PARADOX FOUND (AGAIN): INFANT MORTALITY AMONG THE MEXICAN-ORIGIN POPULATION IN THE UNITED STATES*

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Recent research suggests that the favorable mortality outcomes for the Mexican immigrant population in the United States may largely be attributable to selective out-migration among Mexican immigrants, resulting in artificially low recorded death rates for the Mexican-origin population. In this paper, we calculate detailed age-specific infant mortality rates by maternal race/ethnicity and nativity for two important reasons: (1) it is extremely unlikely that women of Mexican origin would migrate to Mexico with newborn babies, especially if the infants were only a few hours or a few days old; and (2) more than 50% of all infant deaths in the United States occur during the first week of life, when the chances of out-migration are very small. We use concatenated data from the U.S. linked birth and infant death cohort files from 1995 to 2000, which provides us with over 20 million births and more than 150,000 infant deaths to analyze. Our results clearly show that first-hour, first-day, and first-week mortality rates among infants born in the United States to Mexican immigrant women are about 10% lower than those experienced by infants of non-Hispanic, white U.S.-born women. It is extremely unlikely that such favorable rates are artificially caused by the out-migration of Mexican-origin women and infants, as we demonstrate with a simulation exercise. Further, infants born to U.S.-born Mexican American women exhibit rates of mortality that are statistically equal to those of non-Hispanic white women during the first weeks of life and fare considerably better than infants born to non-Hispanic black women, with whom they share similar socioeconomic profiles. These patterns are all consistent with the definition of the epidemiologic paradox as originally proposed by Markides and Coreil (1986).

A large and growing literature exists on the epidemiologic paradox for health and mortality outcomes among Hispanics in the United States (Franzini, Ribble, and Keddie 2001; Guendelman 2000; Landale, Oropesa, and Gorman 2000; Markides and Coreil 1986; Markides and Eschbach 2005; Palloni and Morenoff 2001; Smith and Bradshaw 2006). In particular, the relatively low levels of education, income, and health insurance coverage among Hispanics compared with non-Hispanic whites is thought to place the former at higher risk for negative health outcomes. However, it is well documented that some Hispanic groups exhibit similar observed death rates compared with the non-Hispanic white population and much lower death rates than the non-Hispanic black population, whom they closely resemble with respect to socioeconomic characteristics. The greatest enigma is exhibited by the Mexican-origin population of the United States. This Hispanic subgroup is characterized by low educational attainment; low health insurance

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coverage rates; mortality rates similar to non-Hispanic whites; and much more favorable mortality rates than those of non-Hispanic blacks across most of the life course (Elo et al. 2004; Frisbie and Song 2003; Hummer, Benjamins, and Rogers 2004; Liao et al. 1998; Rogers, Hummer, and Nam 2000; Singh and Siahpush 2001, 2002). Recent studies indicate that the similarity in death rates between the Mexican-origin and non-Hispanic white populations is attributable in part to the especially low 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 experiencing much lower death rates than non-Hispanic blacks (Elo and Preston 1997; Hummer, Biegler, et al. 1999; Hummer, Rogers et al. 1999; Palloni and Arias 2004).

Despite the large volume of literature on this topic, a great deal of debate continues regarding the definition of the epidemiologic paradox itself as well as the health and mortality outcomes to which it pertains. In the case of mortality, there is also the basic question of whether a paradox exists at all, given the data and methodological issues surrounding the estimates of mortality rates among the Hispanic population. Palloni and Arias (2004), for example, recently suggested that out-migration of Mexican-origin elders from the United States to Mexico may result in a serious underreporting of adult deaths in the United States, leading to an artificially low mortality rate among Mexican immigrant adults. Thus, they argue that much of the apparent Mexican immigrant mortality advantage, in relation to non-Hispanic whites in the United States, may be attributable to return migration to Mexico by unhealthy immigrants. This phenomenon has been referred to as a "salmon bias" (Abraido-Lanza et al. 1999).

The central issue in this paper is to determine, to the greatest degree possible, whether the epidemiologic paradox exists for the Mexican-origin population of the United States with regard to one very well-measured outcome: infant mortality. We consider infants of U.S.-born (Mexican American) women as well as infants who are born to foreign-born (Mexican immigrant) women. We compare infant mortality rates for these two population groups with those of non-Hispanic whites, non-Hispanic blacks, Cuban Americans, Puerto Ricans, and other Hispanics, while also separating infants of foreign-born and native-born women in each of those racial/ethnic groups. Perhaps most importantly—and, we believe, unique for this study—we analyze finely grained, age-specific infant deaths rates (less than 1 hour, 1 hour to less than 1 day, 1–6 days, 7–27 days, 28–90 days, 91–180 days, and 181–364 days). This allows us to take advantage of (1) the extreme unlikelihood that women with the very youngest infants born in the United States will have out-migrated to Mexico or elsewhere; (2) the large proportion of infant deaths that occur very early during the first year of life; (3) the virtually 100% registration of births and infant deaths that occur in the United States; and (4) the extremely high match rate between infant death certificates and their corresponding birth certificates that is characteristic of the vital statistics–based data set that we use. We also conduct a similar analysis for large metropolitan counties near the U.S.-Mexico border, where possible out-migration to Mexico may have the greatest impact on the reported infant mortality rates in the United States. Finally, we estimate the extent to which out-migration of Mexican-origin women to Mexico would need to occur for the epidemiologic paradox, as observed in the data we use, to be an artifact of the underregistration of infant deaths in the United States.

BACKGROUND

Evidence for an epidemiologic paradox for the U.S. Hispanic population was perhaps first clearly uncovered by Teller and Clyburn (1974), who, using data from the State of Texas, reported that the infant mortality rate for the Spanish-surname population was slightly lower than that of non-Hispanic whites in the mid-1960s. In a seminal review on the topic about a decade later, Markides and Coreil (1986:253) coined the concept "epidemiologic paradox," summarizing it as follows:

> Despite methodological limitations of much of the research, it can be concluded with some certainty that the health status of Hispanics in the Southwest is much more similar to the health status of other whites than that of blacks although socioeconomically, the status of Hispanics is closer to that of blacks. This observation is supported by evidence on such key health indicators as infant mortality, life-expectancy, mortality from cardiovascular diseases, mortality from major types of cancer, and measures of functional health. On other health indicators, such as diabetes and infectious and parasitic diseases, Hispanics appear to be clearly disadvantaged relative to other whites.

