Trends in A1C Concentrations Among U.S. Adults With Diagnosed Diabetes From 1999 to 2004

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A1C is formed when glucose reacts nonenzymatically with amino acids on hemoglobin. Its concentration represents an integrated measure of glucose concentration during hemoglobin's lifespan, which is about 2–3 months (1). Because A1C concentration predicts the risk for microvascular and macrovascular complications (2,3), it is used in the clinical setting to assess longer-term glycemic control among people with diabetes. Generally, A1C concentrations <7% are regarded as acceptable glycemic control (4).

Approximately 44% of U.S. adults with diagnosed diabetes had a concentration of A1C <7% during 1988–1994 compared with ~36–37.0% during 1999–2000 (5,6). More recently, data from the National Committee for Quality Assurance showed steady increases in the percentage of patients receiving annual testing for A1C and decreases in the percentage of patients with poor glycemic control from 2000 to 2006 (7). Our objective was to examine trends in glycemic control among U.S. adults with diagnosed diabetes from 1999 to 2004.

RESEARCH DESIGN AND METHODS

The National Health and Nutrition Examination Survey (NHANES) 1999–2004 included nationally representative samples of the noninstitutionalized, civilian U.S. population, selected using a multistage, stratified sampling design (8). Participants were asked the following: "Other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?" In addition to answering "yes" or "no," participants could report having "borderline" diabetes. Individuals with borderline diabetes were excluded from further analysis.

Concentrations of A1C were determined by using boronate affinity high-performance liquid chromatography on Primus CLC330 and Primus CLC385 instruments (Primus, Kansas City, MO). Interassay coefficients of variation were <3% (9). All measurements were performed at the Diabetes Diagnostic Laboratory at the University of Missouri-Columbia. The method was standardized to the reference method of the Diabetes Control and Complications Trial. A plot of the mean concentrations of two levels of A1C control subjects from 1999 to 2004 shows no evidence of drift.

Analyses, performed using SUDAAN to account for the complex sampling design, were limited to participants aged ≥20 years who attended the mobile examination center. Prevalence ratios were estimated using log-binomial regression analysis (10).

RESULTS

A total of 1,334 participants with diagnosed diabetes had a measurement of A1C. Of all patients with diabetes, the percentage of participants whose diabetes had been diagnosed was 70.2% in 1999–2000, 68.5% in 2001–2002, and 74.6% in 2003–2004. The mean age, sex, and racial or ethnic composition of the samples were similar for the three 2-year cycles.

In 2003–2004, the geometric mean concentration of A1C was significantly lower than in 1999–2000 (Table 1). The unadjusted percentage of participants with diagnosed diabetes who had a concentration of A1C <7% increased significantly, from 37.0% (95% CI 28.4–45.7) in 1999–2000 to 56.8% (49.6–64.0) in 2003–2004 (Table 1). These percentages were little affected by adjustment for age, sex, ethnicity, educational status, smoking status, hypertension, concentrations of total cholesterol, BMI, waist circumference, treatment (oral glucose-lowering medications only, insulin only, both, or no oral glucose-lowering medications or insulin), and duration of diabetes in logistic regression (1,160 participants with complete data). Compared with participants from NHANES 1999–2000, the adjusted prevalence ratios for having a concentration of A1C <7% were 1.32 (0.98–1.79) for participants from NHANES 2001–2002 and 1.46 (1.08–1.97) for participants from NHANES 2003–2004 (P for linear trend = 0.010). Trends did not differ significantly between men and women.

Improvements in A1C were steadiest among whites but occurred primarily from 1999–2000 to 2001–2002 among African Americans and Mexican Americans. Despite these apparent differences, no significant differences in trends among the ethnic groups were found, possibly as a result of limited statistical power. For the entire 6-year period, glycemic control was similar in men and women (P = 0.235). However, white participants exhibited better control than African-American (P = 0.001) or Mexican-American (P < 0.001) participants.

