

Socioeconomic Differences in Mortality among U.S. Adults:  
Insights into the Hispanic Paradox

Cassio M Turra  
Noreen Goldman  
Office of Population Research, Princeton University

Paper presented at the 2006 Annual Meeting of the Population Association of America,  
Los Angeles, March 29, 2006.

This research was supported in part by the NIA Center for Demography of Aging at the  
Center for Health and Wellbeing, Princeton University. We would also like to thank  
Germán Rodríguez for his statistical advice.

## ABSTRACT

Despite a myriad of studies focused on social disparities in health, surprisingly little is known about SES differentials in mortality among Hispanics in the U.S. This study examines education and income differences in mortality by immigrant status and national origin and explores how ethnic differences in SES gradients in mortality are related to the Hispanic paradox. We use Poisson regression models based on data from the 1989-1994 waves of the National Health Interview Survey, with linked mortality through 1997, to estimate death rates for Hispanics and whites by age, sex and SES. Deaths rates vary significantly ( $p < 0.05$ ) by education and income for whites and for Hispanic subgroups defined by nativity (U.S.-born and foreign-born) and nationality (Mexicans, Puerto Ricans, and other Hispanics). However, with the exception of Puerto Ricans, the effects of education are more modest for Hispanic groups than for whites. The ethnic differences in mortality patterns by income are less notable than those for education. The findings reveal that the mortality advantage for Hispanics is concentrated at lower levels of SES, with little or no advantage at higher levels. We propose several mechanisms related to immigration and assimilation patterns that may underlie these results. The analysis also suggests that, because of the statistical significance of interaction terms between age and other demographic variables in models of mortality, some earlier estimates of ethnic or SES differences in survival are likely to be biased.

Word count: 233

Over the past two decades, epidemiologists and social scientists have devoted considerable attention to identifying what has become known as the “Hispanic mortality paradox.” Despite the unfavorable socioeconomic profile and low rates of health insurance and health care utilization of U.S. Hispanics, Hispanics have higher life expectancy than non-Hispanic whites (Elo et al. 2004; Rosenwaik 1987; Sorlie et al. 1993). There are large variations in mortality within the Hispanic population, with the foreign-born and certain regional subgroups – most notably Mexicans, Central Americans and South Americans – most likely to experience this mortality advantage (Hummer et al. 2000; Markides and Eschbach 2005; Palloni and Arias 2004). The Hispanic mortality advantage extends to some but not all aspects of health. For example, although some Hispanic groups have lower prevalence rates than whites from major chronic illnesses such as heart disease and cancer, have fewer activity limitations, and are less likely to engage in certain unhealthy behaviors such as smoking, they have a higher prevalence of other illnesses including HIV/AIDS and diabetes (Cho et al. 2004; Miller et al. 1996; NCHS 2002).

A second seemingly unrelated topic of interest among researchers in the social and health sciences relates to social inequalities in health. A large number of studies, some dating as far back as the 1800s, have shown that persons of higher socioeconomic status – most frequently defined by education, income or occupational status – experience higher survival rates and typically lower morbidity rates than their respective counterparts (Goldman 2001). Instead of revealing a threshold effect, these associations appear throughout the social hierarchy (for example, even within relatively high social classes), generating what researchers now refer to as a “social gradient” in health and mortality (Adler et al. 1994). Despite the apparent ubiquity of

this gradient across time, place and age, a recent study suggests that similar patterns may not characterize the U.S. Hispanic population (Goldman et al. Forthcoming). That is, a broad range of measures of health – including health-related behaviors, such as smoking and drinking, and measures of health status, such as obesity, work-related limitations, and depressive symptoms – appear to be only weakly, if at all, related to levels to education among U.S. Hispanics or among the subgroup of persons of Mexican origin. In contrast, non-Hispanic whites generally have significant gradients, with more educated individuals having healthier behaviors and better health outcomes.

