Population-Based Estimates of Mortality Associated With Diabetes: Use of a Death Certificate Check Box in North Dakota

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ABSTRACT

Objectives. Overall and cause-specific mortality among persons with diabetes in North Dakota was estimated and compared with estimates from previous population-based studies.

Methods. Data were derived from North Dakota death certificate data, which included unique information on decedents' diabetes status and Behavioral Risk Factor Surveillance System estimates of the diabetic and nondiabetic adult populations of North Dakota.

Results. The risk of death among adults with diabetes was 2.6 (2.2, 2.9) times that of adults without diabetes. Relative risks of death among adults with diabetes were at least twice as high for heart disease, cerebrovascular disease, accidents and adverse events, and kidney disease and 70% to 80% higher for pneumonia and influenza, malignant neoplasms, arterial disease, and other causes. Risks remained substantial in the oldest age group. These findings are comparable to results of other population-based studies.

Conclusions. Diabetes status information enhanced the usefulness of death certificate data in examining mortality associated with diabetes and confirms that the effect of diabetes on death is substantial. (*Am J Public Health.* 2001;91: 84–92)

In comparison with persons without diabetes, persons with diabetes are at increased risk of death, particularly from cardiovascular disease. After age differences have been taken into account, the death rate among persons with diabetes is about twice the rate among persons without diabetes,[1–10] and the risk of heart disease and ischemic heart disease mortality is about 2 to 4 times higher for persons with diabetes.[2,4–7,9–19]

In national and international cause-of-death statistics derived from death certificate data, underlying cause of death—the disease or injury initiating the sequence of events leading to death—is used to count and rank leading causes of death. In the United States, diabetes ranks as the seventh leading cause of death,[20] even though it is listed as the underlying cause of death for only about 10% of decedents known to have diabetes.[21,22] The physician, medical examiner, coroner, or nosologist who completes the death certificate has the responsibility of determining the causal sequence leading to death, using World Health Organization regulations as specified in the *International Statistical Classification of Diseases, 9th Revision* [*ICD-9*].[23] Problems related to the reliability and validity of cause-of-death information on death certificates include improper completion of death certificates,[24–26] inaccuracy of diagnoses,[27,28] variation in interpreting causal sequences and conditions contributing to death,[29–32] changing perceptions of the causal role of diseases,[29] variation in nosologic coding,[33] and lack of training in death certificate completion.[32]

Because diabetes status is not noted on the standard death certificate, death certificate data cannot be used as the sole source of information to identify deaths and their causes among persons with diabetes. One exception is North Dakota, where the death certificate includes a check box to identify decedents with diabetes. This check box, added to the cause-of-death section of the North Dakota death certificate in 1992, solicits a response to the question "Was deceased diabetic?" This information on diabetes status provides a unique opportunity to examine the impact of diabetes on mortality. The purpose of this study was to estimate the number of deaths and causes of death among diabetic decedents, estimate excess and relative mortality due to diabetes, and examine the veracity of our unique data by comparing our results with the findings of previous population-based and cohort studies on mortality associated with diabetes.

Methods

We analyzed death certificate data for the period 1992 through 1996 among North Dakota residents 18 years or older at death (n= 28 795). We used 5 years of data to maximize the number of causes of death that could be examined among diabetic decedents. Decedents with diabetes were defined as those with diabetes as a cause of death (*ICD-9* code 250) or those whose death certificate contained a "yes" response to the question of whether the deceased was diabetic (n=4287). All decedents whose death certificate contained a "no" response to the diabetes question were classified as nondiabetic (n=18 149).

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TABLE 1—Annual Death Rates (per 1000), Relative Risk (RR) of Death, and Age-Adjusted Death Rates for North Dakota Men, 1992–1996

