The Association Between Race/Ethnicity and Major Birth Defects in the United States, 1999–2007

Mark A. Canfield, PhD, Cara T. Mai, MPH, Ying Wang, PhD, Alissa O'Halloran, MPH, Lisa K. Marengo, MS, Richard S. Olney, MD, Christopher L. Borger, MPH, Rachel Rutkowski, MSPH, Jane Fornoff, PhD, Nila Irwin, Glenn Copeland, MBA, Timothy J. Flood, MD, Robert E. Meyer, PhD, Russel Rickard, MS, C. J. Alverson, MS, Joseph Sweatlock, PhD, and Russell S. Kirby, PhD for the National Birth Defects Prevention Network

Objectives. We investigated the relationship between race/ethnicity and 27 major birth defects.

Methods. We pooled data from 12 population-based birth defects surveillance systems in the United States that included 13.5 million live births (1 of 3 of US births) from 1999 to 2007. Using Poisson regression, we calculated prevalence estimates for each birth defect and 13 racial/ethnic groupings, along with crude and adjusted prevalence ratios (aPRs). Non-Hispanic Whites served as the referent group.

Results. American Indians/Alaska Natives had a significantly higher and 50% or greater prevalence for 7 conditions (aPR = 3.97; 95% confidence interval [CI] = 2.89, 5.44 for anotia or microtia); aPRs of 1.5 to 2.1 for cleft lip, trisomy 18, and encephalocele, and lower, upper, and any limb deficiency). Cubans and Asians, especially Chinese and Asian Indians, had either significantly lower or similar prevalences of these defects compared with non-Hispanic Whites, with the exception of anotia or microtia among Chinese (aPR = 2.08; 95% CI = 1.30, 3.33) and Filipinos (aPR = 1.90; 95% CI = 1.10, 3.30) and tetralogy of Fallot among Vietnamese (aPR = 1.60; 95% CI = 1.11, 2.32).

Conclusions. This is the largest population-based study to our knowledge to systematically examine the prevalence of a range of major birth defects across many racial/ethnic groups, including Asian and Hispanic subgroups. The relatively high prevalence of birth defects in American Indians/Alaska Natives warrants further attention. (*Am J Public Health.* 2014;104:e14–e23. doi:10.2105/AJPH.2014.302098)

Birth defects are a leading cause of infant mortality, accounting for 1 in 5 infant deaths in the United States, and these defects contribute substantially to childhood and adult disability, as well as to health care costs.[1–3] The examination of racial/ethnic variations in birth defects provides clues regarding their etiology from genetic, cultural, environmental, and other factors. The United States has a relatively large, diverse population, providing an opportunity to examine variations among racial/ethnic groups and specific subgroups.

Several population-based studies have examined the racial/ethnic variation of selected birth defects in the United States.[4–9] In addition, a number of publications from individual states have included racial/ethnic data for either specific birth defects or a range of conditions.[10–31] These studies have generally focused on a limited number of racial/ethnic groups or birth defects.

Two previous population-based analyses, conducted through the National Birth Defects Prevention Network (NBDPN), provided clues concerning racial/ethnic variation for a range of birth defects using a large US birth sample.[6,32] However, these analyses did not adjust for important covariates and only examined differences among Blacks and Hispanics relative to Whites. For the present study, we used more recent pooled population-based prevalence data over a longer period of time and for a wider range of racial/ethnic groups to examine differences in the prevalence of birth defects. Our objective was to examine the racial/ethnic differences in the occurrence of 27 major birth defects in the United States.

METHODS

Population-based birth defects surveillance data have been routinely collected by state birth defects surveillance programs across the United States.[33] The NBDPN's State Data Committee requested de-identified individual-level data for both birth defect cases and birth records from state birth defects program contacts, inviting them to participate in the present study. To share these data, participating states received approval from their own institutional review boards or received permission to defer to the institutional review board in Texas, where the study was led. The Centers for Disease Control and Prevention served as the repository for the data submitted by the participating states.

Study Cohort and Case Inclusion

We included infants born from 1999 to 2007 who were diagnosed with 1 or more of 27 selected major birth defects in the study. The cases included live births, and where available, fetal deaths, or pregnancy terminations. We selected the 27 birth defect categories included in the study based on the likelihood that these defects were consistently diagnosed during early infancy and ascertained by state surveillance programs.[5,6] The included conditions were anencephaly; spina bifida without anencephaly; encephalocele; anotia or microtia; common truncus; transposition of great arteries; tetralogy of Fallot; atrioventricular septal defect with and without Down syndrome; aortic valve stenosis; hypoplastic left heart syndrome; coarctation of the aorta; cleft palate without cleft lip; cleft lip with or without cleft palate; esophageal atresia; congenital hypertrophic pyloric stenosis; rectal and large intestinal atresia; hypospadias; upper, lower, and any limb deficiency; diaphragmatic hernia; gastroschisis; omphalocele; Down syndrome; trisomy 13; and trisomy 18. Case counts were derived from each occurrence of a condition; therefore, an infant born with multiple birth defects was counted in each relevant category.

The population-based systems used either an active or passive case finding methodology to identify all potential cases within a defined catchment area. Participating states included Arizona, Colorado, Florida, Georgia/Centers for Disease Control and Prevention (metropolitan Atlanta), Illinois, Massachusetts, Michigan, Nebraska, New Jersey, New York (excluding New York City), North Carolina, and Texas. Five of these states (AZ, GA, MA, NC, and TX) used active case finding by reviewing medical charts, whereas the remaining states (CO, FL, IL, MI, NE, NJ, and NY) used a passive case finding methodology and relied on administrative datasets or hospital reporting to collect case information. Some passive systems verified diagnoses for some or all reported or listed cases, which reduced the false positive rate.[5,6]

Participating state programs provided confirmed birth defects cases; 5 states (CO, FL, IL, MI, and NY) were unable to exclude possible or probable cases. Most programs provided all the defects requested for the entire study period. However, for delivery years 2005 to 2007, Arizona excluded cases with atrioventricular septal defect with and without Down syndrome, pyloric stenosis, rectal and large intestinal atresia, and hypospadias. In addition, Michigan was unable to differentiate between gastroschisis and omphalocele cases, and Florida did not provide data on cases with omphalocele. The data collection methods and specifications for the NBDPN were previously described.[33]

Birth Records and Pooled Data Analysis

State birth defects surveillance programs acquired birth records for 1999 to 2007 from the state office of vital statistics. Cases were linked to their vital records to supplement clinical information with selected sociodemographic data.

