Parental Occupation, Hispanic Ethnicity, and Risk of Selected Congenital Malformations in Offspring

Jean D. Brender, PhD, RN; Lucina Suarez, PhD; Peter H. Langlois, PhD

Objectives: Evidence suggests that parental occupation and Hispanic ethnicity may be risk factors for some birth defects. Because few studies have examined the effect of Hispanic ethnicity on occupational associations, we examined whether risk associated with certain occupations was heightened in Hispanics compared with non-Hispanic Whites.

Design: In this case-control study among Texas births occurring from 1996 through 2000, cases of neural tube defects, isolated oral clefts, and chromosomal anomalies were linked to their respective live birth certificates. A random sample of 4965 live births without documented congenital malformations served as the comparison group. Parental occupations were categorized into groups according to previously published associations. Logistic regression was used to obtain odds ratios (OR) and 95% confidence intervals (CI) for the selected congenital malformations in relation to parental occupations.

Results: Maternal occupations as cook or nurse were associated with oral clefts (OR 3.3, 95% CI .6–16.0) and neural tube defects (OR 3.1, 95% CI .5–13.1), respectively, among births to Hispanic mothers, but not with births to non-Hispanic White mothers. Hispanic fathers who were electricians were more likely to have offspring with chromosomal anomalies, especially trisomy 18 (OR 7.4, 95% CI 1.6–25.5), associations not seen among offspring of non-Hispanic White fathers. Risk estimates also differed by Hispanic ethnicity between oral clefts and paternal occupations of electronic equipment operator, farmworker, janitor, police officer, and printer.

Conclusions: In this study, we found differences for risk of several congenital malformations by Hispanic ethnicity in relation to parental occupation. We recommend further study of these risks in other Hispanic populations. (*Ethn Dis*. 2008;18:218–224)

Key Words: Birth Defects, Occupational Groups, Hispanic, Ethnicity

From the Department of Epidemiology and Biostatistics, Texas A&M Health Science Center, School of Rural Public Health, College Station (JDB); Epidemiology and Disease Surveillance Unit (LS), Birth Defects Epidemiology and Surveillance Branch (PHL), Texas Department of State Health Services, Austin, Texas, USA.

Address correspondence and reprint requests to: Jean D. Brender, PhD; Associate Professor; Department of Epidemiology and Biostatistics; Texas A&M Health Science Center, School of Rural Public Health; 201 SRPH Administration Building; College Station, TX 77843-1266; 979-862-1573; 979-458-1877 (fax); jdbrender@srph.tamhsc.edu

Introduction

Congenital malformations remain the greatest contributor to infant mortality.[1] In the United States, the prevalence of several birth defects varies by maternal ethnicity, such as neural tube defects (NTDs: anencephalus, spina bifida, encephalocele), oral clefts (cleft lip with or without cleft palate, cleft palate alone), and chromosomal anomalies. Compared with births to non-Hispanic White mothers, more children born to Hispanic White mothers have neural tube defects[2,3] and Down syndrome.[3] On the other hand, the prevalence of cleft palate is lower among Hispanic births than among non-Hispanic White births.[3–5] Differences in genetic background, nutrition and use of supplements, socioeconomic status, use of prenatal diagnostic technologies, and environmental or occupational exposures might account for the ethnic differential in prevalence of these defects.

During the past 20 years, several studies have been published regarding the relationship between maternal and paternal occupation and various types of congenital malformations. Positive associations have been noted between parental occupation and offspring with NTDs,[6–11] oral clefts,[9,12] and chromosomal anomalies,[13] including Down syndrome.[14]

We examined whether Hispanic ethnicity modified any associations between parental occupations … and risk for NTDs, oral cleft defects, and chromosomal anomalies.

Although several studies have been conducted in the United States regarding the relationship between parental occupation and risk of congenital malformations in offspring, few have specifically addressed the potential differences in these risks by Hispanic ethnicity. In this study, we examined whether Hispanic ethnicity modified any associations between parental occupations (based on job titles and exposures found associated with these defects in other studies) and risk for NTDs, oral cleft defects, and chromosomal anomalies.

