SPECIAL ARTICLE

Achievement of Goals in U.S. Diabetes Care, 1999–2010

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ABSTRACT

BACKGROUND

Tracking national progress in diabetes care may aid in the evaluation of past efforts and identify residual gaps in care.

METHODS

We analyzed data for adults with self-reported diabetes from the National Health and Nutrition Examination Survey and the Behavioral Risk Factor Surveillance System to examine risk-factor control, preventive practices, and risk scores for coronary heart disease over the 1999–2010 period.

RESULTS

From 1999 through 2010, the weighted proportion of survey participants who met recommended goals for diabetes care increased, by 7.9 percentage points (95% confidence interval [CI], 0.8 to 15.0) for glycemic control (glycated hemoglobin level <7.0%), 9.4 percentage points (95% CI, 3.0 to 15.8) for individualized glycemic targets, 11.7 percentage points (95% CI, 5.7 to 17.7) for blood pressure (target, <130/80 mm Hg), and 20.8 percentage points (95% CI, 11.6 to 30.0) for lipid levels (target level of low-density lipoprotein [LDL] cholesterol, <100 mg per deciliter [2.6 mmol per liter]). Tobacco use did not change significantly, but the 10-year probability of coronary heart disease decreased by 2.8 to 3.7 percentage points. However, 33.4 to 48.7% of persons with diabetes still did not meet the targets for glycemic control, blood pressure, or LDL cholesterol level. Only 14.3% met the targets for all three of these measures and for tobacco use. Adherence to the recommendations for annual eye and dental examinations was unchanged, but annual lipid-level measurement and foot examination increased by 5.5 percentage points (95% CI, 1.6 to 9.4) and 6.8 percentage points (95% CI, 4.8 to 8.8), respectively. Annual vaccination for influenza and receipt of pneumococcal vaccination for participants 65 years of age or older rose by 4.5 percentage points (95% CI, 0.8 to 8.2) and 6.9 percentage points (95% CI, 3.4 to 10.4), respectively, and daily glucose monitoring increased by 12.7 percentage points (95% CI, 10.3 to 15.1).

CONCLUSIONS

Although there were improvements in risk-factor control and adherence to preventive practices from 1999 to 2010, tobacco use remained high, and almost half of U.S. adults with diabetes did not meet the recommended goals for diabetes care.

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An estimated 18.8 million adults in the United States have diagnosed diabetes mellitus.[1] Diabetes increases the risk of disabling and life-threatening complications from microvascular disease (affecting the kidneys, eyes, and limbs) and macrovascular disease (involving the coronary vascular, cerebrovascular, and peripheral vascular systems). Two decades ago, the Diabetes Control and Complications Trial (DCCT)[2] and the United Kingdom Prospective Diabetes Study (UKPDS)[3] showed that improved glycemic control is associated with reduced microvascular complications and long-term reductions (at the least) in macrovascular disease.[4,5] Subsequent trials showed that lowering blood pressure, reducing cholesterol levels, and avoiding tobacco decreases the incidence of vascular diseases and mortality.[6-8] Therefore, guidelines for diabetes care[9] recommend risk-factor control and regular screening for complications in order to treat conditions related to diabetes in their early stages.

Diabetes is one of the first conditions for which disease-specific indicators based on practice guidelines have been used to "score" the quality of care and preventive services.[10,11] Previous studies have shown that diabetes care improved between 1988 and 2002.[12] An assessment of the changes in care over the past two decades is particularly important because this period has been characterized by increased public awareness and quality-improvement initiatives and by large trials comparing alternative treatment targets for diabetes.[13-17] These studies showed that there were no incremental cardiovascular benefits of aggressive control and led to a renewed emphasis on individualized glycemic targets based on age, coexisting conditions, and time since the diagnosis of diabetes.[18,19] For this study, we have used national surveillance data from 1999 through 2010 to assess trends in risk-factor control and adherence to preventive practices among U.S. adults with diabetes, to evaluate care based on individualized performance measures, and to assess variation in these trends across different clinical and sociodemographic groups.

METHODS

STUDY DESIGN

We analyzed data from the National Health and Nutrition Examination Survey (NHANES) (1999 through 2002, 2003 through 2006, and 2007 through 2010) and from the Behavioral Risk Factor Surveillance System (BRFSS) survey (2000, 2004, and 2008). The NHANES uses stratified, multistage, probability-cluster techniques to ensure that sample populations are representative of the nation's noninstitutionalized civilians. Data are collected from household interviews and from standardized medical examinations and blood-sample collections performed in mobile examination centers. Response rates for the NHANES cycles between 1999 and 2010 ranged from 75.4 to 80.0%. The BRFSS is an annual state-based survey, conducted over landline telephone networks, that collects self-reported data on health-related behavior from approximately 350,000 adults. The median BRFSS response rates across the years surveyed were 48.9% in 2000, 52.7% in 2004, and 53.3% in 2008. Further details about the study design, the survey instruments, and data-collection methods are available elsewhere.[20,21]