Note that Markides and Coreil (1986; also see Markides and Eschbach 2005) did not define the paradox as *better* health or mortality for Hispanics compared with non-Hispanic whites, nor did they argue that the paradox applied to all health and mortality outcomes. Instead, they defined the paradox with regard to Hispanics exhibiting some key health and mortality outcomes that are *much more similar* to whites than to blacks even though the overall socioeconomic status of Hispanics is much closer to that of blacks than to that of whites.

Three explanations have been offered for the paradox. The first is immigration selectivity. Here, the argument is that immigration is positively selective on good health (Franzini et al. 2001; Markides and Eschbach 2005). Thus, for example, selectively healthy immigrant women of childbearing age are more likely to give birth to healthy infants in the United States in comparison with their native-born counterparts who are not selectively healthy in the same way.

Second, some have suggested that cultural factors tend to encourage healthy behaviors and strong family ties among Hispanics in the United States, particularly in the immigrant generation, helping to explain the relatively favorable observed health and mortality patterns that define the paradox (Franzini et al. 2001; Scribner 1996). Some have suggested that a negative acculturation process may work to help deteriorate the largely positive health and mortality outcomes among immigrant Hispanics over time and across generations, although data limitations have prevented a rigorous test of this hypothesis (Cho et al. 2004; Jasso et al. 2004).

Most recent demographic work in this area of study has focused on the third explanation for the paradox, which is also the main focus of the current study: namely, data quality issues. Indeed, recent demographic work in this area, mostly focusing on adult mortality, has attempted to account for the effect of out-migration on Hispanic mortality estimates in the United States, made corrections for questionable data, and dealt with the issue of disparate race/ethnicity reporting across different data sources and across time (Abraido-Lanza et al. 1999; Elo et al. 2004; Hummer et al. 2004; Liao et al. 1998; Palloni and Arias 2004; Rosenberg et al. 1999; Smith and Bradshaw 2006; Swallen and Guend 2003; Turra and Elo forthcoming). Although these studies concur that U.S. government-reported Hispanic adult mortality rates (e.g., Kochanek et al. 2004) are too low because of data quality issues, there is not yet consensus with regard to whether Hispanic adult mortality rates are actually slightly lower than, equivalent to, or higher than mortality rates for non-Hispanic whites. The answer to that question surely depends on the Hispanic subgroup in question, whether immigrant Hispanics are distinguished from native-born Hispanics, and the specific age groups that are examined.

Most central to the issues in the current paper is recent work by Turra and Elo (forthcoming), who examined the impact of out-migration from the United States (to Mexico and elsewhere) on reported mortality rates among primary beneficiaries of social security (those aged 65 and older) in the United States. They found evidence that both Hispanic and non-Hispanic white out-migrants from the United States do indeed exhibit higher mortality than persons in their same racial/ethnic group who do not out-migrate. However, even when such out-migration is taken into account, Hispanic mortality in the United States for social security beneficiaries aged 65 and older remains between 11% and 18% lower than that of

non-Hispanic whites, depending on the specific age/sex group in question. This happens primarily because the volume of out-migration is simply not large enough to significantly influence adult mortality rates in the United States. Thus, although they show evidence that is consistent with what some refer to as a "salmon bias" (Abraido-Lanza et al. 1999) in terms of Hispanic mortality in the United States, the overall magnitude of its effect on Hispanic versus non-Hispanic white mortality patterns was found to be very slight.

Turning to infant mortality, historical demographic work has found that infant mortality rates for the Spanish-surname population of the United States were not always similar to, or lower than, those for non-Hispanic whites. In fact, they were much higher than those of whites throughout the first half of the twentieth century (Forbes and Frisbie 1991; Gutmann et al. 2000). By 1980, however, data sets from Texas and California showed parity or near-parity between the infant mortality rates of the Hispanic and non-Hispanic white populations (Forbes and Frisbie 1991; Williams, Binkin, and Clingman 1986). These findings were later echoed in national-level data on infant mortality (Becerra et al. 1991; Hummer, Biegler et al. 1999; Singh and Yu 1996). Nevertheless, there was (and continues to be) some skepticism that the relatively low infant mortality rate among Hispanics was (and is), at least in part, attributable to the underreporting of Hispanic infant deaths in the United States, particularly within the Mexican-origin population (Palloni and Morenoff 2001; Williams et al. 1986). The most relevant reason for underreporting, at least during the past few decades, is consistent with that discussed earlier from the adult mortality literature: namely, that out-migration of women and their U.S.-born infants to Mexico or elsewhere results in an underregistration of infant deaths in the United States. Such out-migration of women and infants is not necessarily health based, as defined by the concept of the salmon bias among older adults. However, the general phenomenon of out-migration of women and infants from the United States for health or other reasons would result in an underregistration of infant deaths in the United States.

Recently, for example, Palloni and Morenoff (2001:152–53) reviewed and critiqued the literature on the epidemiologic paradox. Specifically writing about possible explanations for the epidemiologic paradox with regard to infant mortality, they highlighted the issue of underregistration:

> The first explanation (the under-registration of infant deaths in the target population) has been dismissed outright, but probably too quickly and hastily. We are not aware of any large-scale effort to actually test this hypothesis, at least not in a way that is comparable to what has been done for the case of white-black differentials in adult mortality in the U.S. (Preston et al. 1996). Instead, we find assessments of some data sets (e.g., Bexar County) where the authors assert that errors of under-registration could not reasonably be large enough to account for the observed patterns of infant mortality differences (Forbes and Frisbie 1991). Admittedly the claim for that particular data set may be compelling but as a general explanation does not have the power to close the case once and for all. The important point is that this alternative explanation has not yet been excluded and may, together with other problems, undermine the case for a paradox.

