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SHORT REPORT

Prevalence of Diabetes and Impaired Glucose Tolerance Among Navajo Indians

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OBJECTIVE— To estimate the prevalence of diabetes mellitus and impaired glucose tolerance and the incidence of clinically diagnosed diabetes in a community of Navajo Indians.

RESEARCH DESIGN AND METHODS— We conducted a survey of a representative Navajo community screened for diabetes 3 yr previously. We used 75-g oral glucose tolerance tests to determine the prevalence of diabetes mellitus and impaired glucose tolerance and conducted medical record reviews to identify cases of diabetes that were diagnosed during routine medical care after the earlier study.

RESULTS— By World Health Organization diagnostic criteria, the age-adjusted diabetes prevalence among 419 Navajo Indians 20–74 yr of age was 13.9% (95% confidence interval [CI] 9.2–18.5) for men and 18.4% (95% CI 14–22.8) for women. The ratio of the prevalence of diabetes among the Navajo population studied to that in the general United States population was 2.5. The prevalence of impaired glucose tolerance was 8% (95% CI 3.3–12.7) among men and 12.9% (95% CI 7.9–17.9) among women. Based on clinical diagnoses of diabetes made during routine medical care, mean ± SE age-adjusted incidence of diagnosed diabetes among men was 8.6 ± 4.3/1000 person-yr and 11.1 ± 4.4/1000 person-yr among women.

CONCLUSIONS— Although lower than that of some other tribes, the prevalence of diabetes among Navajo Indians is substantially higher than that in the general U.S. population. The high rate of clinical diagnoses suggests that the prevalence of the disease may continue to rise.

A 20-yr prospective study of the Pima Indians of southern Arizona, who have the world's highest reported prevalence of non-insulin-dependent diabetes mellitus (NIDDM; up to 50% among those >40 yr of age), has focused attention on the rising prevalence of non-insulin-dependent diabetes mellitus (NIDDM) among American Indians (1). There are wide variations in the prevalence of diabetes among various North-American Indian communities, just as there is substantial cultural and ethnic diversity among these tribes. Over the last several decades, references to the diversity of diabetes prevalence among American Indians have frequently contrasted the high prevalence of diabetes among many Plains and Pueblo Indians with the substantially lower rates noted among Alaskan Eskimos and Athapaskan tribes such as the Navajo (2,3).

The Navajo Indians, who number ~200,000, comprise the largest Indian tribe in the United States. Diabetes was reported to be a rare disease among Navajos before World War II. Even as rates of diabetes increased through the 1960s, it was thought to be a milder form of glucose intolerance than that found in other populations and was characterized as a "benign chemical abnormality" unassociated with the typical vascular complications of diabetes (4). However, over the past 30 yr, NIDDM has become a common disease among Navajos, and it is associated with a wide range of the typical micro- and macrovascular complications associated with diabetes in other populations (5–9).

In a previous study, we reported the age- and sex-adjusted prevalence of diabetes among Navajo adults in a reservation community in 1987 to be 10.2%, ~60% greater than that in the general U.S. population (5). However, that study relied on a screening strategy that did not include evaluation of glucose tolerance by administration of an oral glucose tolerance test, which is widely accepted as the "gold standard" for the diagnosis of diabetes. Therefore, in addition to underestimating the true prevalence of diabetes among Navajos, the study did not allow estimation of the prevalence of impaired glucose tolerance (IGT).

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This study reexamined the subjects who participated in an earlier population-based study of diabetes prevalence in a Navajo community with a diagnostic strategy designed to estimate more accurately the prevalence of diabetes and to estimate the prevalence of IGT. Because of the availability of clinical data regarding previously diagnosed diabetes among the study cohort, an additional goal was to estimate the incidence of clinically diagnosed diabetes in the same population.

