Paradox Revisited: A Further Examination of Race/Ethnic Differences in Infant Mortality by Maternal Age[1]

Abstract

We use the 1995-2002 U.S. NCHS linked birth-infant death files to analyze infant mortality by maternal age, race/ethnicity, and nativity and to reexamine the epidemiological paradox of lower infant mortality in specific populations relative to US-born non-Hispanic whites—the most relevant comparison groups being US-born Mexican Origin and Foreign-Born Mexican Origin women, due to their similarity to US-born non-Hispanic blacks on a number of risk factors. The six subpopulations considered here exhibit different maternal age distributions of births, with births skewed towards younger ages in the Mexican Origin and US-born Non-Hispanic black populations. Mexican Origin populations exhibit lower infant mortality at younger maternal ages relative to US-born Non-Hispanic whites—consistent with the epidemiological paradox. Infant mortality is higher at older ages in the Mexican Origin populations (relative to US-born Non-Hispanic whites)—consistent with the conceptual framework of "weathering." These patterns persist after controlling for known risk factors in multivariate models.

Introduction

Considerable research has documented the epidemiological paradox of more favorable health and mortality outcomes among Hispanics relative to non-Hispanic whites in the U.S. (Franzini et al. 2001; Guendelman 2000; Landale et al. 2000; Markides and Coreil 1986; Markides and Eschbach 2005; Palloni and Morenoff 2001; Smith and Bradshaw 2006). Perhaps the most puzzling patterns are exhibited by the Mexican Origin population of the United States, who are characterized by low levels of educational attainment and low rates of health insurance coverage, but who exhibit mortality rates similar to non-Hispanic whites and much lower rates than those of non-Hispanic blacks across most of the life course (Elo et al. 2004; Frisbie and Song 2003; Hummer et al. 2004; Liao et al. 1998; Rogers et al. 2000; Singh and Siahpush 2001, 2002). Recent studies attribute some of the similarity in death rates between the Mexican Origin and non-Hispanic white populations to the lower mortality of the Mexican Origin immigrant population, with the Mexican Origin U.S.-born population experiencing modestly higher death rates than non-Hispanic whites—but considerably lower rates than non-Hispanic blacks (Elo and Preston 1997; Hummer et al. 1999a and 1999b; Palloni and Arias 2004).

A great deal of debate exists about the definition of the paradox and its underlying mechanisms. For health and mortality outcomes among elderly Mexican origin population, lower relative mortality could be a methodological artifact of outmigration, or attributed to "salmon bias," which implies that a portion of the at-risk population returns to Mexico to die and, as such, does not appear in the numerator of the relevant U.S. vital rates. However, in the case of infant mortality it has been convincing demonstrated by Hummer et al. 2007 using a detailed

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examination of age-specific infant mortality patterns, that implausible levels of outmigration at the earliest ages of death (i.e., within on week of birth) would be required to equalize Mexican origin and non-Hispanic white infant mortality rates. This research provided strong evidence that effectively "closed the case" on the paradox-as-artifact argument for the case of infant mortality in the neonatal period (i.e., within the first month of life). In so doing, they called upon researchers to investigate *not* whether or not an epidemiologic paradox of Mexican Origin infant mortality exists in the United States, but whether or not Mexican Origin health and mortality outcomes will continue to be characterized by parity or near parity with non-Hispanic whites in a context of continuing social disadvantage in the United States among the Mexican Origin population.

Background

The present research carries out a further examination of the epidemiologic paradox by maternal age. We show that an analysis of overall race/ethnic mortality differentials, or differentials based on age at death masks important features of the dynamics of infant mortality. In particular, given different race/ethnic maternal age profiles of childbearing, we may question whether the epidemiologic paradox exists at all maternal ages or is characteristic of specific maternal age groups. We show that the "paradox" is evident only at younger maternal ages and that a mortality crossover occurs at older maternal ages. A focus on maternal age helps to cast the epidemiologic paradox within the conceptual framework of weathering (Geronimus 1986; 1993; 2001), which may be viewed as an accelerated aging process, or heath deterioration, among young and middle-age adults in certain populations—non-Hispanic blacks in particular. This conceptual framework suggests that the cumulative impact of social inequality (i.e., repeated experience with social, economic, or political exclusion) is an important source of variability in health outcomes across populations in the United States. Although the traditional focus has been on African-American women, we believe that the conceptual framework of weathering is equally applicable to other socially-disadvantaged populations—in particular to US-born and foreign-born Mexican Origin populations. We explore this further though a detailed examination of infant mortality by maternal age, race/ethnicity, and nativity.