This analysis included 3355 adults from the NHANES who reported having received a diagnosis of diabetes from a health professional and 97,310 adults from the BRFSS who reported having diabetes. As in previous studies,[12] we evaluated the control of single or combined risk factors for microvascular and macrovascular complications of diabetes (glycemia, blood pressure, cholesterol level, and tobacco use) and adherence to preventive practices (screenings, glucose monitoring, and vaccinations). Analyzing each survey cycle independently over the study period, we benchmarked these results against a combination of performance measures from the National Quality Forum[22] and the American Diabetes Association (Table 1).[9]

INDICATOR AND COVARIATE DEFINITIONS

We used interview responses to classify participants in terms of age, race or ethnic group, educational level, income, and insurance status. Interview responses and examination data were used to obtain data on weight, duration of diabetes, receipt of glucose-lowering treatments, and the presence of coexisting conditions. Detailed definitions of self-reported, anthropometric, and biochemical indicators are described in the Methods section in the Supplementary Appendix, available with the full text of this article at NEJM.org.

We calculated the weighted proportions of

Table 1. Diabetes-Related Quality-of-Care Indicators, Care Targets, and Data Sources.*

Factor or Practice	Indicator	Target	Guideline	Source of Data
Risk factors				
Glycemia	Glycated hemoglobin level			
General target		<7.0%	ADA	NHANES
		>9.0% indicates poor control	NQF	NHANES
Individualized targets			ADA–EASD	
Age 18–44 yr without complications		≤6.5%		NHANES
Age 18–44 yr with complications		≤7.0%		NHANES
Age 45–64 yr without complications		≤7.0%		NHANES
Age 45–64 yr with complications		≤8.0%		NHANES
Age ≥65 yr without complications†		≤7.0 or ≤7.5%		NHANES
Age ≥65 yr with complications		≤8.0		NHANES
Blood pressure	Systolic	<130 mm Hg	ADA	NHANES
	Diastolic	<80 mm Hg	ADA	NHANES
Lipids	LDL cholesterol level	<100 mg/dl	NQF and ADA	NHANES
	LDL cholesterol level	<70 mg/dl (for persons with CVD)	ADA	NHANES
Tobacco use	Self-reported, or serum cotinine >10 ng/ml	—	ADA	NHANES
Preventive practices				
Lipid measurement	Self-reported	Annual	NQF and ADA	NHANES
Eye examination	Self-reported	Annual	NQF and ADA	BRFSS
Foot examination	Self-reported	Annual	NQF and ADA	BRFSS
Dental examination	Self-reported	Annual	ADA	BRFSS
Urine screening	Self-reported	Annual	NQF and ADA	Not available
Diabetes education	Self-reported	At diagnosis (and as needed subsequently)	ADA	BRFSS
Glucose monitoring	Self-reported	≥1 time/day	ADA	BRFSS
Vaccinations				
Influenza	Self-reported	Annual	NQF and ADA	BRFSS
Pneumococcal	Self-reported	1 time plus booster (if age ≥65 yr)	ADA	BRFSS
Use of ACE inhibitor or ARB	Self-reported	If ACR ≥30 mg/g	ADA	NHANES

* To convert the values for low-density lipoprotein (LDL) cholesterol to millimoles per liter, multiply by 0.02586. ACE denotes angiotensin-converting enzyme, ACR albumin:creatinine ratio, ADA American Diabetes Association, ARB angiotensin-receptor blocker, BRFSS Behavioral Risk Factor Surveillance System, CVD cardiovascular disease, EASD European Association for the Study of Diabetes, NHANES National Health and Nutrition Examination Survey, and NQF National Quality Forum.

† Two values are presented for persons 65 years of age or older without complications because there is no consensus regarding the most appropriate target for this risk group.

survey participants with glycemia that was poorly controlled (glycated hemoglobin level, >9.0%), moderately controlled (<8.0%), or well controlled (<7.0%), as defined by recommended standards. On the basis of recent reports,[18,19,23] we also used individualized glycated hemoglobin targets according to risk profile: participants younger than 45 years of age without complications (glycated hemoglobin level, ≤6.5%) or with complications (≤7.0%); those 45 to 64 years of age without complications (glycated hemoglobin level, ≤7.0%) or with complications (≤8.0%); and those 65 years

of age or older without complications (glycated hemoglobin level, ≤7.0% or ≤7.5%) or with complications (≤8.0%). The target for blood-pressure control was a level below 130/80 mm Hg, and the targets for lipid control were a low-density lipoprotein (LDL) cholesterol level of less than 100 mg per deciliter (2.6 mmol per liter), with a target of less than 70 mg per deciliter (1.8 mmol per liter) for those with preexisting cardiovascular disease.

To convey the benefits of optimizing diabetes care, at each time period, we reported the proportion of participants without microalbuminuria (albumin:creatinine ratio, <30 mg of albumin per gram of creatinine) and calculated the 10-year risk of coronary heart disease with the use of a diabetes-specific score (as calculated in the UKPDS) and a general score (as calculated in the Framingham Heart Study).[24,25]

Indicators that participants were adhering to preventive practices included annual measurement of lipid levels and eye, foot, and dental examinations; receipt of recommended vaccinations (annual influenza vaccination and ≥1 lifetime pneumococcal vaccination, especially for patients 65 years of age or older); receipt of diabetes education at diagnosis; and monitoring of glucose levels (one or more times per day). For participants with an albumin:creatinine ratio of 30 mg of albumin per gram of creatinine or higher, another indicator was the receipt of an angiotensin-converting–enzyme (ACE) inhibitor or angiotensin-receptor blocker (ARB).