Methods

Study Population

Case and control births were selected from births to Texas residents from 1996 through 2000. The Texas Birth Defects Registry (TBDR) conducts active birth defect surveillance by reviewing medical facility log books, hospital discharge lists, and other records. Although the TBDR includes spontaneous abortions, fetal deaths, and elective terminations with eligible defects in the surveillance system, we

restricted this study to live births because of the availability of computerized data from vital records about parental occupation and place of work.

Congenital malformations selected for this study included neural tube defects (British Pediatric Association [BPA] Classification of Diseases codes 740.000–742.090), oral clefts (BPA codes 749.000–749.220), and chromosomal anomalies (BPA codes 758.000–758.990). Chromosomal anomalies were further categorized into Down syndrome (BPA codes 758.000–758.090) and non-Down syndrome (BPA codes 758.100–758.990) anomalies. Oral cleft cases were restricted to those who had isolated defects. ''Isolated'' was operationally defined as an infant having only one BPA code or having one major BPA code with all remaining defects being minor, as proposed by Rasmussen et al.[15] Cleft palate and cleft lip with or without cleft palate were also examined separately if sufficient numbers of cases were available for analysis. Through vital record numbers supplied by the TBDR, registry cases were linked to their respective computerized live birth records.

A total of 4965 control births without documented congenital malformations were randomly selected as a comparison group for all case groups from the computerized live birth certificate files for births occurring from 1996 through 2000. Controls were frequency-matched to the entire sample of congenital malformations by year of birth and public health region of maternal residence. The institutional review boards of the Texas Department of State Health Services and Texas A&M University approved the research protocol.

Data Collection and Analysis

Before categorizing the study population's parental occupations into relevant occupational groups, we conducted a complete literature review and retrieval of published articles of the relationship between parental occupation (job titles) and risk for neural tube defects, oral clefts, and chromosomal anomalies. For the study population, we identified maternal and paternal ''usual occupation'' and ''type of business'' from the computerized live birth certificate files. We used the Standard Occupational Classification system[16] and the North American Industrial Classification System[17] to code and classify occupations and industries, respectively. Coding of occupation and place of work was completed without knowledge of case or control status.

In the data analyses, we used logistic regression to obtain odds ratios (OR) and 95% confidence intervals (CI) for the selected congenital malformations in relation to parental occupational groups; exact logistic regression was used in analyses with sparse data.[18] We compared each maternal and paternal occupational group (as identified from the literature) relative to those persons who worked in other occupations. Homemakers, students, and the unemployed were not included in either maternal or paternal referent categories.

Maternal age (<20, 20–24, 25–29, 30–34, 35–39, >39 years) and education (<9, 9–11, 12, 13–15, >15 years) were considered potential confounding variables in this study, and all ORs were adjusted for these covariates. ORs and 95% CIs were first calculated for all ethnic groups combined (non-Hispanic White, African American, Hispanic White, other) in which at least three each of the case and control mothers or fathers worked in the occupational groups of interest.

We further stratified parental occupation and congenital malformation by maternal and paternal Hispanic ethnicity and conducted separate analyses by ethnicity. We restricted these analyses to occupational groups in which the ORs for the combined ethnic groups were >1.4. Separate analyses were not conducted for African Americans or other ethnicities because of insufficient numbers of cases and controls in the occupational groups of interest.

RESULTS

A total of 608 cases with neural tube defects, 1233 with isolated oral clefts, and 2091 with chromosomal anomalies were available for study; a random sample of 4965 births without documented congenital malformations served as the comparison group. Compared to the controls, mothers of children with chromosomal anomalies tended to be older (Table 1). Children with NTDs were more likely to have Hispanic mothers (OR 1.7, 95% CI 1.4–2.0 [relative to non-Hispanic White mothers]) and mothers with less than nine years of education (OR 2.8, 95% CI 2.0–3.9 [relative to 16 or more years of education]) than comparison births.