To ensure uniform formatting of variables, a single analyst (R. R., then A. O. H.) cleaned the birth defects cases and birth records submitted by participating birth defects surveillance programs, and then pooled the data for statistical analysis. We categorized maternal race/ethnicity, as captured on the birth certificate, as non-Hispanic White, non-Hispanic Black, non-Hispanic American Indian/Alaska Native, non-Hispanic Asian, and Hispanic. We further stratified the non-Hispanic Asian group into subgroups as Chinese, Filipino, Korean, Asian Indian, and Vietnamese, and the Hispanic group into Mexican, Puerto Rican, and Cuban. Designation into Asian or Hispanic subgroups or origins was based on the race or ethnicity field from the birth certificate, respectively. We excluded records with multiple maternal races or missing maternal race/ethnicity (2% of all records) from the analysis. We calculated birth defect prevalence (cases per 10 000 live births) for all racial/ethnic categories combined and for each racial/ethnic group. For this calculation, we used the conventional denominator of all live births (actually a ratio instead of a rate), which is typically done in birth defects surveillance and prevalence studies to compare among systems that might have varying pregnancy outcomes included.[34]

We used Poisson regression to calculate crude prevalence ratios to examine any statistically significant racial/ethnic differences in the prevalence of each birth defect, relative to non-Hispanic Whites. We conducted multivariable analyses to calculate adjusted prevalence ratios (aPRs), adjusting for maternal state of residence (at delivery) and maternal age (< 20, 20–34, and ≥ 35 years). The 95% confidence intervals (CIs) were estimated with the assumption that the cases followed a Poisson distribution. We performed the analyses using SAS version 9.3 (SAS Institute, Cary, NC).

Because of the volume of data and the fact that crude and adjusted prevalence ratios were similar (especially for the larger groups), only aPRs were shown. Data for other Hispanic and Asian subgroups that were not specified previously, as well as maternal multiple race/ethnicity, were also not shown. Examples of groups with data that were too sparse included Polynesians, Hawaiians, and Japanese. Because of the large number of comparisons, we focused on prevalence ratios that were both statistically significant at a P level of less than .05 and of a magnitude of less than 0.7 or greater than or equal to 1.5.

RESULTS

Table 1 characterizes the 12 population-based surveillance systems that contributed data for the study. After excluding 3100 cases with unknown or multiple race/ethnicity, our study included 147 555 cases of birth defects, which either occurred as isolated or with other birth defects. Five systems included cases from live births only, and the remainder of the systems included live births and stillbirths or elective terminations. The study live birth population (approximately 13.5 million) represented 37% of all US live births for 1999 to 2007.

Table 2 provides pooled birth prevalence estimates and 95% CIs for 27 birth defects, both for the total study population and for 5 mutually exclusive racial/ethnic categories: non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic Asian/Pacific Islander, and non-Hispanic American Indian/Alaska Native. The prevalence estimates and 95% CIs for the 5 Asian subgroups (Chinese, Filipino, Korean, Asian Indian, and Vietnamese) and for the 3 Hispanic subgroups (Mexican, Puerto Rican, and Cuban) are available as a supplement to the online version of this article at http://www.ajph.org.

Overall, the birth prevalence ranged from a low of 0.73 cases per 10 000 live births (95% CI = 0.69, 0.78) for common truncus, 0.78 for encephalocele, and 0.93 for trisomy 13, to a high of 58.54 (95% CI = 57.97, 59.12) for hypospadias (among males). However, these prevalences varied across racial/ethnic groups. One of the most pronounced racial/ethnic differences was seen for anotia or microtia, with more than a 6-fold difference in the prevalence for American Indians/Alaska Natives (4.67 cases per 10 000 live births; 95% CI = 3.38, 6.29) versus non-Hispanic Blacks (0.73 per 10 000 live births; 95% CI = 0.61, 0.85).

Table 3 shows the racial/ethnic-specific aPRs and 95% CIs for the 4 major racial/ethnic groups (non-Hispanic Black, Hispanic, non-Hispanic Asian/Pacific Islander, and non-Hispanic American Indian/Alaska Native), relative to non-Hispanic Whites. Focusing on statistically significant results of magnitude greater than or equal to 1.5 or less than 0.7, non-Hispanic Blacks had a 50% or higher prevalence of encephalocele (aPR = 1.75; 95% CI = 1.48, 2.07) and trisomy 18 (aPR = 1.71; 95% CI = 1.53, 1.91). The lowest aPRs seen for non-Hispanic Blacks were for pyloric stenosis (aPR = 0.42; 95% CI = 0.40, 0.44), aortic valve stenosis (aPR = 0.53; 95% CI = 0.46, 0.61), gastroschisis (aPR = 0.55; 95% CI = 0.49, 0.61), and cleft lip with or without cleft palate (aPR = 0.62; 95% CI = 0.58, 0.66).

TABLE 1—Description of State Population-Based Birth Defects Surveillance System Cohorts: National Birth Defects Prevention Network Race/Ethnicity Study, United States, 1999–2007

State	Years	No. of Cases[a]	No. of Total Live Births[a]	No. of Defects	Case Finding	Pregnancy Outcomes
Arizona[b]	1999–2007	6764	798 287	27	A	LSB
Georgia (Atlanta metro area)	1999–2007	4322	438 272	27	A	All
Colorado	1999–2007	8666	609 000	27	P	LB
Florida	1999–2007	23 307	1 918 155	26	P	LB
Illinois	1999–2007	11 996	1 645 536	27	P	LSB
Massachusetts	2000–2007	3972	596 613	27	A	LSB
Michigan	1999–2007	14 078	1 171 081	25	P	LB
Nebraska	1999–2007	2748	222 888	27	P	LSB
New Jersey	1999–2007	10 473	1 000 755	27	P	LB
New York[c]	1999–2007	14 196	1 170 316	27	P	LB
North Carolina	2003–2007	7114	602 978	27	A	All
Texas	1999–2007	39 919	3 378 443	27	A	All
Total		147 555	13 552 324[d]			

Note. A = active case finding; All = live births + stillbirths + terminations; LB = live births only; LSB = live births + stillbirths; P = passive case finding.
[a]Cases and live births exclude unknown race/ethnicity.
[b]Atrioventricular septal defect, atrioventricular septal defect without Down syndrome, pyloric stenosis, rectal and large intestinal atresia, and hypospadias are only available for 1999–2004 in Arizona. All other defects were available for all years.
[c]New York State, excluding New York City.
[d]Total live births is 37% of total live births for the United States.

American Indians/Alaska Natives had a 50% or higher prevalence for 7 conditions, with the highest aPR found for anotia or microtia (aPR = 3.97; 95% CI = 2.89, 5.44). Four defect groups showed an approximately 2-fold increased risk for trisomy 18 (aPR = 1.85; 95% CI = 1.24, 2.75), cleft lip with or without cleft palate (aPR = 1.92; 95% CI = 1.65, 2.23), lower limb deficiency (aPR = 1.91; 95% CI = 1.26, 2.89), and encephalocele (aPR = 2.14; 95% CI = 1.22, 3.76). Higher magnitude aPRs were also observed for upper limb deficiency (aPR = 1.51; 95% CI = 1.10, 2.09) and any limb deficiency (aPR = 1.51; 95% CI = 1.15, 1.98). Only 2 conditions were less prevalent in American Indians/Alaska Natives: hypospadias in males (aPR = 0.61; 95% CI = 0.52, 0.71) and pyloric stenosis (aPR = 0.82; 95% CI = 0.68, 0.99). Asians/Pacific Islanders showed significantly lower aPRs for 16 of the 27 conditions studied, with the lowest aPR found for pyloric stenosis (aPR = 0.26; 95% CI = 0.22, 0.29). Among Hispanics, we observed a mixture of higher and lower aPRs, but we found greater than 50% higher prevalence for 3 conditions: anotia or microtia (aPR = 2.40; 95% CI = 2.18, 2.64), anencephalus (aPR = 1.64; 95% CI = 1.47, 1.83), and encephalocele (aPR = 1.53; 95% CI = 1.32, 1.78).

