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## Racial/Ethnic Differences in Infant Mortality Attributable to Birth Defects by Gestational Age

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### Abstract

**Objective**—Birth defects are a leading cause of infant mortality in the United States. Previous reports have highlighted black-white differences in overall infant mortality and infant mortality attributable to birth defects (IMBD). We evaluated the impact of gestational age on US racial/ethnic differences in IMBD.

**Methods**—We estimated the rate of IMBD (using ICD-10 codes for the underlying cause of death) using the period linked birth/infant death data for US residents for January 2003 to December 2006. We excluded infants with missing gestational age, implausible values based on Alexander's index of birth weight for gestational age norms, or gestational ages <20 weeks or >44 weeks; we categorized gestational age into three groups: 20–33; 34–36; and 37–44 weeks. Using Poisson regression, we compared neonatal and postneonatal mortality attributable to birth defects for infants of non-Hispanic black and Hispanic mothers with that for infants of non-Hispanic white mothers stratified by gestational age.

**Results**—IMBD occurred in 12.2 per 10,000 live births. Among infants delivered at 37–44 weeks, blacks (and Hispanics, to a lesser degree) had significantly higher neonatal and postneonatal mortality attributable to birth defects than whites. However, among infants delivered

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Contributor's Statement

All contributors listed as authors (Broussard, Gilboa, Lee, Oster, Petrini, & Honein) qualify for authorship according to the following criteria:

1. Substantial contribution to conception and design, acquisition of data, and/or analysis and interpretation of data;
2. Drafting the article and/or revising it critically for important intellectual content; and
3. Final approval of the version submitted for publication.

at 20–33 or 34–36 weeks, neonatal (but not postneonatal) mortality attributable to birth defects was significantly lower among blacks compared with whites.

**Conclusions**—Racial/ethnic differences in IMBD were not explained in these data by differences in gestational age. Further investigation should include an assessment of possible racial/ethnic differences in severity and/or access to timely diagnosis and management of birth defects.

### Keywords

infant mortality; birth defects; gestational age; race; ethnicity

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## Introduction

Birth defects affect approximately 3% of births in the United States<sup>1</sup> and are responsible for 1 in 5 infant deaths.<sup>2,3</sup> The prevalence of preterm birth (birth at <37 completed weeks gestation) has steadily increased in recent years, and preterm birth is three times as common among non-Hispanic black compared with non-Hispanic white mothers.<sup>4</sup> Black-white disparities in infant mortality attributable to birth defects (IMBD) have also been reported.<sup>5</sup> US studies have shown that all-cause neonatal mortality rates are higher among term infants of black mothers compared with white mothers, but lower among preterm infants of black mothers compared with white mothers.<sup>6,7</sup> A recent Centers for Disease Control and Prevention (CDC) study examined differences in neonatal mortality rates due to congenital heart defects (the leading cause of IMBD) by race and gestational age.<sup>8</sup> Another recent study focused on heterogeneous risk for infant mortality across the range of term births.<sup>9</sup> The current study sought to expand these analyses by examining differences in both neonatal and postneonatal mortality attributable to all birth defects by race/ethnicity and gestational age.

## Methods

### Data source

We used the CDC National Center for Health Statistics' period linked birth/infant death data for US residents, including live births between January 2003 and December 2006, which represented the most recent available at the time of analysis.<sup>10</sup>

### Inclusion/exclusion criteria

We included records of all infants (under age 1 year) whose underlying cause of death on the death certificate was classified as a birth defect according to the *International Classification of Diseases, 10th Revision*, with codes Q01.0–Q99.9, excluding conditions that are considered normal conditions of prematurity (Q21.1: persistent foramen ovale, Q25.0: patent ductus arteriosus, Q33.6: lung hypoplasia, and Q53.1, 53.2, 53.9: undescended testicles) or cardiovascular conditions that were not considered structural heart defects (Q27.0–Q28.9). We restricted the analysis to infants of mothers from the three largest race/ethnicity categories – non-Hispanic white, non-Hispanic black, and Hispanic – as reported on the US birth certificate; those of other racial/ethnic groups were excluded, as were births to and infant deaths of non-US residents. All analyses were based on maternal race/ethnicity.

The gestational age measure from the birth certificate was based on a clinical estimate of elapsed time since the last menstrual period. We categorized gestational age into three groups: 20–33; 34–36; and 37–44 weeks. We excluded linked records with a missing gestational age (0.6% of the total), those with implausible gestational ages based on Alexander’s index of birth weight for gestational age norms (0.6%),<sup>6</sup> and those with gestational ages <20 weeks or >44 weeks (1.1%).

## Analytic methods

We estimated rates of neonatal (age <28 days) and postneonatal (age 28 days to under 1 year) mortality attributable to birth defects overall, and stratified by race/ethnicity and gestational age categories. We also tabulated mortality rates by individual weeks of gestational age, separately by race/ethnicity.