With all races combined, several maternal and paternal occupations were associated with the congenital malformations under study. With adjustment for maternal age and education, the maternal occupations of cleaner and cook were respectively associated with NTDs (OR 2.3, 95% CI .9–5.4) and oral clefts (OR 3.0, 95% CI 1.0–8.8) in offspring. Fathers who had offspring with NTDs were more likely to have an occupation as farmworker (OR 2.0, 95% CI .9–4.1), and a paternal occupation of printer was strongly associated with oral clefts in offspring (OR 4.5, 95% CI 1.6–12.4). We observed some differences in risk estimates for congenital malformations associated with parental occupations by Hispanic ethnicity. A maternal occupation as a cook was associated with oral clefts with births to Hispanic White mothers, but not among births to non-Hispanic White mothers (Table 2). Hispanic women who were nurses (registered or licensed vocational) were more likely to have children with NTDs, while non-Hispanic White women who were nursing

Table 1. Characteristics of births with selected congenital anomalies* and comparison births, Texas, 1996–2000

Characteristic	Births with neural tube defects		Births with isolated oral clefts		Births with chromosomal anomalies		Comparison births without birth defects	
	n	%	*n*	%	*n*	%	*n*	%
Maternal age (years)								
<20	104	17.1	179	14.5	236	11.3	834	16.8
20–24	174	28.6	377	30.6	398	19.0	1406	28.3
25–29	165	27.1	343	27.8	383	18.3	1313	26.4
30–34	101	16.6	210	17.0	383	18.3	916	18.4
35–39	53	8.7	111	9.0	433	20.7	413	8.3
>39	11	1.8	13	1.1	258	12.3	83	1.7
Maternal education (years)								
≤9	108	18.2	144	11.9	306	15.1	547	11.2
9–11	154	26.0	275	22.6	421	20.7	1147	23.4
12	180	30.4	406	33.4	585	28.8	1532	31.3
13–15	89	15.0	202	16.6	334	16.4	815	16.6
>15	61	10.3	188	15.5	386	19.0	856	17.5
Maternal race/ethnicity								
Non-Hispanic White	178	29.3	510	41.4	729	34.9	1921	38.7
African American	47	7.7	83	6.7	177	8.5	502	10.1
Hispanic White	373	61.3	589	47.8	1120	53.6	2393	48.2
Other	10	1.6	51	4.1	64	3.1	146	2.9
Maternal employment status								
Employed outside home	182	29.9	486	39.4	859	41.1	2030	40.9
Homemaker, student or unemployed	413	67.9	734	59.5	1208	57.8	2881	58.0
Unknown	13	2.1	13	1.1	24	1.1	54	1.1
Paternal race/ethnicity								
Non-Hispanic White	149	30.9	465	44.1	689	39.1	1667	39.2
African American	28	5.8	64	6.1	149	8.5	397	9.3
Hispanic White	297	61.6	487	46.2	873	49.6	2054	48.3
Other	8	1.7	39	3.7	49	2.8	131	3.1
Paternal employment status								
Employed outside home	446	73.4	997	80.9	1639	78.4	3957	79.7
Homemaker, student or unemployed	33	5.4	44	3.6	88	4.2	210	4.2
Unknown	129	21.2	192	15.6	364	17.4	798	16.1

* Only live births included among cases and controls.

aides were more likely to have children with oral clefts. Numbers of women in the occupational categories of interest were sparse, however, leading to imprecise estimates.

Although similar associations were found between Hispanic and non-Hispanic White paternal occupations and congenital malformations (Table 3), we observed some marked differences in risk estimates for several occupations by Hispanic ethnicity. Compared with fathers in other occupations, Hispanic fathers who were electricians were 2.1 times more likely to have a child with Down syndrome and 2.9 times more likely to have a child with other chromosomal anomalies, especially trisomy 18 (OR 7.4, 95% CI 1.6–25.5, data not shown); no positive associations were noted between this occupation and chromosomal anomalies in non-Hispanic White fathers. Among Hispanic fathers, isolated cleft palate in offspring was associated with the paternal occupations of farmworker (OR 3.3, 95% CI 1.0–8.9), janitor (OR 6.8, 95% CI 1.6–23.1), and printer (OR 14.8, 95% CI 2.1–89.0). In this study population, no non-Hispanic White fathers of children with oral clefts were farmworkers or janitors, and the association between a printing occupation and cleft palate was less strong (OR 6.7, 95% CI .6–59.1) than among Hispanic fathers. On the other hand, a paternal occupation as policemen was associated with oral clefts in offspring of non-Hispanic White fathers but not found among children born to Hispanic fathers; this association was restricted to isolated cleft lip with or without cleft palate (OR 3.3, 95% CI 1.4–7.5).

