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Markers of Acculturation and Risk of NTDs among Hispanic Women in California

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Abstract

BACKGROUND—Prevalences of NTDs are typically 50–100% greater among Hispanic women compared to non-Hispanic Whites. This article examines whether markers of acculturation such as “language preference” allow the identification of high-risk groups within the Hispanic population. It also examines whether known NTD risk factors explain observed differences in risk among Hispanic women who are more and less acculturated.

METHODS—This population-based case-control study of deliveries in selected California counties from 1999–2003 included 337 NTD cases and 626 nonmalformed, liveborn controls.

RESULTS—Relative to less acculturated US-born Hispanic women (i.e., women who preferred reading and speaking Spanish), other subgroups (i.e., US-born Hispanic women who preferred English, foreign-born Hispanic women regardless of “language preference”, and non-Hispanic White women) had approximately twofold increased risks of spina bifida. Only the less acculturated foreign-born women (i.e., women with a preference for Spanish) had substantially increased risk of anencephaly (OR 1.7; 95% CI 0.9, 3.4). Adjustment for several NTD risk factors (maternal intake of folic acid-containing supplements, dietary folate intake, body mass index, food insecurity, stressful life events, smoking, alcohol intake, education, income, and neighborhood education and poverty) resulted in modest or no reductions in most of the ORs.

CONCLUSIONS—The explanation for variability in NTD risks among Hispanic and non-Hispanic White women therefore likely extends beyond most known NTD risk factors.

Keywords

birth defects; neural tube defects; acculturation; Hispanic

INTRODUCTION

Prevalences of NTDs are typically 50–100% greater among Hispanic women compared to non-Hispanic Whites (Feuchtbaum et al., 1999; Shaw et al., 1994; Canfield et al., 1996b, 2006). In particular, previous studies in California and Texas have reported that the increased risk was largely confined to foreign-born women, with prevalences being similar between US-born Hispanic women and non-Hispanic White women (Shaw et al., 1994, 1997; Hendricks et al., 1999). Furthermore, a case-control study of California births from 1989–1991 reported that

among foreign-born Hispanic women, more recent immigrants were at particularly increased risk (Shaw et al., 1997; Velie et al., 2006).

Few studies have investigated explanations for these findings (Canfield et al., 1996a). The most detailed analyses were derived from the California case-control study, which found that known risk factors for NTDs such as maternal obesity, intake of folic acid-containing vitamins, and socioeconomic status did not explain the observed differences in risks between US- and foreign-born Hispanics (Shaw et al., 1997; Velie et al., 2006).

Acculturation can be broadly defined as the process of changes in attitudes, values, and behaviors (including language ability) toward mainstream cultural patterns (Marin et al., 1987; Suarez and Pulley, 1995). Nativity and time since migration are often considered as markers of acculturation. Language proficiency and preference are also useful markers, having been shown to capture variability in a variety of other markers of the acculturative process (Cuellar et al., 1980; Marin et al., 1987; Suarez and Pulley, 1995). Although language-based markers of acculturation have limitations, they offer a first step toward measuring acculturation with greater specificity than nativity or time since migration alone.

Improved understanding of the association of acculturation with NTD risk among Hispanic women will facilitate the identification of high-risk groups and the development of appropriate intervention strategies. This article examines NTD risks among Hispanic women using data from a recently conducted, population-based case-control study of California births. Our hypothesis was that less acculturated Hispanic women would have the highest NTD risk. Specifically, we examined whether various markers of acculturation (beyond nativity alone) would allow the identification of high-risk groups within the Hispanic population and whether previously suggested NTD risk factors would explain observed differences in risk among more and less acculturated Hispanic women.

