Use of the Semmes-Weinstein Monofilament in the Strong Heart Study

Risk factors for clinical neuropathy

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OBJECTIVE — We used the Semmes-Weinstein 5.07 monofilament to assess the prevalence of foot insensitivity and its relationship to potential risk factors.

RESEARCH DESIGN AND METHODS — There were 3,638 American Indian participants from Arizona, North and South Dakota, and Oklahoma who attended a study clinic on two occasions: baseline and follow-up, 4 years later. Oral glucose tolerance tests were performed at the visits for those who had not previously been diagnosed as having diabetes. A total of 2,051 participants were diagnosed with diabetes before the study or at the subsequent study visits. At the follow-up visit, participants were tested for their ability to sense the 5.07 (10 g) monofilament at 10 sites of the foot. The prevalence of foot insensitivity was ascertained, and its relation to characteristics of participants was assessed in both univariate and logistic regression analyses.

RESULTS — Diabetic participants had a much higher prevalence of foot insensitivity (defined as greater than or equal to five incorrect responses) than nondiabetic participants (14 vs. 5%, respectively). However, marked foot insensitivity was uncommon within the first few years of diagnosis of diabetes. Among the diabetic participants, those diagnosed before study entry had the highest prevalence of foot insensitivity. The prevalence of foot insensitivity was highest in the Arizona Indians (22 vs. 9% in the Dakotas and 8% in Oklahoma). In a logistic regression analysis, foot insensitivity was significantly and independently related to center (Arizona versus others), age, duration of diabetes, and height.

CONCLUSIONS — Marked foot insensitivity is prevalent in the diabetic American Indian population, especially in Indians in Arizona; however, this insensitivity is apparently uncommon for several years after the diagnosis of diabetes. The data show that Indians with diabetes are particularly vulnerable to the risk of foot ulceration and that the diagnostic screening of diabetes may lead to better prevention of sensory neuropathy and subsequent foot ulceration.

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Lower-extremity ulceration and amputation are costly (1–6) and potentially preventable complications of diabetes (7). A variety of cross-sectional and prospective studies consistently identify sensory or autonomic neuropathy as an important risk factor (8–13). Relatively simple actions taken by the patient and health care provider can significantly increase the early recognition of foot problems and thus reduce the rates of hospitalization and costs (14,15).

The simplest and most available tool for the detection of neuropathy is the Semmes-Weinstein 5.07 (10 g) monofilament. The inability to detect pressure transmitted to the foot by the Semmes-Weinstein monofilament is associated with foot ulcers in diabetic patients (4). Diabetic patients without a history of foot ulceration are more likely to detect the 5.07 monofilament than those who have a history of foot ulceration. Thus, it appears that a failure to detect this amount of pressure on the foot should alert the provider and patient to a higher risk of ulceration and amputation, and it should set in motion simple cost-effective behaviors that can reduce risk.

The Strong Heart Study is a prospective study of cardiovascular risk factors among American Indians living in Arizona, North and South Dakota, and Oklahoma. In the first re-examination of the cohort, a 10-point test for sensory neuropathy using the 5.07 monofilament was added to the protocol. We examine the utility of this tool in a large well-characterized cohort in which there is a high prevalence of diabetes and conversion from normal to abnormal glucose tolerance. This report estimates the prevalence of sensory neuropathy, defines both environmental and potential genetic risk factors, and provides a baseline measurement to assess the subsequent risk of ulceration and amputation.

RESEARCH DESIGN AND METHODS

Background of the Strong Heart Study

The Strong Heart Study (11) was begun in 1988 to measure risk factors and cardiovascular disease (12,13) among diverse groups of American Indians. Participants were from three geographic sites (Arizona, North and South Dakota, and Oklahoma) and were of varying degrees of Indian blood, socioeconomic status, and lifestyles, incorporating both traditional Indian and Western culture. Details summarizing de-

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A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

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Table 1—*Study population characteristics for female diabetic participants*