Because not all infant death records could be linked to the corresponding birth certificate, we weighted estimates of infant deaths according to the percentage of records linked by state and age at death. Weighting was necessary to correct in part for biases in the percentage of records linked by these characteristics -- in general, a slightly lower percentage of neonatal than postneonatal deaths was linked for these years (e.g., 98.5 vs. 99.1% for 2005).<sup>10</sup>

We used Poisson regression to estimate rate ratios (RRs) comparing neonatal and postneonatal mortality rates for infants of non-Hispanic black and Hispanic mothers with those of non-Hispanic white mothers, stratified by the three gestational age categories. Variables available on the birth certificate that we considered as potential confounders included maternal age, education, parity (number of live births), plurality, marital status, diabetes, and infant sex. These were selected based on previous literature or biologic plausibility suggesting their association with either neonatal or postneonatal mortality attributable to birth defects. Besides maternal age and education, other variables did not change the effect estimate by greater than 5% in bivariate analysis and were not included in our final models. We examined descriptive data on ‘medical complications’ and ‘labor and delivery complications’ but did not include these in analyses due to the low quality and incompleteness of these variables;<sup>11, 12</sup> we did not adjust for birth weight due to its strong correlation with gestational age.

With the revision of the US birth certificate in 2003 and its variable introduction by states, information on maternal education was not comparable for all states with each year of linked data --- the number of states with non-comparable data for maternal education ranged from 2 US states in 2003 to 19 states and Puerto Rico in 2006 (Tables 1 & 3). Therefore, only records with maternal age and comparable data on maternal education were included in adjusted analyses. We also calculated unadjusted gestational-week specific neonatal and postneonatal mortality rate ratios.

We estimated infant mortality rates and RRs for all birth defects combined as well as for several major birth defect categories, as grouped by the ICD-10 classification scheme. For regression analyses, we included the cleft lip/cleft palate category with the digestive system defects, and we did not examine the “eye, ear, face, and neck” or “other” categories due to sparse numbers.

## Results

### Overall IMBD

The analysis included 15,145,044 live births in the United States during 2003–2006; 9,071,585 births to non-Hispanic white mothers, 2,312,080 births to non-Hispanic black mothers, and 3,761,379 births to Hispanic mothers. A total of 18,080 infant deaths had a birth defect listed as the underlying cause (18% of all infant deaths) after exclusion of the specific ICD codes specified above, and the overall rate of IMBD was 12.2 per 10,000 live births. Race-specific IMBD rates were 11.1, 14.4, and 12.5 per 10,000 live births for non-Hispanic white, non-Hispanic black, and Hispanic mothers, respectively. Congenital heart defects were noted as the underlying cause of death in 31% of IMBD, followed by chromosomal abnormalities, not elsewhere classified (22%), and central nervous system defects (15%), which include neural tube defects. The prevalence of preterm birth among live births was 11% for non-Hispanic white, 18% for non-Hispanic black, and 12% for Hispanic mothers.

### Neonatal Mortality Attributable to Birth Defects

Nearly 69% of IMBD occurred in the neonatal period (Table 1). Neonatal mortality attributable to birth defects ranged from 7.8 per 10,000 live births among non-Hispanic white mothers to 9.1 per 10,000 live births among non-Hispanic black mothers. Across racial/ethnic categories, neonatal mortality attributable to birth defects was higher among both younger and older mothers, mothers with higher parity, multiple births, and mothers with diabetes, fewer years of education, or tobacco use. However, the most substantial elevations were observed for low birth weight or preterm infants. For example, among non-Hispanic white mothers, neonatal mortality attributable to birth defects was substantially higher at 97.5 per 10,000 live births for infants delivered at 20–33 weeks compared with 3.8 per 10,000 for infants delivered at 37–44 weeks. Congenital heart defects were the underlying cause of 24% of neonatal deaths attributable to birth defects.

Given the differences by gestational age, we did not present the overall effect estimates for weeks 20–44. White infants born early preterm (20–33 completed weeks' gestation) had the highest rates of neonatal mortality for nearly all birth defect categories (Table 2). The rate of neonatal mortality attributable to birth defects was significantly lower among black infants delivered at 20–33 or 34–36 weeks gestation compared with whites (for example, for all birth defects combined, the neonatal mortality rates for infants of black and white mothers delivered at 20–33 weeks were 58.6 and 97.5 per 10,000, respectively; RR: 0.6 [95% CI: 0.5,0.6]). The black-white difference was reversed among infants delivered at 37–44 weeks, with neonatal mortality higher among infants of black compared with white mothers (for all birth defects combined, the neonatal mortality rates for infants of black and white mothers delivered at 37–44 weeks gestation were 4.6 and 3.8 per 10,000, respectively; RR: 1.2 [95% CI: 1.1, 1.3]). The neonatal RRs for each birth defect category were similar to those for all birth defects combined, with blacks having lower mortality rates when born preterm, but higher rates when born at term.

Similar to the black-white differences, among term infants, Hispanics had a significantly higher neonatal mortality rate attributable to birth defects than whites overall (RR: 1.2 [95% CI: 1.1, 1.2]) and in most defect categories; however, the differences in the 20–36 weeks gestational age categories were not statistically significant.

We assessed the race/ethnicity-specific rates of neonatal mortality attributable to birth defects graphically by gestational week (Figure 1). We also examined these patterns for each different birth defect category, and the striking neonatal picture was similar for all birth defect groups (individual graphs by defect category not shown).