Clearly, it is plausible that Mexican-origin women who give birth in the United States return to Mexico. Such a phenomenon would result in a birth being registered in the United States, which increases the denominator of the Mexican-origin infant-mortality rate in the United States. However, if U.S.-born out-migrating infants die in the first year of life in Mexico, such deaths are not recorded in the United States. Thus, the resulting count of deaths in the numerator of the U.S. infant mortality rate is artificially low. No data system is in place for linking infant deaths that may occur in Mexico back to the corresponding birth certificate records in the United States.

This paper makes no claim that such a process cannot, or does not, occur. Rather, this paper sheds light on the magnitude of this issue and its relevance for the epidemiologic

paradox by carefully calculating detailed, age-specific infant-mortality rates for the key ethnicity/nativity groups in question. Given the complete registration of births and infant deaths in the United States (Bryan and Heuser 2004:61), the extremely high match rate between infant deaths that occur in the United States with their corresponding birth certificates in the vital statistics data set we use (National Center for Health Statistics 2000), and the strong unlikelihood that mothers with newborn infants (less than 1 hour, 1 day, 1 week, or even 1 month old) would leave a country that has extremely advanced medical technology (particularly if their infant was born early and/or small, or was otherwise at risk of death), we are very confident that the detailed mortality rates in the neonatal period that we calculate are quite accurate and have little chance of being influenced by the underregistration of infant deaths. Because out-migration becomes a more logical possibility later in infancy, the rates that we calculate for the postneonatal period are more subject to possible underregistration of infant deaths in the United States. We complete the analysis by providing approximations of the number of women and infants who would need to out-migrate from the United States for the observed rates of infant mortality among the Mexican immigrant population to be seriously biased. We conclude that the epidemiologic paradox, at least in terms of infant mortality among the Mexican-origin population in the United States in relation to non-Hispanic whites and non-Hispanic blacks, is not a data artifact.

DATA, MEASURES, AND METHODS

Data

For this analysis, we use the National Center for Health Statistics (NCHS) linked birth and infant death cohort files, concatenated across the years of 1995–2000. The data set includes all infants born alive in the United States during those years, including over 20 million cases. The recorded infant deaths in the United States are matched to their birth certificates at an exceptional rate, which was between 98% and 99% in the 1995–2000 period that we analyze (National Center for Health Statistics 1995, 1996, 1997, 1998, 1999, 2000). Important for present purposes, three additional characteristics about this data set stand out. First, the linked cohort files that we selected include only births to mothers who were identified as residents of the United States; nonresident mothers are not included. This results in the exclusion of about 5,000 births to nonresident mothers per year, over 80% of whom were identified as being of Mexican origin on the birth certificate (National Center for Health Statistics 2000: table B, technical appendix).

Second, race and ethnicity data are nearly complete in this file, with just 1.1% of women not reporting whether they were of Hispanic origin (National Center for Health Statistics 2000: table B, technical appendix). As is customary in this literature, we use maternal identification reported on the birth certificate to measure race/ethnicity (Rogers 1989) and exclude cases with missing identification information.

Third, the data are weighted to account for infant deaths that are not linked to a matching birth record. Although the incidence of unlinked death records is very small nationally—for example, in 2000, just 358 infant deaths (1.3%) were not linked to their original birth certificate—the use of weights is nonetheless a safeguard against error. Weights were calculated by the NCHS separately for each state of residence and by age category of death because each state is responsible for collecting and matching birth and infant death data (National Center for Health Statistics 2000). By far, the lowest successful record linkage was in Oklahoma (92.8% in 2000); in contrast, 17 states successfully matched 100% of their infant deaths to a birth record. The two states where the majority of the Mexican-origin population lives, California and Texas, matched their infant deaths at the rates of 98.1% and 97.0%, respectively, in 2000 (National Center for Health Statistics 2000: table A, technical appendix). In all, the assigned weights for infant deaths in our file ranged from 1.01 to 1.04 (not shown), depending on the state of residence of the mother

and age of death of the infant. Because Mexican-origin women in our data tend to live in states where the successful linkage percentage was slightly lower than in other states, case weights for Mexican-origin infant deaths are slightly higher on average than among other racial/ethnic groups. Thus, this weighting adjustment results in higher Mexican-origin infant mortality rates than would be generated without using the weights. This weighting technique best reflects the modest but important adjustment that needs to be made for slightly differing linkage success rates across the U.S. states.

Measures and Methods

The racial/ethnic categories that we specify include Mexican-origin, non-Hispanic white, non-Hispanic black, Puerto Rican, Cuban, and other Hispanic. Infants born to women from other racial/ethnic groups are excluded. In addition to race/ethnicity, we also consider maternal nativity, dividing each racial/ethnic group into U.S.-born and foreign-born subpopulations.[1] As mentioned earlier, the epidemiologic paradox for infant mortality among the Mexican-origin population is thought to be largely attributable to the relatively low mortality rates among Mexican immigrants. We include infants born to Cuban-origin women in our analysis because unlike Mexican immigrant women, Cuban immigrant women are extremely unlikely to return to their country of origin. Thus, a comparison between Mexican immigrant women and Cuban immigrant women is potentially instructive. We include Puerto Ricans because even though they do not share a mortality advantage compared with non-Hispanic whites with Mexicans and Cubans, Puerto Rican women living on the U.S. mainland can easily return to Puerto Rico. Other Hispanics, consisting mainly of immigrant women from various countries in Central and South America—but also including U.S.-born Hispanic women of unknown national origin—are also included.