DISCUSSION

Findings from this study suggest that the relationship between parental occupation and some congenital malformations may vary by maternal and paternal Hispanic ethnicity. Our selection of occupations for study was based on positive associations reported in the literature between parental jobs and risk for offspring with NTDs, oral clefts,

Table 2. Maternal occupation and selected congenital malformations by maternal Hispanic ethnicity for occupations previously associated with birth defects*

Occupational group and birth defect	Hispanic White Mothers				Non-Hispanic White Mothers			
	Cases *n* (%)	Controls *n* (%)	Unadjusted OR and 95% CI	Adjusted† OR and 95% CI	Cases *n* (%)	Controls *n* (%)	Unadjusted OR and 95% CI	Adjusted† OR and 95% CI
Cleaner								
Neural tube defects	6 (7.2)	20 (2.8)	2.7 (1.0–6.8)	2.8 (.9–7.8)	2 (2.2)	5 (.5)	4.8 (.9–25.2)	3.5 (.3–22.7)
Oral clefts	2 (1.2)	20 (2.8)	.41 (.1–1.8)	.38 (.04–1.6)	2 (.7)	5 (.5)	1.5 (.3–7.9)	.68 (.01–6.2)
Cook								
Oral clefts	4 (2.4)	6 (.9)	2.8 (.8–10.2)	3.3 (.6–16.0)	1 (.4)	4 (.4)	.95 (.1–8.5)	.95 (.02–9.7)
Engineer/technician								
Down syndrome	1 (.4)	2 (.3)	1.6 (.1–17.4)	.57 (.01–14.8)	3 (1.1)	6 (.6)	2.0 (.5–8.0)	1.7 (.3–9.0)
Nursing aide								
Oral clefts	4 (2.4)	19 (2.7)	.87 (.3–2.6)	.86 (.2–2.6)	8 (2.9)	8 (.8)	3.9 (1.4–10.4)	3.7 (1.2–11.7)
Nursing occupations								
Neural tube defects	3 (3.6)	9 (1.3)	2.9 (.8–10.9)	3.1 (.5–13.1)	3 (3.4)	44 (4.2)	.80 (.2–2.6)	.98 (.2–3.2)
Oral clefts	3 (1.8)	9 (1.3)	1.4 (.4–5.2)	1.5 (.3–6.1)	14 (5.0)	44 (4.2)	1.2 (.7–2.3)	1.3 (.7–2.6)
Waitress								
Oral clefts	5 (3.0)	12 (1.7)	1.8 (.6–5.1)	1.7 (.5–5.4)	8 (2.9)	24 (2.3)	1.3 (.6–2.9)	1.3 (.5–3.1)

* Only odds ratios (OR) and 95% confidence intervals (CI) shown for associations >1.4 and with three or more exposed cases (total).
† Adjusted for maternal age and education.

and chromosomal anomalies. Nevertheless, only a few of these associations were corroborated in the present study, and most were confined to either Hispanic or non-Hispanic parents.

In a study of maternal occupation and NTDs among Mexican American women living along the Texas-Mexico border, an overall association was found between work in health care and NTD risk (OR 3.0, 95% CI 1.0–9.0).[11] In the present study, sufficient numbers of cases and controls were available to examine specific healthcare occupations. A positive association between nursing occupations and NTD risk was noted for Hispanic women but not for non-Hispanic White women. Another study found nursing occupations to be associated with NTDs, but this study was conducted in a predominantly non-Hispanic population.[8] In a study of maternal occupational exposure to glycol ethers and birth defects, women in occupations with the most exposure to these compounds, including those working as cooks and nursing aides, were more likely to have offspring with oral clefts.[19] In the present study, Hispanic women who were cooks and non-Hispanic White women who were nursing aides appeared more likely to have babies with these defects.

