

# Poor Control of Risk Factors for Vascular Disease Among Adults With Previously Diagnosed Diabetes

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**D**IABETES PRESENTS A SIGNIFICANT public health burden on the basis of its increased morbidity, mortality, and economic costs.<sup>1,2</sup> Individuals with diagnosed diabetes are at an increased risk for vascular disease, including microvascular complications (eg, retinopathy, neuropathy, and nephropathy) and macrovascular complications (eg, coronary heart disease and stroke), and lower extremity amputations.<sup>3-6</sup> Improved glycemic control clearly reduces the risk of microvascular disease among individuals with diagnosed diabetes and is associated with lower risk of atherosclerosis and macrovascular disease.<sup>4,7-12</sup> While treatment for individuals with diabetes has traditionally focused on control of glycemia to reduce these vascular complications, there is growing evidence highlighting the importance of controlling blood pressure and cholesterol levels.<sup>9,13-16</sup> In addition, while intensive control of glycemia, blood pressure, and cholesterol levels all improve health outcomes for individuals with diabetes, control of blood pressure has been reported to be the most cost-effective intervention.<sup>17</sup>

Current American Diabetes Association (ADA) standards of medical care for individuals with diagnosed diabetes aim to reduce vascular complica-

**Context** Control of blood glucose levels, blood pressure, and cholesterol levels is proven to reduce the risk of vascular disease among individuals with diabetes mellitus; however, the current state of control of these risk factors among individuals in the United States is uncertain.

**Objectives** To examine 1999-2000 national data on control of risk factors for vascular disease among adults with previously diagnosed diabetes and to assess trends during the past decade.

**Design, Setting, and Participants** Review of data from the Third National Health and Nutrition Examination Survey (NHANES III, conducted 1988-1994) and NHANES 1999-2000, cross-sectional surveys of a nationally representative sample of the non-institutionalized civilian US population. Participants were adults aged 20 years and older with previously diagnosed diabetes who participated in both the interview and examination in either NHANES III (n=1265) or NHANES 1999-2000 (n=441).

**Main Outcome Measures** Levels of glycosylated hemoglobin (HbA<sub>1c</sub>), blood pressure, and total serum cholesterol in reference to target goals.

**Results** Compared with NHANES III, participants with previously diagnosed diabetes in NHANES 1999-2000 were similar by age and sex, were less likely to be non-Hispanic white, were diagnosed at an earlier age, had a higher body mass index, and were more likely to use insulin in combination with oral agents. In NHANES 1999-2000, only 37.0% of participants achieved the target goal of HbA<sub>1c</sub> level less than 7.0% and 37.2% of participants were above the recommended "take action" HbA<sub>1c</sub> level of greater than 8.0%; these percentages did not change significantly from NHANES III ( $P=.11$  and  $P=.87$ , respectively). Only 35.8% of participants achieved the target of systolic blood pressure (SBP) less than 130 mm Hg and diastolic blood pressure (DBP) less than 80 mm Hg, and 40.4% had hypertensive blood pressure levels (SBP  $\geq$  140 or DBP  $\geq$  90 mm Hg). These percentages did not change significantly from NHANES III ( $P=.10$  and  $P=.56$ , respectively). Over half (51.8%) of the participants in NHANES 1999-2000 had total cholesterol levels of 200 mg/dL or greater (vs 66.1% in NHANES III;  $P<.001$ ). In total, only 7.3% (95% confidence interval, 2.8%-11.9%) of adults with diabetes in NHANES 1999-2000 attained recommended goals of HbA<sub>1c</sub> level less than 7%, blood pressure less than 130/80 mm Hg, and total cholesterol level less than 200 mg/dL (5.18 mmol/L).

**Conclusion** Further public health efforts are needed to control risk factors for vascular disease among individuals with diagnosed diabetes.

JAMA. 2004;291:335-342

www.jama.com

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tions through control of glycemia, blood pressure, and blood lipid levels, as well as through smoking cessation.<sup>18</sup> The ADA goal for control of glycemia is glycosylated hemoglobin (HbA<sub>1c</sub>) level less than 7%; additional treatment is suggested for individuals with HbA<sub>1c</sub> levels greater than 8%. The goal for control of blood pressure is systolic blood pressure less than 130 mm Hg and diastolic blood pressure less than 80 mm Hg.<sup>18</sup> The Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC) also now recommends this level of blood pressure control although the recommended diastolic target was 85 mm Hg until 2003.<sup>19</sup> The ADA goal for lipid management is aimed at lowering levels of low-density lipoprotein cholesterol to less than 100 mg/dL (2.59 mmol/L), increasing levels of high-density lipoprotein cholesterol to greater than 45 mg/dL (1.16 mmol/L) for men and 55 mg/dL (1.42 mmol/L) for women, and lowering levels of triglycerides to less than 150 mg/dL (1.7 mmol/L).<sup>18</sup> In addition, the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP-III) sets a goal for total cholesterol levels of less than 200 mg/dL (5.18 mmol/L).<sup>20</sup>

Previous analysis of nationally representative surveys found that individuals with diabetes had poor control of risk factors for vascular disease.<sup>21-23</sup> However, these results were based on national surveys conducted in the early 1990s and may not accurately reflect the current state of control of risk factors for vascular disease among individuals with diabetes in the United States.