	Arizona	Oklahoma	South and North Dakota	*P* value
n	623	379	363	
Age (years)	59 (47–80)	62 (48–79)	60 (48–80)	<0.001
BMI (kg/m^2)	32 (19–73)	32 (16–54)	30 (18–47)	0.001
Diabetes duration (years)	15 (0–72)	5 (0–56)	6 (0–52)	<0.001
Height (cm)	157 (140–175)	160 (145–176)	160 (140–177)	<0.001
HbA_{1c}	9 (4–16)	7 (4–19)	8 (4–20)	<0.001
LDL cholesterol (mg/dl)	108 (24–289)	117 (44–246)	120 (16–268)	<0.001
HDL cholesterol (mg/dl)	39 (19–102)	40 (18–99)	38 (10–88)	0.106
Triglycerides (mg/dl)	138 (34–907)	144 (41–1,208)	153 (23–1,347)	0.001
Systolic blood pressure (mmHg)	132 (74–224)	133 (92–243)	126 (88–218)	<0.001
Indian heritage (%)				
<25	0 (0)	0 (0)	7 (2)	<0.001
25–49	0 (0)	5 (1)	13 (4)	
50–74	16 (3)	51 (14)	52 (14)	
75–99	19 (3)	22 (6)	82 (22)	
100	588 (94)	301 (79)	209 (58)	
Current drinker				
No	488 (79)	325 (86)	263 (74)	<0.001
Yes	132 (21)	51 (14)	91 (26)	
Current smoker				
No	554 (91)	281 (76)	218 (63)	<0.001
Yes	54 (9)	89 (24)	128 (37)	

Data are medians (range) or *n* (%). Data for Indian heritage, current drinker, and current smoker are at least 92% complete for all variables.

sign of this study (11), observed cardiovascular risk factors (14,15), and prevalence of diabetes (16) among the 4,549 original baseline participants are summarized in recent publications.

Participants

The Strong Heart Study population consisted of 4,549 American Indians aged 45–74 years living in Oklahoma, South and North Dakota, and Arizona. Participants were members of the following tribes: Pima, Maricopa, and Tohono O'odham of central Arizona living in the Gila River, Salt River, and Ak-Chin Indian communities; seven tribes of Southwestern Oklahoma (Apache, Caddo, Comanche, Delaware, Fort Sill Apache, Kiowa, and Wichita); the Oglala and Cheyenne River Sioux in South Dakota; and the Spirit Lake Sioux in the Fort Totten area of North Dakota.

The baseline examinations occurred between 1 July 1989 and 31 January 1992. Of the surviving cohort, 80% was re-examined in the follow-up examination, which occurred between 1 August 1993 and 31 December 1995. Percent participation rates of the target population in baseline were 71% in Arizona, 53% in North and South Dakota, and 62% in Oklahoma. The participation rates were calculated using the total number of people in the December 1988 tribal lists. Nonrespondents did not differ significantly from respondents in age, BMI, and self-reported incidence of diabetes or hypertension. More respondents were women compared with nonrespondents, and more of the nonresponders were smokers.

There were 2,051 diabetic and 1,505 impaired or normal glucose tolerant participants who had sensory neuropathy tests performed in the follow-up examination. The diabetic group was comprised of participants who met the following criteria for diabetes: receiving treatment with insulin and/or an oral hypoglycemic agent ordiagnosed by a glucose tolerance test under World Health Organization criteria. Among the diabetic group, 360 were newly diagnosed at the first visit, and 956 were diagnosed at the second visit.

Procedures

Briefly, the standardized clinical examination for both baseline and follow-up took place after a 12-h overnight fast. It consisted of a personal interview, a physical examination including a 12-lead electrocardiogram, a review of current medications, seated blood pressure, fasting blood samples, and a 75-g oral glucose tolerance test (OGTT) (Glutol; Paddock Laboratory, Minneapolis, MN). Additional tests, such as echocardiography and pulmonary function testing, were included in the follow-up examination, but the results are not reported here.

Peripheral sensory testing was performed only in the follow-up examination using the Semmes-Weinstein 5.07 monofilament. The right foot was used whenever it was available. Examiners were trained in the use of the fiber and periodically observed to insure uniform and proper technique. The fiber was applied at a 90° angle to the skin. One site on the dorsum of the foot above the base of the toes and nine sites on the plantar surface were tested. The fiber was applied for ~1.5 s. The order of the test sites was randomized to help prevent anticipation of the test by the participant. The participant indicated when he or she felt the fiber. Where a foot ulcer was present, the testing sites were moved to the perimeter of the ulcer. The examining technician recorded the number of positive results.