	Age Group, y					Age-Adjusted	
	18–44	45–64	65–74	≥75	Crude Rate	Rate	95% CI
All deaths							
Death rate, diabetics	8.4	21.0	56.2	219.3	60.9	37.2	28.6, 45.8
Death rate, nondiabetics	1.3	7.1	24.2	104.7	11.3	15.2	13.9, 16.6
RR	6.5	3.0	2.3	2.1	5.4	2.4	
95% CI	3.8, 9.2	2.1, 3.8	1.6, 3.1	1.3, 2.9	4.5, 6.3	1.8, 3.0	
Attributable rate	7.1	13.9	32.1	114.7	49.5	21.9	
95% CI	3.6, 10.6	8.3, 19.5	14.9, 49.2	31.8, 197.5	39.3, 59.7	13.2, 30.6	
All heart disease							
Death rate, diabetics	2.6	8.3	23.5	83.4	23.8	14.1	10.8, 17.4
Death rate, nondiabetics	0.2	2.4	8.4	36.7	3.8	5.2	4.7, 5.6
RR	14.6	3.5	2.8	2.3	6.3	2.7	
95% CI	7.8, 21.5	2.5, 4.6	1.9, 3.7	1.4, 3.2	5.2, 7.4	2.0, 3.4	
Ischemic heart disease							
Death rate, diabetics	...[a]	6.0	17.9	59.6	17.2	9.9	7.6, 12.3
Death rate, nondiabetics	0.1	1.7	6.2	25.4	2.7	3.6	3.3, 3.9
RR	...[a]	3.4	2.9	2.3	6.5	2.7	
95% CI		2.4, 4.4	2.0, 3.8	1.4, 3.3	5.4, 7.6	2.0, 3.4	
Arterial disease							
Death rate, diabetics	...[a]	...[a]	1.7	6.7	1.6	0.9	0.6, 1.1
Death rate, nondiabetics	0	0.1	0.5	3.5	0.3	0.4	0.4, 0.5
RR	...[a]	...[a]	3.1	1.9	5.4	2.0	
95% CI			2.0, 4.3	1.1, 2.7	4.3, 6.4	1.3, 2.7	
Malignant neoplasms							
Death rate, diabetics	...[a]	4.3	12.8	33.2	10.7	5.9	4.6, 7.20
Death rate, nondiabetics	0.1	2.5	8.5	22.9	2.9	3.8	3.5, 4.1
RR	...[a]	1.7	1.5	1.4	3.6	1.5	
95% CI		1.3, 2.2	1.0, 2.0	0.9, 2.0	3.0, 4.3	1.2, 1.9	
Cerebrovascular disease							
Death rate, diabetics	...[a]	0.9	3.8	18.4	4.4	2.5	1.8, 3.2
Death rate, nondiabetics	0	0.2	1.3	9.4	0.8	1.1	1.0, 1.2
RR	...[a]	3.7	2.9	2.0	5.7	2.2	
95% CI		2.5, 4.9	1.9, 3.9	1.2, 2.8	4.7, 6.8	1.5, 2.9	
Accidents/adverse events							
Death rate, diabetics	...[a]	0.9	...[a]	3.3	1.3	1.3	0.9, 1.8
Death rate, nondiabetics	0.4	0.4	0.6	2.2	0.6	0.6	0.6, 0.7
RR	...[a]	2.2	...[a]	1.5	2.2	2.1	
95% CI		1.2, 3.2		0.8, 2.2	1.7, 2.7	1.4, 2.8	
Pneumonia and influenza							
Death rate, diabetics	...[a]	...[a]	...[a]	9.1	1.7	1.0	0.6, 1.4
Death rate, nondiabetics	...[a]	...[a]	...[a]	5.4	0.4	0.6	0.5, 0.7
RR	...[a]	...[a]	...[a]	1.7	4.3	1.7	
95% CI				1.0, 2.3	3.6, 5.1	1.0, 2.3	
Chronic obstructive pulmonary disease							
Death rate, diabetics	...[a]	...[a]	1.7	7.3	1.8	1.0	0.7, 1.3
Death rate, nondiabetics	...[a]	0.2	1.5	6.4	0.6	0.8	0.8, 0.9
RR	...[a]	...[a]	1.1	1.1	3.1	1.2	
95% CI			0.7, 1.5	0.7, 1.6	2.5, 3.6	0.8, 1.6	
Nephritis/nephrotic syndrome/nephrosis							
Death rate, diabetics	...[a]	...[a]	...[a]	3.2	0.6	0.4	0.3, 0.5
Death rate, nondiabetics	...[a]	...[a]	0.3	1.6	0.1	0.2	0.2, 0.2
RR	...[a]	...[a]	...[a]	2.0	5.0	2.1	
95% CI				1.2, 2.9	3.6, 6.3	1.3, 2.8	
All other causes							
Death rate, diabetics	1.8	2.4	4.6	21.8	6.0	4.2	3.2, 5.1
Death rate, nondiabetics	0.5	1.2	2.7	16.5	1.9	2.5	2.3, 2.7
RR	3.7	2.0	1.7	1.3	3.2	1.7	
95% CI	2.1, 5.3	1.4, 2.5	1.2, 2.3	0.8, 1.9	2.7, 3.8	1.3, 2.1	

Note. RRs were based on calculations of unrounded rates. CI = confidence interval.
[a]Number of deaths < 10.

For about 22% of decedents, diabetes was not listed as a cause of death and a response to the question on diabetes status was missing. To adjust for nonresponse to the question, we used multiple imputation, a common statistical technique.[34–36] In our application of this technique, we used age, sex, race, underlying and contributing cause of death, and year of death to impute 5 values for each missing response and then averaged these values to estimate deaths by diabetes status. With this method, 16.3% (1039) of individuals missing a response to the check box were estimated to have diabetes, and 83.7% (5320) were estimated not to have diabetes, resulting in 5326

TABLE 2—Annual Death Rates (per 1000), Relative Risk (RR) of Death, and Age-Adjusted Death Rates for North Dakota Women, 1992–1996