STATISTICAL ANALYSIS

We conducted the statistical analysis with the use of SAS software, version 9.2 (SAS Institute) and SUDAAN software, version 10.0 (Research Triangle Institute), adjusting for complex survey designs and nonresponse. Sample sizes varied according to the primary outcome analyzed. The proportion of study participants with missing data ranged from 0.2% (educational level) to 12.0% (annual measurement of lipid levels). We determined the distribution of risk factors (glycated hemoglobin level, blood pressure, LDL cholesterol level, and status with respect to tobacco use) among participants and tested for distributional differences at successive time points, using adjusted Wald F tests. We calculated the proportions of participants who met single and combined targets in two categories: risk-factor control (control of glycated hemoglobin level, blood pressure, LDL cholesterol level, and tobacco use) and adherence to recommended schedules (eye examinations, foot examinations, and influenza vaccinations). We calculated the predicted change in proportions of participants meeting targets between each period by using an interaction term for survey years in models and standardizing to the covariate distribution for the entire sample. We used nonoverlapping 95% confidence intervals as an indicator of significance and did not adjust for multiple testing because this could have led to misinterpretation of the data.[26] To determine which variables were associated with changes in risk-factor control and preventive practices over time, we used logistic-regression models adjusted for age, sex, race or ethnic group, educational level, health insurance status, and use or nonuse of insulin.

RESULTS

CHANGES IN U.S. POPULATION WITH DIABETES

Among the population surveyed with diabetes, the distribution of age and sex, the proportion without health insurance, and the time since diagnosis remained fairly constant across survey years (Table 2). Increasing proportions of adult patients with diabetes identified themselves as Hispanic or Mexican American or as members of a race or ethnic group other than non-Hispanic white, non-Hispanic black, Hispanic, or Mexican American.

As compared with the population with diabetes covered in NHANES from 1999 through 2002 and in the BRFSS survey in 2000, the population covered in later surveys had larger proportions of participants reporting at least some college education and an income of $20,000 or higher. The proportion of overweight participants decreased, whereas the proportions that were obese increased, as did the proportion of participants taking medications to lower glucose levels (in the NHANES) and the proportion using insulin (in the BRFSS).

Between the 1999–2002 period and the 2007–2010 period (Table 3), the proportion of patients with poor glycemic control decreased (–5.8 percentage points; 95% confidence interval [CI], –10.5 to –1.1). There were significant increases in the proportions of participants who met the recommended targets for glycated hemoglobin level (7.9 percentage points; 95% CI, 0.8 to 15.0),

Table 2. Characteristics of U.S. Adults with Diagnosed Diabetes.*

Characteristic	NHANES			BRFSS		
	1999–2002 (N=912)	2003–2006 (N=999)	2007–2010 (N=1444)	2000 (N=11,600)	2004 (N=25,593)	2008 (N=60,117)
	percent					
Age (yr)						
18–44	17.9±1.9	16.3±1.9	13.0±1.1	16.2±0.8	16.2±0.5	16.5±0.5
45–64	43.6±2.3	44.6±1.7	46.2±1.5	44.0±0.9	44.8±0.6	45.2±0.6
≥65	38.5±2.1	39.1±2.4	40.8±1.5	39.8±0.8	38.9±0.6	38.3±0.5
Mean	58.8±0.7	59.1±1.8	59.8±0.5	59.3±0.3	59.4±0.2	59.5±0.2
Female sex	50.7±2.0	54.2±1.7	50.8±2.1	51.2±0.9	49.5±0.6	49.1±0.6
Race or ethnic group†						
Non-Hispanic white	61.5±3.5	65.4±3.4	61.4±3.7	66.1±1.0	65.0±0.7	63.7±0.6
Non-Hispanic black	16.3±2.5	17.0±2.1	18.0±2.1	15.0±0.6	14.3±0.5	12.4±0.4
Hispanic	—	—	—	14.7±0.9	14.4±0.6	16.7±0.6
Mexican American	6.9±1.2	8.0±1.5	8.4±1.5	—	—	—
Other	15.4±3.8	9.7±1.4	12.2±1.4	4.2±0.4	6.3±0.4	7.2±0.3
Educational level†‡						
<High school	36.7±2.3	28.4±1.6	31.4±1.4	24.6±0.9	20.6±0.6	17.1±0.5
High-school graduate	25.4±2.1	26.7±1.8	23.4±2.2	32.6±0.8	32.1±0.6	32.9±0.5
At least some college	37.9±2.5	44.9±2.6	45.3±2.2	42.8±0.9	47.3±0.7	50.1±0.6
Annual household income <$20,000†‡	37.2±2.7	28.4±1.9	25.9±2.3	34.1±1.0	33.2±0.7	29.5±0.6
Uninsured	9.9±1.4	10.4±1.2	11.1±1.1	10.0±0.6	11.0±0.5	9.6±0.4
Insulin use†	26.6±2.7	26.5±1.4	30.3±1.8	28.1±0.8	24.6±0.6	27.7±0.5
Any diabetes medication‡§¶	82.6±2.1	83.6±1.8	89.0±1.3	82.6±0.7	82.7±0.6	83.1±0.5
Time since diabetes diagnosis						
0 to <5 yr	38.3±2.4	34.8±2.0	34.1±1.6	40.2±0.9	40.2±0.7	38.3±0.5
5 to <15 yr	33.9±2.0	41.2±1.7	39.4±1.3	36.0±1.0	35.9±0.7	37.3±0.5
≥15 yr	27.8±1.8	23.9±1.7	26.5±1.4	23.8±0.7	23.9±0.6	24.4±0.5
Body-mass index†‡‖						
<25.0	17.1±2.0	15.4±1.8	13.0±0.9	21.0±0.7	17.6±0.6	24.2±0.4
25.0–29.9	31.3±2.3	28.5±2.1	24.0±1.5	36.5±0.9	33.3±0.6	34.5±0.5
≥30.0	51.6±2.8	56.1±2.4	63.0±1.9	42.5±0.9	49.1±0.7	41.4±0.5