METHODS

This case-control study included liveborn, stillborn (fetal deaths at ≥ 20 weeks gestation), and prenatally diagnosed, electively terminated cases that occurred to mothers residing in Los Angeles, San Francisco, and Santa Clara counties. The study included data on deliveries that had estimated due dates from July 1999 to June 2003. Study methods are described briefly here, given that detailed descriptions have been published previously (Carmichael et al., 2007a,b). California Birth Defects Monitoring Program staff abstracted information from medical records at hospitals and genetic counseling centers serving the study population, and this information was reviewed by a clinical geneticist. Infants diagnosed with single gene disorders or chromosomal aneusomies were ineligible. Each case was classified as isolated if there was no concurrent major malformation or as nonisolated if there was at least one accompanying major malformation. Cases with spina bifida and anencephaly were included. Spina bifida included lipomeningocele, meningomyelocele, and myelocystocele. Nonmalformed, live-born controls were selected randomly from birth hospitals, to represent the population from which the cases were derived. Maternal interviews were conducted primarily by telephone in English or Spanish using a standardized, computer-based questionnaire. A variety of exposures was assessed, focusing on the periconceptional time period, which was defined as the 2 months before through the 2 months after conception.

In total, 76% (337/441) of eligible case mothers and 80% (626/786) of control mothers were interviewed. Fourteen percent ($n = 62$) of eligible case mothers and 11% ($n = 85$) of control mothers were not locatable, and the remainder of the mothers declined to participate. The median time between estimated due dates and interview completion was 10 months for cases

and 8 months for controls. The current analyses were restricted to the 293 cases and 479 controls whose mothers were Hispanic or US-born, non-Hispanic White.

Among Hispanic women, markers of acculturation included nativity, number of years the mother had resided in the US at the time of conception, age at migration, father's race-ethnicity, and a series of questions about language preference and proficiency (Marin et al., 1987). The language proficiency questions were: (1) In general, what language do you read and speak? (2) What language did you usually speak as a child? (3) What language do you usually speak at home? (4) In which language do you usually think? (5) What language do you usually speak with your friends? The response choices for each of these questions were only Spanish, Spanish more than English, Spanish and English about equally, English more than Spanish, and only English (scored as one through five, respectively). If the mother's answer to the first question was "only English" or "only Spanish," the final three questions were imputed as having the same response. In addition to analyzing the language proficiency questions separately, we also examined the sum of the responses to the five questions.

An additional marker of acculturation was the percentage of households in the mother's neighborhood that were linguistically isolated (i.e., all members ≥ 14 years old spoke Spanish, and they spoke English less than "very well"), which was obtained as follows. Mothers reported addresses at which they lived for at least a month during the periconceptional period. Addresses were geocoded to 2000 US Census block groups using EZ-Locate, an online geocoding service. For subjects with multiple geocoded addresses, one address was randomly selected for analysis. Geocoding was successful for 283 (84%) of interviewed cases and 552 (88%) of interviewed controls. The Census information was downloaded and linked with the analytic data set.

We examined several potential NTD risk factors with regard to their ability to explain differences in risks among Hispanic and non-Hispanic women: maternal periconceptional intake of folic acid-containing supplements, dietary folate intake, prepregnancy body mass index (pregnancy weight divided by height-squared), food insecurity (Blumberg et al., 1999), stressful life events (Carmichael et al., 2007a), smoking, alcohol intake, education, and household income, and from the Census we derived neighborhood education (proportion of the population aged ≥ 25 who did not graduate high school or its equivalent) and poverty (proportion of the noninstitutionalized population living below poverty level, which was \$17,029 for a family of four in 1999). For analyses, we divided the neighborhood-level variables into quartiles based on the distribution among the control population; values below the 25th percentile reflect the highest socioeconomic status category for each measure.

To assess usual dietary intake of folate, women answered a 107-item modified version of the Health Habits and History Questionnaire, a well-known, semiquantitative food frequency questionnaire with demonstrated reliability and validity (Block et al., 1986, 1990). The food frequency questionnaire was modified to include ethnic foods appropriate to the diverse study population; a version with similar modifications demonstrated good validity and reliability among Hispanics (Mayer-Davis et al., 1999). Analytic software developed for the survey instrument (Dietsys) was used to compute the average daily dietary intake of single nutrients. Data were recoded to missing for the following women, due to potentially invalid results: women with four or more missing food items ($n = 5$ total); women who reported eating more than 30 foods per day ($n = 29$) or fewer than four foods per day ($n = 2$ total, but one was retained for analysis, because the interviewer confirmed special circumstances that resulted in reduced food intake); women who reported three or more high frequency foods ($n = 9$; i.e., foods that were eaten two or more times per day or beverages that were consumed more than six times per day); and women who consumed more than 6,000 kilocalories per day (i.e., 25,116 kJ, $n = 16$) or fewer than 500 kilocalories per day (i.e., 2,093 kJ, $n = 1$). In total, these criteria resulted in missing data for 31 mothers of controls and 12 mothers of cases.