	Age Group, y					Age-Adjusted	
	18–44	45–64	65–74	≥75	Crude Rate	Rate	95% CI
All deaths							
Death rate, diabetics	5.1	21.8	39.9	151.1	57.8	27.2	22.9, 31.5
Death rate, nondiabetics	0.6	4.2	11.7	73.1	9.8	9.7	9.1, 10.3
RR	8.8	5.3	3.4	2.1	5.9	2.8	
95% CI	5.1, 12.5	3.6, 6.9	2.5, 4.4	1.5, 2.6	5.0, 6.8	2.3, 3.3	
Attributable rate	4.5	17.7	28.2	78	48	17.5	
95% CI	2.4, 6.6	10.9, 24.5	17.6, 38.9	41.1, 114.9	39.6, 56.3	13.1, 21.8	
All heart disease							
Death rate, diabetics	...[a]	6.9	13.9	58.3	21.3	9.4	7.8, 11.0
Death rate, nondiabetics	0	0.7	2.6	26.3	3.1	3.1	2.8, 3.3
RR	...[a]	9.4	5.4	2.2	6.9	3.1	
95% CI		6.3, 12.5	3.9, 6.9	1.6, 2.8	5.9, 8.0	2.5, 3.6	
Ischemic heart disease							
Death rate, diabetics	...[a]	4.9	9.6	38.0	14.1	6.4	5.3, 7.4
Death rate, nondiabetics	...[a]	0.5	1.7	16.7	1.9	1.9	1.8, 2.1
RR	...[a]	10.0	5.8	2.3	7.3	3.3	
95% CI		6.6, 13.4	4.1, 7.4	1.7, 2.9	6.2, 8.3	2.7, 3.9	
Arterial disease							
Death rate, diabetics	...[a]	...[a]	...[a]	2.8	1.0	0.4	0.3, 0.5
Death rate, nondiabetics	0	0	0.2	2.4	0.3	0.3	0.3, 0.3
RR	...[a]	...[a]	...[a]	1.1	3.7	1.6	
95% CI				0.8, 1.4	3.0, 4.4	1.2, 1.9	
Malignant neoplasms							
Death rate, diabetics	...[a]	5.4	10.0	16.4	8.6	4.3	3.7, 5.0
Death rate, nondiabetics	0.2	2.2	5.0	12.2	2.4	2.4	2.3, 2.5
RR	...[a]	2.4	2.0	1.3	3.6	1.8	
95% CI		1.6, 3.2	1.4, 2.5	1.0, 1.7	3.0, 4.1	1.5, 2.1	
Cerebrovascular disease							
Death rate, diabetics	...[a]	0.9	2.5	17.9	5.8	2.5	2.0, 3.0
Death rate, nondiabetics	0	0.2	0.7	8.8	1.0	1.0	0.9, 1.1
RR	...[a]	4.4	3.3	2.0	5.8	2.5	
95% CI		3.0, 5.8	2.1, 4.4	1.5, 2.6	4.9, 6.6	2.0, 3.0	
Accidents/adverse events							
Death rate, diabetics	...[a]	...[a]	...[a]	1.3	0.7	0.6	0.2, 1.0
Death rate, nondiabetics	0.1	0.1	0.2	1.4	0.3	0.3	0.3, 0.3
RR	...[a]	...[a]	...[a]	1.0	2.8	2.4	
95% CI				0.5, 1.4	1.8, 3.7	1.0, 3.8	
Pneumonia and influenza							
Death rate, diabetics	...[a]	...[a]	0.8	5.3	1.7	0.8	0.6, 0.9
Death rate, nondiabetics	0.1	...[a]	0.3	3.9	0.4	0.4	0.4, 0.5
RR	...[a]	...[a]	2.7	1.4	4.0	1.7	
95% CI			1.6, 3.7	1.0, 1.7	3.3, 4.7	1.4, 2.1	
Chronic obstructive pulmonary disease							
Death rate, diabetics	...[a]	0.8	...[a]	2.8	1.1	0.5	0.4, 0.6
Death rate, nondiabetics	...[a]	0.2	0.7	2.2	0.3	0.3	0.3, 0.4
RR	...[a]	4.2	...[a]	1.2	3.2	1.5	
95% CI		2.7, 5.7		0.9, 1.6	2.7, 3.8	1.2, 1.8	
Nephritis/nephrotic syndrome/nephrosis							
Death rate, diabetics	...[a]	...[a]	...[a]	2.0	0.7	0.3	0.2, 0.3
Death rate, nondiabetics	...[a]	...[a]	0.1	1.1	0.1	0.1	0.1, 0.1
RR	...[a]	...[a]	...[a]	1.9	5.9	2.2	
95% CI				1.3, 2.5	4.7, 7.1	1.6, 2.7	
All other causes							
Death rate, diabetics	...[a]	3.5	4.5	19.2	7.5	3.8	3.2, 4.5
Death rate, nondiabetics	0.2	0.5	1.7	14.8	1.9	1.9	1.7, 2.0
RR	...[a]	6.4	2.6	1.3	4.0	2.1	
95% CI		4.2, 8.6	1.7, 3.4	1.0, 1.6	3.4, 4.6	1.7, 2.4	

Note. RRs were based on calculations of unrounded rates. CI = confidence interval.
[a]Number of deaths < 10.

decedents with diabetes and 23 469 decedents without diabetes.

We used underlying cause-of-death data to examine causes of death among persons with diabetes. Causes of death were classified into 11 categories according to *ICD-9*: malignant neoplasms (codes 140–208), diabetes (code 250), all heart disease (codes 390–398, 402, 404–429), ischemic heart disease (codes 410–414), arterial disease (codes 440–448), cerebrovascular disease (codes 430–438), pneumonia and influenza (codes 480–487), chronic obstructive pulmonary disease (codes 490–496), nephritis/nephrotic syndrome/nephrosis (codes 403, 581–583, 585–588), accidents and

TABLE 3—Annual Death Rates (per 1000), Relative Risk (RR) of Death, and Age-Adjusted Death Rates for North Dakota Men and Women Combined, 1992–1996