### Postneonatal Mortality Attributable to Birth Defects

Postneonatal mortality attributable to birth defects ranged from 3.3 per 10,000 live births among non-Hispanic white mothers to 5.3 per 10,000 live births among non-Hispanic black mothers (Table 3). The same maternal characteristics associated with an increased rate of neonatal mortality were also associated with an increased rate of postneonatal mortality, including gestational age.

Comparing infants of black and white mothers, the rates of postneonatal mortality attributable to birth defects (Table 4) were quite different from the rates of neonatal mortality attributable to birth defects (Table 2). Uniquely for postneonatal mortality, blacks born at 34–36 weeks had a higher rate than whites born late preterm (for all birth defects combined, RR: 1.3 [95% CI: 1.1, 1.6]; for chromosomal abnormalities, RR: 2.2 [95% CI: 1.5, 3.3]), and there was no significant difference in the postneonatal mortality rate among blacks and whites born at 20–33 weeks (with RRs of 0.9 and 1.1 for all birth defects combined and chromosomal abnormalities, respectively). However, similarly to neonatal mortality, among term infants, blacks had a significantly higher postneonatal mortality rate than whites (for all birth defects combined, RR: 1.5 [95% CI: 1.4, 1.7]; for chromosomal abnormalities, RR: 2.2 [95% CI: 1.8, 2.7]). Comparing postneonatal mortality attributable to birth defects between Hispanics and whites, there were no statistically significant differences in any gestational age group for all birth defects combined, with RRs ranging from 1.0 to 1.1 (Table 4); however, Hispanics had significantly higher rates for some defect groups, including central nervous system defects (at term) and chromosomal abnormalities (at any gestational age except 20–33 weeks).

We also assessed the race/ethnicity-specific rates of postneonatal mortality attributable to birth defects graphically by gestational week (Figure 2).

## Discussion

Overall racial/ethnic differences in IMBD cannot be explained by differences in gestational age. For both early and late preterm infants, we found neonatal mortality attributable to birth defects to be significantly less likely among non-Hispanic blacks than among non-Hispanic whites. Previous reports support our findings that infants born to black mothers had higher IMBD rates than infants born to white mothers,<sup>5, 13</sup> and that term infants born to black and Hispanic mothers had higher IMBD rates compared to those born to whites.<sup>9</sup>

Similar patterns have been reported for all-cause neonatal mortality by gestational age group in the United States during 1989–2001.<sup>7</sup> The reason for the lower rate of all-cause neonatal mortality among preterm infants of black mothers compared with white mothers is unclear. One possibility is that live-born infants who die shortly after birth might be misclassified as fetal deaths, particularly those born at early gestational ages.<sup>7</sup> The fetal mortality rate in the United States is approximately twice as high among blacks as among whites,<sup>14, 15</sup> and differences by race in reporting fetal deaths versus early neonatal deaths might exist. Recent research has shown variation by state in classification of neonatal death at <24 hours versus fetal death for infants at the limits of viability (i.e., gestation of <24 weeks or birth weight <500 g).<sup>16</sup> Whether such variation might also occur by race/ethnicity is unknown.

Also unclear is whether factors specific to birth defects contribute to the differences in black and white neonatal mortality patterns by gestational age. Potentially, differences in prevalence of specific types of birth defects might explain the differences in mortality patterns. Whereas several categories of birth defects vary by race/ethnicity, no study has identified overall racial/ethnic differences in all birth defects combined.<sup>17–20</sup> There are also many birth defects for which no racial/ethnic differences have been observed; for instance, among studies that included birth defect prevalence among live births, stillbirths, and pregnancy terminations, no racial difference was observed for prevalence of hypoplastic left heart syndrome, the most common specific cause of death attributable to congenital heart defects.<sup>17, 19</sup> Differences in maternal serum screening uptake might also differ by race/ethnicity, which could contribute to differences in prenatal diagnosis of birth defects.<sup>21, 22</sup> Excess postneonatal mortality attributable to chromosomal defects was observed for non-Hispanic blacks and for all gestational age categories of Hispanics compared with non-Hispanic whites. This is consistent with the finding that median age at death for people with Down syndrome is much lower among blacks and other races than among whites;<sup>23–26</sup> no similar study has assessed median age at death for Down syndrome by Hispanic ethnicity.

Improved technologies and neonatal care might have shifted some deaths to the postneonatal period. For instance, in the last decade, a Norwood procedure with a Sano shunt instead of a Blalock-Taussig shunt has become a common alternative for neonates with single-ventricle physiology such as hypoplastic left heart syndrome. A recent randomized, multi-center, clinical trial found that subjects with a Sano shunt had decreased short-term mortality rates as compared to those with a Blalock-Taussig shunt.<sup>27</sup>

In addition to gestational age and race/ethnicity, we found associations of IMBD with maternal age, parity, plurality, and diabetes in both the neonatal and postneonatal periods. These associations are consistent with previous observations on infant mortality from all causes.<sup>28, 29</sup> Our estimate of the IMBD prevalence (18%) is lower than the typically referenced 20%<sup>28</sup> due to our noted ICD exclusions within the larger group of “all congenital malformations”.