We used logistic regression to estimate ORs and 95% CIs. We first compared risk of having NTD-affected offspring among foreign-born Hispanic women, US-born Hispanic women, and non-Hispanic White women. We then examined whether any of the markers of acculturation described above allowed the identification of any subgroups of Hispanic women at especially high risk of NTDs. We defined five subgroups of women for further analyses based on these results (i.e., foreign-born Hispanic, Spanish preference; foreign-born Hispanic, English preference; US-born Hispanic, Spanish preference; US-born Hispanic, English preference; and non-Hispanic White). We compared the distribution of the potential NTD risk factors described above among these five subgroups of women using chi-square tests. To examine whether these NTD risk factors explained differences in risk observed among these subgroups, we used backward step-wise selection. We used this approach because of the relatively large number of potential covariates, relatively limited sample size in certain subgroups, and missing data on certain variables (e.g., household income and the census-based variables). The initial models included a variable designating the five subgroups of women and all potential covariates listed above. In each step, the term with the highest *p* value was removed, until all terms had *p* < .10. Each model included all women with nonmissing data on the variables included in that particular model. Analyses were run for NTDs overall and separately for anencephaly and spina bifida. Final analyses were rerun excluding nonisolated cases, subjects with a family history of an NTD in a first-degree relative, and subjects whose mothers had type I or II diabetes.

All data collection was approved by the State of California, Health and Human Services Agency, Committee for the Protection of Human Subjects.

RESULTS

Among control mothers, 49% (*n* = 236) were foreign-born Hispanic, 28% (*n* = 134) were US-born Hispanic, and 23% (*n* = 109) were US-born non-Hispanic White. As expected, relative to US-born Hispanic women, foreign-born women were at increased risk of delivering offspring with NTDs (OR 1.6; 95% CI: 1.1, 2.3). Unexpectedly, non-Hispanic White women were also at increased risk, relative to US-born Hispanic women (OR 1.5; 95% CI: 1.0, 2.3). Increased risks were primarily for spina bifida.

We examined whether markers of acculturation allowed identification of high-risk subgroups among US-or foreign-born Hispanic women (Table 1). Among US-born Hispanic women, a preference for reading and speaking English and higher levels of neighborhood language isolation were each associated with approximately twofold increased risks of spina bifida, but CIs included 1. Among foreign-born Hispanic women, a preference for Spanish and migration less than 2 years ago were associated with approximately threefold increased risk of anencephaly. Lower scores for the sum of the language questions (i.e., responses tended to indicate a preference for Spanish), higher levels of neighborhood linguistic isolation, and migration at age 13–22 (vs. younger) were associated with moderately, but not significantly, increased risks of both phenotypes. Adjustment of the markers of acculturation for each other did not substantially change the ORs, and examination of language preference and neighborhood language isolation in combination did not suggest any particularly high-risk groups (data not shown). Father's race-ethnicity was not associated with risk among foreign-born or US-born women (data not shown).

We compared risks among five subgroups of women based on race-ethnicity and language preference, which were created based on the results in Table 1. Relative to US-born women who preferred Spanish, the other subgroups had approximately twofold increased risk of spina bifida, while only foreign-born women with a preference for Spanish had substantially increased risk of anencephaly (Table 2).

We then examined whether the distribution of the potential NTD risk factors described above varied among control mothers in the five subgroups (Table 3). Women with a preference for Spanish were less likely to smoke or drink, had less education and lower income, and lived in neighborhoods with lower levels of education and higher levels of poverty than women with a preference for English. Foreign-born Spanish-speaking women were least likely among all the groups to take folic acid-containing supplements and most likely to report some level of food insecurity, but they were most likely to be in the highest quartile of dietary folate intake. Non-Hispanic White women were most likely to take supplements, smoke, and drink, and least likely to be overweight or obese. They had the highest education and household income, and they were least likely to live in neighborhoods with lower levels of education and higher levels of poverty.

