Short Paper

A comparison of the US birth outcomes among Mexican Women by maternal nativity with Covariate Density Defined mixture of logistic regressions

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ABSTRACT

The study examines the effects of maternal nativity on birth outcome and infant mortality by applying Covariate Density Defined mixture of logistic regressions (CDDmlr) to Mexican American cohorts from the 2001 US national linked-birth-death-file. Nativity is dichotomized as Mexico-born versus US-born. Within each nativity stratum, CDDmlr identifies "normal" and "compromised" births in terms of fetal development. Both "normal" and "compromised" births have higher mean birth weight (by 42 and 87 grams, respectively) by nativity. So overall, births to Mexico-born women have a 20% lower risk of low-birth-weight. Nativity has a "direct" protective effect on infant mortality among "normal" births, reducing mortality by 24% across sex. However, it does not seem to affect mortality among "compromised" births. Therefore, the 15% decrease in the overall infant mortality by nativity is primarily attributed to "normal" births. Also, results support the view that birth weight is not on the causal pathway to mortality.

INTRODUCTION

Attributes such as lower education level, less prenatal care, and poorer socioeconomic status are classic maternal risk factors for poor birth outcomes. However, when compared with non-Hispanic African births in the US, Hispanics (primarily Mexican Americans) often exhibit favorable birth outcomes in terms of low rates of low-birth-weight, prematurity, and infant mortality despite comparable disadvantaged profiles (Markides and Coreil 1986; Buekens, Notzon et al. 2000; Brown, Chireau et al. 2007). Furthermore, Hispanic women have similar or even better birth outcomes than non-Hispanic European American women. This phenomenon has been termed the "epidemiological paradox" (or "Hispanic paradox") (Markides and Coreil 1986).

The "epidemiological paradox" has been studied by many researchers, focusing on maternal nativity (i.e. mother's birth place) (Singh and Yu 1996; Leslie, Diehl et al. 2006; Hummer, Powers et al. 2007), using simple regression techniques. The aim of this study is to investigate the effect of country of maternal birth on birth outcomes among Mexican-American women by using a novel statistical method, Covariate Density Defined mixture of logistic regressions (CDDmlr). CDDmlr resolves the "pediatric" paradox by probabilistically identifying a subpopulation with lower birth weight and lower birth weight specific mortality. Also it has been applied to study the effects of a number of risk factors for adverse birth outcomes (e.g. race, education , maternal age, prenatal care, tobacco use, altitudes, and etc.) in heterogeneous cohorts (Gage, Fang et al. 2009; Gage, Fang et al. 2010; Gage, Fang et al. submitted).

METHODS

Source of Data

The data for this analysis are obtained from 2001 NCHS Birth Cohort Linked Birth/Infant Death dataset. Race/ethnicity (i.e. Mexican American births) and maternal nativity (i.e. US or Mexico) are based on mother's reported race/ethnic origin, and birth place, respectively. Births with missing information on LMP gestational age, or LMP gestational age <20 weeks, or birth weight <500 grams are excluded from the analysis. Summary statistics for the samples used are presented in Table 1. These data are public use samples, freely distributed by NCHS and used with permission.

Table 1 about here

Statistical Model – CDDmlr

The formal definition of the basic CDDmlr and CDDmlr with an exogenous indicator variable has been described in detail in Gage et al. (2004; 2010). In brief, the joint likelihood function of birth weight (x) and survival status (y, infant death ($y=1$) vs. survived longer than a year ($y=0$)) given maternal nativity (z, Mexico-born women ($z=1$) vs. US-born women ($z=0$)) in the case of two subpopulations is the weighted sum of subpopulation-specific likelihood of (polynomial) logistic regressions of mortality by standardized birth weight (rescaled based on the subpopulation-specific mean and standard deviation) with weights determined by the birth weight distribution (i.e. a mixture of two Gaussians truncated at 500 grams with mixing proportion Π), i.e.