	Age Group, y					Age-Adjusted	
	18–44	45–64	65–74	≥75	Crude Rate	Rate	95% CI
All deaths							
Death rate, diabetics	6.6	21.3	48.1	176.9	59.3	31.3	27.3, 35.2
Death rate, nondiabetics	0.9	5.6	17.4	85.0	10.6	12.1	11.5, 12.7
RR	6.9	3.8	2.8	2.1	5.6	2.6	
95% CI	5.0, 8.8	3.0, 4.6	2.2, 3.3	1.6, 2.5	5.0, 6.2	2.2, 2.9	
Attributable rate	5.6	15.7	30.7	91.8	48.8	19.2	
95% CI	3.8, 7.4	11.4, 20.1	21.0, 40.4	55.3, 128.4	42.3, 55.2	15.2, 23.2	
All heart disease							
Death rate, diabetics	1.7	7.7	18.7	67.8	22.5	11.5	10.0, 13.0
Death rate, nondiabetics	0.1	1.5	5.2	30.3	3.4	4.0	3.7, 4.2
RR	16.2	5.0	3.6	2.2	6.6	2.9	
95% CI	10.6, 21.7	3.9, 6.2	2.8, 4.3	1.8, 2.7	5.9, 7.3	2.5, 3.3	
Ischemic heart disease							
Death rate, diabetics	1.0	5.5	13.8	46.2	15.7	7.9	6.8, 8.9
Death rate, nondiabetics	0.1	1.1	3.7	20.0	2.3	2.7	2.5, 2.8
RR	16.7	5.0	3.7	2.3	6.8	3.0	
95% CI	9.9, 23.4	3.9, 6.1	2.9, 4.5	1.8, 2.8	6.1, 7.6	2.5, 3.4	
Arterial disease							
Death rate, diabetics	...[a]	...[a]	1.2	4.3	1.3	0.6	0.5, 0.7
Death rate, nondiabetics	0	0.1	0.4	2.9	0.3	0.3	0.3, 0.4
RR	...[a]	...[a]	3.3	1.5	4.6	1.8	
95% CI			2.3, 4.2	1.1, 1.9	4.0, 5.2	1.4, 2.1	
Malignant neoplasms							
Death rate, diabetics	...[a]	4.8	11.4	22.8	9.7	4.9	4.3, 5.5
Death rate, nondiabetics	0.2	2.4	6.6	16.3	2.7	3	2.8, 3.1
RR	...[a]	2.0	1.7	1.4	3.6	1.7	
95% CI		1.6, 2.4	1.4, 2.1	1.1, 1.7	3.2, 4.0	1.4, 1.9	
Cerebrovascular disease							
Death rate, diabetics	...[a]	0.9	3.1	18.1	5.1	2.5	2.1, 2.9
Death rate, nondiabetics	0	0.2	1.0	9.0	0.9	1.1	1.0, 1.1
RR	...[a]	4.2	3.1	2.0	5.7	2.4	
95% CI		3.2, 5.2	2.5, 3.8	1.6, 2.5	5.0, 6.4	2.0, 2.8	
Accidents/adverse events							
Death rate, diabetics	0.9	0.7	0.5	2.1	1.0	1.0	0.7, 1.2
Death rate, nondiabetics	0.3	0.3	0.4	1.7	0.4	0.4	0.4, 0.5
RR	3.2	2.7	1.1	1.2	2.4	2.2	
95% CI	1.5, 4.9	1.7, 3.7	0.7, 1.5	0.8, 1.6	1.9, 2.9	1.5, 2.8	
Pneumonia and influenza							
Death rate, diabetics	...[a]	...[a]	0.7	6.7	1.7	0.8	0.7, 1.0
Death rate, nondiabetics	0	0.1	0.3	4.5	0.4	0.5	0.5, 0.5
RR	...[a]	...[a]	2.3	1.5	4.2	1.7	
95% CI			1.6, 2.9	1.1, 1.8	3.7, 4.7	1.3, 2.0	
Chronic obstructive pulmonary disease							
Death rate, diabetics	...[a]	0.6	1.1	4.5	1.5	0.7	0.6, 0.8
Death rate, nondiabetics	...[a]	0.2	1.1	3.8	0.5	0.5	0.5, 0.6
RR	...[a]	3.1	1.0	1.2	3.1	1.3	
95% CI		2.3, 3.9	0.8, 1.3	0.9, 1.5	2.7, 3.5	1.1, 1.6	
Nephritis/nephrotic syndrome/nephrosis							
Death rate, diabetics	...[a]	...[a]	0.4	2.4	0.7	0.3	0.3, 0.4
Death rate, nondiabetics	...[a]	...[a]	0.2	1.3	0.1	0.1	0.1, 0.2
RR	...[a]	...[a]	2.5	2.0	5.4	2.1	
95% CI			1.6, 3.4	1.5, 2.4	4.6, 6.2	1.7, 2.5	
All other causes							
Death rate, diabetics	1.4	2.8	4.5	20.2	6.7	3.9	3.4, 4.4
Death rate, nondiabetics	0.3	0.9	2.2	15.4	1.9	2.1	2.0, 2.3
RR	4.2	3.3	2.1	1.3	3.6	1.8	
95% CI	2.9, 5.5	2.6, 4.0	1.6, 2.6	1.0, 1.6	3.2, 4.0	1.6, 2.1	

Note. RRs were based on calculations of unrounded rates. CI = confidence interval.
[a]Number of deaths < 10.

adverse events (codes E800–E948), and all other causes (all other *ICD-9* codes).

We calculated death rates by using 1992 to 1996 estimates of the adult diabetic and nondiabetic populations of North Dakota from the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is an ongoing, state-based, random-digit-dialing telephone survey of noninstitutionalized adults (i.e., 18 years or older) in all 50 states, the District of Columbia, and Puerto Rico.[37] Respondents with diabetes were defined as individuals who responded "yes" to the question "Have you ever been told by a doctor that you have diabetes?" (n = 392). Those with any other response to the question were coded as not hav-

ing diabetes (n=8682). The BRFSS data were weighted to reflect the age and sex distribution of the adult noninstitutionalized population of North Dakota. Between 1992 and 1996, 3.9% of the adult population of North Dakota reported having diabetes. Because of the complex sample design of the BRFSS, we used SUDAAN[38] to calculate diabetic and nondiabetic population estimates and the standard errors of our estimates.

The relative risk of death among persons with diabetes in comparison with persons without diabetes was calculated by dividing diabetic population death rates by nondiabetic population death rates. We estimated the excess mortality attributable to diabetes as the difference between age- and sex-specific death rates in the populations with and without diabetes. We calculated the total number of deaths and the total rate attributable to diabetes by multiplying these age- and sex-specific rate differences by diabetic population estimates and summing across strata. Age-adjusted rates were calculated with the direct method, with the 1992 to 1996 adult population of North Dakota used as the standard. We do not present death rates, relative risks, or attributable rates for populations in which there were fewer than 10 deaths. Confidence intervals (CIs) were calculated to reflect the uncertainty due to missing data and to population sampling.