* Plus–minus values are weighted percentages ±SE.
† The difference across the BRFSS surveys was significant (P<0.05 by the chi-square test).
‡ The difference across the NHANES surveys was significant (P<0.05 by the chi-square test).
§ In the NHANES, these data were based on self-report and medical drug inventory; in the BRFSS, the data were based on self-report only.
¶ Data are from the BRFSS 2007 survey, not the 2008 survey.
‖ The body-mass index is the weight in kilograms divided by the square of the height in meters.

blood pressure (11.7 percentage points; 95% CI, 5.7 to 17.7), and LDL cholesterol level (20.8 percentage points; 95% CI, 11.6 to 30.0). The proportion of participants using tobacco did not change significantly (–1.7 percentage points; 95% CI, –6.2 to 2.8). The population distributions of glycated hemoglobin and LDL cholesterol levels both improved significantly over time (the fraction of participants with poor control became smaller) (Fig. 1). From 1999 to 2010, the mean glycated

Table 3. Changes in Risk-Factor Control and Adherence to Preventive Practices over Time among U.S. Adults with Diagnosed Diabetes.*

Factor or Practice	1999–2002	2003–2006	2007–2010	Change from 1999–2002 to 2007–2010 (95% CI)	Change from 2003–2006 to 2007–2010 (95% CI)
	% of survey participants			percentage points	
Risk factors					
Glycated hemoglobin					
>9.0%	18.4	13.0	12.6	–5.8 (–10.5 to –1.1)	–0.4 (–3.8 to 3.0)
<8.0%	67.4	78.0	79.1	11.7 (6.3 to 17.1)	1.1 (–3.5 to 5.7)
<7.0%	44.3	56.8	52.2	7.9 (0.8 to 15.0)	–4.6 (–11.1 to 1.9)
Blood pressure <130/80 mm Hg	39.6	45.3	51.3	11.7 (5.7 to 17.7)	6.0 (0.4 to 11.6)
LDL cholesterol†					
<100 mm Hg	36.0	46.6	56.8	20.8 (11.6 to 30.0)	10.2 (2.5 to 17.9)
<70 mm Hg for persons with CVD	15.9	23.2	27.5	11.6 (–4.1 to 27.3)	4.3 (–8.5 to 17.1)
Current smoker, self-reported or cotinine >10 ng/ml	24.0	23.4	22.3	–1.7 (–6.2 to 2.8)	–1.1 (–5.4 to 3.2)
Glycated hemoglobin, blood-pressure, and LDL cholesterol targets and nonsmoking status achieved	4.6	9.5	14.3	9.7 (5.1 to 14.3)	4.8 (–0.4 to 10.0)
Preventive practices					
Annual lipid measurement	82.7	86.3	88.2	5.5 (1.6 to 9.4)	1.9 (–2.0 to 5.8)
Annual examinations					
Eye	75.1	72.6	73.4	–1.7 (–3.7 to 0.3)	0.8 (–0.7 to 2.3)
Foot	64.6	67.6	71.4	6.8 (4.8 to 8.8)	3.8 (2.1 to 5.5)
Dental	64.3	60.0	62.5	–1.8 (–6.8 to 3.2)	2.5 (1.0 to 4.0)
Diabetes education	49.3	53.2	54.6	5.3 (3.0 to 7.6)	1.4 (–0.4 to 3.2)
Blood glucose monitoring ≥ once daily	58.2	67.3	70.9	12.7 (10.3 to 15.1)	3.6 (1.9 to 5.3)
Vaccinations					
Annual influenza	55.5	56.8	60.0	4.5 (0.8 to 8.2)	3.2 (1.4 to 5.0)
Pneumococcal	42.1	48.3	49.0	6.9 (3.4 to 10.4)	0.7 (–1.0 to 2.4)
ACE or ARB, if ACR ≥30 mg/g‡	45.0	58.1	64.0	19.0 (10.0 to 28.0)	5.9 (–2.2 to 14.0)
Annual influenza vaccination and eye and foot examinations received	11.5	27.3	22.4	10.9 (9.3 to 12.5)	–4.9 (–6.3 to 3.5)
Risk of complications					
Free of microalbuminuria: ACR <30 mg/g	65.8	69.3	69.8	4.0 (0.0 to 8.0)	0.5 (–3.8 to 4.8)
10-yr risk of CHD					
UKPDS risk score	20.6	16.5	16.9	–3.7 (–6.0 to –1.4)	0.4 (–1.7 to 2.5)
Framingham Heart Study risk score	18.6	16.2	15.8	–2.8 (–4.5 to –1.1)	–0.4 (–1.9 to 1.1)