Body height was obtained with the participant standing erect in the Frankfort plane using a stadiometer fixed to the wall. Weight was measured using a Detecto model 683-p scale (Detecto Manufacturing, Web, MO) calibrated and adjusted daily. Blood pressures are given as the mean of the final two of three measurements obtained using protocol from the Joint National Commission V (JNC-V) for the study of hypertension. Duration of diabetes was defined by the participant's response. Alcohol ingestion, smoking history, and percent Indian heritage are from data obtained during the interview.

Plasma lipoprotein measurements were done in a single fresh plasma sample by lipid research clinic methods. LDL and HDL were isolated by iospycnic ultracentrifugation, and VLDL (top fraction) and the bottom fractions were measured for cholesterol and triglycerides concentrations. HDL cholesterol was measured in the presence of $MnCl_2$ and heparin in which non-HDL lipoproteins are precipitated, leaving HDL in the supernatant. The supernatant was removed after centrifugation and the cholesterol content measured on a separate autoanalyzer channel set to measure low cholesterol values. LDL was calculated as the

difference between the HDL cholesterol and the bottom cholesterol. Triglycerides were measured enzymatically after correction for free glycerol. Glycerol-blanked assays such as this one are preferable in populations with high prevalence of diabetes. Glucose was measured using a hexokinase method calibrated with aqueous controls derived from the National Institutes of Technology. HbA_{1c} was measured by high-performance liquid chromatography.

Statistical methods

The distribution of the number of incorrect sensory responses was first examined in the diabetic and nondiabetic participants. Before examining any further associations, the sensory scores were divided into zero, one to four, and greater than or equal to five incorrect responses based on the investigators' experience with the 5.07 monofilament. The distributions of scores in the diabetic and nondiabetic participants further justified these chosen cut points. In the nondiabetic participants, the 95th percentile of incorrect scores corresponded to five incorrect scores (i.e., 95% of nondiabetic subjects had at most five incorrect scores). Because there are no published guidelines on how to classify an individual's neuropathy status based on sensory scores, it was reasonable to use a cut point that classifies few nondiabetic individuals as having neuropathy (greater than or equal to five incorrect scores). However, having six or more correct responses does not necessarily rule out the presence of neuropathy. The group with one to four incorrect responses is likely to include some neuropathic and non-neuropathic individuals, and it might be a different group than the group with zero incorrect responses, who may be normal. To support separating the group with zero incorrect responses from the group with one to four incorrect responses, it was noted that the greatest increment in the cumulative percentage for incorrect responses is from zero to one incorrect responses.

Center differences in demographic characteristics were compared separately for men and women using the Kruskal-Wallis test (17) and the Mantel-Haenszel χ^2 test. Associations between all levels of sensory scores and categorical characteristics also were examined with Mantel-Haenszel χ^2 tests, which controlled for center and sex. Standardized mid-ranks were used to account for ordinal values. Height was separated by tertiles, and BMI classifications were based on sex-specific criteria.

To minimize the possibility of misclassification of neuropathy, further analyses considered the diabetic participants with zero incorrect responses (n = 1,293) to those with at least five incorrect responses (n = 292). (Sensory neuropathy was defined as having at least five incorrect responses.) Because significant differences existed between Arizona and the other two centers but not between Oklahoma and the Dakotas, Arizona was compared with the two other centers in some analyses.

Logistic regression was used to examine simultaneously the possible risk factors for sensory neuropathy: center, sex, age, duration of diabetes, Indian heritage, height, BMI, HbA_{1c}, systolic blood pressure, LDL cholesterol, triglycerides, HDL cholesterol, smoking status, and drinking status. Duration and heritage are self-reported and may not be completely accurate. Therefore, the model examined broad categories to evaluate these risk factors. A reduced model was selected using backward elimination, and a variable was kept in the model if it was significant at the 0.10 level of significance. The model results are interpreted using the Wald χ^2 test statistic P value, odds ratios, and 95% CIs, which are based on the profile likelihood function (18). Throughout the analyses, no adjustments were made to the P values to control for type I errors.

