple gestation, and extreme reproductive age.

The state of Florida is the third most populous state in the US, with a current population estimate of 20.9 million persons and over 200 thousand pregnant women annually. However, for such a large and dynamic state, little population-based HDP disparity research has been conducted. The goal of this study is to investigate the spatio-temporal variation in HDP disparities between African American and non-African American women in Florida between 2005 and 2014 using incidence data from the statewide population-based birth records.

Materials and Methods

Study population

Individual records of all registered live births in Florida between 2005 and 2015 (n=2,423,064) were obtained from the Bureau of Vital Statistics & Office of Health Statistics and Assessment, Florida Department of Health (Jacksonville, Florida, <http://www.floridahealth.gov/certificates/certificates/>). Births with maternal residential addresses outside Florida (n=12,051) were excluded. Among the 2,411,013 births, a total of 2,409,922 records (99.9%) were successfully geocoded. To avoid fixed cohort bias (Barnett, 2011), we included births based on conception date instead of delivery date. Among the geocoded births, 2,188,207 records with conception date between January 1, 2005 and December 31, 2014 were included. We then excluded duplicated records for women with multiple births, and 2,154,389 women were included. Finally, we excluded women with missing information on HDP or race/ethnicity, and a total of 2,119,273 women were included in the analyses.

Outcome assessment

Diagnoses of pre-pregnancy hypertension, gestational hypertension or preeclampsia, and eclampsia were collected in the Birth Records data. Gestational hypertension was defined as development of hypertension after 20 weeks of pregnancy. We determined preeclampsia as

new onset of hypertension and proteinuria after 20 weeks of pregnancy, and eclampsia by the onset of convulsions, as well as the presence of preeclampsia. Similar to previous studies (Hu et al., 2014; Hu, Ha, & Xu, 2017), we used a restricted definition of HDP which excludes pre-pregnancy hypertension.

Race/ethnicity and Covariates

We categorized race/ethnicity as a binary variable (African Americans and non-African Americans) since similar HDP incidence rates were observed among subgroups of non-African Americans (e.g. non-Hispanic Whites, Hispanics, Asians) in Florida. Age was categorized into six groups (<20, 20–24, 25–29, 30–34, 35–39, and 40 years old), and education was treated as a three-level categorical variable (<high school, high school or equivalent, and > high school). Pregnancy smoking status (yes/no) and pre-pregnancy Body Mass Index (BMI, underweight, normal, overweight, and obese) were also obtained.

Statistical analysis

Distribution of race/ethnicity and covariates between women with HDP and those without HDP was examined. Conventional regression models were firstly fitted to generate the statewide RR/OR of HDP comparing African American with non-African American. We then used a two-step process to assess spatio-temporal patterns of racial disparities in HDP among women with nonmissing information on age, education, and smoking during pregnancy ($n=2,104,057$). Firstly, county-level analyses were performed, and then for counties with high racial disparities detected in the first step, we further conducted a census tract-level analyses to depict spatio-temporal patterns.

County-level Analyses.—In the first set of models, we treated HDP as a count variable, and aggregated it at county-level by race/ethnicity, year of conception, and covariates, with the observed number of HDP cases y_{ijkl} for the i^{th} county, j^{th} year, k^{th} race/ethnicity, and l^{th} covariates. We then calculated the expected number of cases, e_{ijkl} , by assuming each county had the average incidence rate from 2005 to 2014, r_{kl} , by race/ethnicity and covariates:

$$e_{ijkl} = \sum n_{ijkl} \times r_{kl}$$

where n_{ijkl} is the total number of pregnant women for the i^{th} county, j^{th} year, k^{th} race/ethnicity, and l^{th} covariates. A set of Poisson Bayesian hierarchical models were used to assess spatio-temporal patterns of racial disparities at county-level: $y_{ijkl} | \theta_{ijkl} \sim \text{Poisson}(e_{ijkl} * \theta_{ijkl})$, where θ_{ijkl} is the relative risk. We started with a model that does not allow spatio-temporal variations in racial disparities:

$$\begin{aligned}
\ln(\theta_{ijkl}) &= \alpha + \delta \times race_k + \sum_l \beta_l x_l + t_j \\
\alpha &\sim U(-inf, inf) \\
\delta &\sim N(0, .0001) \\
\beta_l &\sim N(0, .0001) \\
t_j &\sim N(0, \tau_t) \\
\tau_t &\sim \log\text{Gamma}(1, .0005)
\end{aligned}$$

where α is the intercept, δ measures the racial disparity between African American and non-African American women, $\sum_l \beta_l x_l$ incorporates the linear predictor effects of the four covariates, and t_j is an unstructured random effect term for time heterogeneity. We used non-informative priors for (hyper-) parameters in all the models.

We then incorporated a convolution spatial prior to allow racial disparities to vary spatially:

$$\begin{aligned}
\ln(\theta_{ijkl}) &= \alpha + \delta_i \times race_k + \sum_l \beta_l x_l + t_j \\
\delta_i &= \delta_\alpha + \delta_{v_i} + \delta_{u_i} \\
\alpha &\sim U(-inf, inf) \\
\delta_\alpha &\sim N(0, .0001) \\
\delta_{v_i} &\sim N(0, \tau_{\delta_v}) \\
\delta_{u_i} &\sim \mathcal{N}\left(\frac{1}{n_i} \sum_{i \sim m} \delta_{u_m}, \frac{1}{n_i \tau_{\delta_u}}\right) \\
\beta_l &\sim N(0, .0001) \\
t_j &\sim N(0, \tau_t) \\
\tau_{\delta_v} &\sim \log\text{Gamma}(1, .0005) \\
\tau_{\delta_u} &\sim \log\text{Gamma}(1, .0005) \\
\tau_t &\sim \log\text{Gamma}(1, .0005)
\end{aligned}$$

where δ_i is a convolution spatial prior, corresponding to the Besag, York & Mollie (BYM) model, which consists of the intercept, δ_α , an unstructured heterogeneity term for each county, δ_{v_i} , and a structured heterogeneity term, δ_{u_i} . Instead of assuming the entire state had

the same racial disparity between African American and non-African American women, δ_i adds more flexibility to the first model by allowing racial disparity to vary spatially across counties.

Finally, we further added a temporally unstructured term to allow racial disparities to vary temporally:

$$\ln(\theta_{ijkl}) = \alpha + \delta_{ij} \times race_k + \sum_l \beta_l x_l + t_j$$

$$\delta_{ij} = \delta_\alpha + \delta_{v_i} + \delta_{u_i} + \delta_{t_j}$$

$$\alpha \sim U(-inf, inf)$$

$$\delta_\alpha \sim N(0, .0001)$$

$$\delta_{v_i} \sim N\left(0, \tau_{\delta_v}\right)$$

$$\delta_{u_i} \sim \mathcal{N}\left(\frac{1}{n_i} \sum_m \delta_{u_m}, \frac{1}{n_i \tau_{\delta_u}}\right)$$

$$\delta_{t_j} \sim N\left(0, \tau_{\delta_t}\right)$$

$$\beta_l \sim N(0, .0001)$$

$$t_j \sim N(0, \tau_t)$$

$$\tau_{\delta_v} \sim \log\text{Gamma}(1, .0005)$$

$$\tau_{\delta_u} \sim \log\text{Gamma}(1, .0005)$$

$$\tau_{\delta_t} \sim \log\text{Gamma}(1, .0005)$$

$$\tau_t \sim \log\text{Gamma}(1, .0005)$$

where the term, δ_{t_j} , is a temporally unstructured random effect for each year, which now allows the disparity to vary not only spatially, but also temporally.