$$f(y,x \mid z;\Pi,\Phi,\Theta) = \sum_{i=s,p}\left[\pi_i(z)\cdot \tilde{N}(x;\mu_i(z),\sigma_i(z))\cdot g\left(y \mid x_i^*, z;\Theta_i\right)\right] \quad \text{(Eq. 1)}$$

$$\pi_i(z) = \pi_{i,0} + z\cdot\pi_{i,1} \text{ and } \pi_s(z)+\pi_p(z)=1 \quad \text{(Eq. 2)}$$

$$\mu_i(z) = \mu_{i,0} + z\cdot\mu_{i,1} \quad \text{(Eq. 3)}$$

$$\sigma_i(z) = \sigma_{i,0} + z\cdot\sigma_{i,1} \quad \text{(Eq. 4)}$$

$$logit\left[g\left(y=1 \mid x_i^*, z;\Theta_i\right)\right] = a_i(z) + b_i(z)\cdot x_i^*(z) + c_i(z)\cdot\left[x_i^*(z)\right]^2 \quad \text{(Eq. 5)}$$

$$x_i^*(z) = \frac{x-\mu_i(z)}{\sigma_i(z)} \quad \text{(Eq. 6)}$$

$$a_i(z) = a_{i,0} + z\cdot a_{i,1} \quad \text{(Eq. 7)}$$

$$b_i(z) = b_{i,0} + z\cdot b_{i,1} \quad \text{(Eq. 8)}$$

$$c_i(z) = c_{i,0} + z\cdot c_{i,1} \quad \text{(Eq. 9)}$$

The full model has 22 parameters, with 10 for the birth weight distribution and 12 for the logistic regressions.

Following Gage et al. (2004; 2010), for a cohort with a specific value of z, the subpopulation accounting for the majority of individuals is labeled the primary (p) subpopulation and the remaining minority component is labeled the secondary (s) subpopulation. Parameters $\pi_{s,1}$, $\mu_{s,1}$, $\sigma_{s,1}$, $\mu_{p,1}$, and $\sigma_{p,1}$ represent the effects of maternal nativity on birth weight. Parameters $a_{i,1}$, $b_{i,1}$, and $c_{i,1}$ represent the effects of maternal nativity on infant mortality (in particular, the standardized birth weight specific mortality curve) in subpopulation i ($i = s$ and p).

Model Fitting

The model (Eq. 1) is fitted using the method of maximum likelihood to individual level data by SPLUS. Nested chi-square analyses are carried out to determine the significance of parameters. Bias-adjusted 95% confidence intervals of each parameter in the parsimonious model are estimated with 200 bootstrap samples.

Decomposition of the Maternal Nativity Effect on Infant Mortality

Using the standard Kitagawa decomposition method (Gupta 1978), the overall infant mortality disparity between births to Mexico-born and US-born women is decomposed into effects attributable to 1) the differences in the mixing proportion, 2) the difference in the death rates of the secondary subpopulations, and 3) the difference in the death rates of the primary subpopulations.

RESULTS

Similar to other studies on birth weight and infant mortality using two-subpopulation CDDmlr (Gage, Bauer et al. 2004; Gage, Fang et al. 2009; Gage, Fang et al. 2010), for births to US-born (or Mexico-born) women, its primary subpopulation accounts for most births in the center of the birth weight distribution and appears to identify births with "normal" fetal development (Fig. 1). The secondary subpopulation accounts for most low-birth-weight and macrosomic births and is hence called "compromised" births.

Figure 1 about here

Maternal nativity influences the birth weight distribution mainly through increasing the mean birth weights of both subpopulations (Figure 1, Table 2). In particular, "normal" and "compromised" births to Mexico-born women usually are ~42 grams and ~87 grams heavier compared to their peers born to US-born women, respectively. For Mexico-born women, the size of its "compromised" subpopulation tends to be smaller by ~10%. These shifts in the birth weight distribution represent improved birth outcomes using the standard metrics, such as mean birth weight, or low-birth-weight rate (i.e. the proportion of births less than 2500 grams). In particular, the low-birth-weight rate declines from 3.2% to 2.4% and 2.4% to 1.8% for "normal" female and male births to Mexico-born women versus those to US-born women, respectively. The risk of low-birth-weight decreases by maternal nativity among "compromised" births of both sexes as well, thought the changes are statistically insignificant. Overall, US-born women have a higher low-birth-weight rate than Mexico-born women (i.e. 5.8% and 5.5% vs. 4.7% and 4.4% for females and males, respectively) as generally observed (Cervantes, Keith et al. 1999; Collins and David 2004; Page 2004; Acevedo-Garcia, Soobader et al. 2007).