We examined the trends in control of risk factors for vascular disease among adults with diagnosed diabetes in the United States over nearly a decade using data from 2 national health surveys: the Third National Health and Nutrition Examination Survey (NHANES III) conducted from 1988-1994 and the NHANES 1999-2000. Specifically, we compared HbA<sub>1c</sub> levels, blood pressure, and total cholesterol levels among adults with previ-

ously diagnosed diabetes between these surveys to assess whether control of risk factors for vascular disease has changed.

## METHODS

### Surveys

The survey instruments, physical examination, and laboratory measurements of NHANES III and NHANES 1999-2000 have been described in detail.<sup>24-28</sup> Both surveys comprised nationally representative samples of the noninstitutionalized civilian US population, obtained by a complex, stratified, multistage probability cluster sample design. Both surveys oversampled non-Hispanic blacks, Mexican Americans, and individuals aged 60 years and older; NHANES 1999-2000 also oversampled low-income individuals. Participants were interviewed in their homes to ascertain sociodemographic, medical, and family history data. A standardized set of physical examinations and laboratory measurements was performed in a mobile examination center. Blood pressure was measured using a mercury sphygmomanometer. In NHANES III, the average of the second and third values was used; in NHANES 1999-2000, 3 to 4 blood pressure measurements were averaged after excluding the first. In both surveys, HbA<sub>1c</sub> measurements were standardized to the Diabetes Control and Complications Trial (DCCT) method and levels of total serum cholesterol were measured enzymatically. The overall response rate for completion of the interview and physical examination was 78% in NHANES III and 75% in NHANES 1999-2000.

### Participants

We included adults aged 20 years and older who completed the interview and examination and who answered "yes" when asked whether a physician (or a health care professional, in NHANES 1999-2000) ever told them they had diabetes (n=1265 in NHANES III and n=441 in NHANES 1999-2000). Women who reported a history of diabetes only during pregnancy were not included. To determine the percentage

with diagnosed diabetes in each survey we included all adults aged 20 years and older who completed the interview (NHANES III, n=18 822; NHANES 1999-2000, n=4874).

### Analysis

To define categories of desirable and undesirable HbA<sub>1c</sub> levels and blood pressure, we used the ADA standards of medical care for persons with diabetes.<sup>18</sup> For desirable and undesirable levels of total cholesterol, we used guidelines from the ADA<sup>18</sup> and the NCEP-ATP-III.<sup>20</sup> We did not evaluate levels of low-density lipoprotein cholesterol or triglycerides, since few participants with diagnosed diabetes in NHANES 1999-2000 (n=99 and n=111, respectively) had valid measurements.

Microalbuminuria was defined as 30 µg or more of albumin per milligram of creatinine determined by spot urine collection for participants in each survey who reported fasting at least 6 hours prior to collection.<sup>18</sup> A history of cardiovascular disease was defined as a history of angina, heart attack, or coronary heart disease. Participants were considered to be current smokers if they reported smoking at least 100 cigarettes in their lifetime and reported smoking on at least some days within the past 30 days.

Risk factors for vascular disease were reported for participants in both surveys overall and by sex. Due to the small number of individuals with diagnosed diabetes in NHANES 1999-2000, we were unable to stratify by age or race/ethnicity.

We report the unadjusted and age-standardized prevalence of diagnosed diabetes in NHANES III and NHANES 1999-2000. We age-standardized the prevalence of diagnosed diabetes to the 2000 US Census population using 3 age groups (20-39 years, 40-59 years, and ≥60 years) and corresponding weights (0.40589, 0.36621, 0.22790).