Census Tract-level Analyses.—For counties with high racial disparities identified in the first step, we further conducted census tract-level analyses. In the second step, we treated HDP as a binary variable, and a set of Logistic Bayesian hierarchical models were used to assess spatio-temporal patterns of racial disparities at census tract-level using un-aggregated individual-level data: $y_{ijkl}/\eta_{ijkl} \sim \text{Binomial}(n_{ijkl}, p_{ijkl})$, where η_{ijkl} is the odds ratio, and

$p_{ijkl} = \frac{e^{\eta_{ijkl}}}{1 + e^{\eta_{ijkl}}}$. Similar to the first step, we started with a model that does not allow spatio-temporal variations in racial disparities:

$$\begin{aligned}\eta_{ijkl} &= \alpha + \delta \times \text{race}_k + \sum_l \beta_l x_l + t_j \\ \alpha &\sim U(-\text{inf}, \text{inf}) \\ \delta &\sim N(0, .0001) \\ \beta_l &\sim N(0, .0001) \\ t_j &\sim N(0, \tau_t) \\ \tau_t &\sim \text{logGamma}(1, .0005)\end{aligned}$$

We then incorporated a convolution spatial prior corresponding to the BYM model to allow racial disparities to vary spatially:

$$\begin{aligned}\eta_{ijkl} &= \alpha + \delta \times \text{race}_k + \sum_l \beta_l x_l + t_j \\ \delta &= \delta_\alpha + \delta_{v_i} + \delta_{u_i} \\ \alpha &\sim U(-\text{inf}, \text{inf}) \\ \delta_\alpha &\sim N(0, .0001) \\ \delta_{v_i} &\sim N\left(0, \tau_{\delta_v}\right) \\ \delta_{u_i} &\sim \mathcal{N}\left(\frac{1}{n_i} \sum_{m \sim i} \delta_{u_m}, \frac{1}{n_i \tau_{\delta_u}}\right) \\ \beta_l &\sim N(0, .0001) \\ t_j &\sim N(0, \tau_t) \\ \tau_{\delta_v} &\sim \text{logGamma}(1, .0005) \\ \tau_{\delta_u} &\sim \text{logGamma}(1, .0005) \\ \tau_t &\sim \text{logGamma}(1, .0005)\end{aligned}$$

Finally, we added a temporally unstructured term to allow racial disparities to vary temporally:

$$\eta_{ijkl} = \alpha + \delta \times \text{race}_k + \sum_l \beta_l x_l + t_j$$

$$\delta = \delta_\alpha + \delta_{v_i} + \delta_{u_i} + \delta_{t_j}$$

$$\alpha \sim U(-\text{inf}, \text{inf})$$

$$\delta_\alpha \sim N(0, .0001)$$

$$\delta_{v_i} \sim N\left(0, \tau_{\delta_v}\right)$$

$$\delta_{u_i} \sim \mathcal{N}\left(\frac{1}{n_i} \sum_m \delta_{u_m}, \frac{1}{n_i \tau_{\delta_u}}\right)$$

$$\delta_{t_j} \sim N\left(0, \tau_{\delta_t}\right)$$

$$\beta_l \sim N(0, .0001)$$

$$t_j \sim N\left(0, \tau_t\right)$$

$$\tau_{\delta_v} \sim \text{logGamma}(1, .0005)$$

$$\tau_{\delta_u} \sim \text{logGamma}(1, .0005)$$

$$\tau_{\delta_t} \sim \text{logGamma}(1, .0005)$$

$$\tau_t \sim \text{logGamma}(1, .0005)$$

We used the Integrated Nested Laplace Approximation (INLA) for model fitting, which is developed to fit latent Gaussian models and offers more computational efficiency compared with the traditional Markov Chain Monte Carlo (MCMC) approach while generates comparable results to MCMC (Blangiardo, Cameletti, Baio, & Rue, 2013; Martins, Simpson, Lindgren, & Rue, 2013). INLA has been increasingly used in spatial epidemiology and health disparities studies (Bravo, Anthopolos, Kimbro, & Miranda, 2018; Sparks, 2015). We implemented INLA using the INLA package in R. Model fits were assessed by the Deviance Information Criterion (DIC), and models with lower DIC values are considered better. Relative risks (RRs) and odds ratios (ORs) of HDP were generated for each year during the study period comparing African American to non-African American for each county and census tract, respectively. Exceedance probabilities of RR/OR greater than the statewide RR/OR were also calculated.