Efforts to reduce infant mortality rates due to birth defects should include both: 1) strategies to decrease mortality among those infants living with birth defects through timely and appropriate medical and surgical treatment, and 2) prevention of birth defects, where possible, by addressing modifiable known risk factors such as folic acid use, avoidance of



teratogenic medicines, prevention of certain infections by getting vaccinated and potential risk factors such as pregestational diabetes, obesity, and maternal smoking.<sup>30–33</sup>

This analysis included over 15 million births to non-Hispanic white, non-Hispanic black, and Hispanic mothers in the United States from 2003–2006. Use of the linked birth/infant death files allowed us to assess infant mortality attributable to specific causes while stratifying or adjusting for variables included on the birth certificate.<sup>28</sup> These data also allowed us to ensure that the same maternal race/ethnicity variable (from the US birth certificate) was used for the numerator (infant deaths) and the denominator (total live births); this was essential given the focus of our analysis on racial/ethnic differences.

Because of the evident effect measure modification by gestational age, of not only the *magnitude* but also the *direction* of the effect, adjusting for gestational age or its correlates (such as birth weight), as has been done in previous studies, would likely obscure important differences in infant mortality rates by gestational age and race/ethnicity.

### Limitations

This study has several limitations. Gestational age can be inaccurate on the birth certificate and may be less accurate among preterm births.<sup>6</sup> Although we excluded cases with implausible gestational age/birth weight combinations, we likely included some births for which gestational age was misclassified. The quality of other covariate data available on the birth certificate is also a limitation. Education data from the birth certificate were missing or lacked comparable data for 30% of mothers, limiting the sample size for adjusted analyses, although the adjusted results were very similar to crude results that included the full data set. This analysis included deaths due to birth defects listed as the underlying cause of death and did not identify those listing the defect as only a contributing cause. This likely resulted in an underestimation of the mortality rate due to birth defects. However, this limitation would only impact our analyses of racial/ethnic differences in mortality rates if there were differential reporting of the underlying cause of death among racial/ethnic groups. Finally, there was an underlying assumption of random missingness on the weighting scheme to account for unlinked birth records, and a violation of this assumption might impact these results; however, given the high percentage of linked records, the unweighted results were similar to our weighted results.

### Conclusion

The reasons why infants of black mothers and, to a lesser extent, Hispanic mothers, have higher rates of IMBD than infants of white mothers are unclear. Similarly, we cannot explain why preterm infants of black mothers with birth defects fare better than preterm infants of white mothers, when stratified by gestational age. Further investigation should include assessments of possible racial/ethnic differences in other factors that contribute to infant mortality – such as severity of the defect, access to timely diagnosis, and the quality of medical care provided. In addition, racial/ethnic differences in the frequency of prenatal diagnosis – and the subsequent termination of pregnancies affected by severe birth defects – can contribute to differences in the live birth prevalence of severe defects.<sup>34</sup> Lastly, racial/ethnic differences in the classification of fetuses at the limits of viability as live births (and

subsequent infant deaths) or fetal deaths, could have influenced our results. Given that stillbirths are more common among US black mothers than white,<sup>14, 15</sup> the occurrence of more neonatal deaths among very preterm infants of white mothers than among very preterm infants of black mothers may be reflective of a racial/ethnic difference in the classification of deliveries at the limits of viability.

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## Abbreviations

**IMBD** infant mortality attributable to birth defects

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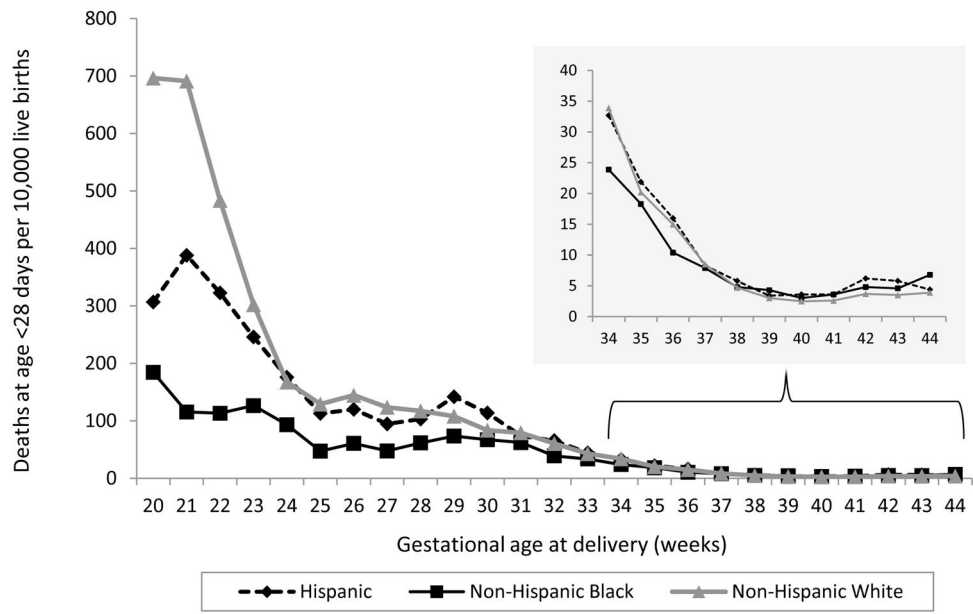
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**What's Known on this Subject**

Birth defects are associated with preterm birth and are a major contributor to infant mortality. There are persistent black-white differences in overall infant mortality and infant mortality attributable to birth defects.