Adjustment of ORs comparing risks among the five subgroups of women for the potential NTD risk factors resulted in modest or no reductions in most of the ORs (Table 4). The most marked changes were that the ORs for anencephaly and spina bifida among non-Hispanic White women were actually higher after adjustment (the crude ORs were 1.3 and 2.6 and the adjusted ORs were 1.9 and 3.6 for anencephaly and spina bifida, respectively). Exclusion of nonisolated cases ($n = 28$), subjects with a family history of an NTD in a first-degree relative ($n = 4$ cases, 1 control), and subjects whose mothers who had type I or II diabetes ($n = 7$ cases, 1 control) did not substantially alter these results (data not shown).

DISCUSSION

In this study of recent births to Hispanic and non-Hispanic White women in California, we found that risks of NTDs varied based on markers of acculturation. For spina bifida, less acculturated US-born Hispanic women (i.e., women who preferred Spanish) were at lowest risk, with risks being approximately twofold higher among more acculturated US-born Hispanic women, among foreign-born Hispanic women, and among non-Hispanic White women. For anencephaly, risks did not vary as much among the Hispanic women. Adjustment for several factors known to be associated with NTD risk and acculturation did not substantially alter these results. The explanation for this study's findings therefore likely extends beyond the known NTD risk factors that we examined. The explanation for our findings is unknown but may include other unmeasured maternal behaviors or characteristics related to the acculturative process.

Several factors may contribute to the lack of a consistent pattern of NTD risk relative to presumed acculturation status. The distributions of several NTD risk factors were not entirely consistent relative to the assumed acculturation level. For example, the least acculturated group of women—i.e., foreign-born, Spanish-speaking women—had a less favorable distribution for some factors (e.g., socioeconomic status, food insecurity, supplemental folic acid) but a more favorable distribution for other factors (e.g., dietary folate, smoking). Differences in factors related to socioeconomic status were relatively consistent, with Spanish-speaking women—whether foreign- or US-born—having the lowest levels, English-speaking women having intermediate levels, and White women having the highest levels. These findings tend to parallel previous studies of these factors among Hispanic women (Crimmins et al., 2007; Detjen et al., 2007; Dubowitz et al., 2007; Wildsmith, 2002). Given that acculturation is positively associated with some NTD risk factors and negatively associated with other risk factors, it is not completely surprising that our results suggest that the association of acculturation subgroups with NTD risk is not entirely consistent.

The increased risk of spina bifida among non-Hispanic White women, relative to US-born Hispanic women, was unexpected. The covariates that were examined did not explain this observation. Prenatal diagnosis and termination of cases may have been more common among

non-Hispanic White women, but differences in prevalence of terminations and/or under-ascertainment of such cases would have to be extreme (which is unlikely) to result in the observed ORs. Study subjects were delivered after folate fortification of the food supply was in place; it is possible that the relative risks among Hispanics and non-Hispanic Whites have changed due to differences in the effectiveness of fortification in these groups of women (e.g., if the percentage of folate-preventable NTDs has changed differentially). However, solid evidence supporting or refuting this hypothesis is not available.

The difference in the pattern of results for spina bifida and anencephaly was also unexpected. However, the expectation was based on just one previous study—a California study of risk of having offspring with NTDs among Hispanic women, which reported that the pattern of observed risks was similar for anencephaly and spina bifida (Shaw et al., 1997).

Strengths of this analysis are its inclusion of more detailed markers of acculturation than previous studies, phenotype-specific analyses, population-based control selection procedures, active case ascertainment, and inclusion of elective terminations in a diverse, recent, and large study population. Although language-based markers of acculturation have limitations, they offer a first step toward measuring acculturation with greater specificity than nativity or time since migration alone, they are predictive of various aspects of the acculturative process (Marin et al., 1987; Cuellar et al., 1980; Suarez and Pulley, 1995), and they lay the groundwork in understanding what causes NTDs (Abraido-Lanza et al., 2006). Given the relatively low frequency of the NTDs, we used a retrospective study design, and recall bias could have occurred. Although there is concern that mothers of malformed infants will over-report or more thoroughly report exposures than controls (Lippman and Mackenzie, 1985; Swan et al., 1992; Khoury et al., 1994), several studies suggest that for many exposures recall bias is likely to be minimal (Swan et al., 1992; Khoury et al., 1994; Klemetti and Saxen, 1967; Werler et al., 1989), but none of them studied acculturation. The Hispanic population in this study is primarily from Mexico, with Mexico being the country of origin for 85% of control mothers and 88% of case mothers. Whether our results are generalizable to Hispanics from other countries is uncertain. Although the study base was relatively large, many of our comparisons were limited to relatively few women, and chance was a likely explanation for many of our results.