This earlier study raises two intriguing questions that we address in the present analysis. The first is whether these relatively flat SES gradients in health-related measures extend to mortality – that is, whether differences in death rates by SES are substantially smaller among U.S. Hispanics than among non-Hispanic whites. The second is whether differences in social gradients in mortality between Hispanics and non-Hispanic whites are related to the “Hispanic paradox.” Despite unabated interest in social gradients in the U.S., surprisingly little is known about SES differentials in mortality for the Hispanic population. Although many analyses have included measures of education, income or occupational status along with measures of ethnicity in statistical models of mortality, SES has typically been viewed as a control variable and assumed to have constant effects across ethnic groups (Hummer et al. 2000; Rogers et al. 1996; Singh and Siahpush 2002). There have been several exceptions, however. In a comparison of life expectancy by SES and ethnic group, one study (Lin et al. 2003) notes that education differences in life expectancy at the lower levels of schooling and income differences appear to be smaller for Hispanic men than for non-Hispanic men; sample sizes were insufficient for obtaining estimates at higher education levels. In contrast, the estimates presented in two

analyses of death rates that use occupational class as a measure of SES (Muntaner, Hadden and Kravets 2004; Wei et al. 1996) and one that uses income (Sorlie et al. 1993) suggest similarly important gradients for Hispanics and non-Hispanic whites. Unfortunately, none of these analyses provide statistical comparisons of the SES differentials across ethnic categories.

Although the study by Goldman and colleagues (Goldman et al. Forthcoming) leads us to hypothesize that mortality differences by SES among Hispanics will be smaller than those for whites, there are two reasons to believe that a social gradient in mortality will still be present for the Hispanic population. The first is the relatively high prevalence of certain health illnesses and risk factors among Hispanics, such as diabetes and obesity, that are likely to vary by SES (Markides et al. 1997). The second is the fact that many Hispanics, particularly those of low SES, are without health insurance – 33 percent in 2003 (Cohen, Coriaty-Nelson and Ni 2004) – and hence are less likely than others to use health care services. Thus, we hypothesize that mortality among Hispanics will vary significantly by education and income, albeit to a lesser degree than among non-Hispanic whites.

In the present analysis, we use data from the National Health Interview Survey (NHIS) and the National Death Index (NDI) to evaluate this hypothesis. Our statistical analysis takes into account potentially complex relationships among ethnicity, SES, sex and age and underscores flaws in the methodology frequently used to investigate ethnic differentials in mortality. By also examining variations in SES differences by immigrant status and national origin, we link our findings to the Hispanic mortality paradox and gain insights into how ethnicity and SES interact to create these enigmatic patterns of health and mortality in the Hispanic population.

## METHODS

### Data

This study is based on data from the 1989-1994 waves of the NHIS with linked mortality data through 1997. NHIS is a nationally representative cross-sectional survey of the non-institutionalized population of the 50 states and the District of Columbia that has been collected annually since 1957. Beginning in 1986, information for NHIS respondents aged 18 and older has been linked with the NDI to create the NHIS Multiple Cause of Death (NHIS-MCD) public use data files.

The matching methodology uses a score constructed on the basis of 12 criteria, which combine several personal identifiers such as social security number, first name, last name and father's surname. Potential matches between the NDI and the NHIS records are classified into five mutually exclusive classes based on number and type of items matched. Ascertainment of the vital status of individuals who fall into classes that do not fulfill the requirements to be considered either true or false matches is made based on cut-off scores calculated from two independent calibration samples (NCHS 2000). Biases in the matching procedure usually result from missing social security numbers, incorrect recording of ethnic names, emigration of foreign-born individuals, and changing surnames among women. The NCHS estimates that about 94 percent of the deaths of women and 97 percent of the deaths of men are correctly classified in the linked files. Among nonwhites, these percentages are lower at about 85 and 88 percent, respectively (NCHS 2000).

Of the 512,073 persons 18 and older interviewed in the 1989-1994 surveys, there were 30,266 presumed deaths from 1989 through 1997. About four percent of the original NHIS sample was excluded because of insufficient information to perform the linkage procedure.

Another 7,712 Hispanics from a supplemental sample in 1992, most of whom were interviewed in 1991, were excluded to avoid duplicates in our analyses. As described below, the present study is restricted to Hispanics and non-Hispanic native-born whites aged 25 and older. Among the persons in the sample satisfying these criteria, 331,079 remained after the exclusion of those with missing data on explanatory variables – 308,939 survivors and 22,140 deaths.