**What This Study Adds**

Among infants delivered at 37–44 weeks, blacks and Hispanics had significantly higher neonatal and postneonatal mortality attributable to birth defects than whites. Among infants delivered at 20–33 or 34–36 weeks, neonatal mortality attributable to birth defects was significantly lower among blacks.



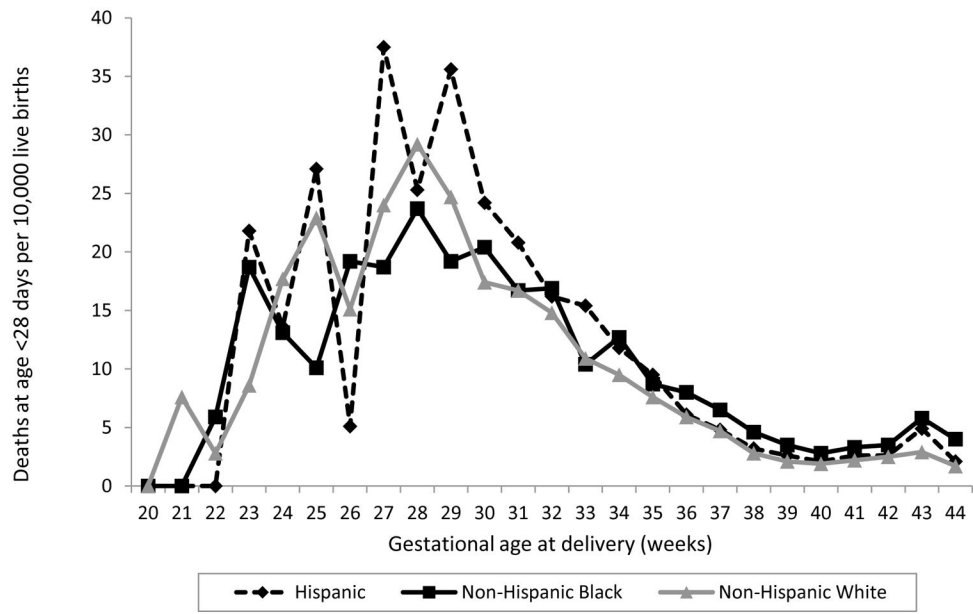
**Figure 1.**  
Neonatal mortality rate attributable to birth defects

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**Figure 2.**  
Postneonatal mortality rate attributable to birth defects

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**Table 1** Maternal and infant characteristics among neonatal deaths attributable to birth defects by race/ethnicity, United States, 2003–2006.

Characteristic	Non-Hispanic White			Non-Hispanic Black			Hispanic		
	Neonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Neonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Neonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births
Total number	7,090	9,071,585	7.8	2,114	2,312,080	9.1	3,250	3,761,379	8.6
Maternal age									
< 20 yrs	590	666,737	8.9	344	397,112	8.7	415	535,193	7.8
20–34 yrs	5,058	6,927,295	7.3	1,390	1,677,422	8.3	2,276	2,828,798	8.1
> 34 yrs	1,442	1,477,553	9.8	380	237,546	16	559	397,388	14.1
Number of previous live births									
1	2,511	3,748,145	6.7	703	880,649	9.0	992	1,351,517	7.3
2–3	3,505	4,482,853	7.8	986	1,068,926	9.2	1,597	1,880,119	8.5
> 3	989	799,493	12.4	395	343,241	11.5	633	516,116	12.3
Missing	85	41,094	20.7	30	19,264	15.6	27	13,627	19.8
Married									
Yes	5,176	6,819,419	7.6	672	704,742	9.5	1,832	1,983,284	9.2
No	1,914	2,252,166	8.5	1,442	1,607,338	9.0	1,418	1,778,095	8.0
Education of Mother**									
<12 years	638	718,851	8.9	360	401,449	9.0	1,118	1,243,939	9.0
12 years	4,393	5,845,041	7.5	1,146	1,331,479	8.6	1,024	1,369,180	7.5
Missing	207	98,907	20.9	90	33,929	26.5	101	53,347	18.9
Exclude***	1,852	2,408,786	7.7	518	545,223	9.5	1,007	1,094,913	9.2
Diabetes									
Yes	273	321,749	8.5	113	78,842	14.3	174	139,928	12.4
No	6,744	8,716,520	7.7	1,986	2,224,794	8.9	3,055	3,610,343	8.5