To compare characteristics and risk factors between the surveys, we age-standardized the NHANES III results by the direct method to the NHANES 1999-2000 diabetes population using

3 age groups (20-39 years, 40-59 years,  $\geq 60$  years) and corresponding weights (0.0505, 0.2283, 0.7212). The NHANES 1999-2000 diabetes population was selected as the standard to minimize random variability.<sup>29</sup> Since NHANES III and NHANES 1999-2000 are independent samples, we used 2-sample *t* tests for testing differences in means and proportions.<sup>30</sup>

Analyses were performed using SUDAAN version 8.0 (Research Triangle Institute, Research Triangle Park, NC) with appropriate sampling weights to account for the complex survey design and to provide nationally representative estimates. Although the NHANES surveys oversampled different groups, survey weighting ensures that the results from the 2 surveys are comparable. Since the primary sampling units and strata were not provided in the NHANES 1999-2000 public release data set, we used the replicate weights provided with the jackknife command. Unreliable estimates, ie, those with a relative standard error greater than 30%, are noted in the tables.<sup>31,32</sup>

## RESULTS

The prevalence of diagnosed diabetes and the characteristics of adults with diabetes are shown in TABLE 1. The unadjusted prevalence of diagnosed diabetes in adults aged 20 years and older in NHANES 1999-2000 was 5.9% (SE, 0.52). The age-standardized prevalence of previously diagnosed diabetes did not increase significantly from NHANES III (5.4%; SE, 0.21) to NHANES 1999-2000 (6.1%; SE, 0.52) ( $P = .17$ ). Participants with diagnosed diabetes were similar by age and sex in the 2 surveys. In NHANES 1999-2000, there were significantly fewer non-Hispanic whites, similar proportions of non-Hispanic blacks and Mexican Americans, and a significantly larger proportion of participants of other race/ethnicity groups compared with NHANES III. These changes in race/ethnicity between the 2 surveys reflect the changes in the US Census between 1990 and 2000. However, the

**Table 1.** Prevalence and Characteristics of Adults Aged 20 Years and Older With Previously Diagnosed Diabetes in NHANES III (1988-1994) and NHANES 1999-2000\*

Characteristic	NHANES III†	NHANES 1999-2000	P Value
<b>Interviewed Samples</b>			
Total	18 822	4874	
Prevalence of diabetes			
Unadjusted	5.1 (0.26)	5.9 (0.52)	.16
Age-standardized to the 2000 US population	5.4 (0.21)	6.1 (0.52)	.17
<b>Characteristics of Adults With Diagnosed Diabetes in the Examined Samples</b>			
Total	1265	441	
Age, mean (SE) [SD], y	60.2 (0.67) [14.2]	59.3 (0.87) [13.8]	.39
Men	43.2 (2.19)	50.0 (3.12)	.08
Race/ethnicity			
Non-Hispanic white	74.6 (1.93)	59.8 (4.77)	.004
Non-Hispanic black	14.4 (1.42)	17.8 (2.82)	.28
Mexican American	5.1 (0.38)	6.1 (0.95)	.36
Other	5.9 (1.43)	16.4 (4.80)	.04
Some college education	22.0 (2.26)	30.1 (3.94)	.08
Body mass index (BMI)‡			
Mean (SE) [SD]	29.9 (0.26) [6.8]	32.3 (0.74) [7.4]	.002
Obese (BMI $\geq 30$ )	41.6 (1.95)	54.6 (4.50)	.008
Overweight (BMI 25-29)	37.4 (1.68)	29.2 (3.68)	.04
Normal (BMI < 25)	21.0 (1.26)	16.2 (3.41)	.19
Current smoker	16.3 (1.69)	15.9 (2.33)	.88
Diabetes diagnosis, mean (SE) [SD]			
Age at diagnosis, y	50.7 (0.67) [14.5]	46.7 (1.09) [15.7]	.003
Years since diagnosis	10.2 (0.38) [9.2]	12.5 (0.99) [13.8]	.03
History of cardiovascular disease§	21.4 (2.27)	24.5 (2.94)	.41
Microalbuminuria	32.8 (2.54)	27.5 (4.46)	.31
Current diabetes treatment			
Insulin alone	27.6 (1.69)	17.0 (2.89)	.002
Oral medication alone	44.2 (2.19)	53.9 (3.51)	.02
Insulin and oral medication	3.5 (0.57)	10.4 (2.71)	.01
Neither insulin nor oral medication	24.8 (1.70)	18.7 (2.75)	.06
Hypertension and high blood pressure control			
Physician-diagnosed hypertension	54.8 (1.84)	51.4 (2.90)	.32
Taking medication for control¶	77.0 (2.62)	85.2 (3.40)	.05
Weight control/loss for control¶	57.4 (2.47)	57.9 (5.20)	.93
Exercise for control¶	52.3 (4.47)	49.0 (4.52)	.60
Hypercholesterolemia and cholesterol control			
Physician-diagnosed hypercholesterolemia	44.9 (2.71)	54.5 (3.19)	.02
Taking medication for control#	27.7 (3.29)	56.1 (4.48)	<.001
Eating less fat for control#	81.9 (2.79)	74.4 (4.87)	.18
Weight control/loss for control#	60.2 (3.62)	62.0 (4.33)	.76
Exercise for control#	48.9 (3.58)	50.5 (6.46)	.83
Aspirin use nearly every day each month	22.2 (1.83)	22.6 (3.28)	.92

Abbreviation: NHANES, National Health and Nutrition Examination Survey.