* Data for risk-factor control are from the NHANES 1999–2002, 2003–2006, and 2007–2010 surveys and data for preventive practices are from the BRFSS 2000, 2004, and 2008 surveys. The data are presented as weighted percentages of survey participants, with the exception of the 10-year risk of coronary heart disease (CHD), for which risk scores are provided. UKPDS denotes United Kingdom Prospective Diabetes Study.
† The values for LDL cholesterol, which were calculated with the use of the Friedewald formula (for all cases in which the triglyceride level was <400 mg per deciliter [4.5 mmol per liter]), are from a subsample of 1310 participants who fasted before testing.
‡ These data were based on self-report and the NHANES Medical Drug Inventory.

hemoglobin level decreased by 0.4 percentage points, to 7.2%; the mean LDL cholesterol level decreased by 17.7 mg per deciliter (0.5 mmol per liter), to 99.5 mg per deciliter (2.6 mmol per liter); and the mean blood pressure decreased by 4/2 mm Hg, to 130/68 mm Hg (data not shown). Improvements in the control of glycated hemoglobin levels occurred between the first two sur-

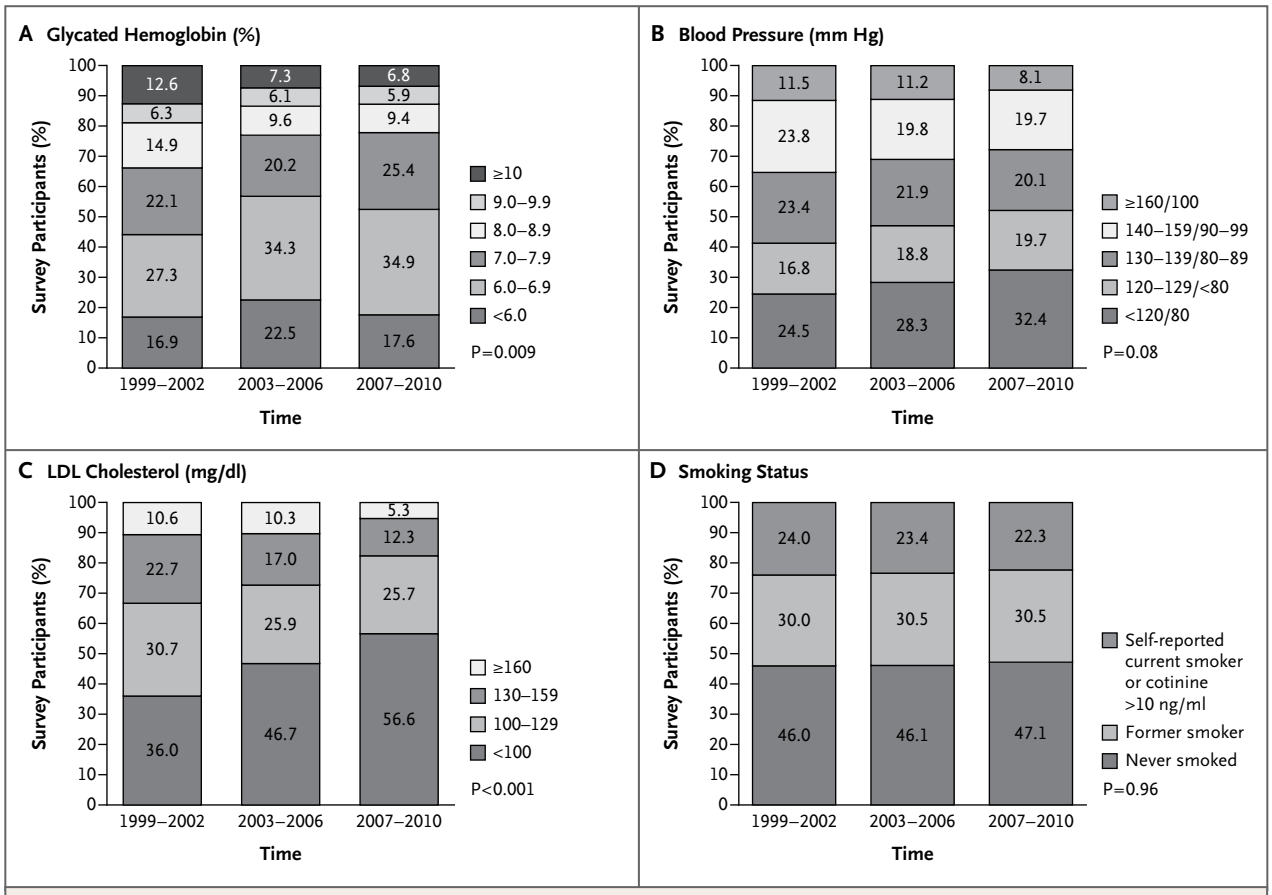

Figure 1. Distribution of Risk Factors for Microvascular and Macrovascular Complications among U.S. Adults with Diabetes, 1999–2010.

The distributions for glycated hemoglobin level (Panel A), blood pressure (Panel B), low-density lipoprotein (LDL) cholesterol level (Panel C), and smoking status (Panel D) are shown according to time periods designated in the National Health and Nutrition Examination Survey. Data are weighted percentages. The P values for the differences in distribution over time were calculated with the use of the adjusted Wald F test. The values for LDL cholesterol level, which were calculated with the use of the Friedewald formula (for all cases in which the triglyceride level was <400 mg per deciliter [4.5 mmol per liter]), are from a subsample of 1310 participants who fasted before testing. To convert the values for LDL cholesterol to millimoles per liter, multiply by 0.02586.

vey periods, whereas the improvements in blood pressure and LDL cholesterol levels occurred gradually over the entire 12-year period.

The proportion of U.S. adults with diabetes who were free of microalbuminuria increased by 4.0 percentage points (95% CI, 0.0 to 8.0), and the 10-year risk of coronary heart disease decreased significantly (–2.8 percentage points [UKPDS] and –3.7 percentage points [Framingham Heart Study]). Nevertheless, one third to one half of participants were not meeting the targets for glycated hemoglobin level, blood pressure, or LDL cholesterol level by 2010; 22.3% still smoked; and only 14.3% met the targets for all four risk factors.