This paper uses the pooled NCHS linked birth- infant death files from 1995-2002 to conduct a detailed analysis of infant mortality by maternal age, race/ethnicity and nativity, with the main goal of re-examining the paradox of lower rates of infant mortality in specific populations relative to US-born non-Hispanic whites (NHW-US). The most relevant comparison groups for the purposes of the evaluating the epidemiological paradox are US-born Mexican Origin (MO-US) and Foreign-Born Mexican Origin (MO-FB) women, as they tend to be compositionally similar to US-born non-Hispanic blacks (NHB-US) on a number of important risk factors, yet exhibit rates of infant mortality similar to US-born non-Hispanic whites. By contrast, US-born non-Hispanic blacks exhibit rates that are over twice as high. We also examine foreign-born NHW and foreign-born and US-born NHB for comparison. The descriptive results show very different maternal age distributions of births across the six sub-populations considered here, where the distribution of births is skewed towards younger maternal ages in the Mexican Origin and the US-born Non-Hispanic black populations. Maternal-age specific infant mortality rates (IMR) reveal a marked survival advantage at younger maternal ages in the Mexican Origin population relative to US-born NHWs, which is consistent with the Hispanic epidemiological paradox. However, at higher maternal ages—where relatively fewer births occur—the Mexican

Origin population experiences a survival disadvantage (relative to US-born NHWs), which is consistent with the "weathering" conceptual framework. The crossover occurs after age 25 for US-born Mexican Origin women and after age 29 for foreign-born Mexican Origin women, with higher relative risks at later ages among the US-born Mexican Origin population.

In a subsequent analysis, we adjust mortality using a multivariate model that allows the effects of a large number of known risk factors to vary by race/ethnicity and maternal age to yield the predicted mortality rates for hypothetical low-risk populations, which are then compared across subgroups. We find that the maternal age crossover pattern in infant mortality rates persists after these adjustments, which suggests that it is driven mainly by differences in the maternal age distribution of births not compositional differences in the distribution of risk factors.

Summary of Results

The pooled NCHS linked birth- infant death files from 1995-2002 (weighted for match rates) are used for all the analysis. There are no restrictions by birthweight and gestational age.

Descriptive Findings

A major interest is the comparison of US-born and Mexican-born Mexican origin (MO-US, MO-FB) population to US-born Non-Hispanic whites (NHW-US). Other comparison groups of interest are US and foreign-born African Americans (NHB-US and NHB-FB), in addition to foreign-born Non-Hispanic whites (NHW-FB).

1. Maternal Age Distribution: The maternal age distribution is very different for non-Hispanic Whites (NHW) and Mexican Americans (MO) due to different population age structures and other factors. This difference could mask important maternal age-specific infant mortality patterns.

    a. Table 1a shows the age distribution of mothers. We see that NHW-US have a more protracted childbearing experience when compared to MO-US, MO-FB, and NHB-US women but have similar age patterns when compared to NHW-FB and NHB-FB women. The maternal age dynamics are such that 59% of the births to MO-US mothers occur under 25 years of age. By contrast, 31% of the births to NHW-US women occur under age 25. Other findings:

    b. 43% of MO-FB births occur under age 25.

    c. 55% of NHB-US births occur under age 25.

    d. Table 1b shows patterns for primiparous women: 45.4% of NHW-US births occur before age 25.

    e. 78.3% of MO-US births occur under age 25.

    f. 60% of MO-FB births occur under age 25.

g. 75% of NHB-US births occur under age 25.

h. The maternal age profile is interesting for NHW-FB (older ages at birth yet lower IMRs at those ages relative to NHW-US).