\*All values are % (SE) except where otherwise noted.

†NHANES III values except those for prevalence of diabetes, mean age, and age at diagnosis were age-standardized to the NHANES 1999-2000 population using age groups 20-39 years, 40-59 years, and  $\geq 60$  years.

‡Calculated as weight in kilograms divided by the square of height in meters.

§Defined as history of angina, myocardial infarction, or coronary heart disease.

||Defined as  $\geq 30$   $\mu$ g albumin/mg of creatinine based on spot urine collection for participants who fasted at least 8 hours (NHANES III: n = 820; NHANES 1999-2000: n = 206).

¶Among participants who reported physician-diagnosed high blood pressure or hypertension (NHANES III: n = 692; NHANES 1999-2000: n = 244).

#Among participants who reported physician-diagnosed hypercholesterolemia (NHANES III: n = 365; NHANES 1999-2000: n = 178).

decrease in the proportion of non-Hispanic whites and the increase in the proportion of persons of other race/ethnicity are more substantial among individuals with diabetes than in the general population (data not shown).

Mean body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters) among adults with diagnosed diabetes increased significantly from 29.9 in NHANES III to 32.3 in NHANES 1999-2000 ( $P=.002$ ), and the percentage of those with diagnosed diabetes who were obese (BMI  $\geq 30$ ) increased from 41.6% to 54.6% ( $P=.008$ ).

Individuals with previously diagnosed diabetes in NHANES 1999-

2000 had been diagnosed at a significantly younger age (46.7 vs 50.7 years;  $P=.003$ ) and had a significantly longer duration of diabetes (12.5 vs 10.2 years;  $P=.03$ ) than those in NHANES III. There was no significant change in the prevalence of microalbuminuria or history of cardiovascular disease.

#### Medication Use

Use of insulin alone decreased significantly (27.6% vs 17.0%,  $P=.002$ ), and insulin use in combination with oral agents increased significantly (3.5% vs 10.4%,  $P=.01$ ) over the 2 surveys. The percentage of adults who reported no pharmacological treatment for diabetes decreased (24.8% vs 18.7%;  $P=.06$ )

and use of blood pressure medications increased (77.0% vs 85.2%;  $P=.05$ ). Use of blood pressure medications could be underreported if use of renin-angiotensin system agents were attributed to nephropathy rather than to hypertension. Among adults with diagnosed high cholesterol, medication use for high cholesterol was more than 2-fold higher in NHANES 1999-2000 (56.1%) compared with NHANES III (27.7%) ( $P<.001$ ). There was no difference in regular use of aspirin.

#### HbA<sub>1c</sub> Levels

The mean HbA<sub>1c</sub> levels did not change from NHANES III to NHANES 1999-2000 (TABLE 2). Overall, only 37.0% of

**Table 2.** Levels of HbA<sub>1c</sub>, Blood Pressure, and Total Serum Cholesterol Among Adults Aged 20 Years and Older With Previously Diagnosed Diabetes in NHANES III (1988-1994) and NHANES 1999-2000\*

	NHANES III†			NHANES 1999-2000			P Value
	Overall‡	Men	Women	Overall	Men	Women	
<b>HbA<sub>1c</sub> Level</b>							
No. of adults	1218	541	677	404	203	201	
Mean (SE) [SD], %	7.6 (0.09) [2.02]	7.5 (0.09) [1.89]	7.7 (0.13) [2.13]	7.8 (0.16) [1.96]	7.7 (0.18) [1.72]	7.9 (0.30) [2.19]	.30
HbA <sub>1c</sub> category, %							
<7.0	44.3 (2.37)	44.4 (3.00)	44.13 (3.15)	37.0 (3.81)	37.0 (5.35)	37.0 (5.27)	.11
7.0-8.0	19.2 (1.49)	21.6 (2.37)	17.9 (2.07)	25.8 (3.30)	28.1 (4.65)	23.5 (4.40)	.07
>8.0	36.5 (2.26)	34.0 (2.44)	38.0 (3.34)	37.2 (3.39)	34.9 (4.90)	39.5 (5.95)	.87
>9.0	21.2 (1.67)	16.8 (1.94)	24.5 (2.42)	20.2 (2.68)	19.1 (4.08)	21.2 (4.64)	.75
>10.0	12.8 (1.57)	8.1 (1.35)	16.4 (2.29)	12.4 (2.55)	10.2 (2.88)	14.8 (4.61)§	.89
<b>Blood Pressure Level</b>							
No. of adults	1263	554	709	414	200	214	
Mean (SE) [SD], mm Hg							
Systolic	137.9 (0.76) [19.48]	135.9 (1.02) [16.12]	139.2 (1.21) [21.72]	134.8 (1.35) [19.90]	131.0 (1.78) [17.54]	138.6 (2.24) [21.36]	.04
Diastolic	73.5 (0.37) [10.08]	75.1 (0.60) [9.72]	72.2 (0.47) [10.11]	71.5 (1.26) [13.93]	73.3 (1.28) [13.32]	69.6 (1.84) [14.27]	.12
Normal (SBP<130 mm Hg and DBP<80 mm Hg)	29.0 (1.73)	28.9 (2.65)	29.6 (2.82)	35.8 (3.67)	38.5 (5.18)	33.1 (5.31)	.10
High normal (SBP of 130-139 mm Hg or DBP of 80-89 mm Hg)	28.2 (1.78)	34.8 (3.48)	23.4 (2.09)	23.8 (2.80)	26.5 (4.52)	21.1 (3.90)	.19
Hypertension (SBP $\geq$ 140 mm Hg or DBP $\geq$ 90 mm Hg)	42.9 (1.87)	36.3 (3.01)	47.0 (2.34)	40.4 (3.67)	35.1 (4.71)	45.8 (6.19)	.56
<b>Total Serum Cholesterol Level</b>							
No. of adults	1210	538	672	390	196	194	
Total, mean (SE) [SD], mg/dL	222.8 (2.14) [51.39]	207.9 (2.69) [46.90]	234.4 (2.83) [51.86]	208.9 (3.07) [43.55]	204.5 (4.51) [41.58]	213.5 (5.52) [45.11]	<.001
Total $\geq$ 200 mg/dL	66.1 (1.98)	55.3 (3.15)	74.5 (2.46)	51.8 (3.33)	50.0 (5.12)	53.8 (5.51)	<.001