Because responses to the diabetes check box on the North Dakota death certificate have not been validated, we examined whether our findings were consistent with the findings of other population-based and cohort studies. In general, this examination was restricted to studies of US populations.

Results

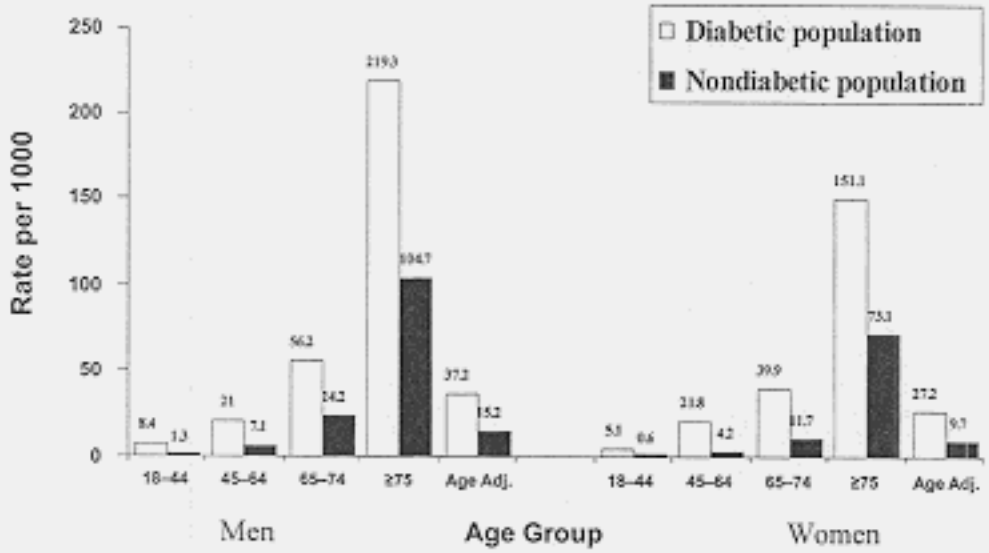
All-Cause Mortality

Between 1992 and 1996, 5326 North Dakota adults with diabetes died. These decedents represented 18.5% (5326/28 795) of all adult deaths in the state. Diabetes prevalence rates at death were 7.5% (97/1296) among decedents aged 18 to 44 years, 18.4% (679/3691) among decedents aged 45 to 64 years, 21.6% (1146/5317) among decedents aged 65 to 74 years, and 18.4% (3404/18 491) among decedents 75 years and older. Diabetes was recorded as the underlying cause of death for about 15% of diabetic decedents and as any mentioned cause (either underlying or nonunderlying) for 43% of diabetic decedents (data not shown).

These data are consistent with data from the 1986 and 1993 versions of the National Mortality Follow-Back Survey.[21,22] Both of these retrospective surveys obtained death certificate data and information about decedents from personal informants in nationally representative samples of US decedents 25 years or older. The prevalence rates of diabetes at death were 17.2% in the 1986 version[21] and 18.5% in the 1993 version.[22] Also, in both of these surveys, diabetes was the underlying cause of death on about 10% of the death certificates of diabetic decedents and was listed anywhere on about 40% of death certificates.[22]

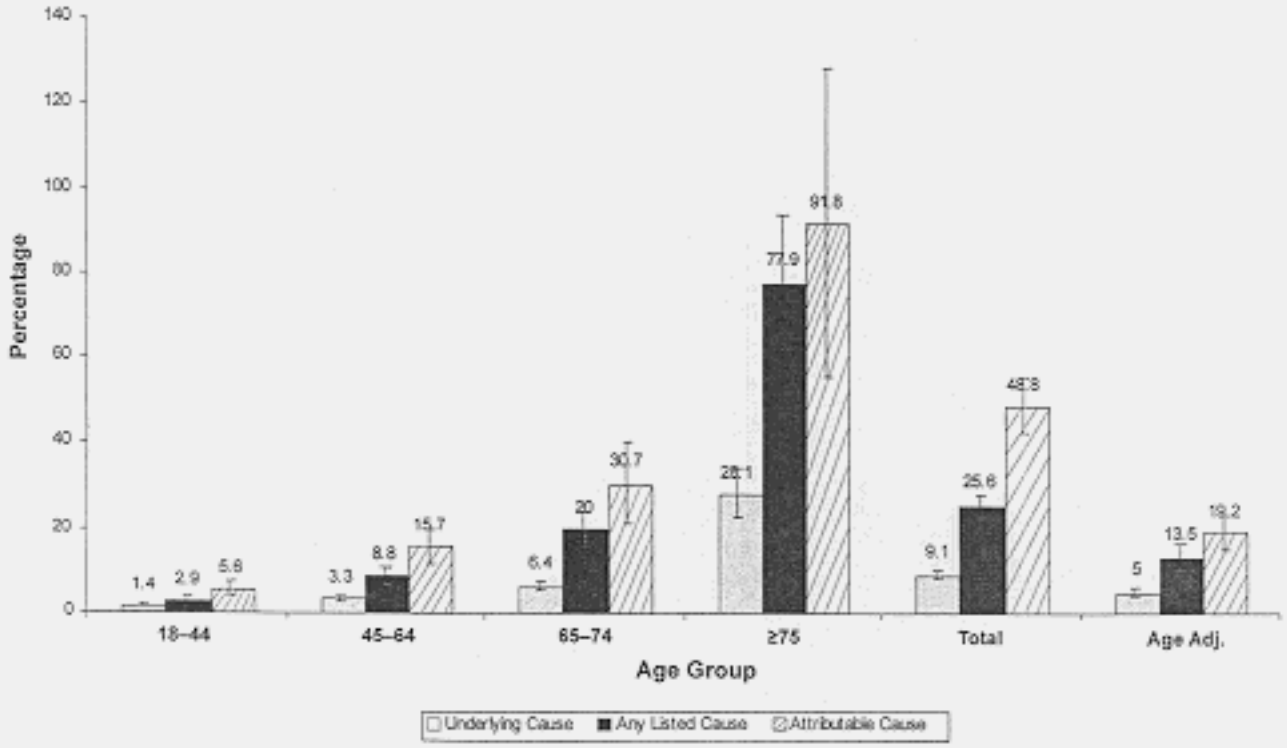
Death rates from all causes increased with age in both the diabetic and nondiabetic populations (see Tables 1–3 and Figure 1). Within each sex and age group, death rates among persons with diabetes exceeded rates among persons without diabetes. Between 1992 and 1996, annual crude death rates were 59.3/1000 among the diabetic population and 10.6/1000 among the nondiabetic population. Although adjustment for age reduced the risk of death among persons with diabetes relative to persons without diabetes, the death rate in the diabetic population remained 2.6 times that of the nondiabetic population. The risk of death among persons with diabetes relative to persons of the same sex without diabetes was highest for the group aged 18 to 44 years (6.5 for men and 8.8 for women) and declined as age increased (2.1 for both men and women 75 years or older) (Tables 1 and 2). In contrast to relative risk, death rates attributable to diabetes increased with age, ranging from 5.6/1000 for the diabetic population aged 18 to 44 years to 91.8/1000 for the diabetic population 75 years or older (Table 3). The same trend was seen for both men and women with diabetes. Overall, the crude and age-adjusted death rates attributable to diabetes did not differ significantly by sex.