The aPRs and 95% CIs for the 5 major Asian subgroups (Chinese, Filipino, Korean, Asian Indian, and Vietnamese), relative to non-Hispanic Whites, are available as a supplement to the online version of this article at http://www.ajph.org. For Asian subgroups, we observed a lower or similar prevalence for most birth defects, compared with non-Hispanic Whites. The lowest aPRs were seen for pyloric stenosis in Filipinos and Vietnamese (aPRs = 0.19) and for gastroschisis in Asian Indians (aPR = 0.21; 95% CI = 0.09, 0.47) and Chinese (aPR = 0.24; 95% CI = 0.08, 0.76). Two conditions had lower prevalence than non-Hispanic Whites across all Asian subgroups: pyloric stenosis (aPRs = 0.19–0.34) and hypospadias in males (aPRs = 0.42–0.79).

The aPRs and 95% CIs for the 3 Hispanic subgroups (Mexican, Puerto Rican, and Cuban), relative to non-Hispanic Whites, are available as a supplement to the online version of this article at http://www.ajph.org. For Mexicans, the only birth defect with a 50% or higher prevalence was anotia or microtia (aPR = 2.53; 95% CI = 2.26, 2.82). Of the 27 conditions, 12 showed lower prevalence for Mexicans, but only 1 defect (hypospadias among males) had more than a modestly lower prevalence compared with non-Hispanic Whites (aPR = 0.41; 95% CI = 0.39, 0.42). Puerto Ricans had a lower prevalence of hypospadias (aPR = 0.68; 95% CI = 0.62, 0.73) and a higher prevalence of anencephalus (aPR = 1.70; 95% CI = 1.15, 2.52). Cubans had a lower or similar prevalence for all birth defects studied, with the largest Cuban to non-Hispanic White differences seen for trisomy 18 (aPR = 0.36; 95% CI = 0.16, 0.82), aortic valve stenosis (aPR = 0.39; 95% CI = 0.20, 0.76), and cleft lip (aPR = 0.52; 95% CI = 0.40, 0.67).

In comparing crude and aPRs (crude data not shown), the overall pattern after adjustment appeared to shift toward a reduction in the number of significant prevalence ratios, particularly for Hispanics and specifically for Mexicans. In addition, only the Hispanic subgroups showed prevalence ratios that changed from significantly greater than 1 to significantly less than 1 with adjustment (gastroschisis in Mexicans and pyloric stenosis in Cubans).

Table 4 lists the aPRs for the 27 birth defects among the main maternal race/ethnic groups, selected Asian subgroups, and selected Hispanic subgroups in the United States, relative to non-Hispanic Whites. Cubans and Asian Indians appeared to have lower risk for the birth defects in this study. American Indians/Alaska Natives had a higher prevalence of 8 birth defects (all but 1 of them ≥ 50% higher), relative to non-Hispanic Whites. Non-Hispanic Blacks had 2 conditions (encephalocele, trisomy 18), for which they had markedly increased prevalence (aPR ≥ 1.5) compared with non-Hispanic Whites. Non-Hispanic Whites had a higher prevalence of hypospadias (in males) and congenital pyloric stenosis than all other racial/ethnic groups, with the exception of pyloric stenosis in Puerto Ricans and hypospadias in Cubans (aPR = 1.0, relative to non-Hispanic Whites). There were a number of birth defects for which the prevalence among

TABLE 2—Birth Prevalence with 95% Confidence Intervals for 27 Birth Defects Among Major Maternal Racial/Ethnic Groups: Data From 12 Population-Based Surveillance Systems, United States, 1999–2007