Abbreviations: DBP, diastolic blood pressure; HbA<sub>1c</sub>, glycosylated hemoglobin; NHANES, National Health and Nutrition Examination Survey; SBP, systolic blood pressure. SI conversion factor: To convert total serum cholesterol levels to mmol/L, multiply mg/dL values by 0.0259.

\*All values are % (SE) unless otherwise noted.

†Age-standardized to the NHANES 1999-2000 population using age groups 20-39 years, 40-59 years, and  $\geq 60$  years.

‡In NHANES III the overall unadjusted mean (SE) HbA<sub>1c</sub> level was 7.7% (0.10) and the overall percentages (SEs) in HbA<sub>1c</sub> categories were 43.5 (2.52) at <7.0%, 17.7 (1.46) at 7.0%-8.0%, 38.8 (2.48) at >8.0%, 23.3 (1.94) at >9.0%, and 14.1 (1.69) at >10%. The overall unadjusted mean (SE) systolic blood pressure was 135.5 (0.85) mm Hg, mean (SE) diastolic pressure was 74.4 (0.45), and the overall percentages (SEs) in blood pressure categories were 33.2 (2.14), 28.8 (2.01), and 38.0 (2.01) in the normal, high normal, and hypertension categories, respectively. The overall unadjusted mean (SE) total serum cholesterol level was 221.6 (2.59) mg/dL and the overall percentage (SE) with levels  $\geq 200$  mg/dL was 66.0 (2.36).

§Relative standard error (SE/estimate  $\times 100\%$ ) >30% and therefore the estimate should be interpreted with caution.

adults in NHANES 1999-2000 had HbA<sub>1c</sub> levels at the ADA goal of less than 7.0%. The percentage of participants with HbA<sub>1c</sub> levels less than 7.0% did not change significantly from NHANES III ( $P=.11$ ) and did not differ by sex. Overall, the percentage of participants with HbA<sub>1c</sub> levels greater than 8%, the level suggested by the ADA for focused treatment action, was 37.2% in NHANES 1999-2000 and was unchanged from NHANES III ( $P=.87$ ).

### Blood Pressure Levels

The mean systolic blood pressure among adults with diagnosed diabetes was significantly lower in NHANES 1999-2000, particularly in men, but the diastolic blood pressure did not change appreciably between the surveys (Table 2). There was a slight increase in the percentage of participants with blood pressure at the level currently recommended by the ADA (systolic <130 mm Hg and diastolic <80 mm Hg) from NHANES III (29.0%) to NHANES 1999-2000 (35.8%) ( $P=.10$ ), with a corresponding small decrease in the percentage with high normal (28.2% vs 23.8%;  $P=.19$ ) and hypertensive (42.9% vs 40.4%;  $P=.56$ ) blood pressures. The proportions based on the recommended levels by the ADA in 1995 (systolic <130 mm Hg and diastolic <85 mm Hg) also did not change significantly from the NHANES III (1988-1994) (32.1%) to NHANES 1999-2000 (36.6%) ( $P=.29$ ).