The age-adjusted relative risk was somewhat higher among women (2.8) than among men (2.4) with diabetes, but the confidence intervals overlapped. In terms of absolute risk, death rates tended to be higher among men with diabetes than among women with diabetes, but, again, the confidence intervals overlapped. However, death rates among women with diabetes were higher than death rates among men without diabetes. The age-adjusted rate among women with diabetes (27.2/1000) was about 80% higher than the rate among men without diabetes (15.2/1000).



Note. Age adj. = age adjusted.

FIGURE 1—Death rates among persons with and without diabetes, by age and sex: North Dakota, 1992–1996.



Note. Age adj. = age adjusted.

FIGURE 2—Death rates per 1000 with diabetes as an underlying cause, any listed cause, or an attributable cause: North Dakota, 1992–1996.

The North Dakota data are consistent with a recent analysis of a national sample of adults aged 25 to 74 years that indicated that the relative risk of mortality among persons with diabetes declined with increasing age but remained substantial in the oldest age group.[3] This study and others[3,6,8,39] also showed that the risk of death was higher among women than among men with diabetes (relative to their nondiabetic counterparts), although confidence intervals often overlapped. Despite the infrequent reporting of such data, a few studies have revealed death rates among women with diabetes to be greater than rates among men without diabetes.[3,4,10]

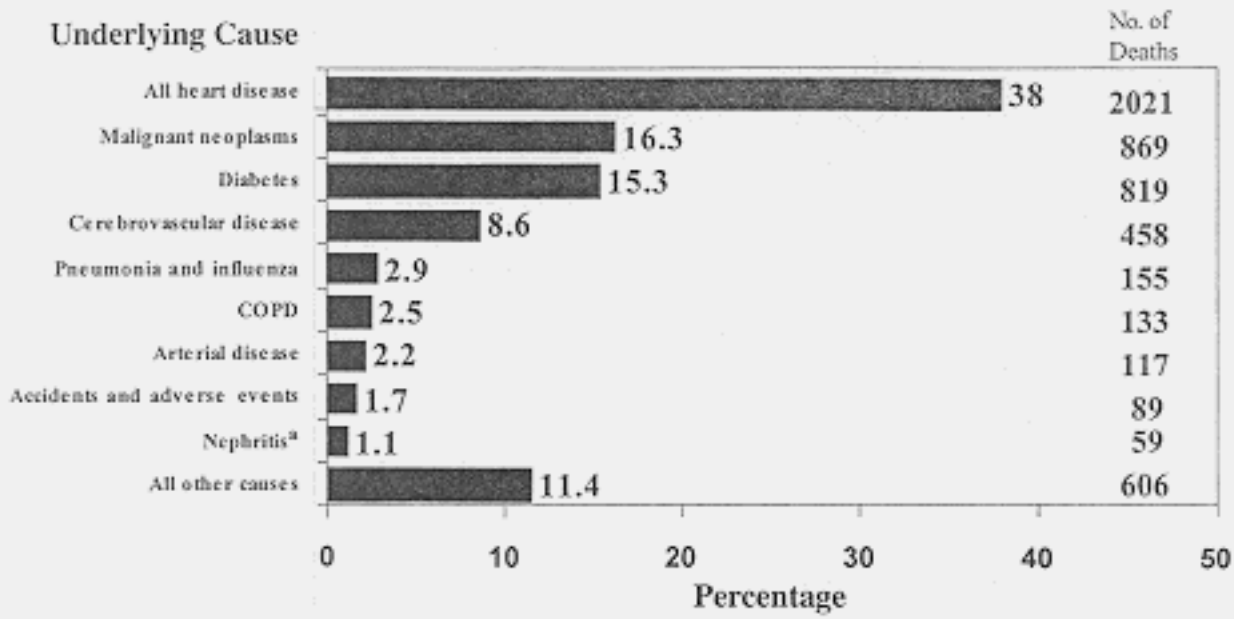
Overall, age-adjusted death rates were 31.3/1000 in the diabetic population and 12.1/1000 in the nondiabetic population. (Table 3). The difference between these rates is 19.2/1000, indicating that about 61% (19.2/31.3) of the mortality among persons with diabetes can be attributed to diabetes. Within each age group, the excess death rate attributable to diabetes was higher than both the death rate for diabetes as the underlying cause of death and the death rate for diabetes as any listed cause of death (Figure 2). Overall, between 1992 and 1996, the age-adjusted death rate per 1000 attributable to diabetes (19.2; 95% CI = 15.2, 23.2) was 3.8 times the age-adjusted death rate with diabetes listed as the underlying cause (5.0; 95% CI = 3.9, 6.1) and 1.4 times the age-adjusted death rate with diabetes as any listed cause (13.5; 95% CI = 10.7, 16.3).