2. IMRs: The maternal age specific IMRs (per 1,000 live births) in Table 1a show the typical U-shaped pattern for all populations (initially higher, decreasing through prime childbearing years and increasing later in life).

   a. It is useful to compare the maternal age-specific patterns to the overall rates.

      i. MO-US have higher overall rates than NHW-US/FB
      ii. MO-FB have lower overall rates than NHW-US/FB

   b. The patterns are very similar for primiparous women (Table 1b).

   c. The overall IMRs are lowest for NHW-FB and MO-FB

3. Table 2 shows IMR ratios (rate ratios) for each group relative to NHW-US. For NHB RR's are higher at all maternal ages (where estimates are precise enough). *For both MO populations, there is a clear crossover from a MO infant survival advantage at ages younger than 30 with increasing survival disadvantage relative to NHW-US women at later maternal ages.*

   a. For MO-US this crossover begins in the 25-29 maternal age interval; for MO-FB this occurs after age 29.

   b. Thus the relatively smaller number of MO women giving birth at 30 years or older comprise a higher risk group relative to whites.

   c. Younger MO women comprise a lower risk group relative to whites.

   d. Older MO mothers likely have a very different risk profile than NHW mothers.

   e. Multivariate models should adjust for risk profiles and permit these to vary by maternal age.

4. Multivariate Models: Risk factors and model specification.

   a. Risk Factors (Table 3): The distribution of risk factors varies across populations and by maternal age in predictable ways. We include an array of risk factors ranging from clinically recognized maternal health and biological factors that can be considered as more proximate determinants to birth outcomes and infant mortality as well as demographic and socioeconomic risk factors. The sociodemographic risk factors can be considered as analytically distinct from (but not necessarily independent of) maternal/biological risk factors. Table 3 shows the distribution of risk factors by maternal age and race/ethnicity.

b. Multivariate models: We allow the effects of risk factors to vary across subpopulations and by maternal age. This enables us to predicted maternal age-specific IMRs that would prevail in each subpopulation if risk factors were eliminated. We specify separate models for each subpopulation in reference to NHW-US in order to calculate log rate ratios and their standard errors for significance testing using the following general specification for the log probability of mortality for the *i*th infant each of 5 maternal age categories: < 20, 20-24, 25-29, 30-34, and > 34. Note that we use a broader age classification than was used with the descriptive statistics in order to maximize statistical precision of the estimates from the multivariate models.

c. Model Specification: (model the log IMR to give IMR and rate ratios directly)

$$\log p_i = a_{1j} R_{ij} M_{i1} + \ldots + a_{5j} R_{ij} M_{i5} + \sum_k b_{1jk} R_{ij} X_{ik} M_{i1} + \ldots + \sum_k b_{5jk} R_{ij} X_{ik} M_{i5}$$

d. This model is estimated separately by race/ethnicity by evaluating two populations at a time. Specifically, we construct race/ethnicity subsets consisting of two groups with NHW-US as the reference group and each of the other racial/ethnic subpopulations as the comparison group for a total of 5 separate models. In each model specification, R_j is a factor denoting a specific maternal race/ethnicity category $j \in \{\text{NHW-US, OTHER}\}$, where OTHER denotes one of the 5 comparison groups. X_k denotes the *k*th of *K* risk factors and M_1-M_5 denote the 5 categories of maternal age outlined earlier.

e. This model provides a flexible specification to yield the maternal age-specific IMRs, and rate ratios for each group relative to non-Hispanic whites reported in Table 4. This model makes no constraints on the proportionality of effects by race/ethnicity and maternal age and thus allows for maximum variation in the effects of risk factors by race/ethnicity/nativity and maternal age. It should be noted that we are more interested in adjusting for rather than interpreting the effects of risk factors (all of which are expected to operate in predictable ways by maternal age, race/ethnicity and nativity). As a consequence of this specification, the number of parameters ranges from 10 to 111 depending on the model. All the resulting estimates are identified (i.e., no estimates are tending toward negative infinity and no standard errors are tending toward positive infinity). Given a data set of over 28 million observations, the statistical precision of all estimates is very high.

f. Model 1 includes only maternal age and will exactly reproduce the observed maternal age-specific IMRs and rate ratios for each interval.