Characteristic	Non-Hispanic White			Non-Hispanic Black			Hispanic		
	Neonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Neonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Neonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births
Missing	73	33,316	21.9	15	8,444	17.8	20	11,108	18.0
Infant sex									
Male	3,768	4,654,163	8.1	1,104	1,175,772	9.4	1,691	1,919,850	8.8
Female	3,322	4,417,422	7.5	1,010	1,136,308	8.9	1,559	1,841,529	8.5
Plurality									
Single	6,485	8,724,539	7.4	1,956	2,227,016	8.8	3,091	3,676,458	8.4
Multiple	605	347,046	17.4	159	85,064	18.7	158	84,921	18.6
Infant birth weight (grams)									
< 1500	1,141	81,265	140.4	441	48,215	91.5	523	31,606	165.5
1500–2499	2,601	547,557	47.5	755	247,018	30.6	1,236	213,379	57.9
2500	2,391	8,415,792	2.8	639	1,992,639	3.2	1,171	3,504,139	3.3
Missing	958	26,971	355.2	280	24,208	115.7	320	12,255	261.1
Infant gestational age (weeks)									
20 – 33	2,478	254,226	97.5	818	139,520	58.6	1,020	111,670	91.3
34 – 36	1,535	776,573	19.8	422	271,762	15.5	690	330,297	20.9
37 – 44	3,077	8,040,786	3.8	874	1,900,798	4.6	1,540	3,319,412	4.6

\*\* Data were based on the 1989 Revision of the U.S. Certificate of Live Birth.

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Excluded data based on the 2003 Revision; states included Pennsylvania and Washington (2003–2006), Idaho, Kentucky, New York (except New York City), South Carolina, Tennessee, Florida, and New Hampshire (2004–2006), Kansas, Nebraska, Texas, Puerto Rico, Vermont (2005–2006), California (partial revision), Delaware, North Dakota, Ohio, South Dakota, and Wyoming (2006).

**Table 2**

Rates of neonatal mortality attributable to birth defects by race/ethnicity, and adjusted<sup>†</sup> rate ratios comparing infants of non-Hispanic black and Hispanic mothers with those of non-Hispanic white mothers, United States, 2003–2006.

Birth defect category, neonatal deaths (Gestational age in weeks)	Non-Hispanic White (N=9,071,585)		Non-Hispanic Black (N=2,312,080)		Hispanic (N=3,761,379)		Hispanic/ Non-Hispanic White	
	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate Ratio (95% CI)	Rate Ratio (95% CI)	
<i>All birth defects, N=12,454*</i>								
(20 – 33 weeks)	97.5	58.6	91.3	0.6 (0.5–0.6)	0.9 (0.8–1.0)			
(34 – 36 weeks)	19.8	15.5	20.9	0.8 (0.7–0.9)	1.0 (0.9–1.1)			
(37 – 44 weeks)	3.8	4.6	4.6	1.2 (1.1–1.3)	1.2 (1.1–1.2)			
<i>Central nervous system defects, N=2,062</i>								
(20 – 33 weeks)	19.0	8.9	19.1	0.5 (0.4–0.6)	1.0 (0.8–1.2)			
(34 – 36 weeks)	3.0	2.1	3.7	0.5 (0.4–0.7)	1.2 (0.9–1.5)			
(37 – 44 weeks)	0.5	0.6	1.0	0.9 (0.7–1.2)	1.6 (1.4–2.0)			
<i>Chromosomal abnormalities, N=2,891</i>								
(20 – 33 weeks)	21.0	13.5	21.0	0.6 (0.5–0.8)	1.0 (0.8–1.2)			
(34 – 36 weeks)	4.8	3.6	4.9	0.7 (0.6–1.0)	1.2 (1.0–1.5)			
(37 – 44 weeks)	0.9	1.1	1.0	1.3 (1.1–1.5)	1.2 (1.0–1.4)			
<i>Congenital heart defects, N=2,943</i>								
(20 – 33 weeks)	14.8	8.0	13.5	0.6 (0.4–0.7)	0.9 (0.7–1.1)			
(34 – 36 weeks)	4.2	2.7	3.8	0.6 (0.5–0.9)	0.8 (0.6–1.0)			
(37 – 44 weeks)	1.3	1.5	1.2	1.2 (1.0–1.4)	0.9 (0.8–1.0)			
<i>Digestive system/cleft defects, N=145</i>								
(20 – 33 weeks)	1.1	1.1	1.4	0.8 (0.4–1.8)	0.7 (0.3–1.7)			
(34 – 36 weeks)	0.2	0.3	0.1	1.4 (0.5–4.3)	0.7 (0.2–2.6)			
(37 – 44 weeks)	0.0	0.1	0.0	1.9 (1.0–3.7)	0.7 (0.3–1.6)			
<i>Genitourinary system defects, N=1,340</i>								
(20 – 33 weeks)	12.6	7.2	9.9	0.5 (0.4–0.7)	0.7 (0.6–0.9)			
(34 – 36 weeks)	3.0	2.9	3.4	0.9 (0.7–1.2)	1.0 (0.8–1.3)			
(37 – 44 weeks)	0.2	0.3	0.4	1.2 (0.9–1.7)	1.5 (1.1–1.9)			
<i>Musculoskeletal system defects, N=1,462</i>								