Findings from this study suggest that the relationship between parental occupation and some congenital malformations may vary by maternal and paternal Hispanic ethnicity.

Among occupations and case groups with sufficient numbers of Hispanic and non-Hispanic fathers (three or more exposed), marked differences were noted in risk estimates by Hispanic ethnicity for electricians and chromosomal anomalies, military occupations and NTDs, and printers and oral clefts in offspring. Most of the previous studies in which these associations were detected were conducted among predominantly non-Hispanic populations,[20,21] or separate risk estimates were not reported by Hispanic ethnicity.[22]

Although the present study had several strengths, such as medical record confirmation of all birth defects and a relatively large sample size, it also had several limitations. Some associations may have been missed because job classifications were based on the usual occupation listed on the birth certificate. Collection of usual occupation instead of jobs during the periconceptional period (three months prior to three months postconception) could lead to misclassification of work exposures during the period of greatest vulnerability for mutagenesis or teratogenesis. Previous studies of comparisons between occupational information on birth certificates with mail or telephone interview data have found some misclassification on certificates.[23,24] The investigators suggested that this misclassification was nondifferential with respect to malformed and normal comparison births and would produce associations closer to the null (no effect) than those obtained from more precise data collection methods.[23,24]

This problem of misclassification was compounded by missing occupations on 16% to 21% of the paternal groups, depending on case group and

Table 3. Paternal occupation and selected congenital malformations by paternal Hispanic ethnicity for occupations previously associated with birth defects*

Occupational group and birth defect	Hispanic White Fathers				Non-Hispanic White Fathers			
	Cases *n* (%)	Controls *n* (%)	Unadjusted* OR and 95% CI	Adjusted† OR and 95% CI	Cases *n* (%)	Controls *n* (%)	Unadjusted* OR and 95% CI	Adjusted† OR and 95% CI
Chemical worker								
Oral clefts	5 (1.1)	9 (.5)	2.4 (.8–7.1)	2.0 (.4–7.1)	5 (1.1)	8 (.5)	2.2 (.7–6.9)	2.3 (.6–7.9)
Electrician								
Down syndrome	9 (1.7)	18 (.9)	1.9 (.9–4.2)	2.1 (.8–5.1)	7 (1.6)	26 (1.6)	1.0 (.4–2.4)	1.0 (.4–2.5)
Non-Down syndrome chromosomal anomalies	8 (2.5)	18 (.9)	2.8 (1.2–6.5)	2.9 (1.1–7.3)	2 (.8)	26 (1.6)	.5 (.1–2.2)	.5 (.1–2.0)
Electronic equipment operator								
Oral clefts	5 (1.1)	9 (.5)	2.4 (.79–7.1)	2.5 (.6–8.2)	2 (.4)	15 (.9)	.5 (.1–2.1)	.5 (.1–2.0)
Engineering technician								
Oral clefts	0	10 (.5)	—	—	5 (1.1)	7 (.4)	2.6 (.8–8.1)	2.6 (.6–9.5)
Farm manager or farmworker								
Down syndrome	9 (1.7)	45 (2.3)	.8 (.4–1.5)	.7 (.3–1.5)	7 (1.6)	18 (1.1)	1.5 (.6–3.5)	1.7 (.6–4.6)
Farmworker								
Neural tube defects	9 (3.1)	31 (1.6)	2.0 (1.0–4.3)	2.0 (.8–4.4)	0	4 (.2)	—	—
Non-Down chromosomal anomalies	7 (2.2)	31 (1.6)	1.4 (.6–3.2)	1.6 (.6–3.8)	1 (.4)	4 (.2)	1.7 (.2–15.3)	2.0 (.04–20.6)
Oral clefts	11 (2.3)	31 (1.6)	1.5 (.8–3.0)	1.5 (.7–3.2)	0	4 (.2)	—	—
Janitor								
Non-Down syndrome chromosomal anomalies	3 (.9)	12 (.6)	1.6 (.4–5.6)	1.4 (.2–5.5)	0	3 (.2)	—	—
Oral clefts	7 (1.5)	12 (.6)	2.5 (1.0–6.3)	2.1 (.7–6.2)	0	3 (.2)	—	—
Material moving equipment operator								
Non-Down syndrome chromosomal anomalies	1 (.3)	20 (1.0)	.3 (.04–2.3)	.3 (.01–1.7)	2 (.8)	8 (.5)	1.7 (.4–8.1)	2.2 (.2–11.0)
Other mechanic								
Down syndrome	25 (4.7)	72 (3.6)	1.3 (.8–2.1)	1.2 (.7–2.0)	15 (3.4)	38 (2.3)	1.5 (.8–2.8)	1.7 (.8–3.3)
Military occupation								
Neural tube defects	3 (1.0)	21 (1.1)	1.0 (.3–3.3)	1.1 (.2–3.9)	6 (4.1)	34 (2.1)	2.0 (.8–4.9)	2.0 (.7–5.1)
Painter								
Neural tube defects	6 (2.1)	51 (2.6)	.8 (.3–1.9)	.8 (.3–1.9)	2 (1.4)	7 (.4)	3.2 (.7–15.6)	2.7 (.3–14.8)
Police								
Oral clefts	0	18 (.9)	—	—	12 (2.6)	19 (1.2)	2.3 (1.1–4.7)	2.3 (1.0–5.1)
Printer								
Oral clefts	5 (1.1)	4 (.2)	5.3 (1.4–19.9)	5.5 (1.2–28.0)	3 (.6)	3 (.2)	3.6 (.7–17.8)	3.5 (.5–26.4)
Transport worker								
Neural tube defects	14 (4.8)	95 (4.8)	1.0 (.6–1.8)	1.0 (.5–1.8)	8 (5.4)	59 (3.6)	1.5 (.7–3.3)	1.5 (.6–3.2)

