Temporal Trends in Diabetes Mortality among American Indians and Hispanics in New Mexico: Birth Cohort and Period Effects

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Rates of diabetes mortality are disproportionately high among ethnic minorities in the United States. To describe ethnic trends and cohort effects in diabetes mortality in New Mexico, the authors examined the trends in mortality rates for non-Hispanic whites, Hispanics, and American Indians in the state during the period 1958–1994. Age-specific rates were examined graphically to qualitatively describe the contribution of calendar period and birth cohort effects to changes in the rates. The authors also fit age-period-cohort models to these data. Age-adjusted diabetes mortality rates for American Indians and Hispanics surpassed rates for non-Hispanic whites for all but the earliest two time periods. In the 1993–1994 period, the age-adjusted mortality rate for American Indians was 3.8 times higher for men and 5.6 times higher for women than for their non-Hispanic white counterparts. Rates for American Indian men and women increased sharply over the 37-year period, by 565% and 1,105%, respectively. Mortality rates increased among Hispanics over the period of study but less rapidly than did rates among American Indians. Graphical analyses of age-specific rates were consistent with birth cohort effects among both American Indians and Hispanics and also with a period effect among American Indians. Results from age-period-cohort models indicate a birth cohort effect starting with the 1912 cohort in American Indians and the 1902 cohort in Hispanics. A period effect was present during the 1960s in American Indians. American Indians have experienced an epidemic rise in diabetes mortality in New Mexico; if current trends continue, diabetes may become the leading cause of mortality among American Indians in the state. Am J Epidemiol 1997;145:422-31.

MATERIALS AND METHODS

We acquired coded death certificate data for residents of New Mexico for the years 1958–1994 from the New Mexico Bureau of Vital Statistics. The underlying cause of death was coded according to the International Classification of Diseases (ICD), Seventh Revision, for 1958–1968 (10); the Eighth Revision, for 1969–1978 (11); and the Ninth Revision, for 1979–1994 (12). For this study, deaths attributed to diabetes included ICD code 260 in the Seventh Revision and ICD code 250 in the Eighth and Ninth revisions. Because the comparability ratios between the Seventh and Eighth and between the Eighth and Ninth ICD revisions were high, 0.9971 (13) and 0.9991 (14), respectively, we made no adjustments for the different ICD revisions. Ethnicity of individuals was assigned...
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By the New Mexico Bureau of Vital Statistics on the basis of information contained on the death certificate, as described previously (15).

Denominators for rate calculations were derived from the censuses of 1960, 1970, 1980, and 1990, as described previously (16). The US Bureau of the Census has used different questions during each census to identify Hispanic ethnicity (17). Estimates of the Hispanic population from 1960 through 1990 were adjusted to account for the different enumeration procedures (15). We used data collected in New Mexico to determine how self-identified Hispanics answered the census questions to make these adjustments (18).

American Indian population estimates for 1960 were modified to account for systematic errors that occurred in the collection, coding, and entry of data (19).


To determine the contribution of birth cohort and calendar period effects to trends in mortality rates, we examined changes in age-specific rates using graphical methods and by fitting age-period-cohort models. For the graphical analyses, we plotted age-specific rates in 5-year age groups for 5-year birth cohorts centered on birth years from 1892 to 1962.

Conventional age-period-cohort analyses were used to investigate the temporal variation in diabetes mortality rates over the 35-year period from 1958 to 1992 (20). We assumed that the number of observed deaths followed a Poisson distribution and that the log-transformed age-specific mortality rates were a linear function of age group, calendar period, and/or cohort effects. Maximum likelihood methods were used to estimate the corresponding parameters.

We estimated parameters for age-period models using the first calendar period (1958-1962) as baseline. In this case, the estimated age effects were interpreted as logarithms of age-specific rates for the reference period, and the estimated period effects were interpreted as logarithms of relative risks, with rates in the 1958-1962 period as the comparison period. Parameters for the age-cohort models were estimated using the cohort centered around 1917 as baseline. The parameter estimates in these models were interpreted in the same manner as the age-period models (21).