Birth defect category, neonatal deaths (Gestational age in weeks)	Non-Hispanic White (N=9,071,585)		Non-Hispanic Black (N=2,312,080)		Hispanic (N=3,761,379)		Non-Hispanic Black/ Non-Hispanic White		Hispanic/ Non-Hispanic White	
	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate Ratio (95% CI)	Rate Ratio (95% CI)	Rate Ratio (95% CI)	Rate Ratio (95% CI)	
(20 – 33 weeks)	10.4	6.5	8.1	0.6 (0.4–0.8)	0.6 (0.5–0.8)					
(34 – 36 weeks)	2.4	1.8	2.5	0.8 (0.5–1.1)	0.9 (0.6–1.2)					
(37 – 44 weeks)	0.5	0.7	0.5	1.4 (1.1–1.8)	1.0 (0.8–1.3)					
<i>Respiratory system defects, N=199</i>										
(20 – 33 weeks)	2.5	1.2	1.5	0.5 (0.3–0.9)	0.7 (0.4–1.3)					
(34 – 36 weeks)	0.3	0.3	0.4	0.8 (0.3–2.1)	1.2 (0.6–2.7)					
(37 – 44 weeks)	0.0	0.0	0.0	1.1 (0.5–2.6)	1.1 (0.5–2.3)					

<sup>†</sup> Adjusted for maternal age and education. Education data from the birth certificate were missing or lacked comparable data for 3,775(30.3%) of mothers.

\* Overall birth defect category includes all subcategories listed in the table plus eye, ear, face, and neck defects (N=5), and defects not included in any other subcategory (N=1,407).

**Table 3** Maternal and infant characteristics among postneonatal deaths attributable to birth defects by race/ethnicity, United States, 2003–2006.

Characteristic	Non-Hispanic White				Non-Hispanic Black				Hispanic			
	Postneonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Postneonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Postneonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Postneonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births
Total number	2,967	9,071,585	3.3	1,224	2,312,080	5.3	1,435	3,761,379	3.8			
Maternal age												
< 20 yrs	289	666,737	4.3	223	397,112	5.6	240	535,193	4.5			
20–34 yrs	2,146	6,927,295	3.1	794	1,677,422	4.7	991	2,828,798	3.5			
> 34 yrs	531	1,477,553	3.6	207	237,546	8.7	204	397,388	5.1			
Number of previous live births												
1	1,103	3,748,145	2.9	398	880,649	4.5	470	1,351,517	3.5			
2–3	1,494	4,482,853	3.3	582	1,068,926	5.4	722	1,880,119	3.8			
> 3	341	799,493	4.3	232	343,241	6.8	230	516,116	4.5			
Missing	29	41,094	7.1	12	19,264	6.2	13	13,627	9.5			
Married												
Yes	2,100	6,819,419	3.1	373	704,742	5.3	711	1,983,284	3.6			
No	866	2,252,166	3.9	851	1,607,338	5.3	724	1,778,095	4.1			
Education of Mother**												
<12 years	351	718,851	4.9	242	401,449	6.0	557	1,243,939	4.5			
12 years	1,818	5,845,041	3.1	673	1,331,479	5.0	442	1,369,180	3.2			
Missing	55	98,907	5.6	15	33,929	4.4	35	53,347	6.6			
Exclude***	743	2,408,786	3.1	294	545,223	5.4	401	1,094,913	3.7			
Diabetes												
Yes	149	321,749	4.6	79	78,842	10.0	74	139,928	5.3			
No	2,792	8,716,520	3.2	1,137	2,224,794	5.1	1,356	3,610,343	3.8			

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Characteristic	Non-Hispanic White			Non-Hispanic Black			Hispanic		
	Postneonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Postneonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births	Postneonatal deaths attributable to birth defects (n)	Live births (n)	Mortality per 10,000 live births
Missing	25	33,316	7.5	8	8,444	9.5	5	11,108	4.5
Infant sex									
Male	1,550	4,654,163	3.3	645	1,175,772	5.5	693	1,919,850	3.6
Female	1,417	4,417,422	3.2	579	1,136,308	5.1	742	1,841,529	4.0
Plurality									
Single	2,789	8,724,539	3.2	1,152	2,227,016	5.2	1,373	3,676,458	3.7
Multiple	177	347,046	5.1	73	85,064	8.6	63	84,921	7.4
Infant birth weight (grams)									
< 1500	238	81,265	29.3	133	48,215	27.6	133	31,606	42.1
1500–2499	913	547,557	16.7	446	247,018	18.1	455	213,379	21.3
2500	1,760	8,415,792	2.1	612	1,992,639	3.1	824	3,504,139	2.4
missing	55	26,971	20.4	32	24,208	13.2	23	12,255	18.8
Infant gestational age (weeks)									
20 – 33	399	254,226	15.7	212	139,520	15.2	212	111,670	19.0
34 – 36	545	776,573	7.0	249	271,762	9.2	271	330,297	8.2
37 – 44	2,023	8,040,786	2.5	763	1,900,798	4.0	952	3,319,412	2.9

\*\* Data were based on the 1989 Revision of the U.S. Certificate of Live Birth.

\*\*\* Excluded data based on the 2003 Revision; states included Pennsylvania and Washington (2003–2006), Idaho, Kentucky, New York (except New York City), South Carolina, Tennessee, Florida, and New Hampshire (2004–2006), Kansas, Nebraska, Texas, Puerto Rico, Vermont (2005–2006), California (partial revision), Delaware, North Dakota, Ohio, South Dakota, and Wyoming (2006).