#### Explanatory variables

Explanatory variables for the statistical models comprise age (single years), sex, race/ethnicity, educational attainment, and income. All variables are defined as of the NHIS interview date and, except for age, are assumed to remain constant throughout the follow-up period. Because this assumption is untenable for educational attainment at the young adult ages, the analysis is restricted to persons 25 and older.

Information on race and ethnicity is based on self-identification: respondents were first asked about their racial background and then asked if their national origin or ancestry could be described by any of eight Hispanic origin categories. Respondents who indicated any of these Hispanic designations were considered to be Hispanic. Additional information for the construction of nativity status is based on a question pertaining to years lived in the U.S. Our analysis focuses on two groups: Hispanics and native-born non-Hispanic whites (referred to simply as “whites” for the remainder of the paper). In later stages of the analysis, we consider two subdivisions of the Hispanic group: (1) US-born vs. foreign-born Hispanics; and (2) Mexicans, Puerto Ricans and other Hispanics. We follow convention by classifying Puerto Ricans born outside the 50 states and D.C. as foreign-born. The sample size of deaths is not sufficiently large to permit further subdivision of these variables or joint classification of nativity and nationality.

SES is measured by educational attainment and family income. Education attainment is classified into five categories: 0-8 years (omitted category), 9-11 years, 12 years, 13-15 years, and 16 or more years. For 86.5% of respondents in our analysis sample, annual family income is reported in categories ranging from less than \$1,000 to \$50,000 and over; for the remainder, annual family income is reported as a dichotomy: <\$20,000 and  $\geq$ \$20,000. Because of the large range of income within these categories, we imputed values for income based on data from the Current Population Surveys for the years 1989-1994. For each of the five years of the NHIS, respondents were assigned the mean family income of persons of the same age, sex, ethnic group and income category who were interviewed in the CPS of the same year. This imputed income variable was then reclassified into quartiles, based on the combined sample of Hispanics and whites.

#### Analytic strategy

We use Poisson regression models to estimate the number of deaths during the follow-up period as a function of person-years of exposure, SES, ethnicity, age, and sex. These estimates are based on survey commands in STATA (StataCorp. 2003) that adjust for clustering and stratification of the NHIS in the estimation of the standard errors (NCHS 2004). Each respondent's exposure begins at the date of interview and terminates at the minimum of the time of death or the end of 1997.

Age is specified as a continuous variable. We estimate two sets of models, one including education levels and the second replacing education levels with income quartiles. Within each of these two sets, we fit three models that include different specifications of the Hispanic variable. The first model includes Hispanics as a single group, the second distinguishes between US-born



and foreign-born Hispanics, and the third identifies Mexicans, Puerto Ricans and other Hispanics. Thus, we estimate a total of six Poisson models.

The models include interaction terms as well as main effects of the explanatory variables. Because our objective is to explore differences in the SES gradient by ethnicity, all models include interaction terms between SES (education or income) and the relevant Hispanic variable(s). In exploratory analyses, we tested for the inclusion of all remaining two-way interaction terms involving age, sex, SES and ethnicity and the three-way interaction term among age, SES and ethnicity. The three-way interaction term was not significant for either education or income. After excluding this term, we retained those two-way interaction terms with p-values below 0.05 (p-values are based on two-sided tests unless indicated otherwise). The interaction terms between age and ethnicity and between age and SES were significant in all models and are included in both the education and income models. The interaction terms between age and sex and between sex and SES were significant in the income but not the education models and are thus included in only the income models.

Because of the many interaction terms included in each of the models, it is not possible to present the coefficients here; however, they are available from the authors on request. Instead, we present predicted death rates for males by education and by income in Figures 1 and 2 respectively; patterns for females are very similar to those shown for men. The predicted death rates are graphed separately for three ages – 30, 50 and 70 – selected to represent young, middle and older ages. For a given model, the predicted death rates were obtained by considering all combinations of values for the categories of sex, ethnicity, SES, and the three selected ages, setting the interaction terms accordingly, and using the coefficients of the model to obtain the predicted number of deaths for the specified person-years of exposure.

## RESULTS

The numbers of deaths and person-years of exposure for each of the explanatory variables are presented in Table 1. The estimates underscore the relatively small number of deaths for some Hispanic subgroups that limits our ability to consider further classifications of ethnicity or interactions between nativity status and ancestry.