A main objective of this paper is to calculate detailed, age-specific infant mortality rates by race/ethnicity, subdivided by maternal nativity. The age groups used for this analysis are less than 1 hour, 1 to 23 hours, 1–6 days, 7–27 days, 28–90 days, 91–180 days, and 181–364 days. We specify these very detailed age categories because of the extreme unlikelihood of out-migration among women and their infants in the first hours and days of life as well as the high proportion of infant deaths that occur in the first hours and days of life. Indeed, about 50% of all infant deaths in the United States occur during the first week of life (calculation not shown). The denominator that we use for each age-specific rate is the number of births that occurred to that racial/ethnic/nativity group of women; thus, the age-specific rates add up to the overall infant mortality rate (IMR) for each group. The age-specific rates used in this paper may be more appropriately viewed as *partial* IMRs insofar as they are age interval-specific contributions to the total IMR. They are defined as the number of deaths for a particular racial/ethnic/nativity group in a given age interval, divided by the number of live births recorded in that group. Formally, let D_{jk} denote the number of deaths in the jth age interval for the kth racial/ethnic/nativity group, with N_k denoting the number of live births in that population. The empirical rates, or partial IMRs, are defined as $\hat{p}_{jk} = D_{jk} / N_k$.

The calculation of rates is followed by a calculation of rate ratios, with rates for each racial/ethnic/nativity group explicitly compared with infants of native-born, non-Hispanic white women. Standard errors of functions of the partial IMRs can be derived based on the sampling distribution of deaths. We assume that for the N_k births occurring in group k, the number of deaths is distributed as multinomial with probability p_{jk} of death in the jth age interval. The maximum likelihood estimator of the rate in group k and age interval j is the

1. Of course, Puerto Ricans from the island of Puerto Rico are U.S. citizens at birth and are not immigrants to the United States. It is common in research such as this to compare island-born Puerto Ricans with mainland-born Puerto Ricans. For simplicity's sake only, we use the terms foreign-born (or immigrant) and U.S.-born, respectively, for all the racial/ethnic populations but fully realize that these concepts do not accurately depict the nativity distinction for Puerto Ricans.

empirical rate $\hat{p}_{jk} = D_{jk} / N_k$, which matches the definition of the partial IMR used earlier. This assumes an age interval *J,* extending from day 365 onward, where deaths eventually occur to all those who survive the first year. In this way, the multinomial probabilities sum to 1.0.

Inferences about relative mortality risks involve rate ratios of the form $\theta_j = p_{j2} / p_{j1}$, which are estimated as ratios of the maximum likelihood estimators $\hat{p}_{j1}$ and $\hat{p}_{j2}$, and where group 1 (infants born to non-Hispanic white, U.S.-born women) is the reference group. Although the rates have large sample normal distributions, the sampling distribution of the estimated rate ratio, $\hat{\theta}_j$, converges to normality at a much slower rate than does the sampling distribution of $\log\hat{\theta}_j$ (Agresti 2002). For this reason, it is customary carry out significance tests on the logarithm of the rate ratios. The logarithm of the rate ratio can be expressed as the difference in log rates,

$$\log\hat{\theta}_j = \log(\hat{p}_{j1} / \hat{p}_{j2}) = \log\hat{p}_{j1} - \log\hat{p}_{j2}. \tag{1}$$

The variance of $\log\hat{\theta}_j$ requires expressions for the asymptotic variances of the log rates, which can be found by using the delta method (Rao 1973) as follows:

$$\text{var}(\log\hat{p}_{jk}) = \text{var}(\hat{p}_{jk})\left[\frac{\partial\log\hat{p}_{jk}}{\partial\hat{p}_{jk}}\right]^2 = \text{var}(\hat{p}_{jk})\left(\frac{1}{\hat{p}_{jk}}\right)^2. \tag{2}$$

Assuming independent groups, the variance of a difference is the sum of the group-specific variances in the log rates, or

$$\text{var}(\log\hat{\theta}_j) = \text{var}(\log\hat{p}_{j1} - \log\hat{p}_{j2}) = \text{var}(\log\hat{p}_{j1}) + \text{var}(\log\hat{p}_{j2}). \tag{3}$$

Using the formula for the variance of a multinomial proportion, applying the delta method in (2), and simplifying, the variance of $\log\hat{p}_{jk}$ can be expressed as

$$\text{var}(\log\hat{p}_{jk}) = \frac{N_k - D_{jk}}{N_k D_{jk}}. \tag{4}$$

This leads to a convenient expression for the variance of $\log\hat{\theta}_j$:

$$\text{var}(\log\hat{\theta}_j) = \frac{N_1 - D_{j1}}{N_1 D_{j1}} + \frac{N_2 - D_{j2}}{N_2 D_{j2}}. \tag{5}$$

The standard error of $\log\hat{\theta}_j$ is the square root of this quantity. Statistical tests are carried out in the usual way by dividing the log rate ratio by its standard error, which results in a standard normal test statistic that is used to directly test the hypothesis that $\log\theta_j = 0$ or that $\theta_j = 1$.[2]

Later in the paper, we separately consider only those births that occurred in large metropolitan counties near the U.S.-Mexico border because of the greater possibility that Mexican-origin women and infants in such areas would have a higher likelihood of out-migrating to Mexico. Finally, we use our data to specify several hypothetical scenarios to

2. The results presented here are robust to alternative specifications of the underlying probability model. For example, a classical life table approach uses the observed mortality to decrement the survivors in order to reflect the effective number at risk at the beginning of each age interval. The usual assumption in this case is that deaths in each age interval follow a binomial distribution. Standard errors calculated based on assuming a binomial distribution show differences at the seventh decimal place from our estimates. This is attributable to the very large sample sizes used in this analysis. Because we do not know the actual number of infant deaths in Mexico for infants born in the United States to resident mothers who later returned to Mexico, we do not decrement the number at risk in each age interval.

assess the possible number of out-migrant women and infants to Mexico that there would need to be for the epidemiologic paradox—as observed in the data set we use—to be an artifact of underreporting due to out-migration. The methods that we use for these latter two analyses are explained in the following sections.