**Table 4**

Rates of postneonatal mortality attributable to birth defects by race/ethnicity, and adjusted<sup>†</sup> rate ratios comparing infants of non-Hispanic black and Hispanic mothers with those of non-Hispanic white mothers, United States, 2003–2006.

Birth defect category, postneonatal deaths (Gestational age in weeks)	Non-Hispanic White (N=9,071,585)		Non-Hispanic Black (N=2,312,080)		Hispanic (N=3,761,379)		Non-Hispanic Black/ Non-Hispanic White		Hispanic/ Non-Hispanic White	
	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate Ratio (95% CI)	Rate Ratio (95% CI)	Rate Ratio (95% CI)	Rate Ratio (95% CI)	
<i>All birth defects, N=5,626*</i>										
(20–33 weeks)	15.7	15.2	19.0	0.9 (0.7–1.1)	1.1 (0.9–1.3)					
(34–36 weeks)	7.0	9.2	8.2	1.3 (1.1–1.6)	1.1 (0.9–1.3)					
(37–44 weeks)	2.5	4.0	2.9	1.5 (1.4–1.7)	1.0 (0.9–1.1)					
<i>Central nervous system defects, N=653</i>										
(20–33 weeks)	2.1	2.9	3.1	1.2 (0.8–2.0)	1.1 (0.7–1.8)					
(34–36 weeks)	0.8	0.8	1.0	1.1 (0.7–1.8)	1.0 (0.6–1.6)					
(37–44 weeks)	0.2	0.4	0.4	1.4 (1.0–1.9)	1.3 (1.0–1.8)					
<i>Chromosomal abnormalities, N=1,005</i>										
(20–33 weeks)	2.1	2.4	2.8	1.1 (0.7–1.9)	1.5 (0.9–2.4)					
(34–36 weeks)	1.1	2.0	1.6	2.2 (1.5–3.3)	1.8 (1.2–2.7)					
(37–44 weeks)	0.4	0.9	0.6	2.2 (1.8–2.7)	1.3 (1.0–1.6)					
<i>Congenital heart defects, N=2,586</i>										
(20–33 weeks)	6.3	5.2	7.1	0.8 (0.6–1.1)	1.0 (0.8–1.4)					
(34–36 weeks)	3.2	3.6	3.0	0.9 (0.7–1.3)	0.8 (0.6–1.0)					
(37–44 weeks)	1.3	1.9	1.3	1.4 (1.2–1.6)	0.9 (0.8–1.1)					
<i>Digestive system/cleft defects, N=213</i>										
(20–33 weeks)	0.9	1.4	1.2	1.3 (0.6–2.6)	1.1 (0.5–2.5)					
(34–36 weeks)	0.2	0.6	0.5	2.4 (1.2–4.7)	1.5 (0.7–3.1)					
(37–44 weeks)	0.1	0.1	0.1	1.1 (0.5–2.1)	1.2 (0.7–2.1)					
<i>Genitourinary system defects, N=74</i>										
(20–33 weeks)	0.3	0.4	1.3	1.1 (0.3–4.1)	3.7 (1.3–10.4)					
(34–36 weeks)	0.1	0.1	0.1	1.5 (0.5–5.3)	1.0 (0.2–3.9)					
(37–44 weeks)	0.0	0.0	0.0	1.5 (0.5–4.7)	1.0 (0.4–3.1)					
<i>Musculoskeletal system defects, N=507</i>										



Birth defect category, postneonatal deaths (Gestational age in weeks)	Non-Hispanic White (N=9,071,585)		Non-Hispanic Black (N=2,312,080)		Hispanic (N=3,761,379)		Hispanic/ Non-Hispanic White	
	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate/10,000 live births	Rate Ratio (95% CI)	Rate Ratio (95% CI)	
(20 – 33 weeks)	1.5	1.3	1.3	1.3	1.3	0.8 (0.4–1.5)	1.0 (0.5–2.0)	
(34 – 36 weeks)	0.8	0.9	0.9	1.0	1.0	1.1 (0.6–1.8)	1.0 (0.6–1.6)	
(37 – 44 weeks)	0.2	0.3	0.3	0.2	0.2	1.2 (0.8–1.6)	0.8 (0.6–1.1)	
<i>Respiratory system defects, N=89</i>								
(20 – 33 weeks)	0.5	0.2	0.2	0.4	0.4	0.3 (0.1–1.3)	0.4 (0.1–1.8)	
(34 – 36 weeks)	0.1	0.3	0.3	0.0	0.0	0.9 (0.3–2.4)	0.2 (0.0–1.3)	
(37 – 44 weeks)	0.0	0.1	0.1	0.0	0.0	1.0 (0.5–2.1)	0.7 (0.3–1.6)	

<sup>†</sup> Adjusted for maternal age and education. Education data from the birth certificate were missing or lacked comparable data for 3,775(30.3%) of mothers.

\* Overall birth defect category includes all subcategories listed in the table plus eye, ear, face, and neck defects (N=4), and defects not included in any other subcategory (N=495).