g. Model 2 includes medical/maternal risk factors: maternal morbidity, labor complications, problem pregnancy, previous loss, plural birth, smoking, first birth, and high parity in addition to social risk factors, which include inadequate prenatal care, unmarried, maternal education less than 12 years. All risk factors are interacted with the dummy variables corresponding to maternal age categories.

i. Focus on MO-US comparisons: The cross-over is apparent after adjustment for covariates. MO-US: The predicted (conditional) IMR's are adjusted downward. See the column labeled %Δ in Table 4. We find that predicted NHW-US rates are between 58% to 75% lower than the observed rates. The predicted MO-US rates are 58% to 75% lower than the observed rates. We continue to see a notable monotonic increase in adjusted risk relative to NHW-US after age 25 after adjusting for risk factors.

ii. For further insight into these differences we construct the risk ratios that would prevail in the MO-US population *if they experienced the same reduction in IMR as NHW-US at every age in response to adjustments for risk factors*. That is, we constrain the MO-US rates to be proportionately lower than the NHW-US rates at any age. This comparison amounts to *imposing a model without interactions of race and maternal age.* We find that the RRs at any age would be less than 1 until the 25-29 age interval if MO-US experienced the same maternal age-specific reduction in predicted rates as NHW-US (see column in the table below labeled E(NHW-US). We can compare the RR under the assumption of equal IMR reductions for NHW-US and MO-US to the predicted RR under the model labeled E(MO-US). We do so by constructing another RR (labeled RRR—ratio of risk ratios) and find that the reductions in IMR for NHW-US and MO-US are similar except at the maternal ages 25-29 and >34 category. Thus the models predicts rates that are between 7% and 20% higher than what would be observed if the rates for MO-US had been adjusted downward to the same extent as for NHW-US.

What if MO-US Experienced the Same Model-Predicted Rates of Decrease in IMR as NHW-US? What would the RR's look like?

	RR		
Maternal Age	E(NHW-US)	E(M0-US)	RRR
< 20	0.77	0.78	1.00
20-24	0.86	0.87	1.02
25-29	1.09	1.17	1.07
30-34	1.28	1.24	0.97
>34	1.38	1.66	1.20

iii. Focus on MO-FB comparisons: The mortality cross-over is apparent after age 30. The predicted IMR for the youngest maternal age interval reflects a larger decline when compared to NHW-US. IMRs for other maternal age intervals are not adjusted downward to a similar extent as for NHW-US. We can compare the model-based reduction in IMR to what would be expected if the reduction in MO-FB IMR was identical to that experienced by NHW-US. Here we find that the predicted IMRs from MO-FB are between 28% lower to 98% higher at any age than what they would be if the reductions in IMR had been equal across groups.

What if MO-FB Experienced the Same Model-Predicted Rates of Decrease in IMR as NHW-US? What would the RR's look like?

	RR		
Maternal Age	E(NHW-US)	E(M0-FB)	RRR
< 20	0.93	0.67	0.72
20-24	0.89	0.75	0.84
25-29	0.85	1.04	1.23
30-34	0.87	1.19	1.36
>34	0.78	1.54	1.98

iv. Focus on NHB-US and NHB-FB: Here we find for the most part that eliminating medical and social risk factors would bring about much greater declines in IMR for NHB compared to NHW. Nevertheless, these declines are not enough to noticeably move the rate ratios close to unity.

Discussion

We provide a closer examination of infant mortality by maternal age. The epidemiological paradox is evident in the Mexican Origin population, which exhibits consistently lower infant mortality relative to US-born non-Hispanic whites. A mortality crossover occurs at later ages, whereby we observe consistently higher rates of infant mortality relative to US-born non-Hispanic whites. This finding is consistent with the notion of weathering. The relative deterioration in infant survival occurs earlier for the US-born Mexican Origin population and somewhat later for the Mexican-born Mexican Origin population. If the US-born Mexican Origin population faces a more prolonged exposure to social inequities compared to the Mexican-born population, this would provide additional support for weathering. However, more detailed data than the NSCH linked infant birth-death records would be required to investigate this further. Using the limited available data, we find that relative differentials persist (and are magnified) after controlling for known risk factors in multivariate models, which suggests that observed patterns do not simply reflect compositional differences between groups.