Cause-Specific Mortality

Heart disease, the leading cause of death among adults with diabetes, accounted for about 38% of deaths (Figure 3). Malignant neoplasms and diabetes were the second and third leading causes of death. Cerebrovascular disease was the fourth leading cause and was followed by pneumonia and influenza, chronic obstructive pulmonary disease, arterial disease, accidents and adverse events, and nephritis, nephrotic syndrome, and nephrosis. These data are in accord with data from previous US population-based studies of diabetes mortality showing heart or cardiovascular disease, diabetes, malignant neoplasms, and cerebrovascular disease to be the 4 leading causes of death among persons with diabetes.[2,6,15,40,41]

Death rates were higher among adults with diabetes than among those without diabetes for each cause of death (Table 3). The overall age-adjusted death rates among adults with diabetes were at least twice as high as rates among adults without diabetes for heart disease (including ischemic heart disease), cerebrovascular disease, accidents and adverse events, and nephritis, nephrotic syndrome, and nephrosis, and they were 70% to 80% higher for pneumonia and influenza, malignant neoplasms, arterial disease, and other causes. The highest overall age-adjusted relative risk, 3.0, was found for ischemic heart disease, and the lowest, 1.3, was found for chronic obstructive pulmonary disease. In general, these data are consistent with those from previous population-based studies showing that persons with diabetes are at excess risk of death from cardiovascular disease,[2,4–7,9–19,42] stroke,[3,6,15,42,43] renal disease,[3,6] and pneumonia and influenza.[3,6,44] In contrast to our study using North Dakota data, a few US studies have not found greater excess risks of cancer mortality among persons with diabetes.[3,15,45] However, cancer has consistently been one of the leading causes of death among persons with diabetes.[2,3,6,15,40,41,45]

The relative risk of death for each cause decreased with age. The highest age-specific relative risk (16.7) was that for ischemic heart disease in the group aged 18 to 44 years. Although the confidence intervals of age- and sex-specific rates generally overlapped in the diabetic population, death rates for most causes of death were higher among men than among women. One exception was cerebrovascular disease, which did not vary by sex for either diabetic or nondiabetic adults. As with all-cause



Note. COPD = chronic obstructive pulmonary disease.
[a]Includes nephritis, nephrotic syndrome, and nephrosis.

FIGURE 3—Percentage distribution of underlying causes of death among decedents with diabetes: North Dakota, 1992–1996.

mortality, cause-specific age-adjusted death rates for diabetic women were similar to or exceeded the rates for nondiabetic men. Chronic obstructive pulmonary disease was the only cause for which the age-adjusted rate was higher for nondiabetic men than for diabetic women.

Discussion

North Dakota death certificate data that include information on the diabetes status of decedents and estimates of the diabetic and nondiabetic populations yield findings similar to those of previous population-based cohort studies of mortality associated with diabetes in regard to prevalence of diabetes at death, distribution of causes of death among diabetic decedents, risk of death for persons with diabetes relative to persons without diabetes, and age- and sex-specific trends in risk of death. These types of estimates would not have been possible without information on the diabetes status of decedents provided by the addition of the diabetes check box to the death certificate.

The check box information on decedents' diabetes status allowed us to further document that the effect of diabetes on mortality is substantial. Age-adjusted death rates among North Dakota adults with diabetes are 2.6 times those of adults without diabetes. Overall, and for most causes of death, the relative risk of death among persons with diabetes in comparison with persons without diabetes declined with age. However, relative risks remained substantial even in the oldest age group for overall mortality and many causes of death. Our data show that although the relative risk of all-cause mortality decreases with age, the effect of diabetes on mortality, as measured by the rate of excess deaths attributable to diabetes, increases with age and is strongest among elderly persons (Tables 1–3). These findings suggest that diabetes will continue to be an important public health problem as the population of North Dakota ages.

Data on underlying cause of death and information about decedents' diabetes status permitted epidemiologic characterization of causes of death among persons with diabetes. Most previous studies of mortality associated with diabetes were limited in their ability to examine causes of death in diabetic populations because of the small numbers of deaths. Information on decedents' diabetes status and the large number of deaths in our unique population-based data allowed us to examine causes of death among the diabetic population in greater detail.

We found only 1 study that included more diabetic decedents than our study.[46] That Finnish study and our data suggest that persons with diabetes are at greater relative risk for most causes of death than are persons without diabetes. In addition to the well-known excess risk of death from cardiovascular, ischemic heart, and cerebrovascular disease, we found excess relative mortality from arterial disease, malignant neoplasms, accidents and adverse events, pneumonia and influenza, kidney disease, and chronic obstructive pulmonary disease. Why diabetes poses an excess risk of death from so many conditions and why this excess risk may be greater among women than among men are unknown and merit further study.