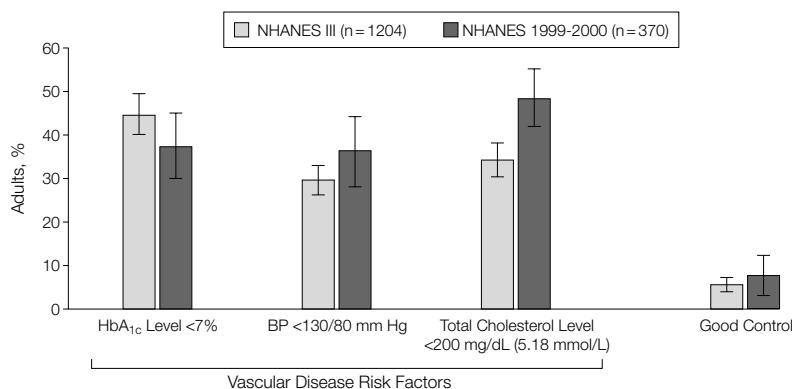
### Total Serum Cholesterol Levels

Overall, total serum cholesterol levels decreased significantly from NHANES III to NHANES 1999-2000 ( $P<.001$ ) (Table 2). However, in NHANES 1999-2000, 50.0% of men and 53.8% of women still had total serum cholesterol levels of 200 mg/dL (5.18 mmol/L) or greater, below which is the NCEP-ATP-III goal.

### Combined Control of Risk Factors

Overall, the percentage of adults with diagnosed diabetes in NHANES 1999-2000 who achieved currently recommended goals of HbA<sub>1c</sub> level, blood

**Figure.** Percentages of Adults With Recommended Levels of Vascular Disease Risk Factors in NHANES III (1988-1994) and NHANES 1999-2000



Includes only adults aged 20 years and older with previously diagnosed diabetes who have information on all 3 risk factors. Those with "good control" had all of these recommended levels; the relative SE (SE/estimate  $\times 100\%$ ) was  $>30\%$  and therefore the estimate should be interpreted with caution. Data from the National Health and Nutrition Examination Survey III (NHANES III) are age-standardized to the NHANES 1999-2000 population using age groups 20-39 years, 40-59 years, and 60 years and older. BP indicates blood pressure; HbA<sub>1c</sub>, glycosylated hemoglobin.

pressure, and total serum cholesterol level was only 7.3% (95% confidence interval, 2.8%-11.9%) (FIGURE). This is similar to the percentage who had these recommended levels in NHANES III (5.2%; 95% confidence interval, 3.8%-6.6%).

### COMMENT

Compelling evidence from well-designed, randomized clinical trials demonstrates that control of glucose levels, blood pressure, and cholesterol levels can dramatically delay or prevent the microvascular and macrovascular complications of diabetes.<sup>8,9,11-15</sup> Based on these data, the ADA,<sup>8</sup> the JNC,<sup>19</sup> and the NCEP<sup>20</sup> have developed guidelines for control of blood glucose levels, blood pressure, and cholesterol levels in individuals with diabetes. Despite these evidence-based guidelines, only a small fraction (2.8% to 11.9%) of adults with diagnosed diabetes in the United States are achieving the currently recommended levels of control. Other studies examining diabetes care in various clinical settings also have found that current medical practice is not achieving goals for management of glucose levels, blood pressure, and lipid levels in individu-

als with diabetes.<sup>23,33-36</sup> This study presents contemporary data from a nationally representative sample of noninstitutionalized adults in the United States with previously diagnosed diabetes. Comparison of the current data and representative data from approximately a decade earlier, obtained through similar standardized procedures, demonstrates significant improvement in the control of total cholesterol levels, but little to no change in control of blood glucose levels and blood pressure.

The period between NHANES III (1988-1994) and NHANES 1999-2000 has seen a substantial accumulation of evidence regarding the benefits of glycemic control. In 1993, the landmark DCCT study showed that intensive glycemic therapy of type 1 diabetes reduced the risk of microvascular disease by up to 70%.<sup>8</sup> Similar dramatic reductions in risk of microvascular complications in type 2 diabetes were subsequently found in the United Kingdom Prospective Diabetes Study (UKPDS).<sup>9</sup> Despite this compelling evidence of benefit, an ADA recommendation of an HbA<sub>1c</sub> target level of less than 7.0% in January 1995, the creation of the National Diabetes Educa-

tion Program (NDEP) in 1997<sup>37</sup> to promulgate the importance of glycemic control, and the advent of several new classes of medications for glycemic control,<sup>38</sup> NHANES 1999-2000 found no change in mean HbA<sub>1c</sub> values or in the fraction of adults with diabetes with HbA<sub>1c</sub> levels below the target levels. Long-term follow-up of the DCCT study population provides impressive new evidence of the importance of glycemic control. The period of improved glycemic control in the intensively treated arm of the DCCT continues to yield potent reduction in risk of microvascular disease well beyond the period of intensive implementation<sup>11</sup> and the beneficial effect of glycemic control now extends to macrovascular disease, indicated by reduced carotid artery wall thickening.<sup>12</sup> These latest observations should strengthen public health efforts to translate intensive glycemic control into clinical practice.