To interpret the full age-period-cohort models, we used the approach suggested by Tarone and Chu (20). In order to obtain unique maximum likelihood estimates, we placed linear constraints on the parameter estimates (22); however, the interpretation of these estimates is considerably more problematic than interpretation of the two-factor age-period and age-cohort models (20, 21, 23). As suggested by Tarone and Chu, we constructed identifiable contrasts that are invariant for all possible linear constraints and that have clear interpretations. We used the constraint that the first age effect and first and last cohort effects were zero, and we tested identifiable contrasts to detect changes in linear calendar period and birth cohort trends, while avoiding overinterpretation of the parameter estimates themselves (20). To determine whether the slopes before and after a calendar period were significantly different, we tested the contrast $(\pi_3 - \pi_1) - (\pi_3 - \pi_2)$, where $\pi_i$ denotes the $i$th period effect and where a negative value indicates an increase in slope. We tested changes in slope for birth cohorts using the same contrasts. It can be shown that this contrast and other similar contrasts are invariant under all possible linear constraints used in the model-fitting process (20).

We used nine age groups, each 5 years in length, ranging from 30-34 to 70-74 years. We did not include older age groups because population figures for American Indians and Hispanics in the 75-79, 80-84, and 85+ age groups were not available from the 1960 and 1970 censuses. The deviance was used as a measure of the goodness of fit, and the difference in deviances was used to compare nested models. Both statistics follow an approximate chi-square distribution (22).

Contrasts were chosen using plots of parameter estimates from the full age-period-cohort models. Although parameter estimates from age-period-cohort models are not identifiable and can vary substantially for the different choices of linear constraints used in fitting the model, changes in the slope of linear cohort and period trends are identifiable (20, 23). We tested the change in slope using interpretable linear contrasts, the values of which are invariant for all possible choices of linear constraints. Contrasts were tested using likelihood ratio statistics, which again follow an approximate chi-square distribution. All analyses were conducted using SAS software (24).

**RESULTS**

Age-adjusted diabetes mortality rates showed marked ethnic variations for men and women (tables 1 and 2). Rates for American Indians and Hispanics surpassed rates for non-Hispanic whites for all but the earliest two time periods. In the 1993-1994 period, the age-adjusted mortality rate for American Indian men was 125.2 per 100,000, 3.8 times higher than the rate for non-Hispanic whites.
of 33.0 for non-Hispanic white men. The rate for American Indian women in the same period was 154.7, 5.6 times higher than the rate of 27.7 for non-Hispanic white women. Rates for Hispanic men and women were 75.1 and 78.7 per 100,000, respectively, lower than American Indian rates but still markedly higher than rates for non-Hispanic whites.

Age-adjusted mortality rates for American Indians and Hispanics showed striking temporal changes over the 37-year period of study. The rates increased 526 percent for American Indian men \((p < 0.001)\) and 1,105 percent for American Indian women \((p < 0.001)\). The rate of the change for American Indians appeared to increase during the most recent periods. The rates increased 353 percent among Hispanic men \((p = 0.001)\) and 250 percent among Hispanic women \((p < 0.001)\) over the period of study. Rates for non-Hispanic white men showed a small, but significant, increase of 36 percent, while rates for non-Hispanic white women remained stable \((p > 0.2)\).

Graphical analysis of rates by birth cohort indicates birth cohort effects among American Indians and Hispanics (figures 1 and 2). Because patterns of age-specific mortality rates were similar for males and females, data are shown for both sexes combined. The graphs show sharp increases in age-specific rates for
successive birth cohorts in older age groups. In contrast, the age-specific mortality rates for non-Hispanic whites do not show similar increases for successive birth cohorts (figure 3).