Very few studies have explored potential explanations for observed differences in NTD risks among Hispanic and non-Hispanic women. The current analyses advance our understanding of disparities in NTD risks between Hispanic and non-Hispanic women by using recent data, examining more in-depth measures of acculturation than previous studies, and considering the ability of a variety of known NTD risk factors to explain the observed differences. The unique features of our study (e.g., the specific geographic area, the use of postfortification data), coupled with the complex pattern of the observed associations and the availability of few previous studies for comparison, make the public health implications of our findings somewhat uncertain. Although we do not know the underlying explanation for our results, our findings do suggest a complex association between acculturation and NTDs that is not easily explained by known NTD risk factors. It would be useful for future studies of NTDs among Hispanics to at least include measures of language preference as a marker of acculturation, so that we can determine whether the current results are replicable in other study areas. In addition, further study of more detailed measures of the acculturative process may improve our understanding of NTD etiology.

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REFERENCES

- Abraido-Lanza AF, Armbrister AN, Florez KR, et al. Toward a theory-driven model of acculturation in public health research. *Am J Public Health* 2006;96:1342–1346. [PubMed: 16809597]
- Block G, Hartman AM, Dresser CM, et al. A data-based approach to diet questionnaire design and testing. *Am J Epidemiol* 1986;124:453–469. [PubMed: 3740045]
- Block G, Woods M, Potosky A, et al. Validation of a self-administered diet history questionnaire using multiple diet records. *J Clin Epidemiol* 1990;43:1327–1335. [PubMed: 2254769]
- Blumberg SJ, Bialostosky K, Hamilton WL, et al. The effectiveness of a short form of the household food security scale. *Am J Pub Health* 1999;89:1231–1234. [PubMed: 10432912]
- Canfield MA, Annegers JF, Brender JD, et al. Hispanic origin and neural tube defects in Houston/Harris County, Texas. II. Risk factors. *Am J Epidemiol* 1996a;143:12–24. [PubMed: 8533743]
- Canfield MA, Annegers JF, Brender JD, et al. Hispanic origin and neural tube defects in Houston/Harris County, Texas. I. Descriptive epidemiology. *Am J Epidemiol* 1996b;143:1–11. [PubMed: 8533740]
- 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;76:747–756. [PubMed: 17051527]
- Carmichael SL, Shaw GM, Yang W, et al. Maternal stressful life events and risks of birth defects. *Epidemiology* 2007a;18:356–361. [PubMed: 17435445]
- Carmichael SL, Yang W, Herring A, et al. Food insecurity and risks of birth defects. *J Nutr* 2007b;137:2087–2092. [PubMed: 17709447]
- Crimmins EM, Kim JK, Alley DE, et al. Hispanic paradox in biological risk profiles. *Am J Public Health* 2007;97:1305–1310. [PubMed: 17538054]
- Cuellar I, Harris LC, Jasso R. An acculturation scale for Mexican American normal and clinical populations. *Hisp J Beh Sci* 1980;2:199–217.
- Detjen MG, Nieto FJ, Trentham-Dietz A, et al. Acculturation and cigarette smoking among pregnant Hispanic women residing in the United States. *Am J Public Health* 2007;97:2040–2047. [PubMed: 17901446]
- Dubowitz T, Smith-Warner SA, Acevedo-Garcia D, et al. Nativity and duration of time in the United States: differences in fruit and vegetable intake among low-income postpartum women. *Am J Public Health* 2007;97:1787–1790. [PubMed: 17761585]
- Feuchtbaum LB, Currier RJ, Riggle S, et al. Neural tube defect prevalence in California (1990–1994): eliciting patterns by type of defect and maternal race/ethnicity. *Genet Test* 1999;3:265–272. [PubMed: 10495925]
- Hendricks KA, Simpson JS, Larsen RD. Neural tube defects along the Texas-Mexico border, 1993–1995. *Am J Epidemiol* 1999;149:1119–1127. [PubMed: 10369506]
- Khoury MJ, James LM, Erickson JD. On the use of affected controls to address recall bias in case-control studies of birth defects. *Teratol* 1994;49:273–281.
- Klemetti A, Saxen L. Prospective versus retrospective approach in the search for environmental causes of malformations. *Am J Pub Health* 1967;57:2071–2075.
- Lippman, A.; Mackenzie, SG. What is “recall bias” and does it exist?. In: Marois, M., editor. *Prevention of physical and mental congenital defects*. Alan R. Liss, Inc.; New York: 1985. p. 205-209.
- Marin G, Sabogal F, Marin BV, et al. Development of a short acculturation scale for Hispanics. *Hisp J Beh Sci* 1987;9:183–205.
- Mayer-Davis EJ, Vitolins MZ, Carmichael SL, et al. Validity and reproducibility of a food frequency interview in a multi-cultural epidemiologic study. *Ann Epidemiol* 1999;9:314–324. [PubMed: 10976858]
- Shaw GM, Jensvold NG, Wasserman CR, et al. Epidemiologic characteristics of phenotypically distinct neural tube defects among 0.7 million California births, 1983–1987. *Teratol* 1994;49:143–149.