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Table 1a: Infant Mortality Rates by Maternal Age and Nativity for Non-Hispanic Whites, Mexican-Origin, Non-Hispanic Black Women: All Births: 1995-2002 Linked Files [all parities]

All Parities	Maternal Age	NHW US		NHW FB		MO US		MO FB		NHB US		NHB FB		OVERALL	
		%	IMR	%	IMR	%	IMR	%	IMR	%	IMR	%	IMR	%	IMR
	<15	0.1	18.0	0.0	12.3 †	0.7	12.9	0.2	11.5	0.8	18.5	0.1	7.6 †	0.24	16.8
	15-19	9.2	9.3	3.5	7.9	24.8	7.1	12.1	5.8	21.8	13.8	6.0	10.9	12.05	9.9
	20-24	22.3	6.8	15.9	5.0	33.8	5.8	30.4	4.6	33.0	13.4	18.7	8.6	25.07	7.8
	25-29	28.0	5.0	28.8	4.3	22.2	5.5	29.7	4.4	22.1	13.4	27.0	8.9	26.97	6.1
	30-34	25.9	4.6	31.3	4.3	12.5	5.8	18.3	4.8	14.1	14.1	28.1	10.0	22.87	5.6
	35-39	12.1	5.3	16.7	5.0	5.1	7.5	7.6	6.1	6.7	14.7	16.2	11.4	10.66	6.5
	40+	2.3	6.7	3.7	7.1	0.9	8.6	1.7	9.1	1.4	15.8	3.9	14.5	2.13	8.1
	Total	100.0	5.8	100.0	4.8	100.0	6.2	100.0	4.9	100.0	13.7	100.0	9.9	100.00	7.0
	Deaths	104,200		4,774		10,192		13,229		58,039		4,724		195,158	
	Births	18,021,839		1,001,622		1,638,104		2,689,077		4,229,098		477,622		28,057,362	

Table 1b: Infant Mortality Rates by Maternal Age and Nativity for Non-Hispanic Whites, Mexican-Origin, Non-Hispanic Black Women: First Births: 1995-2002 Linked Files [first births]

First Births	Maternal Age	NHW US		NHW FB		MO US		MO FB		NHB US		NHB FB		OVERALL	
		%	IMR	%	IMR	%	IMR	%	IMR	%	IMR	%	IMR	%	IMR
	<15	0.2	17.4	0.1	13.0 †	1.6	12.4	0.6	10.8	2.0	17.8	0.28	7.8 †	0.58	16.2
	15-19	18.3	8.3	6.9	7.3	45.3	6.4	27.6	5.4	41.8	12.0	12.82	10.7	23.51	8.8
	20-24	26.9	5.7	22.0	4.4	31.4	5.5	40.8	4.5	31.4	12.8	28.39	7.9	28.74	6.7
	25-29	27.4	4.5	31.9	4.0	13.3	5.8	20.9	5.0	13.5	15.2	29.10	9.3	24.28	5.5
	30-34	18.9	4.7	26.2	4.2	6.0	6.1	7.5	5.9	7.6	17.7	20.23	13.3	15.91	5.8
	35-39	6.9	6.1	10.7	6.0	2.0	9.0	2.2	8.6	3.1	18.9	7.72	16.6	5.84	7.5
	40+	1.3	6.7	2.2	7.4	0.3	9.5	0.4	8.4	0.6	17.2	1.46	22.8	1.13	8.0
	Totals	100.0	5.7	100.0	4.7	100	6.2	100	5.1	100	13.5	100	10.6	100.00	6.9
	Deaths	42,770		1,959		4,076		4,617		21,650		1,945		77,017	
	Births	7,462,601		418,744		661,038		904,990		1,604,902		182,635		11,234,910	

† Estimate is based on fewer than 50 deaths.