	Total		Non-Hispanic White		Non-Hispanic Black		Hispanic		Non-Hispanic Asian/Pacific Islander		Non-Hispanic AI/AN	
Birth Defect	No.	Prevalence (95% CI)	No.	Prevalence (95% CI)	No.	Prevalence (95% CI)	No.	Prevalence (95% CI)	No.	Prevalence (95% CI)	No.	Prevalence (95% CI)
Central nervous system												
Anencephalus	1756	1.30 (1.24, 1.36)	714	0.99 (0.92, 1.07)	212	1.07 (0.93, 1.22)	765	2.03 (1.89, 2.18)	51	0.99 (0.73, 1.30)	14	1.52 (0.83, 2.55)
Spina bifida without anencephalus	4295	3.17 (3.08, 3.27)	2224	3.09 (2.96, 3.22)	541	2.73 (2.50, 2.97)	1430	3.80 (3.60, 4.00)	63	1.22 (0.94, 1.56)	37	4.02 (2.83, 5.54)
Encephalocele	1051	0.78 (0.73, 0.82)	444	0.62 (0.56, 0.68)	219	1.10 (0.96, 1.26)	352	0.94 (0.84, 1.04)	23	0.44 (0.28, 0.67)	13	1.41 (0.75, 2.41)
Ear												
Anotia/microtia	2295	1.69 (1.62, 1.76)	843	1.17 (1.09, 1.25)	144	0.73 (0.61, 0.85)	1178	3.13 (2.95, 3.31)	87	1.68 (1.35, 2.08)	43	4.67 (3.38, 6.29)
Cardiovascular												
Common truncus	995	0.73 (0.69, 0.78)	547	0.76 (0.70, 0.83)	164	0.83 (0.71, 0.96)	261	0.69 (0.61, 0.78)	12	0.23 (0.12, 0.41)	11	1.19 (0.60, 2.14)
Transposition of great arteries	4600	3.39 (3.30, 3.49)	2602	3.62 (3.48, 3.76)	596	3.00 (2.77, 3.26)	1202	3.19 (3.01, 3.38)	172	3.33 (2.85, 3.86)	28	3.04 (2.02, 4.39)
Tetralogy of Fallot	5412	3.99 (3.89, 4.10)	2923	4.06 (3.92, 4.21)	938	4.73 (4.43, 5.04)	1292	3.43 (3.25, 3.62)	216	4.18 (3.64, 4.77)	43	4.67 (3.38, 6.29)
Atrioventricular septal defect[a]	4926	3.72 (3.61, 3.82)	2725	3.85 (3.71, 4.00)	885	4.48 (4.19, 4.79)	1165	3.21 (3.03, 3.40)	127	2.50 (2.08, 2.97)	24	3.23 (2.07, 4.81)
Atrioventricular septal defect without DS[a]	2397	1.81 (1.74, 1.88)	1187	1.68 (1.58, 1.78)	458	2.32 (2.11, 2.54)	667	1.84 (1.70, 1.98)	69	1.36 (1.06, 1.72)	16	2.16 (1.23, 3.50)
Aortic valve stenosis	2726	2.01 (1.94, 2.09)	1712	2.38 (2.27, 2.49)	230	1.16 (1.01, 1.32)	697	1.85 (1.72, 1.99)	65	1.26 (0.97, 1.60)	22	2.39 (1.50, 3.62)
Hypoplastic left heart	3192	2.36 (2.27, 2.44)	1839	2.56 (2.44, 2.68)	518	2.61 (2.39, 2.85)	755	2.01 (1.87, 2.15)	62	1.20 (0.92, 1.54)	18	1.95 (1.16, 3.09)
Coarctation of the aorta	6576	4.85 (4.74, 4.97)	3861	5.37 (5.20, 5.54)	793	4.00 (3.72, 4.29)	1722	4.57 (4.36, 4.80)	148	2.86 (2.42, 3.36)	52	5.65 (4.22, 7.41)
Orofacial												
Cleft palate w/out cleft lip	7685	5.67 (5.54, 5.80)	4573	6.36 (6.17, 6.54)	831	4.19 (3.91, 4.48)	1938	5.15 (4.92, 5.38)	283	5.47 (4.85, 6.15)	60	6.52 (4.97, 8.39)
Cleft lip +/- cleft palate	12 601	9.30 (9.14, 9.46)	6955	9.67 (9.44, 9.90)	1189	5.99 (5.66, 6.34)	3852	10.23 (9.91, 10.56)	420	8.12 (7.36, 8.94)	185	20.09 (17.30, 23.20)
Gastrointestinal												
Esophageal atresia	3219	2.38 (2.29, 2.46)	1948	2.71 (2.59, 2.83)	382	1.93 (1.74, 2.13)	792	2.10 (1.96, 2.26)	73	1.41 (1.11, 1.78)	24	2.61 (1.67, 3.88)
Pyloric stenosis[a]	21 670	16.34 (16.13, 16.56)	12 943	18.30 (17.99, 18.62)	1707	8.65 (8.24, 9.07)	6686	18.41 (17.97, 18.86)	216	4.25 (3.70, 4.85)	118	15.90 (13.16, 19.04)
Rectal and large intestinal atresia[a]	5664	4.27 (4.16, 4.38)	2989	4.23 (4.08, 4.38)	730	3.70 (3.44, 3.98)	1707	4.70 (4.48, 4.93)	212	4.17 (3.63, 4.77)	26	3.50 (2.29, 5.13)
Genitourinary: hypospadias[a,b]	39 711	58.54 (57.97, 59.12)	26 171	72.17 (71.29, 73.04)	5696	56.77 (55.31, 58.27)	6505	35.09 (34.24, 35.95)	1188	45.36 (42.82, 48.02)	151	40.04 (33.91, 46.96)
Musculoskeletal												
Upper limb deficiency	3860	2.85 (2.76, 2.94)	1985	2.76 (2.64, 2.88)	564	2.84 (2.61, 3.09)	1170	3.11 (2.93, 3.29)	101	1.95 (1.59, 2.37)	40	4.34 (3.10, 5.91)
Lower limb deficiency	2107	1.55 (1.49, 1.62)	1079	1.50 (1.41, 1.59)	372	1.88 (1.69, 2.08)	579	1.54 (1.42, 1.67)	53	1.03 (0.77, 1.34)	24	2.61 (1.67, 3.88)
Any limb deficiency	5557	4.10 (3.99, 4.21)	2898	4.03 (3.88, 4.18)	860	4.34 (4.05, 4.64)	1600	4.25 (4.04, 4.46)	144	2.79 (2.35, 3.28)	55	5.97 (4.50, 7.77)
Diaphragmatic hernia	3435	2.53 (2.45, 2.62)	1791	2.49 (2.38, 2.61)	477	2.40 (2.19, 2.63)	1026	2.73 (2.56, 2.90)	114	2.20 (1.82, 2.65)	27	2.93 (1.93, 4.27)
Gastroschisis[c]	4130	3.34 (3.23, 3.44)	1967	3.10 (2.97, 3.24)	414	2.33 (2.11, 2.56)	1617	4.38 (4.16, 4.59)	73	1.52 (1.19, 1.91)	59	6.85 (5.22, 8.84)
Omphalocele[d]	1617	1.55 (1.47, 1.62)	795	1.47 (1.37, 1.58)	259	1.91 (1.68, 2.15)	515	1.61 (1.48, 1.76)	37	0.86 (0.60, 1.18)	11	1.36 (0.68, 2.44)

Continued

TABLE 2—*Continued*

Chromosomal													
Down syndrome	17 006	12.55 (12.36, 12.74)	9024	12.54 (12.28, 12.80)	2127	10.72 (10.27, 11.19)	5205	13.83 (13.45, 14.21)	540	10.44 (9.58, 11.36)	110	11.95 (9.82, 14.40)	
Trisomy 13	1264	0.93 (0.88, 0.99)	640	0.89 (0.82, 0.96)	217	1.09 (0.95, 1.25)	356	0.95 (0.85, 1.05)	41	0.79 (0.57, 1.08)	10	1.09 (0.52, 2.00)	
Trisomy 18	2404	1.77 (1.70, 1.85)	1168	1.62 (1.53, 1.72)	458	2.31 (2.10, 2.53)	673	1.79 (1.66, 1.93)	79	1.53 (1.21, 1.90)	26	2.82 (1.84, 4.14)	

Note. AI/AN = American Indian/Alaska Native; CI = confidence interval; DS = Down syndrome; +/− = with or without. Prevalence is the number of cases per 10 000 live births. Total for 12 states does not include mothers of unknown race/ethnicity. Whites, Blacks, Asian/Pacific Islanders, and American Indians/Alaska Natives are non-Hispanic.

[a]Arizona data excludes years 2005–2007.

[b]Among male deliveries.

[c]Excludes Michigan data.

[d]Excludes Florida and Michigan data.

non-Hispanic Whites was either higher or similar to that of all other racial/ethnic groups. These included common truncus, aortic valve stenosis, hypoplastic left heart syndrome, transposition of the great arteries, coarctation of the aorta, cleft palate, and esophageal atresia. Birth defects that demonstrated the greatest variation (with significantly lower and higher prevalence ratios observed across the racial/ethnic groups) included spina bifida, anotia or microtia, and Down syndrome. By contrast, rectal and large intestinal atresia, tetralogy of Fallot, and transposition of the great arteries demonstrated the least amount of variation among the racial/ethnic groups.

DISCUSSION

This was the largest population-based study in the United States to examine racial/ethnic differences in birth defects for a range of racial/ethnic categories. Our study provided the first multistate estimates for American Indians/Alaska Natives, Asian subgroups, and Hispanic subgroups. The live birth population for this study (13.5 million) represented 37% of all US live births from 1999 to 2007.

With this analysis, we produced multistate prevalence estimates for the first time for anotia or microtia, atrioventricular septal defect without Down syndrome, aortic valve stenosis, hypoplastic left heart syndrome, coarctation of the aorta, congenital pyloric stenosis, hypospadias, and any limb deficiency. For the majority of the birth defect groups included in this study, national estimates had been published previously for 1999 to 2001 and 2004 to 2006[5,6]; for these defects, the crude prevalence estimates for 1999 to 2007 were generally consistent with the earlier estimates, with some exceptions, explained in part by the sample consisting of a mixture of states that conducted active or passive case finding methodology. The most noteworthy differences with previously published data[5] were the higher prevalences in our study for esophageal atresia and transposition of the great arteries.