Overall, our results are consistent with our hypothesis that death rates vary significantly by education and by income for whites and for Hispanic subgroups ( $p < 0.05$ , based on Wald tests on the set of education or income coefficients for a given ethnic group, evaluated at the mean age of the sample – 50.3 years). The only two exceptions are the education coefficients for “other Hispanics” and the income coefficients for Puerto Ricans, both of which are marginally significant ( $p < 0.10$ ) – presumably because of the small size of these two groups. Figures 1 and 2 reveal that the SES gradients decrease with age, sometimes becoming flat at the oldest ages for Hispanics. Such decreasing social inequalities in health with age have been attributed to several factors, including government transfers to older persons, biologically-driven frailty that dominates socioeconomic factors, and selective mortality (Beckett 2000; House et al. 1994).

Although mortality varies significantly by SES for most ethnic groups considered here, the SES patterns of mortality vary among groups. As shown in Figure 1, the education effects are generally more modest for Hispanic groups than for whites – e.g., the difference in mortality between the least and most educated group is smaller for Hispanics. One notable exception occurs for Puerto Ricans, for whom the education gradients in mortality are generally as steep as those for whites. As shown in Figure 2, the ethnic differences in mortality patterns by income are less notable than those for education, although the graphs suggest more modest income

differentials for foreign-born Hispanics and “other Hispanics” as compared with whites. Statistical tests of the relevant interaction terms confirm that, with the exception of Puerto Ricans, the interaction terms comparing the set of education coefficients for a given Hispanic subgroup with the corresponding coefficients for whites are statistically significant ( $p < 0.05$ ). For income, the only (marginally) significant interaction term pertains to “other Hispanics” ( $p < 0.10$ ).

Several additional patterns that can be discerned from the predicted death rates in Figures 1 and 2 are consistent with findings from previous studies related to the Hispanic paradox. First, with the exception of “other Hispanics”, the Hispanic mortality advantage is not apparent at younger ages. At age 30, death rates for Hispanics as a group are *higher* than those for whites, but this differential reverses and the Hispanic mortality advantage increases through middle and older ages. This result is consistent with studies that suggest that a mortality crossover between Hispanics and whites occurs between ages 40 and 50 (Liao et al. 1998; Rosenwaike 1987). Second, the mortality advantage is more notable for foreign-born Hispanics than for Hispanics born in the U.S. at middle and older ages. Third, the mortality advantage is most prominent for “other Hispanics”, whereas Puerto Ricans are generally disadvantaged relative to whites, especially at the younger ages.

Figures 1 and 2 also underscore a pattern that has received little attention to date: the Hispanic mortality advantage pertains primarily to persons of lower SES. At middle and older ages, Hispanics with little schooling or low income experience lower mortality than their white counterparts, whereas Hispanics in the highest education and income categories have generally similar or higher death rates than whites. Indeed, although sample sizes are relatively small for Hispanics in the highest education category, the estimates suggest that US-born Hispanics with

16 or more years of education have higher mortality at adult ages than similarly educated whites ( $p < 0.05$ , one-sided test evaluated at the mean age of the sample).

## DISCUSSION

The findings presented here confirm our central hypothesis that death rates vary significantly by education and income within Hispanic groups. Our results, particularly those for education, are also consistent with recent research suggesting that persons of Mexican origin are characterized by shallower SES gradients in health measures than whites (Goldman et al. Forthcoming). Our finding that the negative associations between income and mortality for Hispanic groups are typically stronger than those between education and mortality may reflect reverse causality. That is, because poor health is much more likely to depress income than it is to deter educational advancement at adult ages (Smith 2004), a negative association between income and mortality may be present even in the absence of mechanisms linking higher income to better health and survival among Hispanic groups (or whites).

The estimates provide an important insight into the relationship between the observed SES patterns in mortality and the Hispanic mortality paradox. The concentration of the mortality advantage for Hispanics at lower levels of SES, with little or no advantage at higher levels, leads to flatter SES gradients for Hispanics than for whites. Although many researchers have explored the robustness of the Hispanic mortality advantage to the introduction of controls for SES, few researchers have paid attention to how the mortality advantage varies by level of SES. There are two noteworthy exceptions. The first is a study (Wei et al. 1996) that uses data from the San Antonio Heart Study to demonstrate that mortality differences between Mexican Americans and whites are modest in the middle and higher SES categories but larger at lower levels of SES. A second analysis (McWilliams et al. 2004) demonstrates that Hispanics with health insurance

experience similar death rates to whites, but that uninsured Hispanics have lower mortality than both uninsured and insured whites.