RESEARCH DESIGN AND METHODS

— Between 1 April 1986 and 31 March 1987, 474 Navajo Indians 20–74 yr of age participated in a community-based study designed to estimate the prevalence of diabetes (survey 1 [S1]). The study was conducted in the Teec Nos Pos chapter of the Shiprock Service Unit located in northeastern Arizona on the 25,000-square-mile Navajo Indian reservation. The 360-square-mile area is a typical rural reservation community whose residents pursue a wide range of life-styles. Many residents reside in one-room hogans—hexagonal mud and wooden buildings without plumbing or electricity—and adhere to a life-style based on sheepherding and the traditional Navajo religion. Others are employed in wage work in schools or government agencies and live in homes with modern amenities and appliances.

The methods used in the previous study were described previously (5). Briefly, in an attempt to screen all adults in the community, residents ≥20 yr of age were approached through a house-to-house survey, supplemented by screening in public places (such as stores and the post office) and a local clinic, and invited to participate in the study. A capillary blood sample was obtained without regard to the time of a previous meal and analyzed with a reagent strip and a portable reflectance meter. Individuals with a random capillary blood glucose level <7.8 mM were considered nondiabetic unless they reported a personal history of diabetes. The diagnosis of diabetes conforming to the diagnostic criteria was confirmed by medical record review for all subjects reporting a personal history of diabetes. Subjects whose random blood glucose levels were ≥7.8 mM were referred to a clinical laboratory for fasting plasma glucose determination. Subjects whose fasting plasma glucose was >7.8 mM were referred to Indian Health Service (IHS) clinical providers for further evaluation and therapy. The diagnosis of diabetes mellitus was made after an overnight fast in those with a fasting plasma glucose ≥7.8 mM on two occasions or with random plasma glucose on two occasions ≥11.1 mM plus classic signs and symptoms of diabetes mellitus. In S1, screening was performed on 76% of the estimated population ≥20 yr of age.

For this study (survey 2 [S2]), a roster of all participants in the original cohort was obtained, and attempts were made to identify the whereabouts and vital status of each subject. Vital status was assessed by extensive interviews in the small close-knit community, supplemented by reviews of medical records at local IHS facilities. However, vital records such as death certificates were not reviewed. Subjects reporting themselves to be Navajo Indians 20–74 yr of age at the time of examination in S1 were eligible for inclusion in S2.

Between 23 February 1989 and 1 February 1990, efforts were made to contact each member of the cohort studied in S1 to invite participation in S2. Those who agreed to participate were examined in their homes or in a local IHS clinic (according to their preference) with the protocol described below. As Navajo Indians, all study subjects are eligible to receive medical care from the IHS without charge. Although the exact proportion of subjects who do not receive primary care from the IHS is unknown, it is believed to be low. The medical records of subjects examined in S1, which were located at the Teec Nos Pos Health Center or at the Shiprock Public Health Service Hospital 30 miles away, were reviewed. New clinical diagnoses of diabetes were included in the analyses if they conformed to the diagnostic criteria described above.

Subjects were instructed to fast for at least 10 h before examination. Those who admitted to noncompliance with this instruction were rescheduled. A venous blood sample was collected, and the subject was administered 75 g of Koladex (Custom, Baltimore, MD). Blood was then obtained by venipuncture 1 and 2 h later. Venipuncture samples were collected in tubes containing potassium oxalate and sodium fluoride for glycolytic inhibition (Vacutainer, Becton Dickinson, Rutherford, NJ) and were centrifuged for 5 min at 3000 × g. In most cases, centrifugation occurred immediately after collection, although there was occasionally a delay of several hours when collection took place at remote locations. In these cases, the specimens were stored in a portable cooler until centrifugation. Plasma glucose was measured by the glucose oxidase method with an autoanalyzer (Synchron CX3, Beckman, Brea, CA). Lyphochek levels 1 and 2 chemistry control, an unassayed bovine serum–based lyophilized product (Bio-Rad, Anaheim, CA), was used to establish coefficients of variation for glucose assays as part of a continuous quality control program. The cumulative coefficients of variation for levels 1 and 2 were 3.2 and 3%, respectively. Subjects with a previously confirmed diagnosis of diabetes received a fasting blood glucose test but not a glucose tolerance test. Diabetes and IGT were diagnosed according to the criteria of the World Health Organization (WHO) for the oral glucose tolerance test (10).