Table 2 about here

A series of hierarchal chi-square tests on how maternal nativity affects infant mortality after controlling for its effects on the birth weight distribution are carried out and the results are presented in Table 3. The full model (i.e. the 1st model in Table 3) fits both the birth weight distributions and the birth weight specific mortality curves remarkably well (not shown) as demonstrated in previous studies which applied the same model to birth outcome and mortality (Gage and Therriault 1998; Gage, Bauer et al. 2004; Gage, Fang et al. 2010). Given the full model, the parsimonious model at $\alpha = 0.05$ level is the 15th model with 17 parameters (10 for the birth weight distribution and 7 for the logistic regressions). According to the parsimonious model, the standardized birth weight specific mortality curve of "compromised" births is the same regardless of mother's birth place (Fig. 2a). However, maternal nativity lowers the mortality curve (more precisely, the log odds of infant death) across standardized birth weight among “normal” births, that is births to Mexico-born women have lower mortality at each standardized birth weight compared to births to US-born women (Fig. 2a).

Table 3 about here

Figure 2 about here

Using the parsimonious model, the predicted risk of infant death among the “compromised” subpopulation to US-born women is comparable to that to Mexico-born women (Table 4), while the risk of infant death among “normal” births to Mexico-born women is 22.3% and 26.2% lower than their peers to US-born women for females and males, respectively. Overall, births to Mexico-born women have significant advantage with respect to infant mortality. Kitagawa decomposition analysis confirms that this advantage is mostly due to lower death rate among “normal” births (Table 5).

Table 4 about here

Table 5 about here

DISCUSSION

The birth weight specific infant mortality curve and birth weight distribution appear to shift right together among the “compromised” (or “normal”) subpopulation in response to the stressor (maternal nativity here) (Fig. 2b, Table 4). Using the definitions of Wilcox and Russell (Wilcox and Russell 1990; Wilcox 2001), maternal nativity appears to change mortality “directly” (i.e. independent of birth weight) among the “normal” subpopulation and has no any effect among the “compromised” subpopulation. Since birth weight dose not seem to medicate the effects of stressors (e.g. maternal nativity, low education level (Gage, Fang et al. submitted), older maternal age at delivery (Gage, Fang et al. 2009), lack of prenatal care utilization (unpublished), tobacco use (unpublished), and higher elevation (unpublished)) on infant mortality, our results are consistent with the Wilcox-Russell hypothesis (Wilcox and Russell 1990; Wilcox 2001) that suggests birth weight is not on the “causal pathway” to infant mortality at least for “normal” births.

Our results show that babies (particularly "normal" births) to Mexico-born women are heavier and have lower risk of infant death than those to US-born women. However, this analysis does not propose that maternal nativity itself is causal to the "epidemiological paradox". Instead, it is simply a proxy for a collection of maternal risk factors for adverse birth outcomes that are the underlying causes (including low levels of education, lack of prenatal care, poor life style, and etc., some of which can not be addressed with the US vital statistics data alone). As shown in Table 1, there are significant differences in some of the maternal characteristics depending on mother's birth place among the 2001 Mexican American birth cohorts. For instance, ~20% more Mexico-born women do not complete a high school education compared to US-born women. However, Mexico-born women are much less likely to get pregnant as teenage than US-born women, instead ~44% of Mexico-born women give birth between 26 and 35 years old compared to ~32% of US-born women. Also, there are some differences by maternal nativity with respect to tobacco use during pregnancy, prenatal care utilization, and parity.

Based on the studies using maternal nativity as well as other variables, the healthy immigrant effect (i.e. Mexican immigrants are believed to be sturdier and have fewer reproductive losses than US-born women) (Guendelman and English 1995; Kennedy, McDonald et al. 2006; Wingate and Alexander 2006) and the acculturation effect (i.e. acculturation and assimilation is associated with worse health outcomes) (Crump, Lipsky et al. 1999; Callister and Birkhead 2002; Lara, Gamboa et al. 2005; Gallo, Penedo et al. 2009) have been demonstrated to be very important in resolving this paradox. Similar to the use of maternal nativity, each of these two phenomena reflects an integrated effect of a wide variety of socio-demographic, behavioral, cultural, psychosocial, and biological variables, which may be difficult to measure. A third line of work has focused on data quality issues (i.e. the "salmon bias") , though it is unlikely this explanation can explain the "epidemiological paradox" (Abraido-Lanza, Dohrenwend et al. 1999; Hummer, Powers et al. 2007).