The crude prevalence ratios computed for non-Hispanic Blacks and Hispanics, relative to non-Hispanic Whites, were generally consistent with those found in 2 previous national population-based studies that examined a subset of the conditions included in our study.[6,32] The most interesting findings of our study were the higher prevalences for a number of birth defects in American Indians/Alaska Natives. Previous literature on American Indians/Alaska Natives was limited, but a high prevalence of orofacial clefts and microtia were reported.[25,35–37]

We also noted a relatively low prevalence of birth defects in Cubans and Asians, especially among Chinese and Asian Indians. It was difficult to compare these results with other estimates because limited data existed for Hispanic and Asian subgroups who were US residents. One study in California[15] examined birth defect prevalence in Vietnamese, and our crude Vietnamese to White ratios were generally consistent with those findings. The majority in these groups were foreign-born. The low prevalence might, in part, be explained by a "healthy immigrant effect," in which people who tended to be healthier or who were of higher socioeconomic status (both of these factors were associated with better health or pregnancy outcomes) were more likely to immigrate to the United States and have children.[38]

In the adjusted analyses, we controlled for maternal age using 3 categories (< 20 years, 20–34 years, and ≥ 35 years) and state of residence at delivery. Two additional models were evaluated using 6 maternal age categories and age as a continuous variable, with essentially the same results. Adjusting for state of residence at delivery addressed some differences in case ascertainment across states, including differences in the pregnancy outcomes captured across state systems. It would have been optimal to also adjust for a socioeconomic variable, such as maternal education, but we chose to limit the number of covariates because of the small cell sizes in some instances.

Limitations and Strengths

Our study had several limitations. First, a number of prevalence and prevalence ratio calculations were based on cell sizes of less than 5 cases, especially for some Asian subgroups, which led to imprecise estimates. However, the presentation of the data was important because of the lack of data on these populations in the United States. In addition, some states did not conduct prenatal

TABLE 3—Adjusted Prevalence Ratios With 95% Confidence Intervals for 27 Birth Defects Among Major Maternal Racial/Ethnic Groups: Data From 12 Population-Based Surveillance Systems, United States, 1999–2007

Birth Defect	Non-Hispanic Black, aPR (95% CI)	Hispanic, aPR (95% CI)	Non-Hispanic Asian/Pacific Islander, aPR (95% CI)	Non-Hispanic AI/AN, aPR (95% CI)
Central nervous system				
Anencephalus	1.09 (0.93, 1.28)	1.64 (1.47, 1.83)	1.05 (0.79, 1.40)	1.30 (0.76, 2.22)
Spina bifida without anencephalus	0.88 (0.80, 0.97)	1.24 (1.15, 1.33)	0.43 (0.34, 0.56)	1.19 (0.86, 1.66)
Encephalocele	1.75 (1.48, 2.07)	1.53 (1.32, 1.78)	0.80 (0.53, 1.22)	2.14 (1.22, 3.76)
Ear				
Anotia/microtia	0.66 (0.55, 0.79)	2.40 (2.18, 2.64)	1.36 (1.09, 1.70)	3.97 (2.89, 5.44)
Cardiovascular				
Common truncus	1.08 (0.90, 1.29)	1.00 (0.85, 1.17)	0.34 (0.19, 0.60)	1.74 (0.95, 3.20)
Transposition of great arteries	0.83 (0.75, 0.91)	0.93 (0.86, 1.00)	0.95 (0.82, 1.11)	1.02 (0.70, 1.48)
Tetralogy of Fallot	1.19 (1.10, 1.28)	0.93 (0.87, 1.00)	1.07 (0.93, 1.23)	1.23 (0.91, 1.67)
Atrioventricular septal defect[a]	1.25 (1.15, 1.35)	0.86 (0.80, 0.93)	0.66 (0.56, 0.79)	0.85 (0.57, 1.28)
Atrioventricular septal defect without DS[a]	1.38 (1.23, 1.54)	1.01 (0.91, 1.11)	0.85 (0.67, 1.09)	1.16 (0.70, 1.91)
Aortic valve stenosis	0.53 (0.46, 0.61)	0.75 (0.68, 0.82)	0.57 (0.45, 0.74)	0.82 (0.54, 1.26)
Hypoplastic left heart	1.05 (0.95, 1.16)	0.88 (0.81, 0.97)	0.53 (0.41, 0.69)	0.78 (0.49, 1.25)
Coarctation of the aorta	0.77 (0.71, 0.83)	0.87 (0.82, 0.93)	0.58 (0.49, 0.68)	1.08 (0.82, 1.42)
Orofacial				
Cleft palate without cleft lip	0.68 (0.63, 0.74)	0.81 (0.77, 0.86)	0.88 (0.78, 1.00)	0.98 (0.75, 1.27)
Cleft lip +/– cleft palate	0.62 (0.58, 0.66)	1.00 (0.96, 1.04)	0.88 (0.80, 0.97)	1.92 (1.65, 2.23)
Gastrointestinal				
Esophageal atresia	0.75 (0.67, 0.84)	0.86 (0.78, 0.93)	0.55 (0.43, 0.69)	1.06 (0.70, 1.59)
Pyloric stenosis[a]	0.42 (0.40, 0.44)	0.88 (0.85, 0.91)	0.26 (0.22, 0.29)	0.82 (0.68, 0.99)
Rectal and large intestinal atresia[a]	0.90 (0.83, 0.98)	1.08 (1.01, 1.15)	1.03 (0.90, 1.19)	0.86 (0.58, 1.27)
Genitourinary: hypospadias[a,b]	0.80 (0.78, 0.82)	0.47 (0.46, 0.49)	0.63 (0.60, 0.67)	0.61 (0.52, 0.71)
Musculoskeletal				
Upper limb deficiency	1.02 (0.93, 1.13)	0.97 (0.90, 1.05)	0.70 (0.57, 0.85)	1.51 (1.10, 2.09)
Lower limb deficiency	1.24 (1.10, 1.40)	0.98 (0.88, 1.09)	0.69 (0.52, 0.91)	1.91 (1.26, 2.89)
Any limb deficiency	1.08 (1.00, 1.17)	0.96 (0.90, 1.02)	0.69 (0.58, 0.81)	1.51 (1.15, 1.98)
Diaphragmatic hernia	0.94 (0.85, 1.05)	1.09 (1.00, 1.18)	0.94 (0.78, 1.14)	1.26 (0.86, 1.85)
Gastroschisis[c]	0.55 (0.49, 0.61)	0.96 (0.90, 1.03)	0.60 (0.47, 0.76)	1.39 (1.06, 1.81)
Omphalocele[d]	1.36 (1.18, 1.58)	0.99 (0.88, 1.12)	0.62 (0.44, 0.86)	0.87 (0.47, 1.59)
Chromosomal				
Down syndrome	1.04 (0.99, 1.09)	1.36 (1.31, 1.41)	0.82 (0.75, 0.90)	1.21 (1.00, 1.47)
Trisomy 13	1.38 (1.18, 1.62)	1.05 (0.92, 1.21)	0.90 (0.65, 1.23)	1.16 (0.62, 2.19)
Trisomy 18	1.71 (1.53, 1.91)	1.18 (1.06, 1.30)	0.91 (0.72, 1.14)	1.85 (1.24, 2.75)

Note. AI/AN = American Indian/Alaska Native; aPR = adjusted prevalence ratio; CI = confidence interval; DS = Down syndrome; +/– = with or without. Whites, Blacks, Asian/Pacific Islanders, and American Indians/Alaska Natives are non-Hispanic. All aPRs are adjusted for maternal age and US state of residence, relative to non-Hispanic Whites.
[a]Arizona data excludes years 2005–2007.
[b]Among male deliveries.
[c]Excludes Michigan data.
[d]Excludes Florida and Michigan data.

surveillance or include pregnancy terminations, which would underestimate the true prevalence for several birth defects and even some subgroups of birth defects (especially for anencephaly and trisomies), possibly affecting the prevalence ratios.