RESULTS

Findings From the United States as a Whole

Panel A of Table 1 shows the age-specific rates of death (per 1,000 births) for U.S. infants born to resident mothers, by maternal race/ethnicity and nativity. The overall infant mortality rates for each racial/ethnic/nativity group are shown at the bottom of this panel. They reflect what is widely known about infant mortality patterns in the United States: the highest rate is exhibited among infants of U.S.-born, non-Hispanic black women, and the lowest overall rates are exhibited by infants of foreign-born Hispanic women, particularly Cuban immigrant women, other Hispanic immigrant women, and Mexican immigrant women. Indeed, infants of immigrant women in each racial/ethnic group except Puerto Ricans, for whom this distinction may be less meaningful, have lower infant mortality than infants of native-born women (Hummer, Biegler et al. 1999; Singh and Yu 1996).

Of greater interest in the present paper are the detailed age-specific death rates by race/ethnicity and nativity. The rates for infants born to Mexican immigrant women, compared with U.S.-born, non-Hispanic white women, are clearly favorable during the first hours and days of life. Indeed, the rate ratios in Panel B of Table 1 show that infants of Mexican immigrant women have age-specific death rates that are 9% to 11% lower than those of infants of U.S.-born white women during the first month of life, a time period during which out-migration to Mexico is highly unlikely (and perhaps even more so if the infants are born early or small, or are otherwise in poor health and at a heightened risk of death). Similar patterns are exhibited among infants of other Hispanic immigrant women. Moreover, the detailed age-specific rates during the first month of life for infants of Mexican immigrant women are far lower than infants of non-Hispanic black women, with whom they tend to share socioeconomic and health care characteristics. These patterns provide strong evidence in support of the epidemiologic paradox, as defined by Markides and Coreil (1986), among infants of both Mexican immigrant women and infants of other Hispanic immigrant women.

The age-specific death rates among infants of both Mexican immigrant women and other Hispanic immigrant women become even more favorable compared with infants of non-Hispanic white women during the 28–90 day time period and the 91–180 day time period. For example, the rate ratios of 0.77 and 0.70 for infants of Mexican immigrant women, respectively, are even lower than the 0.89 to 0.91 ratios exhibited for this group during the specific first month of life time periods. These lower rate ratios are consistent with the idea that women and infants may be more likely to out-migrate to Mexico as the infants become older, with some postmigration infant deaths going unrecorded in the United States. A parallel pattern is evident among infants of other Hispanic immigrant women. However, a similar pattern is also evident when looking at the rate ratios for Puerto Rican, black, white, and Cuban immigrant women compared with non-Hispanic, white U.S.-born women. That is, all rate ratios for infants of immigrant women are lower in the 28–90 day and 91–180 day periods than during the earlier periods. One possibility is that this is consistent with a greater likelihood of woman-infant out-migration during these periods and, thus, an underreporting of U.S. infant mortality among infants of immigrant women. However, the fact that this pattern is also seen for both Puerto Rican and Cuban immigrant women casts at least some doubt on the out-migration hypothesis. Indeed, Cuban immigrant women are not at all likely to out-migrate to Cuba, given the political relationship between Cuba and the United States. Second, deaths to infants of island-born Puerto Rican women, even if the deaths occur in Puerto Rico, are linked to birth certificates in the data that we are using

Table 1. Infant Mortality Rates (IMRs) and Rate Ratios for Births to Mexican-Origin and Other Racial/Ethnic Groups of Women in the United States, 1995–2000

	Mexican-Origin		Puerto Rican		Cuban-Origin		Other Hispanic		Non-Hispanic Black		Non-Hispanic White	
	Immigrant	U.S.-born	Island-born	U.S.-born	Immigrant	U.S.-born	Immigrant	U.S.-born	Immigrant	U.S.-born	Immigrant	U.S.-born
Panel A. Age-Specific IMR (per 1,000 Births)												
Less than 1 hour	0.74	0.84	1.38	0.98	0.63	0.70	0.75	0.88	1.55	1.93	0.69	0.81
1–23 hours	1.23	1.41	2.22	2.11	1.16	0.97	1.24	1.49	3.10	3.95	1.21	1.38
1–6 days	0.77	0.88	1.12	1.21	0.79	0.60	0.74	1.02	1.54	1.58	0.80	0.87
7–27 days	0.74	0.96	1.15	1.13	0.94	1.06	0.73	0.85	1.46	1.73	0.72	0.82
28–90 days	0.73	1.05	1.07	1.34	0.58	0.86	0.70	1.13	1.14	2.31	0.67	0.95
91–180 days	0.47	0.79	0.69	0.76	0.36	0.36	0.45	0.77	0.75	1.46	0.46	0.67
181–364 days	0.43	0.54	0.63	0.59	0.26	0.40	0.38	0.53	0.67	1.01	0.35	0.43
Total IMR	5.11	6.47	8.26	8.13	4.71	4.95	5.00	6.66	10.21	13.98	4.90	5.93
Linked deaths	9,711	7,716	1,025	1,731	222	151	3,095	1,793	3,487	44,698	3,586	80,942
Resident births	1,899,926	1,192,690	124,111	212,783	47,227	30,456	619,388	269,127	341,407	3,198,271	732,232	13,659,178
Panel B. Rate Ratios of Infant Death												
Less than 1 hour	0.91[a]	1.04	1.70[a]	1.22[a]	0.77	0.86	0.93	1.09	1.92[a]	2.38[a]	0.85[a]	1.00
1–23 hours	0.90[a]	1.02	1.61[a]	1.54[a]	0.84	0.70	0.90[a]	1.08	2.25[a]	2.87[a]	0.88[a]	1.00
1–6 days	0.89[a]	1.02	1.30[a]	1.40[a]	0.91	0.69	0.85[a]	1.18[a]	1.78[a]	1.83[a]	0.93	1.00
7–27 days	0.90[a]	1.18[a]	1.41[a]	1.39[a]	1.15	1.30	0.89	1.04	1.79[a]	2.12[a]	0.88[a]	1.00
28–90 days	0.77[a]	1.11[a]	1.13	1.41[a]	0.61	0.90	0.74[a]	1.19[a]	1.20[a]	2.43[a]	0.70[a]	1.00
91-180 days	0.70[a]	1.18[a]	1.02	1.12	0.54	0.54	0.67	1.14	1.10	2.17[a]	0.68[a]	1.00
181–364 days	0.99	1.24[a]	1.45[a]	1.36[a]	0.59	0.92	0.88	1.21	1.55[a]	2.34[a]	0.82[a]	1.00
Total rate ratio	0.86[a]	1.09[a]	1.39[a]	1.37[a]	0.79[a]	0.84	0.84[a]	1.12[a]	1.72[a]	2.36[a]	0.83[a]	1.00

Note: The weighted numbers in the "Linked deaths" and the "Resident births" rows are rounded to eliminate decimal places.