Since late 1980s to early 2000, the proportion of Mexico-born women has increased from 55% (Singh and Yu 1996) to 65% (Table 1) among Mexican women in the US. Despite that more women present an elevated risk profile for adverse birth outcomes, the "epidemiological paradox" between Mexican and non-Hispanic European American birth had remained. However, further analysis has shown that births to US-born Mexican women (Table 1) begin to demonstrate significantly higher infant mortality compared to European American birth of the same year (Gage, Fang et al. 2010), while the advantage of Mexico-born Mexican women seems to decrease. If the maternal nativity advantage of Mexico-born women on birth outcomes continue to erode because of a bigger acculturation effect and a smaller healthy immigrant effect (e.g. due to the decrease in the number of new immigrants and/or the decline in the health of new immigrants) without significant improvements in some socio-economic attributes, it is possible that the paradox might disappear. Instead, a significant ethnic disparity might emerge in a couple of decades.

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REFERENCES

Abraido-Lanza, A. F., B. P. Dohrenwend, et al. (1999). "The Latino mortality paradox: a test of the" salmon bias" and healthy migrant hypotheses." American Journal of Public Health **89**(10): 1543-1548.

Acevedo-Garcia, D., M. J. Soobader, et al. (2007). "Low birthweight among US Hispanic/Latino subgroups: the effect of maternal foreign-born status and education." Soc Sci Med **65**(12): 2503-16.

Brown, H. L., M. V. Chireau, et al. (2007). "The "Hispanic paradox": an investigation of racial disparity in pregnancy outcomes at a tertiary care medical center." American Journal of Obstetrics and Gynecology **197**(2): 197 e1-9.

Buekens, P., F. Notzon, et al. (2000). "Why do Mexican Americans give birth to few low-birth-weight infants?" American Journal of Epidemiology **152**(4): 347-51.

Callister, L. C. and A. Birkhead (2002). "Acculturation and perinatal outcomes in Mexican immigrant childbearing women: an integrative review." The Journal of Perinatal & NHeonatal Nursing **16**(3): 22-38.

Cervantes, A., L. Keith, et al. (1999). "Adverse birth outcomes among native-born and immigrant women: replicating national evidence regarding Mexicans at the local level." Maternal and Child Health Journal **3**(2): 99-109.

Collins, J. W., Jr. and R. J. David (2004). "Pregnancy outcome of Mexican-American women: the effect of generational residence in the United States." Ethnicity and Disease **14**(3): 317-21.

Crump, C., S. Lipsky, et al. (1999). "Adverse birth outcomes among Mexican-Americans: are US-born women at greater risk than Mexico-born women?" Ethnicity and Health **4**(1-2): 29-34.

Gage, T. B., M. J. Bauer, et al. (2004). "Pediatric paradox: Heterogeneity in the birth cohort." Human Biology **76**(3): 327-342.

Gage, T. B., F. Fang, et al. (2010). "Racial disparities in infant mortality: What has birth weight got to do with it and how large is it?" BMC Pregnancy and Childbirth **10**: 86.

Gage, T. B., F. Fang, et al. (2009). "Maternal age and infant mortality: A test of the Wilcox-Russell hypothesis." American Journal of Epidemiology **169**(3): 294-303.

Gage, T. B., F. Fang, et al. (submitted). "Education, birth weight, and infant mortality: Does birth weight mediate effects of socioeconomic level on infant mortality in the USA?"

Gage, T. B. and G. Therriault (1998). "Variability of birth-weight distributions by sex and ethnicity: Analysis using mixture models." Human Biology **70**(3): 517-534.

Gallo, L. C., F. J. Penedo, et al. (2009). "Resiliency in the face of disadvantage: do Hispanic cultural characteristics protect health outcomes?" Journal of Personality **77**(6): 1707-46.

Guendelman, S. and P. B. English (1995). "Effect of United States residence on birth outcomes among Mexican immigrants: An exploratory study." American Journal of Epidemiology **142**(S9): S30.