Impressive evidence that intensive control of blood pressure in adults with type 2 diabetes prevents both microvascular and macrovascular diseases also emerged during and after NHANES III,<sup>13,14,39</sup> leading to recommendations by the JNC-5 in 1993 and the ADA in 1995 that blood pressure levels for patients with diabetes should be lower (<130/85 mm Hg) than in other hypertensive groups. The recommended blood pressure level was further reduced to less than 130/80 mm Hg by the ADA in 2001<sup>18</sup> and the JNC-7 in 2003.<sup>19</sup> From NHANES III to NHANES 1999-2000, the prevalence of hypertension increased significantly in the general US population, and its prevalence was associated with risk factors for diabetes including older age, non-Hispanic black race, and higher BMI.<sup>40</sup> When individuals with diabetes were excluded from analysis, the prevalence of hypertension was no longer significantly increased. That analysis of individuals with diagnosed hypertension found that the percentage of those with diabetes and hypertension controlled to less than 140/90 mm Hg declined nonsignificantly (to 46.9%) in those with

diabetes. We found a small but statistically significant decrease in mean systolic blood pressure in individuals with diagnosed diabetes and a small and nonsignificant increase in the fraction of participants with diabetes with normal blood pressure. The new guidelines for control of blood pressure issued near the conclusion of NHANES III may have contributed to the small but statistically significant decrease in mean systolic blood pressure in individuals with diagnosed diabetes in NHANES 1999-2000, but there has been minimal, if any, effect in reducing the proportion of those with blood pressure of 140/90 mm Hg or greater.

Data from NHANES 1999-2000 was collected just after clinical trials demonstrated that, by lowering lipid levels, individuals with diabetes can substantially reduce the risk of developing cardiovascular disease.<sup>15</sup> Moreover, in 1998, diabetes was identified as a risk factor for cardiovascular disease equivalent to having preexisting coronary artery disease.<sup>41</sup> The ADA guidelines on management of lipid disorders issued in 1993 were revisited in 1998 based on these new data<sup>42</sup> and the American Heart Association<sup>43</sup> and the NCEP<sup>20</sup> also subsequently issued guidelines for lipid management in diabetes. Thus the improvement in total cholesterol levels observed in NHANES 1999-2000 occurred on the cusp of new data showing the benefits of lowering lipid levels, and further reductions in total cholesterol levels may be anticipated in the future as a result of dissemination of the new guidelines.

Progress in improving risk factors for vascular disease among individuals with diagnosed diabetes in the United States over nearly a decade has been modest. While there has been increased awareness among physicians and individuals with diabetes of the use of HbA<sub>1c</sub> levels to monitor glycemic control,<sup>23</sup> only 37.0% of adults with diagnosed diabetes in the United States are achieving the ADA goal of HbA<sub>1c</sub> levels less than 7.0%. In addition, 37.2% of adults with diagnosed diabetes have HbA<sub>1c</sub> levels greater than 8.0%, the level of additional treat-

ment action suggested by the ADA. Although the percentage of adults with diagnosed diabetes and diagnosed hypertension who use blood pressure medication has increased in the past decade, only 35.8% of individuals with diagnosed diabetes have achieved the current ADA blood pressure goal of less than 130/80 mm Hg and only 36.6% achieved the ADA goal set in 1995 (<130/85 mm Hg); 40.4% have hypertensive blood pressure levels. Finally, although the percentage of adults with diagnosed high cholesterol levels has increased and twice as many of these adults report taking medication for their high cholesterol in NHANES 1999-2000 compared with NHANES III (1988-1994), more than half the individuals with diagnosed diabetes have total cholesterol levels greater than 200 mg/dL (5.18 mmol/L). The increased use of medication to control high cholesterol levels and high blood pressure has not been accompanied by attention to lifestyle change; fewer adults with diabetes report eating less fat to control cholesterol than approximately a decade ago, and there has been no change in the use of weight control or exercise to control lipid levels or blood pressure. Due to the small sample size, we were unable to stratify the analysis by previously diagnosed high blood pressure or high cholesterol levels.