For estimating diabetes prevalence, all subjects (diabetic and nondiabetic) who had died since S1 were ex-

cluded from the numerator and the denominator. The remainder of those studied in S1 who were 20–74 yr of age during S2, regardless of whether they were reexamined, comprise the denominator for the prevalence. Subjects were included in the numerator if the diagnosis of diabetes was made either before or during S1 or between S1 and S2 or if the diagnosis was confirmed by glucose tolerance testing during S2. The denominator for the prevalence of IGT included only respondents studied in S2.

Subjects who were reexamined were classified according to their age at the time of the second examination. To estimate the age of subjects who were not reexamined, the mean duration between the first and second examination (2.97 yr) was added to each nonrespondent's age at the time of the first examination. Regardless of the age during S1, subjects ≥75 yr of age during S2 were not included in the prevalence estimates. Subjects not diagnosed as diabetic during the original survey accrued person-days of observation from the time of testing in the original survey until the second examination or the date of diagnosis of diabetes, whichever was earlier. All other subjects who were not reexamined were estimated to have accrued 2.97 person-yr of observation. Incidence rates of clinically diagnosed diabetes are expressed as cases per 1000 person-yr of observation.

Age-adjusted prevalence and incidence rates for subjects 20–74 yr of age were calculated by the direct method with the age distribution of the 1980 U.S. census population as reference (11). Confidence limits for age-adjusted and age- and sex-adjusted prevalence were computed with the assumption that age- and sex-specific rates are independent binomial random variables. SE for the age-adjusted and age- and sex-adjusted incidence rates (calculated with person-days) were computed with Knowler et al's (12) modification of the method of Chiang (13), assuming that the number of incident cases is a random Poisson variable.

This study was approved by the local elected Health Board and the regional and national Institutional Review Boards of the IHS. All subjects gave informed consent before participation. Subjects were informed of the results of their tests, and clinical care was arranged for subjects with newly diagnosed diabetes. Subjects were offered $15 for participation in the study.

RESULTS— Of 444 subjects 20–74 yr of age included in S1, 9 had their initial age incorrectly recorded (and was outside the eligibility range) or were included twice (due to duplicate screening with different names). During the medical record review, 4 subjects were identified who were known to have been diabetic at the original survey but who failed to identify themselves as such and who had blood glucose levels lower than the screening cutoff level or who did not appear for follow-up diagnostic testing. Therefore, the actual age-adjusted prevalence of diabetes at the first survey was 10.8%, which is similar to the originally reported rate of 10.2%.

Among the remaining 435 subjects, 10 (1 diabetic, 9 nondiabetic) died before the beginning of S2. Two hundred seventy-five (64.7%) of the remaining subjects agreed to be reexamined. A comparison among respondents and nonrespondents by age, sex, capillary blood glucose as measured at S1, body mass index (BMI) as determined in S1, and previous diabetes status is shown in Table 1. Although the differences were not statistically significant, BMI was slightly greater among respondents compared with nonrespondents. Diabetes was diagnosed before S2 among a greater proportion of respondents than nonrespondents. Figure 1 summarizes the vital status and the results of glucose tolerance testing and medical record reviews for all subjects from S1 who were eligible for participation in S2.

Of the 425 living subjects from S1, 6 were >74 yr of age during S2. The age-specific and age-adjusted prevalence of known diabetes among the 419 subjects 20–74 yr of age during S2 compared with those in the general U.S. population are shown in Table 2. The U.S. data were collected during the second National Health and Nutrition Examination Survey from a probability sample of the U.S. population that closely reflected the age distribution of the population as determined by the 1980 census. Diabetes was diagnosed with glucose tolerance testing and WHO diagnostic criteria equivalent to those in this study (14). The age-adjusted diabetes prevalence for Navajo Indians 20–74 of age was 13.9% (95% confidence interval [CI] 9.2–18.5) for men and 18.4% (95% CI 14–22.8) for women compared with 5.9 and 7.7% for men and women, respectively, in the general U.S. population. The age- and sex-adjusted diabetes prevalence among the study population was 16.5% (95% CI 13.2–19.7). Therefore, prevalence of diabetes among the Navajo population studied was 2.5 times that of the general U.S. population.