Heart disease and cerebrovascular disease accounted for nearly half of all deaths of persons with diabetes in North Dakota. In light of recent clinical trials showing that blood pressure control,[47,48] lipid-lowering therapy,[49] and glycemic control[50] reduce diabetic complications and mortality among persons with diabetes, our data reinforce the need for increased cardiovascular risk factor reduction among persons with diabetes in North Dakota. A substantial proportion of deaths among persons with diabetes could probably be prevented by reducing or preventing cardiovascular risk factors through the adoption of healthful lifestyles, including weight reduction and obesity prevention, increased physical activity, smoking cessation and prevention, glycemic control, blood pressure control, and lipid-lowering therapy.

The statistical method used here to calculate mortality attributable to diabetes estimates the excess mortality due to a disease. This method assumes that mortality among persons with diabetes in excess of what they would have experienced in the absence of diabetes is due solely to diabetes. However, because the validity of this method depends on

several factors, including control of relevant confounders and accurate measurement of the prevalence of disease or exposure,[40,41] our estimates may be biased by these factors. Although we controlled for age in our calculation of the excess death rate attributable to diabetes, we lacked appropriate data to control for other possible confounding factors such as cardiovascular disease risk factors, other comorbid conditions, education, and income. However, previous studies showed little reduction in the age-adjusted risk of all-cause mortality or cardiovascular disease mortality among persons with diabetes relative to persons without diabetes when controlling for additional sociodemographic (e.g., race, income, and education) and cardiovascular (e.g., smoking, blood pressure, cholesterol levels, and obesity) risk factors.[1,3,5,7,10,13,14,19,42,51–57]

No ideal method exists for estimating mortality due to diabetes. Although federal and state efforts to improve the accuracy of cause-of-death data from death certificates are ongoing,[58] selection of a single underlying cause of death, as specified by international coding rules, may be problematic in the case of decedents with multiple chronic diseases. Diabetes is a complex disease capable of affecting nearly every organ system of the body. The effects on these organs are usually insidious and, over several years, result in organ failure and death. Because persons with diabetes often experience multiple chronic conditions during their lifetime, the presence of these competing causes of death and the distance between the onset of diabetes and its complications and death often make it impossible to determine the role diabetes played in the death. Although cause-of-death data from death certificates are used widely to estimate causes of death, the complexity of the natural history of diabetes limits the usefulness of these data in estimating deaths caused by diabetes. Our findings suggest that vital statistics data based on underlying cause-of-death data understate the public health importance of diabetes in North Dakota almost 3-fold.

The data presented are representative of the population of North Dakota, not the total US population. However, the age-adjusted risk of death among adults with diabetes relative to adults without diabetes in North Dakota (i.e., 2.6) is identical to previously reported national data on adults 25 years and older.[2] Similarly, diabetes is recorded as the underlying cause of death on only about 10%[21,22] of the death certificates of diabetic decedents in the United States and 15% in North Dakota. These similarities in mortality data suggest that the amount of underreporting of diabetes as a cause of death in the total US population may be comparable to that found in North Dakota.

Our study has a number of limitations. First, there were cases of missing data for the diabetes check box. Both ignoring missing data and adjusting for missing data can bias estimates.[34] However, we chose to adjust for nonresponse by using multiple imputation because of its advantages: less chance of bias, confidence intervals that properly reflect missing data, and all available information being used. Furthermore, if we had ignored missing data on the question of diabetes status, we would have underestimated substantially the number of diabetic and nondiabetic deaths and their corresponding population death rates. However, both ignoring and adjusting for missing data yielded identical estimates of the overall age-adjusted relative risk.

Second, because of the small numbers of racial and ethnic minority decedents and BRFSS respondents in North Dakota, we were unable to present separate estimates by race. Third, the large sampling variability of our estimates of the diabetic population resulted in the confidence intervals around many of our estimates being large and may have affected our ability to detect truly significant differences in mortality risk among subgroups. Finally, because our estimates of the diabetic population were based on self-report, we were unable to account for persons with undiagnosed diabetes. If persons with undiagnosed diabetes die at rates similar to those who are diagnosed and die of similar causes, and if one third of all persons with diabetes in North Dakota have their diabetes undiagnosed, our relative risks are underestimated by 10%.

North Dakota is the only state in the nation to have a diabetes check box on its death certificate to identify decedents with diabetes. Through the use of these unique data and estimates of the diabetic and nondiabetic populations in North Dakota, our assessment of mortality associated with diabetes produced findings consistent with the findings of previous population-based studies and highlighted the excess risk of death posed by diabetes. The addition of a diabetes check box enhances the surveillance potential of death certificate data by enabling public health authorities in North Dakota to monitor the effect of diabetes on mortality in their state and trends in overall and cause-specific mortality within their diabetic population. This latter capability may be particularly important in examining whether persons with diabetes experience the same decline as do persons without diabetes in total mortality and mortality from certain causes (e.g., heart disease) and in evaluating the ultimate impact of current public health efforts to reduce specific causes of death in the diabetic population (e.g., deaths due to pneumonia and influenza). □

Contributors

E. F. Tierney contributed to the design of the study, management and analysis of the data, interpretation of the results, and writing of the paper. L. S. Geiss contributed to the conception and design of the study, management and analysis of the data and interpretation of the results, and writing of the paper. M. M. Engelgau contributed to the design of the study, analysis and interpretation of the results, and writing of the paper. T. J. Thompson contributed to the imputation and analytic methods, interpretation of the results, and editing of the paper. D. Schaubert contributed to the conception and design of the study, interpretation of the results, editing of the paper, and discussion of the results. L. A. Shireley, P. J. Vuketic, and S. L. McDonough contributed to the interpretation of the results, editing of the paper, and discussion of the results.

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