Results from the age-period-cohort models are consistent with the graphical analyses (table 3). For non-Hispanic whites, we found little evidence of temporal variation in age-specific rates; however, for American Indians and Hispanics, we found highly significant temporal trends (table 4). Both the age-period and age-cohort models were superior to the age only model in the American Indian and Hispanic populations.
Relative risk plots based on parameter estimates obtained from fitting the two-factor models for American Indians indicate that a large increase in relative risk occurred between the 1912 and 1937 birth cohorts (figure 4), and relative risks increased through successive calendar periods (figure 5). The plots also show increasing trends for Hispanics, but they are less pronounced. Generally, estimates of the relative risks for the earliest and most recent cohorts are based on very few observations, and for this reason they are not reliable. For the later cohorts, this problem is exacerbated by the small number of deaths, and the apparently erratic behavior of the parameter estimates is probably artifactual.

We fit full age-period-cohort models for American Indian and Hispanic populations using the constraint that the first age effect and the first and last cohort effects were zero. Figures 6 and 7 show the maximum likelihood estimates for the calendar period and birth cohort effects for the American Indian and Hispanic populations. For American Indians, the calendar period slope increased, beginning around 1965. To determine whether the slopes before and after 1965 were significantly different, we tested the contrast $- \pi_1 + 2\pi_2 - \pi_3 = (\pi_2 - \pi_1) - (\pi_3 - \pi_2)$, where $\pi_i$ denotes the $i$th period effect and where a negative value indicates an increase in slope (table 5). The likelihood ratio statistic for this contrast is 5.83, indicating a significant increase in slope after 1965. Using the same approach, we also found a significant decrease in the calendar period slope, beginning around 1970, and an apparent increase in the cohort trend, beginning with the cohort centered around 1912 (table 5). For Hispanics, we found no discernible change in calendar period slope and a significant increase in the cohort effect slope around the 1902 cohort (table 5).

### DISCUSSION

Trends in mortality from diabetes show striking ethnic variation among American Indians, Hispanics, and non-Hispanic whites residing in New Mexico. From 1958 to 1994, diabetes mortality showed an epidemic increase among American Indian men (526 percent) and women (1,100 percent) that appeared to accelerate during the most recent 10-year period. By the 1993-1994 period, rates for American Indians were 3.8-fold higher for men and 5.6-fold higher for women than were rates for non-Hispanic white men and women, respectively. For Hispanics, the increase in rates was smaller but still substantial. Rates for non-Hispanic whites did not show large increases.

National data from the Indian Health Service indicate that diabetes mortality is higher for American Indians than for the US general population. From 1955 to 1988, the rate ratio comparing mortality rates for American Indians with rates for the general US population increased from 1.3 to 2.7 (25). When corrected for the national underreporting of American Indians on death certificates, the ratio increased to 4.3. Diabetes mortality for American Indians varies by tribe and geography (2). Some tribes, such as the Pimas, have particularly elevated mortality rates from diabetes. During the period 1975–1984, Pimas had 11.9 times the state mortality rate ratio for American Indians and the general population increased during the 1958–1994 period.
period, largely as a result of stable rates for non-Hispanic whites and greatly increased rates for American Indians.

The high and rising mortality rate among American Indians is associated with additional increases in the already high prevalence of diabetes (2). Pima Indians have the highest worldwide prevalence of non-insulin-dependent diabetes mellitus known, greater than 60 percent for people over 45 years of age, and the prevalence in this group is rising (9, 30). The prevalence of diabetes among American Indians in New Mexico is also high: 31 percent for individuals ≥35 years of age (31). Studies suggest that the increase in prevalence is probably a result of increased incidence,
not simply an increase in survival for people with diabetes (9).

The rapidly rising diabetes mortality for American Indians reflects both birth cohort and period effects. Age-specific mortality rates have increased for successive birth cohorts of American Indians, especially for those in the 1912–1937 birth cohorts. We are unaware of other studies examining cohort effects in diabetes mortality among American Indians; however, Hanson et al. (32) have reported increasing incidence rates of non-insulin-dependent diabetes mellitus in successive birth cohorts of Pima Indians. The increased risk in recent birth cohorts was associated with an increased body mass index; however, the risk remained significant after adjusting for body mass index. If the trends for Pimas are indicative of broader changes among American Indians in the Southwest, then mortality rates in New Mexico are probably a reflection of the increased incidence and prevalence of non-insulin-dependent diabetes mellitus associated with obesity and exposure to other diabetogenic lifestyle factors. The explanation for the abrupt increases for cohorts born early in the century is not readily apparent. We also observed increasing rates during the mid-1960s, a
period when the Indian Health Service expanded clinics into previously underserved rural reservation areas. We hypothesize that the period effect is related to improved access to Western medical care, increased diagnosis of prevalent cases of diabetes, and improved accuracy of death certification.