Table 2: Rate Ratios Relative to US Born Non-Hispanic Whites by Maternal Age and Nativity: All Births and First Births, 1995-2002 Linked Files

All Births										
Maternal Age	**NHW FB**		**MO US**		**MO FB**		**NHB US**		**NHB FB**	
<15	0.69	†	0.72	*	0.64	*	1.03		0.42	†
15-19	0.86	*	0.76	*	0.63	*	1.49	*	1.18	*
20-24	0.73	*	0.86	*	0.67	*	1.96	*	1.27	*
25-29	0.87	*	1.09	*	0.89	*	2.67	*	1.77	*
30-34	0.94	*	1.28	*	1.04	*	3.07	*	2.19	*
35-39	0.93	*	1.41	*	1.15	*	2.75	*	2.14	*
40+	1.07	*	1.29	*	1.36	*	2.37	*	2.18	*
Overall	0.82	*	1.08	*	0.85	*	2.37	*	1.71	*

First Births										
Maternal Age	**NHW FB**		**MO US**		**MO FB**		**NHB US**		**NHB FB**	
<15	0.75	†	0.72	*	0.62	*	1.02		0.45	†
15-19	0.88	*	0.77	*	0.65	*	1.45	*	1.29	
20-24	0.77	*	0.95	*	0.78	*	2.24	*	1.37	*
25-29	0.90	*	1.30	*	1.11	*	3.40	*	2.08	*
30-34	0.88	*	1.29	*	1.26	*	3.74	*	2.82	*
35-39	0.98	*	1.47	*	1.40	*	3.09	*	2.71	*
40+	1.10	*	1.41		1.25		2.55	*	3.40	*
Overall	0.82	*	1.08	*	0.89	*	2.35	*	1.86	*

† Estimate is based on fewer than 50 deaths in the comparison group.
* Significantly different from 1.0 ($p < 0.05$ two tailed test)