Our statistical analysis not only underscores the importance of incorporating interactions between SES and ethnicity in analyses of mortality, but also of including interactions with age. In the present analysis, there are significant interactions between age and each of the remaining explanatory variables: SES, ethnicity, and sex. Unfortunately, some previous studies pertaining to ethnic differences in mortality have either employed proportional hazards models, which are based on the assumption that the effects of the covariates are constant across age, or have failed to consider important interaction terms (Rogers et al. 1996; Sorlie et al. 1993; Wei et al. 1996). Indeed, many have restricted the statistical models to the main effects of the covariates. Thus, some earlier estimates of ethnic or SES differences in longevity may be misleading because they are likely to mask underlying variations by age and SES.

What processes underlie the differential SES gradients in mortality – in particular, what leads Hispanics of low SES to have lower death rates than their white counterparts and Hispanics to have shallower SES gradients in mortality than whites? We propose three sets of explanations, which we refer to as (1) immigration-related, (2) assimilation, and (3) data errors.

Two immigration-related processes, which are similar to explanations proposed in an earlier study (Goldman et al. Forthcoming), may be particularly important for the foreign-born population. The first is that SES gradients in Mexico and other parts of Latin America have been weak or reversed for some health-related variables, such as smoking and obesity, in part because the poor have been less able to afford such luxuries as cigarettes and high-calorie diets (Kain, Vio and Albala 2003; Rivera and Sepulveda 2003; Vazquez-Segovia, Sesma-Vazquez and Hernandez-Avila 2002). Migrants from these areas are apt to bring these gradients with them

when they move to the U.S., a process that is likely to ultimately affect SES differences in mortality. The second pathway comprises two potential selection mechanisms that are related to what have been termed the “healthy migrant” and “salmon bias” effects: migration to the U.S. may be selective of those in better health (or those with healthier behaviors) and return migration to Latin America may be selective of those in poorer health, *especially for persons of low SES*.

Although little is known about how these aspects of migration differ between Puerto Ricans and other Hispanics, it is possible that the steeper SES gradients found here for Puerto Ricans result both from Puerto Ricans experiencing weaker (or different) migration-related selection processes as a consequence of their status as American citizens (Landale et al. 1999) and from stronger gradients in health and health-related behaviors being present in Puerto Rico as compared with Mexico and other Latin American countries. It is important to recognize that these migration-related pathways may affect mortality for U.S.-born Hispanics as well as the foreign-born, e.g., through intergenerational transmission of behaviors or of health status.

A second set of explanations, referred to broadly as assimilation, may help to further explain why death rates decline more modestly among Hispanics than whites as income and especially education increase. Whereas some immigrants retain their healthier behaviors with increasing time spent in the U.S., discrimination and the lack of opportunity faced by other immigrants, even (or especially) those with higher levels of education and earnings, may lead them to adopt detrimental behaviors and to experience the negative health consequences of stress. Immigrants from less-favored ethnic groups often have little alternative but to assimilate into disadvantaged segments of U.S. society, increasing the likelihood that they and their children experience the negative health behaviors, restricted access to high quality health services and poor health outcomes typical of residents in their neighborhoods.

A third set of mechanisms pertains to errors in the data. Death rates for Hispanics, particularly at lower SES, may be biased downward because of both age misreporting (Preston, Elo and Stewart 1999) and errors related to matching death records to the NHIS (Elo et al. 2004). An earlier study (NCHS 2000) suggests that the matching algorithm may be especially problematic for nonwhites because they are more likely to have missing social security numbers and complex (e.g., hyphenated) surnames. Moreover, omission of deaths during the follow-up period may be more common among foreign-born individuals, since they are more apt to emigrate and die outside the U.S. than native groups (Turra et al. 2005).