* Only odds ratios (OR) and 95% confidence intervals (CI) shown for associations >1.4 and with three or more exposed cases (total).
† Adjusted for maternal age and education.

case-control status. We compared aggregated paternal occupational groups (aggregated according to schema suggested by the US Office of Management and Budget)[16] in this study with the distribution of fathers' occupations during the periconceptional period for Texas participants in the National Birth Defects Prevention Study.[25] For both Hispanic and non-Hispanic White fathers, the distributions of fathers' occupations were similar between the two studies by case and control status.

Associations may have also been missed or weakened by confining the case groups to live births. Because of increased prenatal mortality with some defects, associations with weak teratogens may go undetected in case-control studies restricted to live births.[26] In the present study, this selection bias would have more likely occurred with chromosomal anomalies and NTDs than with isolated oral clefts.

The live birth certificates lacked information on maternal folic acid use, which has been shown to reduce risk for both NTDs[27] and oral clefts.[28] Maternal folic acid use may vary by parental occupation, and lack of adjustment for supplementation may have resulted in confounded risk estimates. On the other hand, we adjusted all risk estimates for maternal age and education, factors strongly associated with maternal folic acid intake during the periconceptional period.[29–31]

In conclusion, the observed differences in risk estimates by Hispanic ethnicity for

congenital malformations from parental occupational exposures may have several explanations. Susceptibility to the harmful effects of chemical exposures may vary by ethnicity either because of genetic variations or behavioral factors. For instance, folic acid supplementation has been associated with reduced risk for NTDs and oral clefts in offspring.[27,28] However, a recent survey indicated that Hispanic women of childbearing age were less likely than non-Hispanic White women to take multivitamins, prenatal vitamins, or folic acid supplements on a daily basis.[32] With respect to chromosomal anomalies and NTDs, potential selection biases for prenatal diagnosis and elective terminations by various parental occupations may be different for Hispanic and non-Hispanic women. Occupation has also been found correlated with residential location.[33] Several studies have found ethnic disparities in residential proximity to industrial pollution,[34,35] and proximity to sources of environmental contamination has been associated with increased risk for some congenital malformations.[36] Differences found in this study for risk of several congenital malformations by Hispanic ethnicity in relation to parental occupation warrant further study in other Hispanic populations.