Gupta, P. D. (1978). "A general method of decomposing a difference between two rates into several components." Demography **15**(1): 99-112.
Hummer, R. A., D. A. Powers, et al. (2007). "Paradox found (again): infant mortality among the Mexican-origin population in the United States." Demography **44**(3): 441-57.
Kennedy, S., J. T. McDonald, et al. (2006). The healthy immigrant effect and immigrant selection: evidence from four countries, SEDAP Research Program.
Lara, M., C. Gamboa, et al. (2005). "Acculturation and Latino health in the United States: a review of the literature and its sociopolitical context." Annual Review of Public Health **26**: 367.
Leslie, J. C., S. J. Diehl, et al. (2006). "A comparison of birth outcomes among US-born and non-US-born Hispanic Women in North Carolina." Maternal and Child Health Journal **10**(1): 33-8.
Markides, K. S. and J. Coreil (1986). "The health of Hispanics in the southwestern United States: An epidemiologic paradox." Public Health Reports **101**(3): 253-265.
Page, R. L. (2004). "Positive pregnancy outcomes in Mexican immigrants: what can we learn?" Journal of Obstetric, Gynecologic, & Neonatal Nursing **33**(6): 783-90.
Singh, G. K. and S. M. Yu (1996). "Adverse pregnancy outcomes: Differences between US-and foreign-born women in major US racial and ethnic groups." American Journal of Public Health **86**(6): 837.
Wilcox, A. J. (2001). "On the importance - and the unimportance - of birthweight." International Journal of Epidemiology **30**(6): 1233-1241.
Wilcox, A. J. and I. Russell (1990). "Why small black infants have a lower mortality-rate than small white infants - the case for population-specific standards for birth-weight." Journal of Pediatrics **116**(1): 7-10.
Wingate, M. S. and G. R. Alexander (2006). "The healthy migrant theory: variations in pregnancy outcomes among US-born migrants." Social Science & Medicine **62**(2): 491-8.

Figure 1 Parsimonious CDDmlr-predicted birth weight distributions by maternal nativity: Females

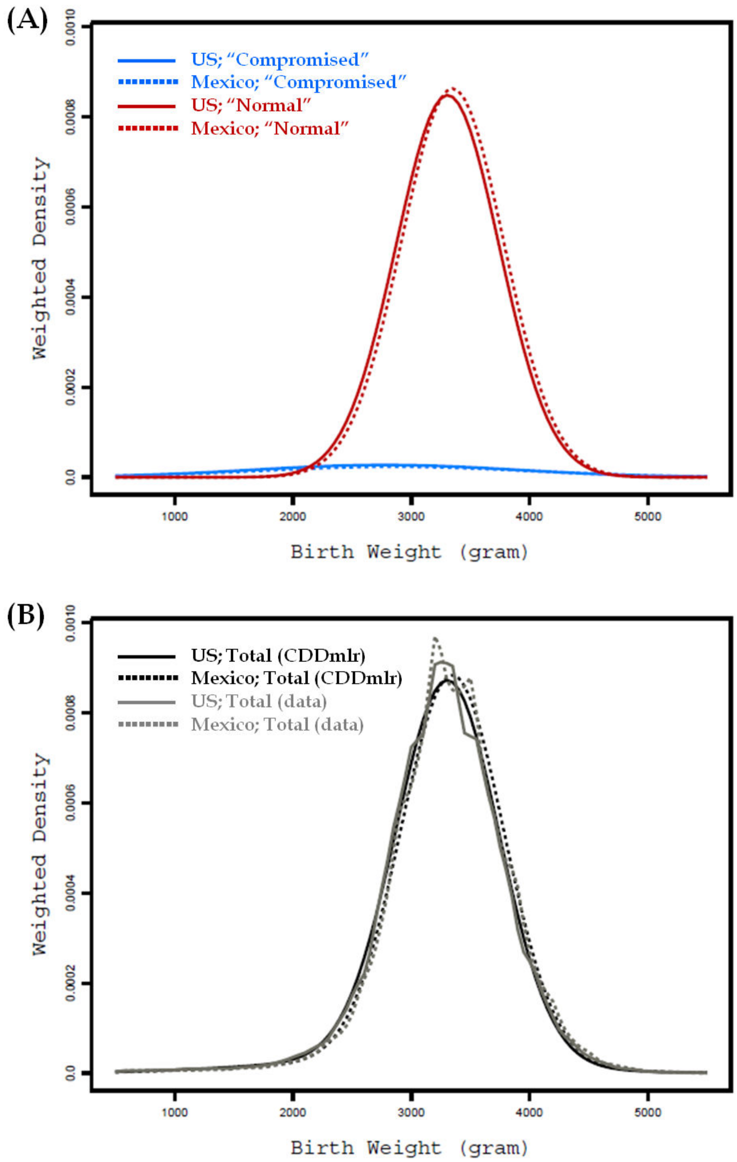

Figure 2 Parsimonious CDDmlr-predicted (standardized) birth weight specific infant mortalities by maternal nativity: Males