How do these various mechanisms account for the finding that the mortality advantages of lower SES Hispanics are apparent only at middle and older ages? An important part of the answer may pertain to the different types of causes of death that dominate at younger vs. older ages. At younger ages, deaths result largely from external causes, such as homicide and accidents, which are strongly associated with environmental factors. In contrast, at middle and older ages, chronic illnesses, which are related to detrimental health-related behaviors as well as to health status at younger ages, are the major causes of death. Thus, the negative impacts on mortality of assimilation into poor neighborhoods are likely to be proportionately larger at younger ages, and immigration-related processes are likely to offer survival *protection* primarily at middle and older ages. These suppositions are consistent with recent studies that found excess external-cause mortality for Hispanics compared to whites (Hummer et al. 2000; Rogers et al. 1996), as well as lower death rates for Hispanics as compared with whites from some leading chronic diseases, including cancer and cardiovascular disease (Rogers et al. 1996; Sorlie et al. 1993). Puerto Ricans are an exception to the finding for chronic disease: their risks of dying from heart disease (Hummer et al. 2000; Rosenwaike 1987), liver diseases (Rosenwaike 1987),

and cancer particularly among women (Hummer et al. 2000), are comparable to or higher than those of whites, in part because they have less favorable health-related behaviors compared with other Hispanics (Perez-Stable et al. 2001; Rogers 1991). In addition, Puerto Ricans report higher levels of psychological distress and mobility limitations than Mexicans and other Hispanics (Bratter and Eschbach 2005; Cho et al. 2004). These unique patterns for Puerto Ricans may emanate from both distinct migration processes and different assimilation experiences.

This analysis provides new insights into two important and inter-related phenomena, the Hispanic mortality paradox and social inequalities in mortality. Our findings underscore previous results indicating that the Hispanic mortality advantage does not apply to all Hispanics; rather, the advantage is concentrated among the foreign-born from some national origins and is present only at middle and older ages. Our estimates further suggest that efforts to understand this epidemiological paradox should focus on examining why Hispanics of lower SES experience most of the advantage and Hispanics with additional income and especially additional education benefit relatively little in comparison with whites. Researchers also need to identify the health-related pathways that offer survival protection to many Hispanic groups of low SES, but apparently not to Puerto Ricans. For example, are most of the benefits stemming from the adoption of healthier behaviors or rejection of harmful habits among Hispanics as compared with whites? Are these patterns being driven by immigration-related mechanisms or by behaviors adopted (or not adopted) by Hispanics living in the U.S.? Recent evidence suggests that gradients in some health-related variables in Mexico and other immigrant-sending countries are changing in ways that resemble those in industrialized countries whereby more educated and wealthier individuals have healthier behaviors (Bobak et al. 2000; Filozof et al. 2001). The likely consequence of a widening of SES differences in mortality in Latin America and subsequently



for immigrants and their descendants suggests that researchers need to pay increased attention to variations in social gradients in health and mortality among ethnic groups in the U.S.