ACKNOWLEDGMENTS

This work was supported by the Centers for Disease Control and Prevention Cooperative Agreement U50/CCU613232 and Texas Department of State Health Services (DSHS) Center for Birth Defects Research and Prevention Contract 7097097093B. Birth certificate data were made available by the Texas DSHS Center for Health Statistics. The authors gratefully acknowledge the assistance of Zunera Gilani, MPH, with linking of birth defect cases with their respective vital records and Karen Moody, MS, Texas DSHS, with coding of occupation and industry.

REFERENCES

1. Petrini J, Damus K, Russell R, Poschman K, Davidoff MJ, Mattison D. Contribution of birth defects to infant mortality in the United States. *Teratology*. 2002;66(Suppl 1):S3–6.
2. 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.
3. 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 (Part A)*. 2006;76(11):747–756.
4. Croen LA, Shaw GM, Wasserman CR, Tolarova MM. Racial and ethnic variations in the prevalence of orofacial clefts in California, 1983–1992. *Am J Med Genet*. 1998;79(1):42–47.
5. Hashmi SS, Waller DK, Langlois P, Canfield M, Hecht JT. Prevalence of nonsyndromic oral clefts in Texas: 1995–1999. *Am J Med Genet*. 2005;134(4):368–372.
6. Olshan AF, Teschke K, Baird PA. Paternal occupation and congenital anomalies in offspring. *Am J Ind Med*. 1991;20(4):447–475.
7. Brender JD, Suarez L. Paternal occupation and anencephaly. *Am J Epidemiol*. 1990;131(3): 517–521.
8. Matte TD, Mulinare J, Erickson JD. Case-control study of congenital defects and parental employment in health care. *Am J Ind Med*. 1993;24(1):11–23.
9. Schnitzer PG, Olshan AF, Erickson JD. Paternal occupation and risk of birth defects in offspring. *Epidemiology*. 1995;6(6): 577–583.
10. Shaw GM, Velie EM, Katz EA, Morland KB, Schaffer DM, Nelson V. Maternal occupational and hobby chemical exposures as risk factors for neural tube defects. *Epidemiology*. 1999;10(2):124–129.
11. Brender J, Suarez L, Hendricks K, Baetz RA, Larsen R. Parental occupation and neural tube defect-affected pregnancies among Mexican Americans. *J Occup Environ Med*. 2002;44(7): 650–656.
12. Garcia AM, Fletcher T. Maternal occupation in the leather industry and selected congenital malformations. *Occup Environ Med*. 1998; 55(4):284–286.
13. Chia SE, Shi LM, Chan OY, Chew SK, Foong BH. Parental occupations and other risk factors associated with nonchromosomal single, chromosomal single, and multiple birth defects: a population-based study in Singapore from 1994 to 1998. *Am J Obstet Gynecol*. 2003;188(2):425–433.
14. Olshan AF, Baird PA, Teschke K. Paternal occupational exposures and the risk of Down syndrome. *Am J Hum Genet*. 1989;44(5): 646–651.
15. Rasmussen SA, Olney RS, Holmes LB, Lin AE, Keppler-Noreuil KM, Moore CA, National Birth Defects Prevention Study. Guidelines for case classification for the National Birth Defects Prevention Study. *Birth Defects Res A Clin Mol Teratol*. 2003;67(3):193–201.
16. US Office of Management and Budget. *Standard Occupational Classification Manual*. Springfield, Va: National Technical Information Service; 2002. p. 257.
17. US Office of Management and Budget. *North American Industry Classification System. United States, 2002*. Springfield, Va: National Technical Information Service; 2002. p. 1419.
18. Mehta C, Patel N. *LogXact 5*. Cambridge, Mass: Cytel Software Corporation; 2002.
19. Cordier S, Bergeret A, Goujard J, et al. Congenital malformations and maternal occupational exposure to glycol ethers. *Epidemiology*. 1997;8(4):355–363.
20. Hansteen IL. Occupational and lifestyle factors and chromosomal aberrations of spontaneous abortions. *Prog Clin Biol Res*. 1990;340B: 467–475.
21. Kristensen P, Irgens LM, Daltveit AK, Andersen A. Perinatal outcome among children of men exposed to lead and organic solvents in the printing industry. *Am J Epidemiol*. 1993;137:134–144.
22. Shaw GM, Nelson V, Olshan AF. Paternal occupational group and risk of offspring with neural tube defects. *Paediatr Perinat Epidemiol*. 2002;16(4):328–333.
23. Marshall EG, Gensburg LJ, Roth GB, Davidson GK, Dlugosz LJ. Comparison of mother's occupation and industry from the birth certificate and a self-administered questionnaire. *J Occup Med*. 1992;34(11):1090–1096.
24. Shaw GM, Malcoe LH, Croen LA, Smith DF. An assessment of error in parental occupation from the birth certificate. *Am J Epidemiol*. 1990;131(6):1072–1079.
25. Yoon PW, Rasmussen SA, Lynberg MC, et al. The National Birth Defects Prevention Study. *Public Health Rep*. 2001;116(Suppl 1): 32–40.
26. Khoury MJ, Flanders WD, James LM, Erickson JD. Human teratogens, prenatal mortality, and selection bias. *Am J Epidemiol*. 1989;130(2):361–370.
27. Goh YI, Bollano E, Einarson TR, Koren G. Prenatal multivitamin supplementation and rates of congenital anomalies: a meta-analysis. *J Obstet Gynaecol Can*. 2006;28(8):680–689.
28. Badovinac RL, Werler MM, Williams PL, Kelsey KT, Hayes C. Folic acid-containing supplement consumption during pregnancy and risk for oral clefts: a meta-analysis. *Birth Defects Res A Clin Mol Teratol*. 2007;79(1): 8–15.
29. Sen S, Manzoor A, Deviasumathy M, Newton C. Maternal knowledge, attitude and practice regarding folic acid intake during the periconceptional period. *Public Health Nutr*. 2001; 4(4):909–912.