Biological and behavioral characteristics of individuals with diagnosed diabetes are likely to affect control of risk factors for vascular disease. The earlier age at diagnosis of diabetes in NHANES 1999-2000 may reflect an earlier onset of disease or may be due to increased screening for undiagnosed diabetes leading to individuals being diagnosed at an earlier point in the disease pathway. This earlier age at diagnosis corresponded to a significantly longer duration of diabetes in 1999-2000. The longer duration might also reflect increased longevity due to better treatment. The increase in BMI of adults with diagnosed diabetes in the United States over nearly a decade mirrors the increase in prevalence of overweight and obesity in the US popula-

tion as a whole.<sup>44</sup> Both longer duration of diabetes and increased BMI are likely to correspond to higher levels of glycemia, blood pressure, and cholesterol; however, these levels did not appear to increase over the past decade. This may be due in part to the greater use of medications for control of blood glucose levels, blood pressure, and cholesterol levels that was observed in NHANES 1999-2000. Thus, although progress toward achieving guidelines for therapy has been disappointing, maintenance of levels of HbA<sub>1c</sub> control, in the face of increased BMI and duration of diabetes, may reflect intensification of therapy. The greater improvement in cholesterol levels compared with glycemic control may reflect differences in the complexity of the medical regimens for these conditions, as well as the earlier initiation and broader dissemination of messages from the NCEP compared with the NDEP. These factors could influence both prescription of and adherence to therapy.

A major limitation of this study is the small number of participants with diagnosed diabetes in NHANES 1999-2000, which limits analyses by subgroups, specifically by age, race/ethnicity, or treatment group. In addition, the surveys only include non-institutionalized adults. There were 68 500 residents with a diagnosis of diabetes in nursing homes in 1995<sup>45</sup> and 81 700 residents in 1999.<sup>46</sup> We have no information on risk factors for vascular disease among these individuals with diagnosed diabetes. In addition, the NHANES surveys are cross-sectional in design. Although we can draw inferences on trends among participants with diagnosed diabetes, different adults participated in each survey and therefore we cannot draw conclusions on temporal relationships of observations.

Rapidly increasing rates of type 2 diabetes in the United States have been attributed to aging of the population, increased prevalence of overweight and obesity, and decreased physical activity.<sup>47,48</sup> We recently reported<sup>49</sup> and show here a slight trend for an increase in the

overall prevalence of previously diagnosed diabetes among adults aged 20 years and older, although the change was not significantly different. The lack of a statistically significant increase in the prevalence of previously diagnosed diabetes in NHANES 1999-2000 could be due to the small sample size of the survey. The 95% confidence interval for the change in the prevalence of diagnosed diabetes between the 2 surveys ranges from a decrease of 0.34 percentage points to an increase of 1.98 percentage points. The estimated prevalence of diagnosed diabetes in NHANES 1999-2000 is similar in magnitude to that obtained by the National Health Interview Survey (prevalence of 5.9% for persons aged  $\geq 18$  years in 2000), which interviews a much larger number of participants resulting in more precise estimates.<sup>50</sup>

The cost of providing care for diabetes and its complications in the United States is rapidly increasing and was estimated at \$132 billion annually in 2002.<sup>2</sup> The failure to achieve recommended levels of control of vascular risk factors, coupled with the rise in type 2 diabetes and its occurrence in individuals at earlier ages—which increases the risk of duration-dependent vascular complications—have ominous implications for the future burden of morbidity, mortality, and health care costs associated with diabetes.

The increased awareness of the importance of controlling risk factors for vascular disease among adults with diabetes has led to national programs such as the “Control the ABCs” (for which A, B, and C indicate HbA<sub>1c</sub>, blood pressure, and cholesterol, respectively) campaign by the NDEP<sup>37</sup> and the Diabetes Quality Improvement Project.<sup>51</sup> While these programs represent important steps toward improving the quality of diabetes care, further measures are needed to reduce the large proportion of adults with diagnosed diabetes in the United States who continue to have high levels of blood glucose, blood pressure, and total cholesterol. Ongoing monitoring and measurement of the

quality of care, empowering clinicians with medical decision-support tools and patients with information to improve the quality of care they receive, and building incentives for providing comprehensive care into the health care delivery system<sup>52</sup> are essential to translating into practice the therapies that have been proven effective in reducing the risk of vascular disease in individuals with diabetes.

**Author Contributions:** Drs Saydah and Cowie had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

**Study concept and design; analysis and interpretation of data; drafting of the manuscript:** Saydah, Fradkin, Cowie.

**Acquisition of data:** Cowie.

**Critical revision of the manuscript for important intellectual content; statistical expertise; administrative, technical, or material support:** Saydah, Cowie.

**Obtained funding; study supervision:** Fradkin, Cowie.

**Funding/Support:** The National Institute of Diabetes and Digestive and Kidney Diseases funded portions of the data collected in the NHANES III and NHANES 1999-2000. Dr Saydah was an employee of Social & Scientific Systems Inc during the completion of this work, under a contract (N01-DK-1-2478) from the National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health.

**Acknowledgment:** We thank Anthony Pridgen, BS, and Danita Byrd-Holt, BBA, from Social & Scientific Systems Inc for their programming support and Keith Rust, PhD, from Westat for his statistical guidance.

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