Source: Cohort linked birth and infant death files for the United States, 1995–2000 (National Center for Health Statistics 1995–2000).

[a]Rate ratios are significantly different from U.S.-born, non-Hispanic whites for that age group ($p < .01$).

(National Center for Health Statistics 2000). Thus, although some of the observed patterns at ages 28–90 days and 91–180 days are consistent with an out-migration hypothesis, there is clearly not unambiguous evidence in support of such patterns.

The concept of the epidemiologic paradox is not limited to Hispanic immigrants (Markides and Coreil 1986). Thus, it is instructive to also examine patterns of infant mortality among U.S.-born Hispanic women relative to non-Hispanic whites and non-Hispanic blacks. Infants of U.S.-born Mexican-origin women display death rates that are statistically equal to those of non-Hispanic white, U.S.-born women during the early neonatal period; the similarity in death rates between these two groups is perfectly consistent with the concept of the epidemiologic paradox. During the later stages of the first year of life, rates of mortality among infants of U.S.-born, Mexican-origin women are statistically higher than those of U.S.-born, non-Hispanic white women, with the rate ratios varying from 1.11 to 1.24 (Table 1, Panel B). This divergence from the equality observed during the early neonatal period is troubling, given the socioeconomic disadvantages that second- and third-generation Mexican Americans in the United States face relative to non-Hispanic whites (National Research Council 2006). Nonetheless, infant mortality rates among U.S.-born, Mexican-origin women are still far closer to those of non-Hispanic whites than to those of non-Hispanic blacks across the entire first year of life, which is again fully consistent with the concept of the epidemiologic paradox.

Findings From Metropolitan Counties in the Southwest Region of the United States

Table 2 reports infant mortality rate ratios for the two Mexican-origin groups (that is, foreign-born and U.S.-born women, respectively) compared with U.S.-born, non-Hispanic whites among women residing in large counties (> 250,000 population) close to the U.S.-Mexico border. These include counties in the southern portions of California, Arizona, and

Table 2. Infant Mortality Rate (IMR) Ratios for Births to Mexican-Origin Women (compared with U.S.-born, non-Hispanic white women) Residing in Large Metropolitan Counties Near the U.S.-Mexico Border, 1995–2000

	Mexican-Origin		Non-Hispanic White, U.S.-born
	Immigrant	U.S.-born	
Age			
Less than 1 hour	0.88	1.10	1.00
1–23 hours	0.97	1.16	1.00
1–6 days	0.90	1.03	1.00
7–27 days	1.04	1.25	1.00
28–90 days	0.87	1.10	1.00
91–180 days	0.74	1.08	1.00
181–364 days	1.02	1.44	1.00
Total Rate Ratio	0.92	1.14[a]	1.00
Total IMR	4.98	6.21	5.42
Linked Deaths	4,002	2,905	3,858
Resident Births	803,145	468,050	711,345

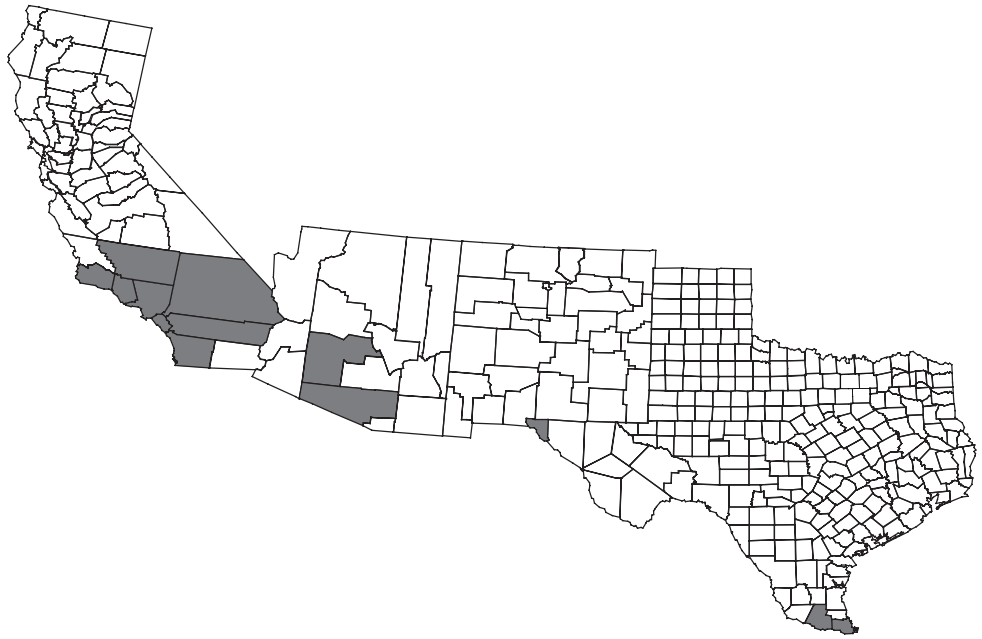
Source: Cohort linked birth and infant death files for the United States, 1995–2000 (National Center for Health Statistics (1995–2000).

[a]Rate ratio is significantly different from U.S.-born, non-Hispanic whites ($p < .05$).