We relied on race/ethnicity classification from vital records. To simplify the analysis, we followed the general convention of first grouping by Hispanic ethnicity and then by race categories, in which Hispanic ethnicity took precedence over race for classifying an individual into a racial/ethnic group. Similarly, we did not consider unknown or multiple races, although this affected only 2% of the total cases in the study. Also, we did not present data on maternal nativity (foreign- vs US-born), which might contribute to some of

TABLE 4—Summary Table of Adjusted Prevalence Ratios for 27 Birth Defects Among Main Maternal Racial/Ethnic Groups, Selected Asian Subgroups, and Selected Hispanic Subgroups Relative to Non-Hispanic Whites: Data From 12 Population-Based Surveillance Systems, United States, 1999–2007

	Main Racial/Ethnic Groups aPRs				Selected Asian Subgroups aPRs					Selected Hispanic Subgroups aPR Magnitude		
Birth Defect	Non-Hispanic Black	Hispanic	Non-Hispanic Asian	Non-Hispanic AI/AN	Chinese	Filipino	Korean	Asian Indian	Vietnamese	Mexican	Puerto Rican	Cuban
Anencephalus	1.1	↑ 1.6	1.1	1.3	0.5	0.9	0.4	1.4	0.8	↑ 1.3	↑ 1.7	0.4
Spina bifida without anencephalus	↓ 0.9	↑ 1.2	↓ 0.4	1.2	↓ 0.4	↓ 0.3	0.4	↓ 0.4	0.5	↑ 1.3	↑ 1.3	↓ 0.6
Encephalocele	↑ 1.8	↑ 1.5	0.8	↑ 2.1	0.3	0.9	1.3	1.0	0.7	↑ 1.4	1.4	0.4
Anotia/microtia	↓ 0.7	↑ 2.4	↑ 1.4	↑ 4.0	↑ 2.1	↑ 1.9	1.4	1.3	1.4	↑ 2.5	1.2	1.0
Cardiovascular												
Common truncus	1.1	1.0	↓ 0.3	1.7	0.2	0.5	0.0	0.4	0.0	1.0	1.2	0.5
Transposition of great arteries	↓ 0.8	0.9	1.0	1.0	↓ 0.6	0.9	0.8	1.2	0.8	1.0	0.9	1.0
Tetralogy of Fallot	↑ 1.2	0.9	1.1	1.2	0.7	1.4	0.9	1.1	↑ 1.6	0.9	1.1	0.9
Atrioventricular septal defect[a]	↑ 1.3	↓ 0.9	↓ 0.7	0.9	↓ 0.6	↓ 0.5	0.7	↓ 0.5	0.7	↓ 0.8	1.0	↓ 0.6
Atrioventricular septal defect without DS[a]	↑ 1.4	1.0	0.9	1.2	1.2	0.4	0.9	↓ 0.5	0.9	1.0	1.1	1.0
Aortic valve stenosis	↓ 0.5	↓ 0.8	↓ 0.6	0.8	↓ 0.3	0.6	0.3	↓ 0.6	0.5	↓ 0.8	0.8	↓ 0.4
Hypoplastic left heart	1.1	↓ 0.9	↓ 0.5	0.8	0.5	↓ 0.4	1.0	↓ 0.5	↓ 0.1	↓ 0.8	1.0	0.8
Coarctation of the aorta	↓ 0.8	↓ 0.9	↓ 0.6	1.1	↓ 0.4	0.8	0.5	↓ 0.7	↓ 0.5	↓ 0.9	0.9	0.8
Cleft palate without cleft lip	↓ 0.7	↓ 0.8	0.9	1.0	1.1	1.3	0.7	0.9	↓ 0.6	↓ 0.8	1.0	↓ 0.7
Cleft lip +/- cleft palate	↓ 0.6	1.0	↓ 0.9	↑ 1.9	0.8	1.2	0.9	↓ 0.6	1.1	1.0	0.9	↓ 0.5
Esophageal atresia	↓ 0.8	↓ 0.9	↓ 0.6	1.1	↓ 0.5	↓ 0.2	0.5	↓ 0.5	0.8	↓ 0.8	1.0	1.1
Pyloric stenosis[a]	↓ 0.4	↓ 0.9	↓ 0.3	↓ 0.8	↓ 0.2	↓ 0.2	↓ 0.3	↓ 0.3	↓ 0.2	↓ 0.9	1.0	↓ 0.7
Rectal and large intestinal atresia[a]	↓ 0.9	↑ 1.1	1.0	0.9	1.0	0.9	1.0	1.2	0.7	1.0	1.2	0.9
Hypospadias[a,b]	↓ 0.8	↓ 0.5	↓ 0.6	↓ 0.6	↓ 0.5	↓ 0.7	↓ 0.4	↓ 0.8	↓ 0.5	↓ 0.4	↓ 0.7	1.0
Musculoskeletal												
Upper limb deficiency	1.0	1.0	↓ 0.7	↑ 1.5	0.7	0.6	0.9	0.8	↓ 0.4	0.9	1.2	1.0
Lower limb deficiency	↑ 1.2	1.0	↓ 0.7	↑ 1.9	0.7	0.9	0.7	0.8	0.8	↓ 0.9	1.0	1.0
Any limb deficiency	1.1	1.0	↓ 0.7	↑ 1.5	↓ 0.6	0.7	1.0	0.8	↓ 0.4	↓ 0.9	1.2	1.0
Diaphragmatic hernia	0.9	1.1	0.9	1.3	0.8	1.1	0.3	1.2	0.6	1.0	↑ 1.4	0.8
Gastroschisis[c]	↓ 0.6	1.0	↓ 0.6	↑ 1.4	↓ 0.2	1.1	0.6	↓ 0.2	0.6	↓ 0.9	1.1	0.7
Omphalocele[d]	↑ 1.4	1.0	↓ 0.6	0.9	0.8	0.8	0.3	0.6	0.3	↓ 0.8	1.4	0.5
Down syndrome	1.0	↑ 1.4	↓ 0.8	1.2	↓ 0.5	1.2	0.7	↓ 0.7	0.9	↑ 1.4	↑ 1.3	↓ 0.7
Trisomy 13	↑ 1.4	1.1	0.9	1.2	0.9	1.3	0.4	0.8	1.0	1.0	1.2	0.7
Trisomy 18	↑ 1.7	↑ 1.2	0.9	↑ 1.9	0.6	1.2	0.2	0.7	1.2	1.0	1.4	↓ 0.4

Continued

TABLE 4—*Continued*

Significant results by aPR magnitude													
> 2.0	0	1	0	2	1	0	0	0	0	1	0	0	
1.5–1.9	2	2	0	5	0	1	0	0	1	0	1	0	
1.1–1.4	6	4	1	1	0	0	0	0	0	4	3	0	
No. of significantly elevated aPRs ($P < .05$)	8	7	1	8	1	1	0	0	1	5	4	0	
No. of markedly elevated aPRs (≥ 1.5; $P < .05$)	2	3	0	7	1	1	0	0	1	1	1	0	
0.7–0.9	8	7	6	1	0	1	0	3	0	11	1	3	
0.5–0.6	3	1	7	1	6	1	0	6	3	0	0	3	
< 0.5	1	0	3	0	5	4	2	3	4	1	0	2	
No. of significantly lower aPRs ($P < .05$)	12	8	16	2	11	6	2	12	7	12	1	8	
No. of markedly lower aPRs (< 0.7; $P < .05$)	4	1	10	1	11	5	2	9	7	1	0	5	

Note. AI/AN = American Indian/Alaska Native; aPR = adjusted prevalence ratio; DS = Down syndrome; +/- = with or without. All aPRs adjusted for maternal age and US state of residence relative to non-Hispanic Whites and rounded to 1 decimal place. Adjusted prevalence ratios use arrows if significantly elevated (↑) or significantly lower (↓).