CONCLUSIONS

Although glycemic control as determined by a concentration of A1C <7% did not change significantly from 1988–1994 to 1999–

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Abbreviations: NHANES, National Health and Nutrition Examination Survey.

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

Table 1—*Unadjusted percentage of A1C <7% and unadjusted geometric mean A1C among U.S. adults with diagnosed diabetes aged ≥20 years*

	NHANES 1999–2000		NHANES 2001–2002		NHANES 2003–2004		*P* for linear trend	*P* for interaction*
	n†	A1C <7%‡	*n*†	A1C <7%‡	*n*†	A1C <7%‡		
Total	404	37.0 (4.3)	446	49.7 (3.6)	484	56.8 (3.6)	0.001	—
Men	203	37.0 (4.6)	224	46.6 (4.4)	244	55.3 (4.5)	0.007	0.913
Women	201	37.0 (5.9)	222	52.7 (4.2)	240	58.1 (4.6)	0.007	—
White§	120	41.8 (6.5)	188	53.6 (4.2)	218	63.5 (4.4)	0.008	0.324
African American	110	28.1 (4.1)	101	44.2 (4.2)	104	43.5 (4.9)	0.021	—
Mexican American	132	28.9 (4.4)	118	42.4 (3.1)	138	34.0 (3.9)	0.388	—

	n†	A1C (%)‡	*n*†	A1C (%)‡	*n*†	A1C (%)‡	*P* for linear trend	*P* for interaction*
Total	404	7.60 ± 0.15	446	7.24 ± 0.14	484	7.01 ± 0.09	0.002	—
Men	203	7.56 ± 0.13	224	7.37 ± 0.19	244	7.11 ± 0.19	0.134	0.439
Women	201	7.64 ± 0.24	222	7.12 ± 0.14	240	6.92 ± 0.09	0.006	—
White§	120	7.34 ± 0.21	188	7.04 ± 0.12	218	6.78 ± 0.10	0.024	0.401
African American	110	7.97 ± 0.18	101	7.53 ± 0.19	104	7.42 ± 0.18	0.032	—
Mexican American	132	7.95 ± 0.21	118	7.62 ± 0.14	138	7.75 ± 0.20	0.657	—

Data are percent (SE) or geometric means ± SE unless otherwise indicated. *P* for linear trend determined from linear contrasts generated from orthogonal polynomial coefficients. *Interactions tested in log-binomial regression models for dichotomized concentration of A1C and in a linear regression model for log-transformed A1C. †Unweighted sample size. ‡Weighted percentage or mean. §Results for race or ethnicity designation "other" not shown because of small sample size.

2000 (5,6), it is encouraging that a significant improvement appears to have occurred from 1999–2000 to 2003–2004. After controlling for factors known to be associated with A1C (11–14), we still found a substantial increase in glycemic control, suggesting that other factors must have been at work during the study period. A trend toward earlier detection of diabetes could have explained the improvement in glycemic control. However, we did not find evidence of such a trend during the study period. Therefore, it is conceivable that the concerted efforts of professional organizations and clinicians at improving glycemic control are bearing fruit. A variety of approaches can improve glycemic control (15–20). Learning whether these approaches or other factors may have positively impacted the recent trends in glycemic control could provide important lessons for effecting further improvements in glycemic control in the future.

Significant ethnic disparities in glycemic control were noted and are consistent with previous findings (21). The disparity in glycemic control stands in contrast to the results from some studies that showed no or little ethnic difference in annual testing for A1C (22,23).

Some limitations should be considered. We were unable to provide separate estimates of glycemic control for type 1 and type 2 diabetes. Sample sizes were inadequate to provide detailed estimates when the sociodemographic variables were considered simultaneously.

In conclusion, our results are consistent with other data suggesting that improvements in glycemic control have occurred among patients with diabetes in the U.S. As welcome as the recent favorable trends in glycemic control are, additional efforts are needed to help the ~40% of patients with diabetes who do not have adequate glycemic control.

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