30. de Jong-van den Berg LT, Hernandez-Diaz S, Werler MM, Louik C, Mitchell AA. Trends and predictors of folic acid awareness and periconceptional use in pregnant women. *Am J Obstet Gynecol*. 2005;192(1):121–128.
31. Nilsen RM, Vollset SE, Gjessing HK, Magnus P, Meltzer HM, Haugen M, Ueland PM. Patterns and predictors of folic acid supplement use among pregnant women: the Norwegian Mother and Child Cohort Study. *Am J Clin Nutr*. 2006;84(5):1134–1141.
32. Canfield MA, Przybyla SM, Case AP, Ramadhani T, Suarez L, Dyer J. Folic acid awareness and supplementation among Texas women of childbearing age. *Prev Med*. 2006;43(1): 27–30.
33. Diez Roux AV, Kiefe CI, Jacobs DR, et al. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. *Ann Epidemiol*. 2001;11(6):395–405.
34. Woodruff TJ, Parker JD, Kyle AD, Schoendorf KC. Disparities in exposure to air pollution during pregnancy. *Environ Health Perspect*. 2003;111(7):942–946.
35. Perlin SA, Wong D, Sexton K. Residential proximity to industrial sources of air pollution: interrelationships among race, poverty, and age. *J Air Waste Manag Assoc*. 2001;51(3): 406–421.
36. Marshall EG, Gensburg LJ, Deres DA, Geary NS, Cayo MR. Maternal residential exposure to hazardous wastes and risk of central nervous system and musculoskeletal birth defects. *Arch Environ Health*. 1997; 52(6):416–425.

AUTHOR CONTRIBUTIONS

Design concept of study: Brender, Suarez
Acquisition of data: Brender, Suarez, Langlois
Data analysis and interpretation: Brender, Suarez, Langlois
Manuscript draft: Brender, Suarez
Statistical expertise: Suarez, Langlois
Acquisition of funding: Suarez, Langlois
Administrative, technical, or material assistance: Brender
Supervision: Brender