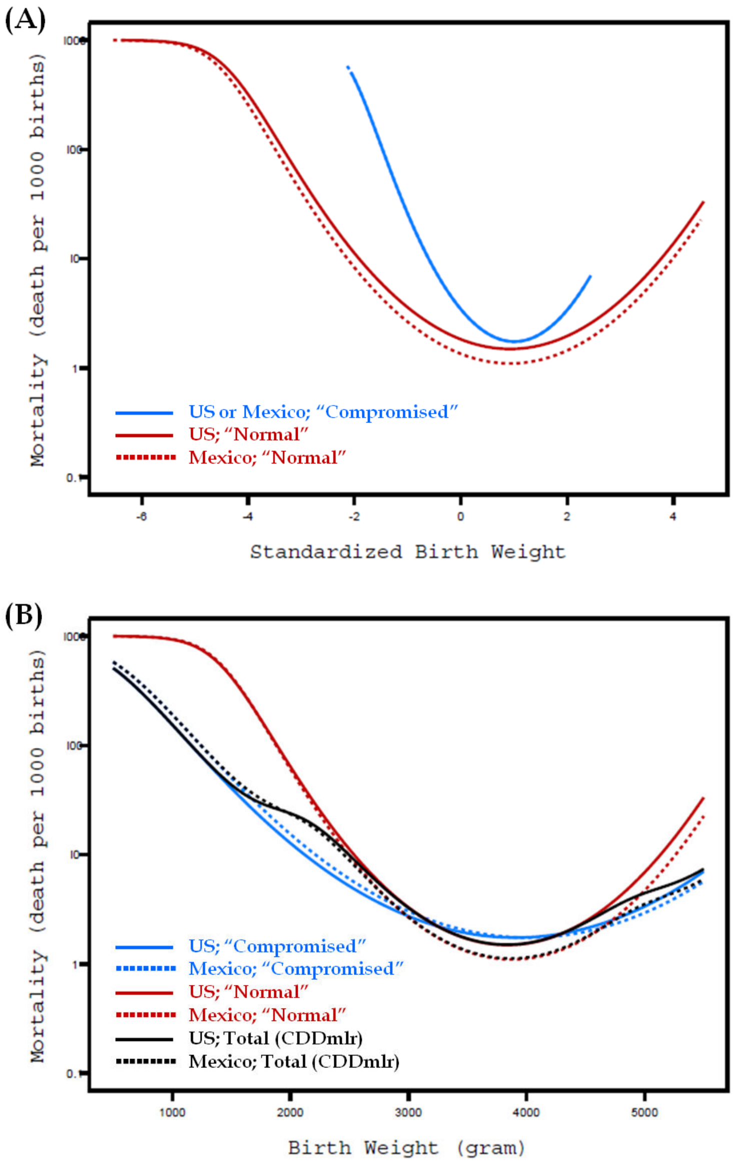

Table 1 Summary of the 2001 Mexican American births by sex and maternal nativity

	Females		Males	
maternal nativity	US	Mexico	US	Mexico
# live birth	95,919	173,250	99,976	179,301
# infant death	376	572	477	725
mortality (death/1000)	3.9	3.3	4.8	4.0
birth weight distribution				
mean	3271	3320	3364	3417
st.dev	522	512	557	546
median	3289	3319	3390	3430
composition (%) by maternal education level				
high school and below	72.6	87.3	72.6	87.4
college and above	26.5	10.3	26.5	10.2
unknown	0.9	2.4	0.9	2.4
composition (%) by mother's age				
<19	15.6	8.0	15.6	8.0
19-20	15.9	9.7	16.0	9.7
21-25	32.4	30.5	32.3	30.7
26-30	20.9	28.1	20.7	27.9
31-35	10.7	16.3	10.8	16.4
36-40	4.0	6.3	4.0	6.3
>40	0.5	1.1	0.6	1.1
composition (%) by tobacco use				
smoker	3.4	0.4	3.4	0.4
nonsmoker	62.0	63.3	61.9	63.7
unknown	34.6	36.2	34.7	35.8
composition (%) by prenatal care utilization defined by the Kessner Index				
adequate	68.4	59.1	67.7	58.8
intermediate	20.9	26.0	21.4	26.2
inadequate	6.4	9.9	6.5	10.0
unknown	4.3	5.0	4.4	5.0
composition (%) by live birth order				
1	39.2	34.4	39.5	34.3
2	30.4	29.7	30.4	29.9
3	17.5	20.2	17.6	20.2
4	7.6	9.2	7.3	9.2
5 & more	4.4	6.1	4.4	6.1
unknown	0.8	0.4	0.8	0.4