Results

Of the 2,119,273 women included in this study, 108,771 (5.1%) had HDP. A total of 2,104,057 women including 108,051 HDP cases had complete data for all covariates except for BMI. Figure 1 shows the incidence of HDP by race/ethnicity during 2005–2014 in

Florida. Consistent racial disparities in HDP were observed in the study period. In 2005, 6.2% and 4.5% African American and non-African American women had HDP during pregnancy, respectively, while in 2014, 6.6% and 4.7% African American and non-African American women had HDP, respectively. Supplemental Figures 1 and 2 shows the spatial distributions of maternal characteristics at county-level and census tract-level, respectively.

Table 1 shows the distribution of maternal characteristics by HDP status. Women with HDP were less likely than those without HDP to be between 25 and 34 years old, and more likely to be African Americans. Compared with women without HDP, HDP cases were less likely to have smoked during pregnancy, and had higher pre-pregnancy BMI.

Table 2 shows the RRs and ORs of HDP comparing African Americans vs. non-African Americans from the Poisson and Logistic models, respectively. The unadjusted models showed that African Americans had a RR of 1.42 (95% CI: 1.40, 1.44) and an OR of 1.45 (95% CI: 1.43, 1.45) compared with non-African Americans. Consistent results were observed after controlling for covariates. Compared to non-African Americans, African Americans had a RR of 1.25 (95% CI: 1.23, 1.27) and an OR of 1.27 (95% CI: 1.25, 1.29).

Supplemental Table 1 shows the model fits for the alternative Bayesian model specifications. For county-level analyses, there is strong evidence that Model 1 with no spatio-temporal variations and Model 2 with only pure spatial variations are not adequate to describe the patterns of racial disparities in HDP, compared to Model 3 using the DIC. Figure 2 presents the county-level estimated relative risk (RR) of racial disparities (e^{δ}) and exceedance probability (EP) of $RR > 1.25$ for HDP for each year during 2005 to 2014, estimated from Model 3. Each panel in Figure 2 shows the spatial distribution of the RR and EP for each year between 2005 and 2014. Consistent elevated RRs were observed in the Big Bend region during the study period. These counties include Gadsden, Liberty, Franklin, Leon, Wakulla, Jefferson, Madison, and Taylor, with the highest RRs consistently observed in Wakulla and Jefferson County. Lower risk for African Americans occurs in South Florida and along the west coastline. Figure 2 also shows the exceedance probabilities of $RR > 1.25$ over time. The Big Bend region has persistent and significant exceedance probabilities over 95% of $RR > 1.25$.

Census tract-level analyses were conducted mainly focusing on the Big Bend region where consistently elevated racial disparities in HDP have been observed (Supplemental Figure 3). Similar to the county-level analyses, a model incorporating both spatial and temporal variations shows the best fit (Supplemental Table 1). Figure 3 shows the estimated odds ratio (OR) and EP of $OR > 1.27$ during 2005 and 2014. When focusing on census tracts, larger temporal variations were found compared with the county-level analyses, with the highest ORs observed in 2012 and 2013. Supplemental Table 2 shows the ORs and 95% credible intervals (95% CIs) for each census tract. In addition to the census tracts in Wakulla and Jefferson that have elevated ORs similar to the results of county-level analyses, a census tract in Gadsden County also shows consistently higher OR across the study period. Exceedance probabilities over 95% of $OR > 1.27$ were also observed in these census tracts.

Discussion

In this study, we found that there were large spatiotemporal variations of racial disparities in HDP in Florida. Using the statewide birth records data, we conducted two sets of analyses focusing on county- and census tract-levels. The county-level analyses showed large spatial variations and little temporal variations in HDP racial disparities. The Big Bend region had the highest racial disparities consistently across the study period. Further analyses at the census tract-level focusing on the Big Bend region identified large spatial variations as well as large temporal variations at the census tract-level.

These results add to the literature in health disparities within the state of Florida by using advanced Bayesian statistical methods to assess the spatiotemporal non-stationarity of health disparities in HDP. In both the county-level analyses and the census tract-level analyses, the models that best fit the data are the space-time models with both spatially and temporally varying slopes for the disparity between African Americans and non-African Americans. These findings suggests that a spatiotemporally structured model which allows for spatiotemporally structured variations in disparities can explain HDP disparity between African Americans and non-African Americans best. In addition, these results also shows that there are areas (i.e. counties and census tracts) within the state where the African Americans are at higher risk for HDP, and that these areas typically located closely to one another spatially.