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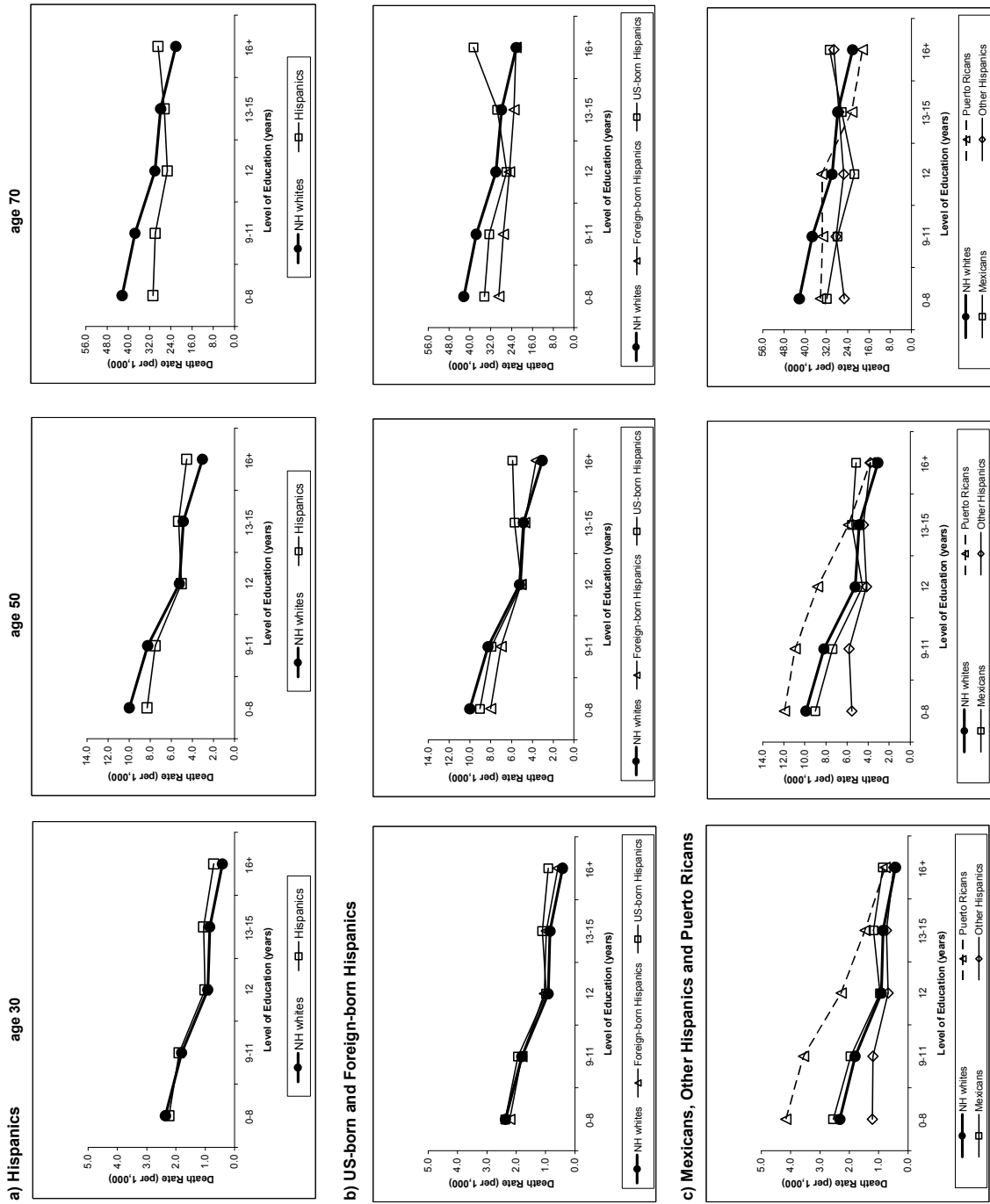
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**Table 1: Number of Deaths and Person-Years of Exposure by Selected Characteristics, National Health Interview Survey (1989-1994) Linked to the National Death Index through 1997**