Table 2 Nested chi-square tests on the logistic regression parameters

Model #	parameters of nativity effect [#]						Females			Males		
	$a_{s,1}$	$b_{s,1}$	$c_{s,1}$	$a_{p,1}$	$b_{p,1}$	$c_{p,1}$	M.L.V.	D.F.	p-value	M.L.V.	D.F.	p-value
1	√	√	√	√	√	√	2055848.64			2150992.88		
2	√	√	√	√	√		2055851.71	1	0.01	2150993.76	1	0.18
3	√	√	√	√			2055851.71	2	0.05	2150994.59	2	0.18
4	√	√	√				2055854.79	3	0.01	2151003.17	3	0.00
5	√	√		√	√	√	2055848.64	1	0.97	2150992.88	1	0.98
6	√			√	√	√	2055849.62	2	0.38	2150993.78	2	0.41
7				√	√	√	2055849.93	3	0.46	2150994.34	3	0.40
8	√	√		√	√		2055852.03	2	0.03	2150993.78	2	0.41
9	√	√		√			2055852.11	3	0.07	2150994.68	3	0.31
10	√	√					2055854.97	4	0.01	2151003.26	4	0.00
11	√			√	√		2055852.05	3	0.08	2150996.28	3	0.08
12				√	√		2055852.05	4	0.14	2150996.35	4	0.14
13	√			√			2055852.12	4	0.14	2150997.85	4	0.04
14	√						2055855.70	5	0.01	2151003.73	5	0.00
15				√			2055852.12	5	0.22 *	2150997.85	5	0.08 *
16							2055855.88	6	0.02	2151004.09	6	0.00

[#]: baseline parameters $a_{s,0}$, $b_{s,0}$, $c_{s,0}$, $a_{p,0}$, $b_{p,0}$, and $c_{p,0}$ are included in all models

*: parsimonious model at α=0.05 level

Table 3 Parameter estimates of the birth weight distributions for the 2001 Mexican American births by sex

	Females	Males
$\pi_{s,0}$ (%)	7.4	8.5
$\pi_{s,1}$ (%)	-0.9	-0.6
$\mu_{s,0}$ (g)	2776	2791
$\mu_{s,1}$ (g)	77	98
$\sigma_{s,0}$ (g)	1107	1108
$\sigma_{s,1}$ (g)	26	11
$\mu_{p,0}$ (g)	3306	3413
$\mu_{p,1}$ (g)	42	45
$\sigma_{p,0}$ (g)	435	457
$\sigma_{p,1}$ (g)	-3	-4

Table 4 Parsimonious CDDmlr-predicted infant mortality characteristics for the 2001 Mexican American births by sex and maternal nativity

	Females		Males	
maternal nativity	US ($z = 0$)	Mexico ($z = 1$)	US ($z = 0$)	Mexico ($z = 1$)
"compromised"				
standardized OBW	1.2	1.2	1.0	1.0
OBW (g)	4158	4266	3906	4016
mortality* at OBW	1.4	1.4	1.7	1.7
death rate*	20.6	21.9	24.1	25.6
percent of TDR (%)	39.0	43.2	42.9	49.9
"normal"				
standardized OBW	0.8	0.8	0.9	0.9
OBW (g)	3673	3712	3836	3877
mortality* at OBW	1.3	1.0	1.5	1.1
death rate	2.6	2.0	3.0	2.2
percent of TDR (%)	61.0	56.8	57.1	50.0
total death rate* (TDR)	3.9	3.3	4.8	4.0

OBW: optimal birth weight where the minimal birth weight specific mortality occurs
*: death per 1000 births

Table 5 Kitagawa decomposition of the disparity of maternal nativity in infant mortality (death per 1000 births) of the 2001 Mexican American births by sex

	Females	Males
mixing proportion effect	-0.17	-0.14
death rate effect		
"compromised"	0.09	0.13
"normal"	-0.53	-0.72
total disparity	-0.62	-0.73