Table 2—*Study population characteristics for male diabetic participants*

	Arizona	Oklahoma	South and North Dakota	*P* value
n	264	229	193	
Age (years)	56 (48–79)	60 (48–80)	60 (48–79)	0.001
BMI (kg/m²)	30 (19–60)	32 (20–64)	30 (18–48)	0.002
Diabetes duration (years)	11 (0–48)	6 (0–51)	5 (1–46)	<0.001
Height (cm)	170 (155–188)	174 (157–193)	174 (161–196)	<0.001
HbA_{1c}	8 (4–15)	7 (3–18)	7 (4–14)	<0.001
LDL cholesterol (mg/dl)	99 (34–243)	117 (21–200)	120 (12–252)	<0.001
HDL cholesterol (mg/dl)	36 (17–108)	33 (13–109)	35 (10–101)	0.002
Triglycerides (mg/dl)	122 (27–1,528)	150 (38–853)	143 (16–1,288)	<0.001
Systolic blood pressure (mmHg)	133 (86–216)	129 (89–209)	126 (86–214)	<0.001
Indian heritage (%)				
<25	0 (0)	0 (0)	6 (3)	<0.001
25–49	0 (0)	4 (2)	20 (10)	
50–74	7 (3)	38 (16)	29 (16)	
75–99	9 (3)	11 (5)	45 (23)	
100	248 (94)	176 (77)	93 (48)	
Current drinker				
No	126 (48)	154 (68)	100 (53)	<0.001
Yes	135 (52)	73 (32)	89 (47)	
Current smoker				
No	188 (73)	161 (72)	105 (56)	0.001
Yes	71 (27)	64 (28)	81 (44)	

Data are medians (range) or *n* (%). Data for Indian heritage, current drinker, and current smoker are at least 89% complete for all variables.

RESULTS — The characteristics of the diabetic participants according to center are shown for men and women separately in Tables 1 and 2. Those in Arizona differed for most of the characteristics from those in Oklahoma and the Dakotas. The Arizona participants tended to be younger and shorter in stature and had higher glycosylated hemoglobin values. They also had a longer known duration of diabetes. Cholesterol and triglyceride levels were lower in the Arizona participants, while the extent of Indian heritage was higher.

Figure 1 shows the cumulative frequency distributions of the number of incorrect responses to monofilament testing for those with diabetes and those who had nondiabetic glucose tolerance tests at both the phase 1 (no later than 31 January 1992) and follow-up (no later than 21 December

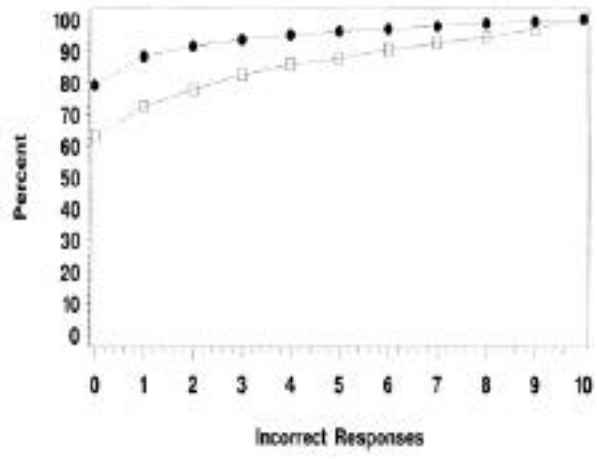

Figure 1—*Cumulative frequency distributions of incorrect responses to the 5.07 monofilament for participants according to the presence (□, diabetes) or absence (●, normal glucose tolerance/impaired glucose tolerance) of diabetes. The lower curve for the diabetic participants indicates their greater frequency of incorrect responses. Each point represents the percentage of individuals who have the number of incorrect responses. Thus, ~95% of the nondiabetic individuals had less than or equal to five incorrect responses, while ~86% of the diabetic individuals had less than or equal to five incorrect responses.*