The prevalence of IGT among subjects examined in S2 is shown in Table 3. The age-adjusted prevalence of IGT was 10% (95% CI 4.3–15.6) among men and 15.9% (95% CI 9.8–22) among women compared with 10.3 and 12% in the general U.S. population.

Based on 11 new clinical diagnoses of diabetes during routine medical care since S1, age-adjusted incidence of diagnosed diabetes was 8.6 ± 4.3/1000 person-yr among men and 11.1 ± 4.4/1000 person-yr among women. The overall age- and sex-adjusted incidence was 9.9 ± 3.1/1000 person-yr.

CONCLUSIONS— The prevalence of diabetes among Navajo Indians, which

Table 1—*Comparison of characteristics of subjects in 1986–1987 Teec Nos Pos Diabetes Study (S1) examined (responders) and not examined (nonresponders) in 1989–1990 study (S2)*

Characteristic	Responders (%)		Nonresponders (%)	
	Men	Women	Men	Women
Age-group (yr)				
20–44	63.4 (59)	56.3 (89)	36.6 (34)	43.7 (69)
45–54	58.8 (20)	78.6 (33)	41.2 (14)	21.4 (9)
55–64	74.1 (20)	76.7 (23)	25.9 (7)	23.3 (7)
65–74	82.7 (14)	70.8 (17)	17.6 (3)	29.2 (7)
Total	66.1 (113)	63.8 (162)	33.9 (58)	36.2 (92)
Capillary blood glucose from S1 (mM)*	92.4 ± 2.3 (111)	91.2 ± 2.4 (144)	92.8 ± 6.1 (51)	88.4 ± 3.2 (89)
Body mass index (kg/m^2) from S1*†	27.7 ± 0.5 (98)	28.2 ± 0.5 (132)	26.6 ± 0.7 (48)	26.8 ± 0.6 (83)
Diabetes diagnosed before S2 (%)	13.3 (15)	16.7 (27)	12.1 (7)	7.6 (7)

Dead subjects were excluded. *n* given in parentheses.
*Values are means ± SE (subjects diabetic before S2 were excluded; differences in means between respondents and nonrespondents not significant at $P = 0.05$ by 2-tailed *t* test).
†Not available for all subjects from S1.

was reported to be low as recently as the late 1960s, is now greater than twice that in the general U.S. population. Although earlier studies among Navajos likely suffered from varying degrees of incomplete ascertainment of diabetes, there has been a significant increase in diabetes prevalence (9). Although there are several contemporary reports describing the prevalence of diabetes among different American-Indian communities, few, with the exception of those describing the Pima Indians, have relied on population-based screening with glucose tolerance tests. Because many cases of diabetes (46%) in this study were diagnosed through active screening during S1 and S2, it would be misleading to compare the rates from this study with those based on computations including only patients with clinically diagnosed diabetes identified by medical record review.

The overall prevalence of IGT is similar to that in the U.S. population. Because the prevalence of IGT is influenced by both its incidence and duration and it is likely that the high preva-