The significantly elevated racial disparities observed in the Big Bend region are consistent with previous findings. Counties in the Big Bend region are ranked among the most unhealthy counties in Florida (Remington, Catlin, & Gennuso, 2015), and many of them have significantly higher proportion of African Americans (e.g. 55.3% in Gadsden and 38.2% in Madison) compared with the state average of 15.6%. A previous study assessing late-stage diagnoses of prostate cancer also found larger racial disparities in the Big Bend region (Xiao, Tan, & Goovaerts, 2011). Temporally, an elevated incidence of HDP was observed among both African Americans and non-African Americans in 2008–2009 and 2012, with the largest racial disparities were observed in 2012–2013. We observed larger temporal variations of racial disparities in HDP at census tract-level compared with county-level, suggesting time-dependent factors with high spatial heterogeneity may largely contributing to racial disparities in HDP. Previous studies suggested that the Great Recession of 2007–2009 are associated with many adverse health outcomes but its impact on health disparities are uncertain (Burgard, Ailshire, & Kalousova, 2013), which may be a potential explanation to the elevated incidence and relatively small racial disparities observed in 2008–2009. The increases in racial disparities in 2012–2013 may be potentially linked to the implementation of the Affordable Care Act (Chen, Vargas-Bustamante, Mortensen, & Ortega, 2016), which narrowed the longstanding disparities in health coverage between African Americans and non-African Americans and may lead to more reductions in underdiagnoses of HDP among African Americans. Our findings provide important evidence to guide medical interventions as well as public health and policy interventions to reduce racial disparities in HDP.

Racial residential segregation has been regarded as the fundamental cause of racial disparities in health (Williams & Collins, 2001). In the US, it usually refers to the residential separation of African American neighborhoods from those of other racial groups. Although overt discrimination in housing markets were made illegal by the Civil Rights Act in 1968, racial residential segregation persisted in forms such as racial steering and lending discrimination (Mendez, Hogan, & Culhane, 2013). Previous studies suggested that the average residential context of African American communities is worse than the worst residential context for Whites (Sampson & Wilson, 1995; Williams & Collins, 2001). Studies have linked racial residential segregation to hypertension in the general population (Kershaw et al., 2011). In a parallel literature, racial residential segregation has been associated with adverse birth outcomes (Anthopolos, James, Gelfand, & Miranda, 2011; Anthopolos, Kaufman, Messer, & Miranda, 2014; J. F. Bell, Zimmerman, Almgren, Mayer, & Huebner, 2006; Grady, 2006; Grady & Ramírez, 2008; Osypuk & Acevedo-Garcia, 2008). Combined with the higher temporal variations at the census tract-level, it is highly plausible that the differential exposure to environmental factors, many of which have high spatiotemporal variations, due to racial residential segregation may contribute to racial disparities in HDP. Future studies are needed to identify environmental factors contributing to racial disparities in HDP to inform better intervention strategies. Our findings also demonstrate the impacts of different spatiotemporal scales on study results, especially when the potential risk factors have high spatiotemporal heterogeneity. Future studies with data in high spatiotemporal resolution are warranted to generate precise evidence to support policy changes and interventions.

Our study has several strengths. The Florida Vital Statistics Birth Records data provide a unique opportunity to generate highly representative spatiotemporal distributions of racial disparities in HDP. In addition, instead of many ecological studies, this study is based on individual level data and we were able to account for several important covariates. In spite of these strengths, several limitations need to be noted. Firstly, residential histories of women were not available. However, as suggested by previous studies (M. L. Bell & Belanger, 2012; Hodgson, Lurz, Shirley, Bythell, & Rankin, 2015), most of women who moved during pregnancy tend to move to places nearby. Since we focused on county and census tract in this study, and the Bayesian approach incorporated information from neighboring areas, this limitation may not have substantial impact on the results.