Table 3: Distribution of Risk Factors by Maternal Age and Nativity

	US Born						Foreign Born					
	Maternal Age						Maternal Age					
Risk Factors	**<20**	**20-24**	**25-29**	**30-34**	**35+**	**Total**	**<20**	**20-24**	**25-29**	**30-34**	**35+**	**Total**
maternal morbidity												
NHW	28.6%	27.9%	27.8%	28.8%	33.8%	29.0%	23.0%	21.4%	22.0%	24.0%	29.5%	24.1%
NHB	31.4%	31.2%	32.2%	34.5%	39.6%	32.6%	27.1%	25.9%	26.9%	29.8%	35.3%	29.2%
MO	22.2%	20.9%	22.3%	24.4%	30.1%	22.5%	19.3%	17.4%	18.0%	20.1%	25.1%	19.0%
Total	28.6%	28.0%	28.1%	29.3%	34.3%	29.2%	20.2%	18.7%	19.9%	22.8%	28.5%	21.4%
labor complications												
NHW	33.4%	33.0%	33.9%	34.3%	35.7%	34.0%	30.5%	30.7%	31.6%	32.4%	33.9%	32.2%
NHB	33.5%	32.3%	33.6%	36.0%	38.1%	33.8%	34.3%	35.6%	37.3%	37.9%	39.3%	37.4%
MO	24.9%	23.8%	24.3%	26.0%	28.1%	24.7%	27.2%	26.5%	25.7%	25.8%	27.3%	26.3%
Total	32.2%	31.9%	33.3%	34.2%	35.7%	33.3%	28.0%	27.9%	28.3%	29.7%	31.9%	28.9%
problem pregnacy (adequate+ prenatal care)												
NHW	27.4%	29.5%	31.1%	31.6%	33.7%	30.9%	23.0%	23.7%	25.8%	28.2%	30.8%	27.1%
NHB	25.5%	28.7%	32.3%	34.0%	35.7%	30.1%	19.5%	22.5%	24.9%	26.6%	28.9%	25.4%
MO	24.7%	27.0%	30.5%	33.0%	36.0%	28.5%	20.1%	20.9%	22.7%	25.1%	28.5%	22.8%
Total	26.5%	29.1%	31.2%	31.9%	34.0%	30.6%	20.3%	21.5%	23.7%	26.4%	29.4%	24.2%
previous loss												
NHW	11.1%	21.3%	25.3%	29.5%	38.2%	26.0%	9.3%	15.7%	20.1%	25.5%	34.2%	23.6%
NHB	12.5%	27.4%	36.4%	38.3%	41.0%	28.6%	13.9%	26.2%	30.1%	33.6%	39.0%	31.1%
MO	8.1%	17.5%	23.6%	27.4%	33.2%	18.7%	5.3%	10.2%	14.9%	19.4%	25.1%	14.1%
Total	11.1%	22.4%	26.8%	30.4%	38.3%	26.0%	6.3%	12.4%	17.8%	23.4%	30.9%	18.3%
plural birth												
NHW	1.4%	2.1%	3.0%	4.2%	5.2%	3.3%	1.3%	2.0%	2.8%	3.9%	5.1%	3.4%
NHB	2.0%	3.2%	3.8%	4.1%	4.1%	3.3%	1.7%	2.3%	3.0%	3.5%	3.9%	3.1%
MO	1.3%	1.8%	2.4%	3.0%	3.5%	2.1%	1.2%	1.5%	1.9%	2.3%	2.6%	1.8%
Total	1.6%	2.3%	3.1%	4.1%	5.1%	3.2%	1.2%	1.7%	2.2%	3.0%	3.8%	2.4%
smoking												
NHW	26.6%	22.1%	12.5%	8.9%	9.2%	14.5%	11.8%	7.7%	4.9%	4.1%	4.5%	5.3%
NHB	6.1%	8.9%	10.1%	12.3%	15.5%	9.6%	2.4%	1.8%	1.3%	1.1%	1.2%	1.4%
MO	3.2%	3.5%	3.0%	2.9%	3.4%	3.2%	0.4%	0.4%	0.5%	0.6%	0.8%	0.5%
Total	17.0%	17.3%	11.6%	9.0%	9.8%	12.9%	1.6%	1.6%	1.6%	1.8%	2.2%	1.7%
inadequate prenatal care												
NHW	20.3%	14.4%	8.9%	7.6%	8.9%	10.8%	28.0%	21.6%	15.6%	12.9%	13.8%	15.8%
NHB	32.2%	25.7%	21.1%	20.2%	22.1%	25.1%	39.4%	28.0%	23.5%	22.2%	22.2%	24.7%
MO	29.0%	22.9%	17.1%	14.7%	15.7%	21.7%	36.2%	29.8%	25.2%	23.2%	24.2%	27.5%
Total	25.2%	17.8%	11.2%	9.2%	10.6%	14.1%	35.7%	28.4%	22.7%	19.6%	20.0%	24.4%
unmarried												
NHW	72.5%	37.7%	14.1%	8.1%	9.3%	22.6%	51.1%	21.4%	9.2%	6.5%	7.9%	11.5%
NHB	96.0%	81.6%	59.8%	47.0%	44.9%	72.2%	87.9%	62.5%	38.7%	29.5%	29.3%	41.7%
MO	74.9%	48.6%	29.9%	22.2%	23.2%	46.3%	60.8%	41.9%	30.1%	24.5%	24.7%	35.9%
Total	80.2%	49.0%	21.8%	12.8%	13.8%	33.0%	61.9%	40.6%	26.0%	19.2%	19.3%	30.7%
less than HS education												
NHW	56.2%	18.8%	6.5%	3.4%	3.2%	12.6%	47.5%	17.0%	8.1%	5.4%	5.8%	9.6%
NHB	61.9%	23.1%	13.6%	10.5%	10.5%	27.0%	48.9%	18.1%	13.1%	11.6%	14.5%	16.1%
MO	68.1%	32.5%	21.2%	16.0%	16.5%	36.0%	80.2%	66.7%	62.6%	61.3%	67.1%	66.2%
Total	59.6%	21.1%	8.4%	4.6%	4.5%	16.8%	75.0%	55.2%	44.4%	35.6%	35.2%	46.8%
first birth												
NHW	82.4%	49.9%	40.5%	30.2%	23.6%	41.4%	82.9%	57.7%	46.3%	35.0%	26.4%	41.8%
NHB	73.6%	36.1%	23.1%	20.3%	17.5%	37.9%	82.4%	58.0%	41.2%	27.6%	17.4%	38.2%
MO	74.4%	37.5%	24.2%	19.3%	15.6%	40.4%	77.1%	45.2%	23.7%	13.8%	9.6%	33.7%
Total	78.5%	45.5%	37.0%	28.7%	22.7%	40.7%	78.0%	48.1%	30.9%	22.8%	17.2%	36.1%
high parity												
NHW	0.2%	3.4%	7.2%	10.9%	19.5%	8.4%	0.2%	2.8%	7.0%	10.5%	18.7%	9.6%
NHB	0.9%	11.1%	22.1%	26.3%	32.8%	15.1%	0.3%	3.5%	9.1%	16.3%	29.8%	13.7%
MO	0.5%	7.8%	18.1%	24.9%	33.8%	11.9%	0.4%	4.5%	15.4%	30.7%	49.8%	16.2%
Total	0.5%	5.6%	10.0%	13.1%	21.5%	9.9%	0.3%	4.2%	12.7%	21.9%	34.7%	14.3%
N	3,054,477	5,966,459	6,352,104	5,477,653	3,038,348	23,889,041	394,413	1,067,158	1,216,016	940,203	550,531	4,168,321