[a]Arizona data excludes years 2005–2007.

[b]Among male deliveries.

[c]Excludes Michigan data.

[d]Excludes Florida and Michigan data.

the racial/ethnic differences; this topic will be the focus of a subsequent and related article. However, the majority of Asians (86%) and Hispanics (56%) in this sample were foreign-born. An additional consideration was that Asians and Asian subgroups were underrepresented in the sample, compared with the US population, because no states from the West Coast nor Hawaii were able to contribute data. In a similar manner, Cubans were overrepresented in the sample because this group was concentrated in 1 of our study states (FL). Another limitation was our inability to classify birth defects into isolated versus nonisolated phenotypes, which might slightly overstate or understate the racial/ethnic impact for a particular birth defect.

A final issue was that of multiple comparisons, given the number of birth defects and racial/ethnic categories examined in this study. With 27 birth defect categories and 12 non-White racial/ethnic groups having sufficient data, we would have expected approximately 16 significantly elevated or lower prevalence ratios simply by chance ($P < .05$). We found 132 differences at a P level of less than .05 and 74 differences that were both statistically significant ($P < .05$) and of greater magnitude (aPR < 0.7 or ≥ 1.5). The number of racial/ethnic differences compared with non-Hispanic Whites greatly exceeded what we would have expected by chance alone.

The study limitations were balanced by several strengths. The very large sample (approximately 13.5 million births) was population-based and represented more than one-third of all live births in the United States. The study population had proportions for the 5 major racial/ethnic categories similar to the distribution of the US population. In addition, we were able to adjust for 2 important study factors (maternal age and state of residence) to better elucidate associations between race/ethnicity and individual birth defects. Adjusting for state partially accounted for ascertainment differences across study sites, such as pregnancy outcomes included in each system. We selected specific birth defects that were considered likely to be reliably diagnosed during infancy.

Conclusions

This was the largest study to examine associations between race/ethnicity and a range of specific birth defects in the United States. Less-studied groups, including American Indians/Alaska Natives, Cubans, and Asian subgroups residing in the United States, were examined. Future research should consider stratifying each racial/ethnic group by nativity status, and if possible, limit certain birth defects to isolated cases to see if the racial/ethnic relationships remain. In addition to providing relatively precise estimates of the prevalence of major birth defects for a large number of racial/ethnic populations residing in the United States, this study identified several findings that deserve further study. The relatively high prevalence of birth defects among American Indians/Alaska Natives warrants further investigation. ■

About the Authors

Mark A. Canfield and Lisa K. Marengo are with the Texas Department of State Health Services, Austin. Cara T. Mai, Alissa O'Halloran, Richard S. Olney, and C.J. Alverson are with the National Center on Birth Defects and Developmental Disabilities, Centers for Disease Control and Prevention, Atlanta, GA. Ying Wang is with the New York State Department of Health, Albany. Christopher L. Borger is with the Massachusetts Department of Public Health, Boston. Rachel Rutkowski is with the Florida Department of Health, Tallahassee. Jane Fornoff is with the Illinois Department of Public Health, Springfield. Nila Irwin is with the Nebraska Department of Health and Human Services, Lincoln. Glenn Copeland is with the Michigan Birth Defects Registry, Michigan Department of Community Health, Lansing. Timothy J. Flood is with the Arizona Department of Health Services, Phoenix. Robert E. Meyer is with the North Carolina Birth Defects Monitoring Program, Raleigh. Russel Rickard is with the Colorado Department of Public Health and Environment, Denver. Joseph Sweatlock is with the New Jersey Department of Health, Trenton. Russell S. Kirby is with the Department of Community and Family Health, University of South Florida, Tampa.

Correspondence should be sent to Mark A. Canfield, PhD, Birth Defects Epidemiology and Surveillance Branch, Texas Department of State Health Services, P.O. Box 149347, MC 1964, Austin, TX 78714-9347 (e-mail: mark.canfield@dshs.state.tx.us). Reprints can be ordered at http://www.ajph.org by clicking the "Reprints" link.

This article was accepted May 16, 2014.

Contributors

All of the authors contributed to the data compilation, data checking, analysis design, and writing of this article.

Acknowledgments

We thank the following programs for contributing data to the study: Arizona Birth Defects Monitoring Program (ABDMP), Metropolitan Atlanta Congenital Defects Program (MACDP), Colorado Responds to Children With Special Needs (CRCSN), Florida Birth Defects Registry (FBDR), Illinois Adverse Pregnancy Outcomes Reporting System (APORS), Massachusetts Birth Defects Monitoring Program (BDMP), Michigan Birth Defects Registry (MBDR), Nebraska Birth Defects Registry, New Jersey Special Child Health Services Registry (SCHS REGISTRY), New York State Congenital Malformations Registry (CMR), North Carolina Birth Defects Monitoring Program (NCBDMP), and Texas Birth Defects Epidemiology and Surveillance Branch (TBDES).

Human Participant Protection

This National Birth Defects Prevention Network (NBDPN) study had the institutional review board approval of the State of Texas as the primary and deferring state approval, as well as that of the states of Arizona, Illinois, Colorado, Massachusetts, Michigan, Nebraska, and New Jersey.

References

1. Matthews TJ, MacDorman MF. Infant mortality statistics from the 2010 period linked birth/infant death data set. *Natl Vital Stat Rep.* 2013;61:28.

2. Decouflé P, Boyle CA, Paulozzi LJ, Lary JM. Increased risk for developmental disabilities in children who have major birth defects: a population-based study. *Pediatrics.* 2001;108(3):728–734.

3. Russo CA, Elixhauser A. Hospitalizations for birth defects, 2004: Statistical brief #24. *Healthcare Cost and Utilization Project (HCUP) Statistical Briefs.* Rockville, MD: Agency for Healthcare Research and Quality; 2006.

4. Mai CT, Kucik JE, Isenburg J, et al., for the National Birth Defects Prevention Network. Selected birth defects data from population-based birth defects surveillance programs in the United States, 2006 to 2010: featuring trisomy conditions. *Birth Defects Res A Clin Mol Teratol.* 2013;97(11):709–725.

5. Parker SE, Mai CT, Canfield MA, et al. Updated national birth prevalence estimates for selected birth defects in the United States, 2004–2006. *Birth Defects Res A Clin Mol Teratol.* 2010;88(12):1008–1016.