- 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;87:1467–1471. [PubMed: 9314798]
- Suarez L, Pulley L. Comparing acculturation scales and their relationship to cancer screening among older Mexican-American women. *Monogr Natl Cancer Inst* 1995;18:41–47. [PubMed: 8562221]
- Swan SH, Shaw GM, Shulman J. Reporting and selection bias in case-control studies of congenital malformations. *Epidemiol* 1992;3:356–363.
- Velie EM, Shaw GM, Malcoe LH, et al. Understanding the increased risk of neural tube defect-affected pregnancies among Mexico-born women in California: immigration and anthropometric factors. *Paediatr Perinat Epidemiol* 2006;20:219–230. [PubMed: 16629696]
- Werler MM, Poher BR, Nelson K, et al. Reporting accuracy among mothers of malformed and nonmalformed infants. *Am J Epidemiol* 1989;129:415–421. [PubMed: 2643303]
- Wildsmith EM. Testing the weathering hypothesis among Mexican-origin women. *Ethn Dis* 2002;12:470–479. [PubMed: 12477132]

Table 1

Association of Risk of Having Offspring with NTDs with Maternal Race-Ethnicity and with Markers of Acculturation among US-Born and Foreign-Born Hispanic Women

	No. cases			Unadjusted OR (95% CI)		
	Anencephaly (<i>n</i> = 121)	Spina bifida (<i>n</i> = 172)	No. controls (<i>n</i> = 479)	NTDs	Anencephaly	Spina bifida
All women						
Foreign-born Hispanic	66	98	236	1.6 (1.1, 2.3)	1.3 (0.8, 2.2)	1.9 (1.2, 2.9)
U.S.-born Hispanic	28	30	134	Reference	Reference	Reference
Non-Hispanic White	27	44	109	1.5 (1.0, 2.3)	1.2 (0.7, 2.1)	1.8 (1.1, 3.1)
US-born Hispanic women						
Language preference [*]						
Only Spanish or Spanish more than English	1	2	11	0.8 (0.2, 3.0)	0.4 (0.05, 3.8)	1.2 (0.2, 6.5)
Spanish and English about equally	11	8	53	Reference	Reference	Reference
Only English or English more than Spanish	16	20	68	1.5 (0.8, 2.9)	1.1 (0.5, 2.6)	1.9 (0.8, 4.8)
Sum of language questions [†]						
Only or mostly Spanish (5–10)	0	2	9	0.5 (0.1, 2.4)	–	1.2 (0.2, 7.3)
Mix of Spanish and English (11–15)	8	5	27	Reference	Reference	Reference
Only or mostly English (16–25)	20	22	96	0.9 (0.4, 1.9)	0.7 (0.3, 1.8)	1.2 (0.4, 3.6)
Neighborhood language isolation [‡]						
Lowest quartile (<7.0%)	9	5	45	Reference	Reference	Reference
Higher quartiles (≥7.0%)	19	21	78	1.6 (0.8, 3.4)	1.2 (0.5, 2.9)	2.4 (0.9, 6.9)
Foreign-born Hispanic women						
Language preference [*]						
Only Spanish or Spanish more than English	60	78	185	1.5 (0.8, 2.6)	3.2 (1.1, 9.2)	1.0 (0.5, 1.9)
Spanish and English about equally	4	16	39	Reference	Reference	Reference
Only English or English more than Spanish	2	2	11	0.7 (0.2, 2.5)	1.8 (0.3, 11.0)	0.4 (0.1, 2.2)
Sum of language questions [†]						
Only or mostly Spanish (5–10)	57	79	183	1.5 (0.8, 3.0)	1.8 (0.7, 4.9)	1.4 (0.6, 3.1)
Mix of Spanish and English (11–15)	5	9	29	Reference	Reference	Reference
Only or mostly English (16–25)	4	8	22	1.1 (0.4, 2.9)	1.1 (0.3, 4.4)	1.2 (0.4, 3.5)
Neighborhood language isolation [‡]						