Table 4: Multivariate Models: Predicted IMR per 1000, Rate Ratios, and Percent Reduction in Predicted IMR from Observed IMR

Model 1[a]	NHW US			NHW FB			MO US			MO FB			NHB US			NHB FB		
Maternal Age	IMR	%Δ	RR	IMR	%Δ	RR	IMR	%Δ	RR	IMR	%Δ	RR	IMR	%Δ	RR	IMR	%Δ	RR
< 20	9.3	NA	1	8.0	NA	0.85 *	7.2	NA	0.77 *	5.9	NA	0.63 *	14.0	NA	1.50 *	10.8	NA	1.16 *
20-24	6.8	NA	1	5.0	NA	0.73 *	5.8	NA	0.86 *	4.6	NA	0.67 *	13.4	NA	1.96 *	8.6	NA	1.27 *
25-29	5.0	NA	1	4.3	NA	0.87 *	5.5	NA	1.09 *	4.4	NA	0.89 *	13.4	NA	2.67 *	8.9	NA	1.77 *
30-34	4.6	NA	1	4.3	NA	0.94 *	5.8	NA	1.28 *	4.8	NA	1.04 *	14.1	NA	3.07 *	10.0	NA	2.19 *
>34	5.5	NA	1	5.4	NA	0.97	7.7	NA	1.38 *	6.7	NA	1.20 †	14.9	NA	2.68 *	12.0	NA	2.17 *
Model 2[b]																		
Maternal Age																		
< 20	3.9	58.1%	1	3.5	55.7%	0.90	3.0	58.0%	0.78 *	2.6	55.1%	0.67 *	6.3	55.1%	1.60 *	3.7	65.5%	0.95
20-24	2.3	65.8%	1	2.0	60.0%	0.85 †	2.0	65.2%	0.87 *	1.7	61.7%	0.75 *	4.1	69.4%	1.75 *	2.1	76.1%	0.89
25-29	1.4	72.1%	1	1.2	71.2%	0.89	1.6	70.0%	1.17 *	1.5	67.1%	1.04	3.2	76.1%	2.29 *	1.6	81.9%	1.15
30-34	1.2	74.3%	1	1.1	74.5%	0.93	1.5	74.9%	1.24 *	1.4	70.5%	1.19 *	3.0	79.0%	2.51 *	2.1	79.4%	1.75 *
>34	1.4	74.7%	1	1.2	78.0%	0.84	2.3	69.7%	1.66 *	2.2	67.6%	1.54 *	3.6	75.6%	2.59 *	2.5	79.2%	1.79 *

[a] Maternal age only

[b] Maternal age, and biological and maternal risk factors: maternal morbidity, labor complications, problem pregnancy, previous loss, plural birth, smoking, first birth, high parity, inadequate prenatal care, unmarried, and maternal education less than 12 years. All risk factors are interacted with the dummy variables corresponding to maternal age categories with interactions varying by race/ethnicity and nativity.