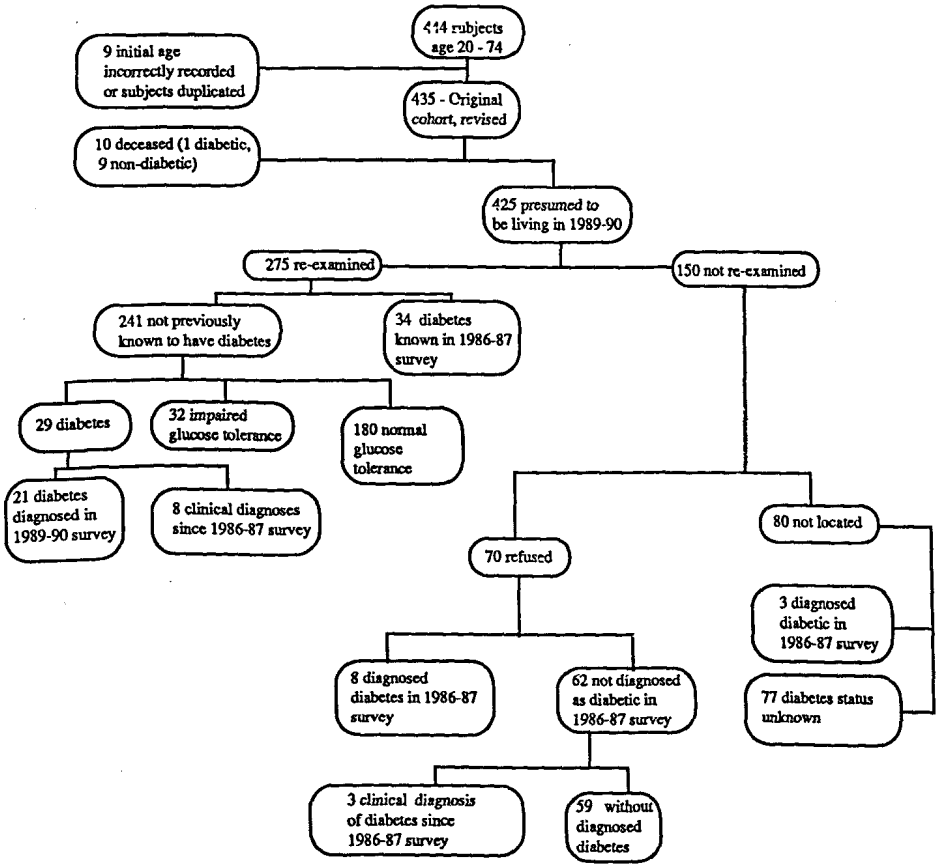

Figure 1—*Follow-up status of cohort in 1986–1987 Teec Nos Pos diabetes survey.*

Table 2—*Age- and sex-specific prevalence (%) of diabetes among Navajo Indians, Teec Nos Pos, Arizona, 1990, and in United States population, 1976–1980*

	Age (yr)				
	20–74	20–44	45–54	55–64	65–74
Teec Nos Pos*					
Men	16.2 (27 of 167)	3.5 (3 of 85)	28.6 (10 of 35)	29.2 (7 of 24)	30.4 (7 of 23)
Women	17.9 (45 of 252)	5.5 (8 of 145)	26.7 (12 of 45)	45.7 (16 of 35)	33.3 (9 of 27)
Both	17.2 (72 of 419)	4.8 (11 of 230)	27.5 (22 of 80)	39 (23 of 59)	32 (16 of 50)
Age-adjusted prevalence					
Men	13.9				
95% CI	9.2–18.5				
Women	18.4				
95% CI	14–22.8				
Both	16.5				
95% CI	13.2–19.7				
U.S.					
Men	5.9	1.4	7.9	9.9	20.1
Women	7.7	2.5	9.1	16.4	17.4
Both	6.6	2	8.5	13.4	18.7

CI, confidence interval. U.S. data from Harris et al. (14).
*n given in parentheses.

lence and incidence of NIDDM among Navajos are accompanied by a high incidence of IGT, it is possible that the progression from IGT to NIDDM is more rapid among Navajo Indians than among the U.S. population. The cumulative incidence of NIDDM among Pima Indians with IGT was 25% after 5 yr and 61% after 10 yr (15), but no information regarding the incidence of NIDDM among Navajo Indians with IGT is available.