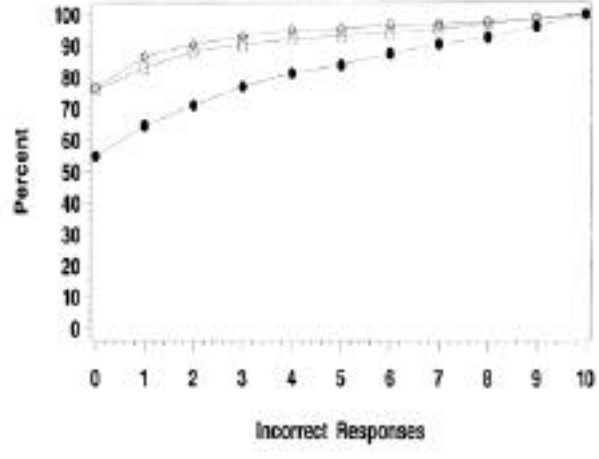

Figure 2—*Cumulative frequency distributions of incorrect responses to the 5.07 monofilament for participants according to the timing of the development of diabetes (●, pre-baseline; □, baseline; ◇, follow-up examination). The frequency of incorrect responses was much greater in those diagnosed before baseline.*

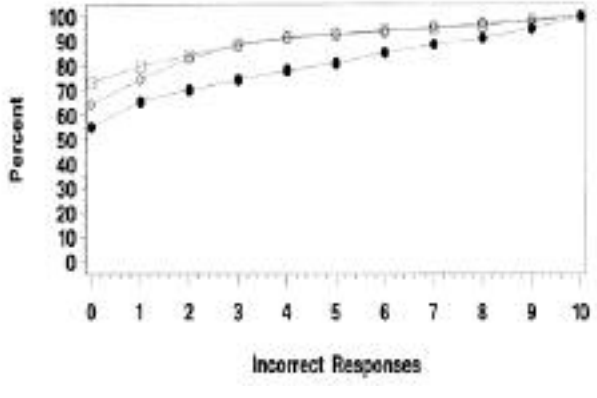

Figure 3—*Cumulative frequency distributions of incorrect responses to the 5.07 monofilament for diabetic participants according to center (●, Arizona; □, Oklahoma; ◇, South Dakota/North Dakota). The frequency of incorrect responses is much greater for participants from Arizona.*

1995) visits. The diabetic participants had a much larger number of incorrect responses; 14% of the diabetic participants had five or more incorrect responses compared with 5% of the nondiabetic participants.

In Fig. 2, cumulative frequency distributions are shown separately for diabetic participants according to the timing of diagnosis of diabetes: before the baseline visit, at the baseline visit, and several years later at the follow-up visit. The curves indicate that the number of incorrect responses was appreciably higher for those diagnosed with diabetes before the baseline visit. Only 55% of these individuals had zero incorrect responses, yet ~75% of participants diagnosed at the baseline or follow-up visits had zero incorrect responses. There was only a slightly higher number of incorrect responses for those diagnosed with diabetes at the baseline visit than for those diagnosed at the follow-up visit.

The cumulative frequency distributions are shown according to center for diabetic participants in Fig. 3. The number of incorrect responses was greater for Arizona participants than participants at other sites, where 22% of the Arizona participants had greater than or equal to five incorrect responses compared with 8 and 9% of those in Oklahoma and the Dakotas, respectively.

Table 3 shows the relationship between the number of incorrect responses and individual characteristics among only the diabetic participants. Controlling for center and sex, there were significant associations of the number of incorrect responses with age, diabetes duration, extent of Indian heritage, height, BMI, HbA_{1c}, systolic blood pressure, and triglycerides.

Associations between neuropathy and potential risk factors were examined simultaneously in a logistic regression analysis, and Table 4 displays the results of the reduced model using backward elimination. For this analysis, the diabetic participants were categorized according to whether they had greater than or equal to five incorrect responses (neuropathic) or no incorrect responses (non-neuropathic). Neuropathy was associated with center, age, duration of diabetes, and height ($P < 0.01$). Independent of other covariates in the model, the odds ratio for neuropathy among the Arizona residents was 2.99 in comparison to the Oklahoma and Dakota residents combined. Moreover, individuals who had diabetes between 5 and 10 years were twice as likely to have had sensory neuropathy than those who had diabetes

<5 years, and the odds ratio was even greater for those who had diabetes >10 years. The odds ratio for a 10-year increase in age and a 5-cm increase in height were 1.74 and 1.39, respectively.