A comparison of the data from 2000 and 2008 showed nonsignificant reductions in the percentage of adults with diabetes who were receiving annual eye examinations (–1.7 percentage points; 95% CI, –3.7 to 0.3) or dental examinations (–1.8 percentage points; 95% CI, –6.8 to 3.2). Increases were noted in annual checks of lipid levels (5.5 percentage points; 95% CI, 1.6 to 9.4), annual foot examinations (6.8 percentage points; 95% CI, 4.8 to 8.8), annual influenza vaccinations (4.5 percentage points; 95% CI, 0.8 to 8.2), and receipt of one pneumococcal vaccination (6.9 percentage points; 95% CI, 3.4 to 10.4), as well as at least daily self-monitoring of glucose levels (12.7 percentage points; 95% CI, 10.3 to 15.1), the receipt of diabetes education at diagnosis (5.3 percentage points; 95% CI, 3.0 to 7.6), and the use of ACE inhibitors or ARBs among those eligible for prescriptions (19.0 percentage points; 95% CI, 10.0 to 28.0). In the 2007–2010

surveys, more than 70% of participants reported undergoing annual eye examinations (73.4%), foot examinations (71.4%), and lipid checks (88.2%) and performing self-monitoring of glucose levels (70.9%), whereas 49 to 60% reported receiving vaccinations and 54.6% reported receiving diabetes education. Despite a marked increase (10.9 percentage points; 95% CI, 9.3 to 12.5) over the decade in the proportion of adults with diabetes who underwent annual influenza vaccination and eye and foot examinations, overall, only 22.4% of adults with diabetes met all three criteria in 2008.

CHANGES ACCORDING TO RISK GROUP

When individualized, risk-specific targets were used for glycated hemoglobin (Table 4), improvement in glycemic control was observed in every subgroup except younger adults with complications (i.e., persons 18 to 44 years of age with self-reported cardiovascular disease or retinopathy or with an albumin:creatinine ratio of 30 mg of albumin per gram of creatinine or higher [dropping from 39.4% in the 1999–2002 period to 28.2% in the 2007–2010 period]). Cumulatively, across all risk groups, individualized glycemic control improved by 9.4 percentage points (95% CI, 3.0 to 15.8) (data not shown). In the 2007–2010 period, up to three quarters of adults with diabetes who were 45 years of age or older were meeting their glycemic targets.

In logistic-regression models adjusted for age, race or ethnic group, educational level, and use or nonuse of insulin (Tables S2 and S3 in the Supplementary Appendix), persons 45 years of age or older had improved care profiles. Also, only those persons with health insurance began with generally better status in the 1999–2002 surveys than uninsured persons and were also more likely to improve with regard to meeting most recommended targets for care.

DISCUSSION

Adults with diabetes in the United States had substantial improvements in the control of risk factors for microvascular and macrovascular disease and in adherence to preventive practices during the period from 1999 to 2010. However, important gaps in care and prevention remain — 30 to 50% did not meet individualized targets for glycemic control, blood pressure, or lipid control, and more than 20% remained smokers. These gaps were particularly noteworthy because tobacco use and hypertension remain the leading modifiable risk factors for death in the United States.[27] Adults with diabetes also did not meet goals for preventive practices: 40 to 50% did not receive diabetes education, vaccinations, or annual dental examinations.