	No. cases			Unadjusted OR (95% CI)		
	Anencephaly (n = 121)	Spina bifida (n = 172)	No. controls (n = 479)	NTDs	Anencephaly	Spina bifida
Lowest quartile (<7.0%)	7	9	38	Reference	Reference	Reference
Higher quartiles (≥7.0%)	45	71	169	1.6 (0.9, 3.1)	1.4 (0.6, 3.5)	1.8 (0.8, 3.9)
Age at migration (years)						
<=12	9	22	61	Reference	Reference	Reference
13–17	24	31	61	1.8 (1.0, 3.1)	2.7 (1.1, 6.2)	1.4 (0.7, 2.7)
18–22	17	29	53	1.7 (1.0, 3.1)	2.2 (0.9, 5.3)	1.5 (0.8, 3.0)
>22	14	12	53	1.0 (0.5, 1.8)	1.8 (0.7, 4.5)	0.6 (0.3, 1.4)
Years since migration						
<2	4	2	5	1.6 (0.5, 5.4)	2.9 (0.7, 11.4)	0.8 (0.2, 4.5)
2–4	17	12	50	0.8 (0.5, 1.3)	1.2 (0.6, 2.4)	0.5 (0.3, 1.0)
5–9	13	29	63	0.9 (0.6, 1.4)	0.7 (0.4, 1.5)	1.0 (0.6, 1.7)
10+	32	55	116	Reference	Reference	Reference

* Language preference reflects the mother's response to the question "In general, what language do you read and speak?"

† Categories reflect the sum of responses to five questions regarding language proficiency, each of which was scored from one to five (see Methods).

‡ Categories reflect quartile cut-offs for language isolation based on all Hispanic controls.

Table 2
Association of Risk of Having Offspring with NTDs with Maternal Race-Ethnicity and Language Preference Subgroups

Maternal race-ethnicity and language preference*	No. subjects			Unadjusted OR (95% CI)		
	NTDs	Anencephaly	Spina bifida	Controls	NTDs	Anencephaly
Foreign-born Hispanic, Spanish preference	138	60	78	185	2.2 (1.3, 3.7)	1.7 (0.9, 3.4)
Foreign-born Hispanic, English preference	24	6	18	50	1.4 (0.7, 2.8)	0.6 (0.2, 1.8)
US-born Hispanic, Spanish preference	22	12	10	64	Reference	Reference
US-born Hispanic, English preference	36	16	20	68	1.5 (0.8, 2.9)	1.3 (0.6, 2.9)
Non-Hispanic White	71	27	44	109	1.9 (1.1, 3.3)	1.3 (0.6, 2.8)

* Language preference was defined as follows, based on responses to the question: "In general, what language do you read and speak?" Foreign-born women who responded "only Spanish" or "Spanish more than English" were designated as preferring Spanish; US-born women who responded "only English" or "English more than Spanish" were designated as preferring English.