Neuropathy had modest associations with sex, Indian heritage, and triglycerides ($P = 0.068$, 0.047, and 0.044, respectively). BMI, HbA_{1c}, systolic blood pressure, LDL cholesterol, HDL cholesterol, smoking status, and drinking status were excluded from the model ($P > 0.10$).

Of the eliminated variables, BMI, HbA_{1c}, and systolic blood pressure were significantly related to neuropathy in the univariate analysis (Table 3) yet were not significantly related in the logistic regression model. In a post hoc analysis, duration of diabetes had a strong association with these three factors ($P < 0.001$) and thus appears to overpower them in estimating risk.

Table 3—*Distributions of characteristics of diabetic participants according to category of number of incorrect responses to 5.07 monofilament controlling for center and sex*

	Incorrect responses			
	0	1–4	≥5	*P* value
Age (years)				
<55	422 (69)	132 (21)	62 (10)	<0.001
55–64	511 (62)	177 (22)	133 (16)	
≥65	360 (59)	157 (25)	97 (16)	
Diabetes duration (years)				
<5	551 (77)	125 (17)	41 (6)	<0.001
5–10	259 (66)	95 (24)	39 (10)	
>10	388 (48)	223 (28)	197 (24)	
Indian heritage (%)				
<25	11 (85)	2 (15)	0 (0)	<0.001
25–49	33 (79)	7 (17)	2 (5)	
50–74	147 (76)	32 (17)	14 (7)	
75–99	131 (70)	45 (24)	12 (6)	
100	971 (60)	380 (24)	264 (16)	
Height (cm)				
140–159	507 (68)	150 (20)	87 (12)	0.010
160–167	428 (65)	149 (23)	76 (12)	
>167	358 (55)	166 (25)	127 (20)	
BMI (kg/m^2)*				
Normal weight	261 (56)	117 (25)	91 (19)	<0.001
Overweight	375 (63)	140 (23)	84 (14)	
Obese	657 (67)	207 (21)	114 (12)	
HbA_{1c} (%)				
<6	358 (72)	102 (20)	40 (8)	<0.001
6–8	349 (62)	127 (23)	86 (15)	
>8	541 (59)	217 (24)	159 (17)	
Systolic blood pressure (mmHg)				
<140	908 (66)	289 (21)	181 (13)	<0.001
≥140	384 (57)	177 (26)	110 (16)	
Triglycerides (mg/dl)				
<200	951 (65)	326 (22)	195 (13)	0.002
≥200	323 (59)	134 (24)	93 (17)	
HDL cholesterol (mg/dl)				
<35	486 (62)	168 (22)	125 (16)	0.950
≥35	777 (63)	291 (24)	162 (13)	
LDL cholesterol (mg/dl)				
<130	832 (61)	318 (23)	208 (15)	0.090
≥130	408 (67)	125 (21)	72 (12)	
Current drinker				
No	951 (65)	302 (21)	203 (14)	0.673
Yes	328 (57)	155 (27)	88 (15)	
Current smoker				
No	948 (63)	337 (22)	222 (15)	0.740
Yes	310 (64)	114 (23)	63 (13)	

Data are *n* (%). *Women: normal weight: BMI <27.30; overweight: 27.30 ≤ BMI < 32.29; obese: BMI ≥32.30. Men: normal weight: BMI <27.80; overweight: 27.80 ≤ BMI < 31.09; obese: BMI ≥31.10.

CONCLUSIONS — The 5.07 monofilament is extensively used to assess risk for diabetic foot ulceration in both clinical and research settings (6,19,20). As an easily performed clinical measure of foot insensitivity, it is particularly useful for large epidemiologic studies, such as the Strong Heart Study. The present study is by far the largest to use the 5.07 monofilament to assess foot insensitivity in a well-defined diabetic population. In addition, no other studies have examined the prevalence of insensitivity to this monofilament in newly diagnosed diabetic individuals.