We noted that younger adults were less likely than older adults to meet goals for treatment and preventive practices; furthermore, younger adults had no significant improvements in these areas over time. It is unclear whether physician inattentiveness, poor access to health care, or other factors account for these gaps. Because early control of the risk factors for microvascular and macrovascular disease may confer benefits, these results suggest that younger adults with diabetes need further attention.[4,5]

Historically, 44% of the reduction in U.S. mortality from coronary heart disease has been associated with preventive interventions that reduced the population distribution of risk factors (e.g., reduced tobacco exposure), with the remaining improvements attributed to better treatments (e.g., care provided in coronary care units and the use of revascularization procedures).[28] We observed that the proportions of U.S adults with diabetes who monitored glucose levels and met glycemic targets, in particular, increased a few years after the results of the DCCT and UKPDS were published.[2,3] Improvements in control of blood pressure and LDL cholesterol levels accrued more gradually from 1999 to 2010. The more recent improvements in preventive practices may be related to the use of quality-of-care measures in comparing provider performance or the use of performance incentives.[10,11] However, the benefits of adherence to preventive practices are unclear. Some assessments have shown weak links between adherence to preventive practices and health outcomes,[29] whereas others have shown cost savings[30] and longer-term benefits.[31] Nonetheless, national surveillance data have shown parallel improvements in risk factors and preventive practices from the 1988–1994 period to the 1999–2002 period[12] and declining rates of amputation, end-stage renal disease, hospitalizations related to cardiovascular disease, hyperglycemic crises, and death since the mid-1990s.[32,33]

Table 4. U.S. Adults with Diabetes Who Had Glycated Hemoglobin Levels That Met Individualized Targets, According to Age and Presence or Absence of Complications.*

Age and Complication Status†	Treatment Intensity	Target Glycated Hemoglobin Level	1999–2002		2003–2006		2007–2010	
			Population	Target Met	Population	Target Met	Population	Target Met
		%	*millions*	*% (95% CI)*	*millions*	*% (95% CI)*	*millions*	*% (95% CI)*
18–44 yr without complications	Intensive	≤6.5	1.2	37.0 (20.9–56.6)	1.4	35.2 (23.5–49.1)	1.2	55.4 (40.9–68.9)
18–44 yr with complications	Less	≤7.0	1.0	39.4 (23.0–58.6)	1.0	53.2 (36.3–69.5)‡	1.1	28.2 (15.7–45.3)
45–64 yr without complications	Less	≤7.0	2.9	52.0 (43.1–60.8)	3.3	58.3 (47.9–67.9)	4.7	59.6 (51.6–67.1)
45–64 yr with complications	Moderate	≤8.0	2.7	57.1 (47.4–66.3)	3.6	66.9 (57.3–75.3)	3.5	70.9 (64.8–76.3)
≥65 yr without complications§	Intermediate A	≤7.0	1.4	57.1 (46.1–67.6)	2.4	73.4 (63.5–81.4)	2.8	65.2 (57.6–72.0)
	Intermediate B	≤7.5	1.4	69.4 (56.3–79.9)	2.4	88.6 (82.7–92.7)	2.8	81.1 (76.3–85.1)
≥65 yr with complications	Moderate	≤8.0	3.4	74.6 (65.7–81.9)	3.7	88.8 (83.8–92.4)	4.3	84.3 (79.9–87.8)
All adults ≥18 yr	Intermediate A	≤7.0	12.6	57.2 (52.1–62.2)	15.4	67.4 (63.4–71.2)	17.6	66.6 (62.2–70.6)
	Intermediate B	≤7.5	12.6	58.6 (53.6–63.4)	15.4	69.7 (65.7–73.4)	17.6	69.1 (64.9–73.0)

* Population size was estimated on the basis of the weighted sample size for each risk group among persons with diagnosed diabetes; the weighted proportions of survey participants who met glycated hemoglobin targets are presented as weighted percentages.
† Complications were defined as a self-reported history of cardiovascular disease (heart attack, coronary heart disease, or stroke) or retinopathy or a measured albumin:creatinine ratio of 30 mg of albumin per gram of creatinine or higher.
‡ This estimate may be unreliable due to standard error (≥30%) or sample size (<50).
§ Two values are presented for persons 65 years of age or older without complications because there is no consensus regarding the most appropriate target for this risk group.