The estimates of incidence based on new clinical diagnoses since S1 (9.9/1000 person-yr) are ~8 times the incidence of 1.17/1000 person-yr estimated on physician-defined diagnoses in three predominantly white Minnesota communities (16) and 40 times the 24/100,000 person-yr reported for subjects 18–50 yr of age living in nine British towns (17). The incidence rates of NIDDM based on physician-generated diagnoses later confirmed by WHO criteria among Hispanics and non-Hispanic whites 20–74 yr of age living in the San Luis Valley of Colorado (2.4 and 1.2/1000 person-yr, respectively) are also substantially lower than those in this study (18).

There are several possible limitations to this study in addition to those previously mentioned. The study cohort examined in S1 was not selected on the basis of a random sample of an enumerated population but was constructed by community-wide screening in households and public places. However, because the number of subjects screened represented a high proportion (76%) of the estimated adult population of Teec Nos Pos and it is unlikely that the method of screening disproportionately excluded any segment of the population, it is unlikely that significant bias was introduced into the estimates of diabetes prevalence in S1. Respondents in S2 were similar to nonrespondents based on comparison of several pertinent characteristics (Table 1). However, the BMIs of subjects studied in S2 were slightly greater than those studied only in S1. Because obesity is an important risk factor for NIDDM, it is possible that subjects with NIDDM and IGT were more likely to participate in S2. All living subjects from S1 who met the age criteria are included in the denominator, even if they were not reexamined in S2. Therefore, even if those who were reexamined were more obese or had a higher prevalence of diabetes than those not reexamined, the effect would be to underestimate diabetes prevalence. Two contradictory forces may have influenced the estimates of IGT prevalence. On the one hand, there may have been a tendency to overestimate because of the slightly increased prevalence of obesity in S2. On the other hand, the high proportion of subjects with diabetes who appear in the denominator but, by definition, were not at risk for IGT may result in an underestimate of IGT prevalence. It is difficult to determine whether the members of the single community of Teec Nos Pos are representative of the entire Navajo population, but the community is generally typical of the reservation in terms of range of life-styles and available resources.

The high prevalence of diabetes among Navajo Indians is of particular interest and concern for several reasons. First, as the largest Indian tribe in the U.S. (almost 20% of the estimated number of American Indians and Alaska Natives enrolled in federally recognized tribes), the number of diabetic Navajo Indians is likely to exceed that in any other tribe, and attempts to reduce diabetes-associated morbidity and mortality will require significant health-care resources. Second, the high prevalence of diabetes among Navajo Indians

Table 3—*Age- and sex-specific prevalence (%) of impaired glucose tolerance among Navajo Indians, Teec Nos Pos, Arizona, 1990, and in United States population, 1976–1980*

	Age (yr)				
	20–74	20–44	45–54	55–64	65–74
Teec Nos Pos*					
Men	8.9	3.4	15	20	7.1
	(10 of 113)	(2 of 59)	(3 of 20)	(4 of 20)	(1 of 14)
Women	13.6	9	27.3	8.7	17.7
	(22 of 162)	(8 of 89)	(9 of 33)	(2 of 23)	(3 of 17)
Both	11.6	6.6	22.6	14	12.9
	(32 of 275)	(10 of 148)	(12 of 53)	(6 of 43)	(4 of 31)
Age-adjusted prevalence					
Men	8				
95% CI	3.3–12.7				
Women	12.9				
95% CI	7.9–17.9				
Both	11				
95% CI	7.4–14.6				
U.S.					
Men	10.3	4.7	13.1	17.2	22.8
Women	12	7.8	16.3	13.4	22.7
Both	11.2	6.4	14.8	15.1	22.8

CI, confidence interval. U.S. data from Harris et al. (14).
*n given in parentheses.

implies that other Athapaskan tribes to whom the Navajo Indians are closely related, such as those living in Alaska (19) and that currently have low rates of diabetes, may be at risk for significant increases in the prevalence of NIDDM. Finally, because the epidemic of diabetes among Navajo Indians is a recent phenomenon and there are many Navajo Indians with IGT and NIDDM, closer study of the Navajo population may provide clues to the environmental and genetic determinants of NIDDM.

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