The data from this study indicate that an appreciable number of the diabetic participants have marked foot insensitivity. These same individuals, therefore, are at risk for foot ulceration because it has been well documented that foot insensitivity is a strong risk factor for the development of foot ulcers (4). It is likely that an even higher number of the study participants are at risk for foot ulceration because the 5.07 monofilament may not be optimally sensitive for detecting such risk (23). The particularly high risk of Arizona Indians for diabetic foot ulceration may have contributed to the increased risk for lower-extremity amputation observed in diabetic Pima Indians (21).

In a logistic regression analysis of the diabetic participants, foot insensitivity was associated with center, age, diabetes duration, and height. Each of the latter three characteristics have been shown to be related to neuropathy in other studies (22–24). A potentially important observation is the greater degree of foot insensitivity among the Arizona Indians. The reasons for this are not readily evident, although several explanations are possible. In contrast to the other two centers, the Pima Indians had little non-Indian admixture, and this may put them at increased risk for neuropathy. We might also postulate that the phase of preclinical diabetes may be longer in the Arizona participants. Finally, there may be a variety of potential environmental factors that protect or promote neu-

Table 4—*Associations of diabetic participant characteristics and sensory neuropathy from logistic regression analysis*

	Prevalence odds ratio	95% CI	*P* value
Center (AZ vs. OK and SD/ND)	2.99	2.09–4.31	<0.001
Sex (F vs. M)	1.59	0.97–2.60	0.068
Age (per 10-year increase)	1.74	1.40–2.16	<0.001
Duration of diabetes			
5–10 vs. <5 years	2.12	1.25–3.59	0.005
>10 vs. <5 years	7.04	4.68–10.88	<0.001
Indian heritage (<100 vs. 100%)	1.64	1.02–2.72	0.047
Height (per 5-cm increase)	1.39	1.21–1.61	<0.001
Triglycerides (per 20 mg/dl increase)	1.03	1.00–1.05	0.044

Prevalence odds ratio defined as the odds of greater than or equal to five incorrect responses to the odds of zero incorrect responses. Associations are independent of other variables in the model. Hosmer and Lemeshow goodness of fit test *P* value = 0.551. Data are 84% complete.

ropathy. Further study will be needed to offer an explanation for the differences detected among the three centers.

There was an association between sensory neuropathy and the extent of Indian heritage that was of modest significance in the logistic regression analysis. It is possible that this association is the result of as yet unexplained constitutional and/or environmental factors. Studies have previously identified differences between American Indians and other groups with regard to metabolic status and susceptibility to certain pathologic conditions and complications of diabetes, such as proteinuria (25). Such differences also have been observed between various Indian tribes themselves (25).

The strict criterion of no incorrect responses for the group designated as "non-neuropathic" was intended to minimize the inclusion of mildly neuropathic individuals. If this criterion did not fully exclude such participants in that group, observed associations may actually have been underestimated.

Participants diagnosed as diabetic by screening at the baseline and follow-up visits did not have a notable increase in incorrect responses to monofilament testing compared with those who were nondiabetic. It is still possible that a sizable number of those diabetic participants had mild neuropathy that was not detected by the 5.07 monofilament. While convenient and inexpensive, the monofilament may not be the most sensitive method to detect early peripheral neuropathy. Participants diagnosed at the baseline visit had a diabetes duration of up to 4 years before 5.07 monofilament testing. Thus, the data suggest that foot insensitivity is not well detected by this method in relatively new-onset diabetic patients. Nevertheless, the diagnostic screening of diabetes may provide the opportunity for interventional measures before appreciable neuropathy develops.

The high rate of foot insensitivity observed in this study emphasizes the need for the institution of measures that prevent the development of neuropathy. Furthermore, foot ulcer prevention programs need to be developed for those who already have significant sensory neuropathy. This need appears to be especially important for Arizona Indians. The data suggest a complex interaction between genetics, metabolic control, and possibly yet-to-be defined environmental factors. Further investigation could lead to better understanding of the pathogenesis of diabetic sensory neuropathy and to improved prevention and treatment.

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