Conclusion

In summary, this study identified large spatiotemporal variations of racial disparities in HDP, and significantly elevated racial disparities were observed in the Big Bend region of Florida. Findings from this study provide important information for public health agencies and policymakers for developing targeted interventions and allocating limited resources more efficiently to reduce HDP disparities at the population level. Further research is needed to identify factors contributing to the racial disparities in HDP.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments:

This work was supported by the Scientist Development Grant (17SDG33630165) from the American Heart Association (AHA). The data were provided by the Bureau of Vital Statistics, Florida Department of Health (DOH). All conclusions are the authors' own and do not necessarily reflect the opinion of the AHA or the Florida DOH.

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Fig. 1.
Incidence of hypertensive disorders of pregnancy by race/ethnicity during 2005–2014 in Florida, USA.

Fig. 2.
Estimated county-level relative risk and exceedance probability for hypertensive disorders of pregnancy comparing African Americans to non-African Americans during 2005–2014 in Florida, USA.

Fig. 3. Estimated census tract-level odds ratio and exceedance probability for hypertensive disorders of pregnancy comparing African Americans to non-African Americans during 2005–2014 in the Big Bend region, Florida, USA.

Table 1.

Maternal characteristics by HDP status among women with conception date during 2005–2014 in Florida, USA [n(%)].

Maternal characteristics	HDP (n=108,771)	No HDP (n=2,010,502)	Total (n=2,119,273)
Race/ethnicity			
African American	26,133 (24.0)	359,840 (17.9)	385,973 (18.2)
Non-African American	82,638 (76.0)	1,650,662 (82.1)	1,733,300 (81.8)
Age (years)			
<20	10,641 (9.8)	174,919 (8.7)	185,560 (8.8)
20–24	26,325 (24.2)	497,820 (24.8)	524,145 (24.7)
25–29	29,231 (26.9)	568,808 (28.3)	598,039 (28.2)
30–34	24,368 (22.4)	473,148 (23.5)	497,516 (23.5)
35–39	13,910 (12.8)	238,570 (11.9)	252,480 (11.9)
40	4,295 (3.9)	57,188 (2.8)	61,483 (2.9)
Missing	1 (0.0)	49 (0.0)	50 (0.0)
Education			
<High school	16,894 (15.5)	344,002 (17.1)	360,896 (17.0)
High school or equivalent	34,725 (31.9)	625,250 (31.1)	659,975 (31.1)
>High school	56,587 (52.0)	1,030,369 (51.2)	1,086,956 (51.3)
Missing	565 (0.5)	10,881 (0.5)	11,446 (0.5)
Smoking during pregnancy			
No	101,897 (93.7)	1,863,156 (92.7)	1,965,053 (92.7)
Yes	6,702 (6.2)	143,437 (7.1)	150,139 (7.1)
Missing	172 (0.2)	3,909 (0.2)	4,081 (0.2)
Pre-pregnancy BMI (kg/m ²)			
Underweight (<18.5)	2,528 (2.3)	94,521 (4.7)	97,049 (4.6)
Normal (18.5–24.9)	33,452 (30.8)	950,630 (47.3)	984,082 (46.4)
Overweight (25.0–29.9)	27,792 (25.6)	472,038 (23.5)	499,830 (23.6)
Obese (≥ 30.0)	37,883 (34.8)	375,663 (18.7)	413,546 (19.5)
Missing	7,116 (6.5)	117,650 (5.9)	124,766 (5.9)

Abbreviations: BMI, body mass index; HDP, hypertensive disorders of pregnancy.

Table 2.

RRs and ORs (95% CIs) of HDP.

	Poisson Models		Logistic Models	
	Unadjusted	Adjusted ^a	Unadjusted	Adjusted ^a
Non-African American	Reference	Reference	Reference	Reference
African American	1.42 (1.40, 1.44)	1.25 (1.23, 1.27)	1.45 (1.43, 1.45)	1.27 (1.25, 1.29)

^a Adjusted for age, education, smoking during pregnancy, pre-pregnancy BMI, and year of conception