6. Canfield MA, Honein MA, Yuskiv N, et al. National estimates and race/ethnic-specific variation of selected birth defects in the United States, 1999–2001. *Birth Defects Res A Clin Mol Teratol.* 2006;76(11):747–756.

7. Parker SE, Mai CT, Strickland MJ, et al. Multistate study of the epidemiology of clubfoot. *Birth Defects Res A Clin Mol Teratol.* 2009;85(11):897–904.

8. Kirby RS, Marshall J, Tanner JP, et al. Prevalence and correlates of gastroschisis in 15 states, 1995 to 2005. *Obstet Gynecol.* 2013;122(2 pt 1):275–281.

9. Williams LJ, Rasmussen SA, Flores A, Kirby RS, Edmonds LD. Decline in the prevalence of spina bifida and anencephaly by race/ethnicity: 1995–2002. *Pediatrics.* 2005;116(3):580–586.

10. Nembhard WN, Wang T, Loscalzo ML, Salemi JL. Variation in the prevalence of congenital heart defects by maternal race/ethnicity and infant sex. *J Pediatr.* 2010;156(2):259–264.

11. Nembhard WN, Salemi JL, Wang T, Loscalzo ML, Hauser KW. Is the prevalence of specific types of congenital heart defects different for non-Hispanic white, non-Hispanic black and Hispanic infants? *Matern Child Health J.* 2010;14(2):184–193.

12. Shaw GM, Velie EM, Wasserman CR. Risk for neural tube defect-affected pregnancies among women of Mexican descent and White women in California. *Am J Public Health.* 1997;87(9):1467–1471.

13. Hashmi SS, Waller DK, Langlois P, Canfield MA, Hecht JT. Prevalence of nonsyndromic oral clefts in Texas: 1995–1999. *Am J Med Genet A.* 2005;134(4):368–372.

14. Canfield MA, Marengo L, Ramadhani TA, Suarez L, Brender JD, Scheuerle A. The prevalence and predictors of anencephaly and spina bifida in Texas. *Paediatr Perinat Epidemiol.* 2009;23(1):41–50.

15. Shaw GM, Carmichael SL, Nelson V. Congenital malformations in offspring of Vietnamese women in California, 1985–97. *Teratology.* 2002;65(3):121–124.

16. Husain T, Langlois PH, Sever LE, Gambello MJ. Descriptive epidemiologic features shared by birth defects thought to be related to vascular disruption in Texas, 1996–2002. *Birth Defects Res A Clin Mol Teratol.* 2008;82(6):435–440.

17. Forrester MB, Merz RD. Descriptive epidemiology of selected congenital heart defects, Hawaii, 1986–1999. *Paediatr Perinat Epidemiol.* 2004;18(6):415–424.

18. Kucik JE, Alverson CJ, Gilboa SM, Correa A. Racial/ethnic variations in the prevalence of selected major birth defects, metropolitan Atlanta, 1994-2005. *Public Health Rep.* 2012;127(1):52–61.

19. Benjamin BG, Ethen MK, Van Hook CL, Myers CA, Canfield MA. Gastroschisis prevalence in Texas 1999–2003. *Birth Defects Res A Clin Mol Teratol.* 2010;88(3):178–185.

20. Carmichael SL, Shaw GM, Kaidarova Z. Congenital malformations in offspring of Hispanic and African-American women in California, 1989–1997. *Birth Defects Res A Clin Mol Teratol* 2004;70(6):382–388.

21. Carmichael SL, Shaw GM, Nelson V, Selvin S, Torfs CP, Curry CJ. Hypospadias in California: trends and descriptive epidemiology. *Epidemiology.* 2003;14(6):701–706.

22. Wang J, Waller DK, Hwang LY, Taylor LG, Canfield MA. Prevalence of infantile hypertrophic pyloric stenosis in Texas, 1999–2002. *Birth Defects Res A Clin Mol Teratol.* 2008;82(11):763–767.

23. Forrester MB, Merz RD. Descriptive epidemiology of oral clefts in a multiethnic population, Hawaii, 1986–2000. *Cleft Palate Craniofac J.* 2004;41(6):622–628.

24. Forrester MB, Merz RD. Rates for specific birth defects among native Hawaiians compared to whites, Hawaii 1986-2000. *Hawaii Med J.* 2004;63(8):238–242.

25. Croen LA, Shaw GM, Wasserman CR, Tolarová MM. Racial and ethnic variations in the prevalence of orofacial clefts in California, 1983–1992. *Am J Med Genet.* 1998;79(1):42–47.

26. Centers for Disease Control and Prevention. Update on overall prevalence of major birth defects—Atlanta, Georgia, 1978–2005. *MMWR Morb Mortal Wkly Rep.* 2008;57(1):1–5.

27. McBride KL, Marengo L, Canfield MA, Langlois P, Fixler D, Belmont JW. Epidemiology of noncomplex left ventricular outflow tract obstruction malformations

(aortic valve stenosis, coarctation of the aorta, hypoplastic left heart syndrome) in Texas, 1999–2001. *Birth Defects Res A Clin Mol Teratol.* 2005;73(8):555–561.

28. Salemi JL, Pierre M, Tanner JP, et al. Maternal nativity as a risk factor for gastroschisis: a population-based study. *Birth Defects Res A Clin Mol Teratol.* 2009;85(11):890–896.

29. Shaw GM, Carmichael SL, Kaidarova Z, Harris JA. Epidemiologic characteristics of anotia and microtia in California, 1989–1997. *Birth Defects Res A Clin Mol Teratol.* 2004;70(7):472–475.

30. Canfield MA, Langlois PH, Nguyen LM, Scheuerle AE. Epidemiologic features and clinical subgroups of anotia/microtia in Texas. *Birth Defects Res A Clin Mol Teratol.* 2009;85(11):905–913.

31. Agopian A, Marengo L, Mitchell LE. Descriptive epidemiology of nonsyndromic omphalocele in Texas, 1999–2004. *Am J Med Genet A.* 2009;149A(10):2129–2133.

32. Canfield MA, Collins JS, Botto LD, et al. Changes in the birth prevalence of selected birth defects after grain fortification with folic acid in the United States: findings from a multi-state population-based study. *Birth Defects Res A Clin Mol Teratol.* 2005;73(10):679–689.

33. National Center on Birth Defects CDC, Prevention. State birth defects surveillance program directory, updated September 2012. *Birth Defects Res A Clin Mol Teratol.* 2012;94:S121–S169.

34. Mason CA, Kirby RS, Sever LE, Langlois PH. Prevalence is the preferred measure of frequency of birth defects. *Birth Defects Res A Clin Mol Teratol.* 2005;73(10):690–692.

35. Niswander JD, Adams MS. Oral clefts in the American Indian. *Public Health Rep.* 1967;82(9):807–812.

36. Luquetti DV, Leoncini E, Mastroiacovo P. Microtia-anotia: a global review of prevalence rates. *Birth Defects Res A Clin Mol Teratol.* 2011;91(9):813–822.

37. Aase JM, Tegtmeier RE. Microtia in New Mexico: evidence for multifactorial causation. *Birth Defects Orig Artic Ser.* 1977;13(3A):113–116.

38. Argeseanu Cunningham S, Ruben JD, Narayan KM. Health of foreign-born people in the United States: a review. *Health Place.* 2008;14(4):623–635.