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With regard to preventive practices, especially, we noted that once a high level of adherence is achieved, subsequent improvement tends to be marginal.[29] For example, increases in the proportion of participants who had their lipid levels checked annually (from 82.7% in the 1999–2002 period to 88.8% in the 2007–2010 period) and the proportion of participants who had annual eye examinations (from 75.1% to 73.4% during the respective periods) appeared to flatten over time. Consequently, our data point to the importance, challenges, and costs of closing residual gaps in care and preventive practices. Similarly, although only 12.6% of participants had glycated hemoglobin levels that were higher than 9.0% in the 2007–2010 period, this is the group at highest risk for the development of microvascular and macrovascular complications and may also have disease that is the most refractory to treatment, as suggested by the findings in the Action to Control Cardiovascular Risk in Diabetes (ACCORD) trial.[34]

With the evolving evidence, debates over how to optimize care guidelines and performance indicators continue. However, we echo cautions that any revision of quality indicators should be evidence-based, patient-centered, and free of conflicts of interest, and should avoid the simplicity of dichotomous performance measures, which have the potential to harm patients.[11,29]

There has been renewed support for the individualization of glycemic targets, with the selection of targets based on the risks and benefits given the patient's clinical and socioeconomic profiles.[18,19] However, the very nature of individualization makes it a challenge to evaluate the achievement of goals of care in the entire adult population with diabetes. Therefore, we segmented the population into mutually exclusive subgroups based on age and presence or absence of preexisting complications. We found that when targets for glycated hemoglobin level were tailored to the profile of each subgroup, there was greater achievement of the targets than when generic targets were assigned. The probable reason is that individualized targets are generally less intensive. However, further data are needed, especially longitudinal data that allow comparisons across different levels of glycemic control within each risk stratum.

Improved diabetes outcomes result from complex interactions among factors at the patient level (e.g., motivation), the provider level (e.g., therapy intensification), and the system level (e.g., organization of and patient access to care). Although it is possible that more widespread screening for diabetes over the study period has led to earlier detection and therefore may have made targets more achievable for a younger population with less severe diabetes, national surveillance data show that the mean and median age at diagnosis have not varied since 1980, and our data show a stable distribution for time since diagnosis over the 12-year study period.[33] In addition, during the past 15 to 20 years, U.S. adults with diabetes have been receiving prescriptions for more, increasingly complex, and costlier medications.[35] Last, limited access to care and lower socioeconomic status continue to be related to suboptimal control of risk factors.[36] Our findings concur with previous reports: health insurance coverage was significantly and consistently associated with better, more improved risk-factor profiles and preventive practices during the 12 years examined in our study.[37,38] Unfortunately, the proportion of persons with diabetes who do not have health insurance has remained the same, despite increases in mean income and educational level over the study period.

Relevant but nonrepresentative trend data from specific third-party payers (commercial plans, Medicaid, and Medicare) provide an important source of comparison with our data. For the 2007–2010 period in our study, 79.1% of survey participants had glycated hemoglobin levels that were lower than 8.0%, 72.2% had blood pressure that was lower than 140/90 mm Hg, 56.8% had LDL cholesterol levels that were lower than 100 mg per deciliter, and 73.4% underwent annual eye examinations; the respective percentages for those covered by commercial plans and Medicare from 2009 through 2011 ranged from 48.0 to 65.6%, 46.3 to 65.8%, 36.8 to 52.5%, and 42.6 to 66.0%.[39] These differences probably represent differences in the severity of disease among the populations surveyed.

This study has some limitations. First, our analyses were confined to persons with a self-reported diagnosis of diabetes. Although persons with undiagnosed diabetes constitute a quarter of all those affected by diabetes,[1] the inclusion of such persons in our study would have resulted in different risk-factor and adherence profiles, since awareness of disease status is a key aspect

of achieving goals for care. Second, recall and social-desirability bias are inherent limitations of self-reported data. Third, data for LDL cholesterol were available only for participants who fasted before testing (e.g., participants taking insulin were excluded). Fourth, we used updated guidelines with more stringent targets than previously recommended (e.g., LDL cholesterol level <100 mg per deciliter) and different, contemporary practices (e.g., not including aspirin use as a standard performance indicator, since aspirin is now recommended only for those with an intermediate risk of cardiovascular disease and a low risk of bleeding).[9] However, our definitions of targets were applied consistently throughout the survey periods. Finally, because we used cross-sectional surveys, the changes observed reflect only the risk profiles of the diabetes population at the time of the individual surveys.

Our study has several strengths. We used data from successive, nationally representative surveys to illustrate trends in the U.S. population with diabetes, and we used a combination of established and nontraditional performance indicators and thresholds. In particular, we applied an innovative segmentation approach to estimate the achievement of individualized glycemic targets.

In conclusion, our findings provide nationally representative snapshots of risk-factor control and preventive practices between 1999 and 2010 among U.S. adults with diabetes, identify residual gaps in the quality of care, and reveal the factors influencing these gaps. Preventive practices, glycemic control, and lipid control all improved during this period, but little progress was made in addressing the problems of tobacco use, blood pressure, and the flattening of improvements in preventive practices. Furthermore, continued increases in the incidence of diabetes suggest that the absolute numbers of affected persons and those with poor control of risk factors continue to grow. Continued nationwide evaluation of diabetes control will be important to sustain improvements in care and to evaluate the effects of upcoming legislative changes, new insurance products (e.g., reduced copayments for essential treatments),[38,40] and the increased integration of care management models into systems of care.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official positions of the Centers for Disease Control and Prevention or the National Institutes of Health.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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