Texas (see Figure 1). Unfortunately, county of residence for women living in less-populated counties are not identified in the linked birth–infant death data. The comparison of age-specific infant mortality rates in these counties is instructive because of their proximity to the U.S.-Mexico border. In such locations, the possibility of Mexican immigrants in the United States returning to Mexico shortly after the birth of a child may be greater because of the shorter distance. Thus, if out-migration of mothers and their infants is more pronounced in this geographic area, one might expect to see especially favorable infant mortality outcomes—particularly for Mexican immigrant women compared with non-Hispanic whites—in this portion of the analysis.

Table 2 shows that the overall infant mortality rate for both Mexican immigrant women and for U.S.-born Mexican-origin women are slightly less favorable for this geographic area than for the country as a whole (compared with the parallel findings from Table 1). Because of much smaller cell sizes for deaths by age, no statistically significant age-specific differences exist between either of the Mexican-origin groups and non-Hispanic whites. Nevertheless, the findings from Table 2 continue to demonstrate an overall pattern of favorable age-specific infant mortality rates for Mexican immigrant women in the first hours and days of life as well as near-parity between U.S.-born, Mexican-origin women and native-born, non-Hispanic whites in the early age periods. Concurrent with the findings from the nation as a whole, no evidence exists here that the favorable infant mortality rates for the Mexican-origin population are strongly influenced by out-migration. Simply put, the low mortality rates for infants of Mexican immigrant women and the relatively low mortality rates for infants of U.S.-born Mexican-origin women in the earliest age periods are firmly

Figure 1. Map of the Southwestern States Depicting the Large Metropolitan Counties (population > 250,000) Near the U.S.-Mexico Border



consistent with the concept of an epidemiologic paradox. And there are no exceedingly low age-specific rates for infants born to Mexican immigrant women throughout the first year that suggest out-migration as an influential factor.

Findings From an Exercise Simulating Out-Migration

Table 3 reports on our calculations that address the question of how many Mexican immigrant women and infants would need to out-migrate from the United States to Mexico—under different assumptions regarding the level of infant mortality for out-migrants—to equalize the infant mortality rates between infants of Mexican immigrant women and infants of U.S.-born, non-Hispanic white women in the United States. We focus on Mexican immigrant women, rather than Mexican American women, in this exercise because it is highly unlikely that more than a tiny fraction of U.S.-born, Mexican American women would out-migrate to Mexico with their infants. The left side of Panel A begins by reporting that an additional 1,548 infant deaths of Mexican immigrant women would have needed to be recorded in the United States over the 1995–2000 period for their overall rate (IMR = 5.11; see Table 1) to be equivalent to that of non-Hispanic white, native-born women (IMR = 5.93; see Table 1). The right side of Panel A simply reports this figure as an annual average over the six years. That is, the overall lower infant mortality of Mexican immigrant

Table 3. Simulations of Infant Out-Migration Needed to Account for the Mexican Immigrant Infant Mortality Advantage Compared With Non-Hispanic Whites in the United States, 1995–2000

	1995–2000		Annual Average	
Infants Born in United States to Mexican Immigrant Women Versus U.S.-born, Non-Hispanic White Women	Additional Deaths Needed to Match IMR for Non-Hispanic Whites	Out-Migrants Required	Additional Deaths Needed to Match IMR for Non-Hispanic Whites	Out-Migrants Required
Panel A				
Hypothetical out-migrant deaths: Infants who died at ages 0–364 Days	1,548		258	
If out-migrant infants died				
At their observed U.S. IMR of 5.11 (IMR for U.S.-born Mexican immigrant)		302,935		50,489
At an IMR of 16.0 (in between estimates for U.S. and Mexico)		96,750		16,125
At an estimated Mexican IMR of 27.0 (Pan American Health Organization[a] estimate for Mexico 1997–1998)		57,333		9,556
Panel B				
Hypothetical out-migrant deaths: Infants who emigrated after 6 days and died at ages 7–364 days	1,548		258	
Exposure to an IMR of 5.11 for days 7–364		605,871		100,978
Exposure to an IMR of 16.0 for days 7–364		193,500		32,250
Exposure to an IMR of 27.0 for days 7–364		114,667		19,111

Note: Calculations in Panel B are based on the assumption that one-half of infant deaths occur during the first six days of life and the other half occur throughout the remainder of the year.

[a]Data come from Pan American Health Organization (2005).

women compared with non-Hispanic white native-born women resulted in 258 fewer infant deaths per year, on average, among the former group.

Panel A of Table 3 specifies three different levels of infant mortality among hypothetical out-migrants: (1) Mexican out-migrant infants die at a hypothetical rate equivalent to that experienced by Mexican immigrant infants in the United States between 1995 and 2000 (IMR = 5.11); (2) Mexican out-migrant infants die at a hypothetical rate roughly halfway between that experienced by Mexican immigrants in the United States and Mexicans in Mexico (IMR = 16.0); and (3) Mexican out-migrant infants die at a hypothetical rate equivalent to that estimated for infants in Mexico in 1997–1998 (IMR = 27.0).

An IMR of 5.11 for the hypothetical out-migrants requires over 300,000 out-migrating women and infants over the six-year period (or over 50,000 per year), with all of their resulting infant deaths occurring in Mexico and going unrecorded in the United States, for the Mexican immigrant infant mortality rate in the United States to be equivalent to the rate of U.S.-born, non-Hispanic white women. Under conditions of higher infant mortality, the resulting out-migration numbers are lower but still very high. For example, under the assumption of an infant mortality rate of 16.0 for the hypothetical out-migrants, it would take nearly 100,000 women and infants out-migrating from the United States over the six-year period—over 16,000 per year—for the Mexican immigrant women in the United States to experience the same infant mortality rate as non-Hispanic white, native-born women. These numbers can be compared with recent data from Mexico that estimated that 139,661 Mexican-origin females aged 5 and older migrated from the United States and other countries back to Mexico between January 1995 and February 2000 (INEGI 2003). It is highly implausible that such a large fraction of Mexican-origin women migrating from the United States to Mexico are not only of childbearing age but also out-migrate with a newborn infant.