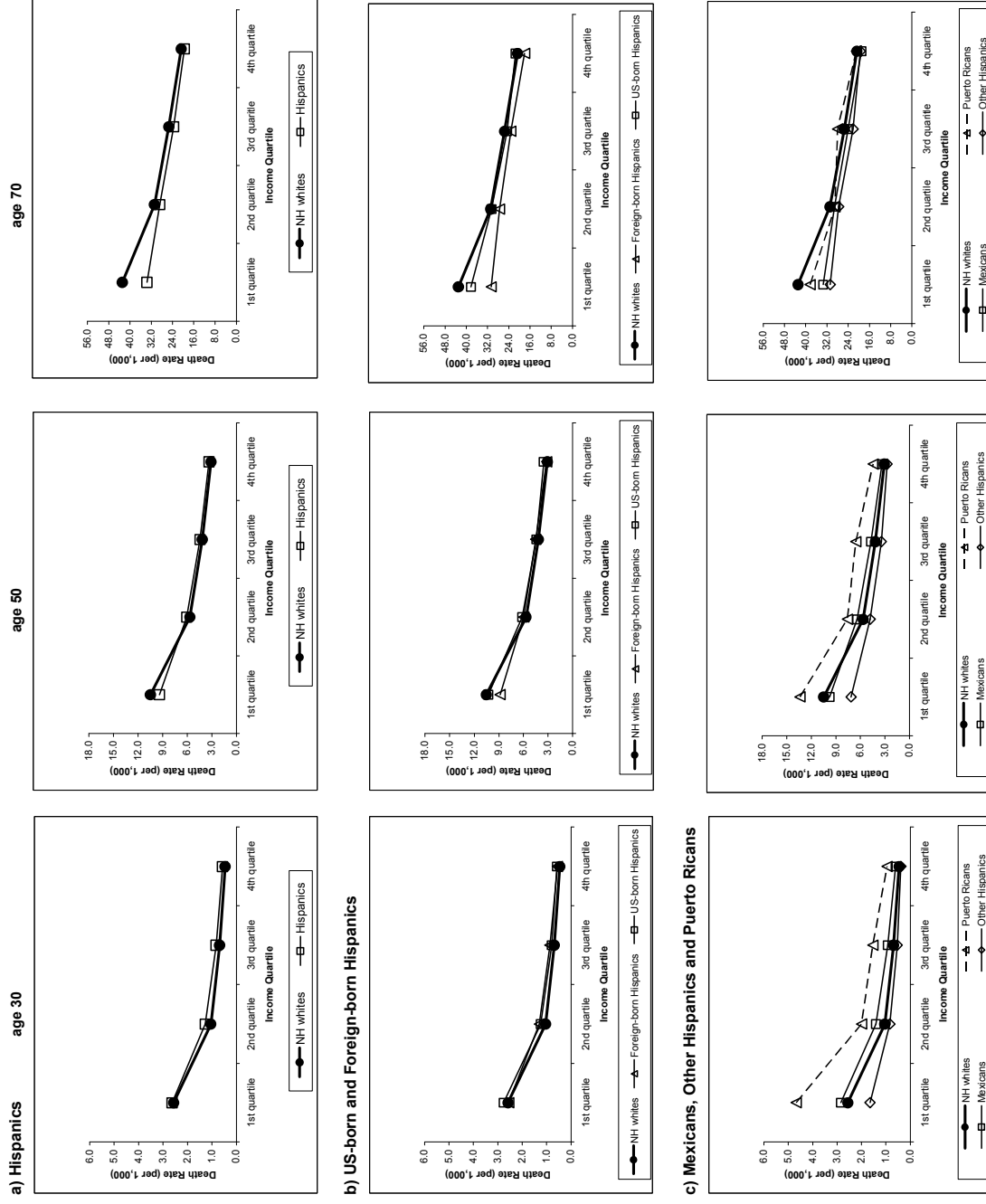
	Deaths	Person-Years of Exposure	Death Rate (per 1,000)
<b>Age</b>			
25-34	362	338,068	1.07
35-44	830	512,917	1.62
45-54	1,389	385,910	3.60
55-64	2,544	268,311	9.48
65-74	5,510	237,464	23.20
75+	11,505	181,150	63.51
<b>Sex</b>			
Male	11,685	896,746	13.03
Female	10,455	1,027,074	10.18
<b>Race/Nativity</b>			
US-born NH-whites	21,015	1,752,329	11.99
Hispanics	1,125	171,491	6.56
<b>Nativity</b>			
US-born	505	74,314	6.80
Foreign-born	620	97,177	6.38
<b>Ancestry</b>			
Mexican	577	92,829	6.22
Puerto-Rican	147	19,290	7.62
Other	401	59,372	6.75
<b>Education Level</b>			
0-8 years	5,681	170,738	33.27
9-11 years	3,696	201,003	18.39
High School Graduate	7,353	740,678	9.93
13-15 years	2,864	381,072	7.52
16+ years	2,546	430,329	5.92
<b>Income Level</b>			
1 <sup>st</sup> Quartile	11,175	473,485	23.60
2 <sup>nd</sup> Quartile	5,180	485,112	10.68
3 <sup>rd</sup> Quartile	3,649	490,308	7.44
4 <sup>th</sup> Quartile	2,136	474,915	4.50

Figure 1. Predicted Death Rates<sup>a</sup> by Level of Education for Men at Ages 30, 50 and 70, National Health Interview Survey (1989-1994) Linked to the National Death Index through 1997



<sup>a</sup> Predicted death rates are based on coefficients from Poisson models; see the text for method of calculation.

Figure 2. Predicted Death Rates<sup>a</sup> by Income Quintile for Men at Ages 30, 50 and 70, National Health Interview Survey (1989-1994) Linked to the National Death Index through 1997



<sup>a</sup> Predicted death rates are based on coefficients from Poisson models; see the text for method of calculation.