Table 3

Association of Maternal Characteristics with Maternal Race-Ethnicity and Language Preference Subgroups among 476 Control Mothers

Maternal characteristics *	Foreign-born Hispanic, Spanish preference (n = 185)	Foreign-born Hispanic, English preference (n = 50)	US-born Hispanic, Spanish preference (n = 64)	US-born Hispanic, English preference (n = 68)	Non-Hispanic White (n = 109)	p value
Any intake of folic acid-containing supplement [†] (n = 2 missing)	46%	57%	56%	57%	83%	<.001
Dietary folate intake [†] (n = 30 missing)						
Lowest quartile	17%	37%	25%	38%	37%	<.001
Highest quartile	32%	20%	27%	9%	12%	
Pregnancy body mass index (n = 39 missing)						
Underweight	9%	11%		16%	26%	.006
Normal weight	54%	57%	14%	47%	58%	
Overweight	15%	6%	54%	13%	4%	
Obese	21%	26%	16%	24%	13%	
Food insecurity (questions with a "yes" response) [†] (n = 2 missing)						
0	73%	94%	89%	85%	96%	<.001
1	9%	4%	2%	4%	2%	
2 or more	18%	2%	9%	10%	2%	
Stressful life events [†] (n = 0 missing)						
0	46%	50%	47%	34%	51%	.27
1	17%	24%	17%	21%	21%	
2 or more	37%	26%	36%	46%	28%	
Any smoking [†] (n = 0 missing)	1%	4%	5%	12%	15%	<.001
Any alcohol intake [†] (n = 2 missing)	5%	20%	11%	21%	35%	<.001
Education (n = 3 missing)						<.001
<12 years	65%	18%	38%	18%	4%	
=12 years	21%	46%	34%	33%	14%	
>12 years	14%	36%	28%	49%	81%	
Annual household income (n = 62 missing)						
<\$10,000	49%	14%	20%	29%	6%	<.001

Maternal characteristics*	Foreign-born Hispanic, Spanish preference (n = 185)	Foreign-born Hispanic, English preference (n = 50)	US-born Hispanic, Spanish preference (n = 64)	US-born Hispanic, English preference (n = 68)	Non-Hispanic White (n = 109)	p value
\$10,000–40,000	47%	47%	60%	32%	18%	
\$40,000 or more	4%	40%	20%	39%	76%	
Neighborhood education† (n = 53 missing)						
Worst quartile	30%	16%	35%	10%	0%	<.001
Best quartile	18%	22%	17%	51%	82%	
Neighborhood poverty† (n = 53 missing)						
Worst quartile	32%	20%	25%	8%	2%	<.001
Best quartile	16%	33%	23%	41%	76%	

* See Methods for variable definitions.

† During the 2 months before pregnancy or during the first 2 months of pregnancy.

Association of Risk of Having Offspring with NTDs with Maternal Race-Ethnicity and Language Preference Subgroups, Adjusted for NTD Risk Factors

Table 4

Maternal race-ethnicity and language preference [†]	No. subjects			Adjusted OR (95% CI) [*]		
	NTDs	Anencephaly	Spina bifida	NTDs	Anencephaly	Spina bifida
Foreign-born Hispanic, Spanish preference	105	60	58	1.8 (1.0, 3.2)	1.5 (0.7, 3.0)	2.2 (1.1, 4.7)
Foreign-born Hispanic, English preference	23	6	18	1.4 (0.7, 2.8)	0.7 (0.2, 2.0)	2.4 (1.0, 5.7)
US-born Hispanic, Spanish preference	22	12	10	Reference	Reference	Reference
US-born Hispanic, English preference	36	16	20	1.5 (0.8, 2.9)	1.3 (0.5, 2.9)	1.9 (0.8, 4.5)
Non-Hispanic White	69	27	42	2.6 (1.4, 4.7)	1.9 (0.9, 4.2)	3.6 (1.6, 8.0)

* All models are adjusted for intake of folic acid supplements, smoking, and stressful life events; in addition, results for NTDs and spina bifida are adjusted for body mass index, and results for anencephaly are adjusted for food insecurity.

[†] Language preference was defined as follows, based on responses to the question: "In general, what language do you read and speak?" Foreign-born women who responded "only Spanish" or "Spanish more than English" were designated as preferring Spanish; US-born women who responded "only English" or "English more than Spanish" were designated as preferring English.

[‡] Number of controls for models for anencephaly are shown first; numbers for models for spina bifida are in parentheses; numbers are different because the set of covariates was different.