Panel B of Table 3 reports results from similar calculations as Panel A but does so by only considering infant mortality that occurs between ages 7 and 364 days. This panel makes the assumption that there is no return migration of Mexican immigrant women to Mexico with infants who are less than one week old (which seems plausible, and particularly so if infants are premature, of low birth weight, or in otherwise poor health). Thus, there are no unrecorded deaths in the first week of life among Mexican-origin infants born in the United States. As a result, the hypothetical number of out-migrants in Panel B for those scenarios is much higher than the number in Panel A because approximately one-half of all infant deaths in the United States occur during the first week of life (authors' calculation; not shown in the table). The results show that huge numbers of Mexican immigrant women and their infants would need to out-migrate on a yearly basis for the infant mortality rates between Mexican immigrant women and U.S.-born, non-Hispanic white women to be equivalent. Under any of the three mortality scenarios presented, the overall conclusion remains unchanged: it would take an implausibly large number of Mexican immigrant women and their infants out-migrating from the United States to Mexico, with subsequent infant deaths going unrecorded in the United States, for the rates between the two groups to be equivalent. Even then, the equivalency of rates between Mexican immigrant and U.S.-born, non-Hispanic white women would still qualify as an epidemiologic paradox under the definition by Markides and Coreil (1986).

CONCLUSION

Although a great deal of research has documented the relatively favorable health and mortality outcomes among both the Mexican American and Mexican immigrant populations, recent work has suggested that the favorable mortality outcomes for the Mexican immigrant population may largely be attributable to selective out-migration among Mexican immigrants, resulting in artificially low recorded death rates for the Mexican-origin population in the United States. In this paper, we specified and examined detailed age-specific infant

mortality for two important reasons: (1) women of Mexican origin are extremely unlikely to migrate to Mexico with newborn babies who were born in the United States, especially if the infants are only a few hours or a few days old; and (2) more than 50% of all infant deaths in the United States occur in the first week of life, when the chances of out-migration are small. We used concatenated data from the U.S. linked birth and infant death files from 1995 through 2000, which provided us with over 20 million births and more than 150,000 infant deaths to analyze. Our results clearly show that first hour, first day, and first week mortality among infants born to Mexican immigrant women in the United States are about 10% lower than that experienced by infants of non-Hispanic white, U.S.-born women. It is implausible that such favorable rates are artificially caused by the out-migration of Mexican-origin women and their newborn infants. Although the rates for infants of Mexican immigrant women become even more favorable than rates for infants of non-Hispanic white women during the postneonatal period—which would be consistent with an out-migration interpretation—the same pattern arises for Cuban immigrant women, who are almost surely not returning to Cuba, as well as for several other groups of immigrant women. Further, infants born to Mexican American women, even though exhibiting rates of mortality that are slightly higher than those of non-Hispanic white women during the first weeks of life, also fare considerably better than infants born to non-Hispanic black women, with whom the former share similar socioeconomic profiles. All these patterns are completely consistent with the concept of the epidemiologic paradox.

Our analysis of specific metropolitan counties along the U.S.-Mexico border and our additional simulation calculations using different out-migration scenarios and infant mortality assumptions further bolstered this conclusion. Even with a higher likelihood of out-migration in counties along the border, our analysis of these areas resulted in findings that are similar to those for the United States as a whole. Our additional simulation calculations based on different mortality rates for hypothetical out-migrant women demonstrated that even though out-migration of Mexican immigrant women and their infants surely can and does occur, with some subsequent deaths of U.S.-born infants going unrecorded in U.S. data, the extent to which this would need to happen to influence observed U.S. death rates even moderately is very substantial. Thus, we conclude that the epidemiologic paradox for U.S. infant mortality among the Mexican-origin population—both among immigrant women and among U.S.-born women—is real and not a data artifact. Such a conclusion is fully consistent with that of Turra and Elo (forthcoming) with regard to old-age mortality among the Hispanic population of the United States. Our findings should, at least for now, "close the case" (Palloni and Morenoff 2001:152–53) regarding the underreporting explanation for the epidemiologic paradox of infant mortality. Instead, future research should focus on understanding why the Mexican immigrant population exhibits the low mortality rates that it does. One important intent of such research should be to apply the lessons learned from this health-achieving population to other population groups in the United States. Indeed, one area of focus should be on the exceptionally healthy behaviors (e.g., very low rates of smoking, alcohol use, and drug use) exhibited by immigrants to the United States, particularly women (Lopez-Gonzalez, Aravena, and Hummer 2005). Such healthy behaviors by immigrant women may be especially important in helping to account for the positive health outcomes of Mexican-origin infants.

In closing, we would be remiss in not commenting on another very important pattern observed in our data. Among the Mexican-origin population, as well as for most of the other racial/ethnic groups considered here, infant mortality is higher among U.S.-born women than among immigrant women. Further, among Mexican American (U.S.-born) women, the statistical parity in infant mortality with non-Hispanic whites observed in the first week after birth disappeared in the later periods of infancy, when the Mexican American women exhibited a moderate disadvantage compared with U.S.-born, non-Hispanic white women. Such patterns of less-favorable Mexican American health over time and across generations

in comparison with non-Hispanic whites are consistent with a negative acculturation interpretation of Hispanic health (National Research Council 2006), or longer exposure to a less-healthy social environment for the Mexican-origin population compared with non-Hispanic whites. Thus, the most important issue in moving forward in this area of research is not whether an epidemiologic paradox of Mexican-origin infant mortality exists in the United States; it does, at least for now. Rather, the more important issue is whether 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. Along these lines, it will be vitally important in the coming decades to continue to monitor the health and health behavior of second- and third-generation Mexican-origin individuals throughout the country while pursuing an aggressive social policy agenda that attempts to close the educational, income, and health insurance gaps between minority groups in the United States and the majority white population.

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