The higher mortality from diabetes for Hispanics than for non-Hispanic whites probably reflects the higher prevalence and poorer prognosis of non-insulin-dependent diabetes mellitus in Hispanics compared with non-Hispanic whites (3). In the United States, the San Luis Valley of Colorado, and New Mexico, the prevalence of diabetes in Hispanics is at least twice that in non-Hispanic whites (3). American Indian admixture has been suggested as one determinant of increased risk among Hispanics in the Southwest (3). Although we lack data to examine this hypothesis for residents of New Mexico, the birth cohort effect indicates that changes in other risk factors are likely to underlie the recent increases in rates.

Limitations

A number of potential limitations must be considered in the interpretation of the findings of this study. The interpretation of the trends requires additional information about migration, access to medical care, death certification, and competing causes of death; however, data sources for these factors are limited, especially for Hispanics and American Indians. The use of death certificates to study diabetes mortality using diabetes as the underlying cause of death has a number of recognized biases. While the mortality rate among American Indians is remarkable, it is probably an underestimate, as these data are limited by the use of the underlying cause of death listed on the death certificate. In an earlier study in New Mexico, only 55 percent of the death certificates that mentioned diabetes listed diabetes as the underlying cause of death (6). However, this did not vary substantially by ethnicity and could not explain the ethnic differences in rates. Physicians in New Mexico may be aware that diabetes is a major public health problem among American Indians and Hispanics and may list diabetes more frequently than in other regions of the country. The trends in rates may also reflect better classification of the cause of death during recent periods (29). We lack data to quantify the magnitude of this potential bias; however, the Office of the Medical Investigator has reviewed the majority of all deaths since 1974, suggesting that improved death certification may have occurred since 1974 (29). Because the Office of the Medical Investigator reviewed the majority of deaths during the most recent periods, it is unlikely that changes in death classification completely account for the substantial increase in rates. Increased access to care and the increased diagnosis of diabetes provided through the Indian Health Service are likely to explain some of the increase in diabetes mortality for American Indians during the period 1960–1970 when the Indian Health Service expanded services in rural areas (33). Changes in access to care for American Indians have not been large in the most recent periods. Approximately 30 percent of New Mexico’s Hispanic population lacks health insurance (34). The lack of insurance and geographic isolation indicate that Hispanics are less likely to have consistent medical care for chronic diseases, such as diabetes, that may contribute to a higher risk for death. The rate calculations based on ethnic identification are subject to bias (15). In contrast to national data, ethnic and racial misclas-
sification is not large in New Mexico Vital Statistics data (18).

Conclusions

Diabetes mortality for American Indians in New Mexico showed epidemic increases during the 37-year period from 1958 to 1994. Diabetes mortality also increased for Hispanics but to a lesser degree. Risk factors have been studied extensively in one tribe and in several Hispanic populations. As in the limited number of other populations studied, it is likely that the rising mortality in New Mexico is related to increased incidence and prevalence for diabetes from increased exposure to diabetogenic lifestyle factors in susceptible populations. If the rapid rise in diabetes mortality continues, diabetes may become the leading cause of mortality for American Indians in New Mexico during the next decades. Further studies are needed to establish the etiology of diabetes in additional populations of American Indians. However, the rapidly rising diabetes mortality rate among American Indians and Hispanics in New Mexico reemphasizes the urgent need for efficacious, culturally competent interventions based on our currently limited understanding of the pathogenesis of this disease.

REFERENCES

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