Thirty-year Trends in Cardiovascular Risk Factor Levels among US Adults with Diabetes


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Among US adults with diabetes, using data from the National Health and Nutrition Examination Survey for 1971–1974, 1976–1980, 1988–1994, and 1999–2000, the authors describe 30-year trends in total cholesterol, blood pressure, and smoking levels. Using Bayesian models, the authors calculated mean changes per year and 95% credible intervals for age-adjusted mean total cholesterol and blood pressure levels and the prevalence of high total cholesterol (≥5.17 mmol/liter), high blood pressure (systolic blood pressure: ≥140 mmHg and/or diastolic blood pressure: ≥90 mmHg), and smoking. Between 1971–1974 and 1999–2000, mean total cholesterol declined from 5.95 mmol/liter to 5.48 mmol/liter (–0.02 (95% credible interval: –0.03, –0.01) mmol/liter per year). The proportion with high cholesterol decreased from 72% to 55%. Mean blood pressure declined from 146/86 mmHg to 134/72 mmHg (systolic blood pressure: –0.5 (95% credible interval: –1.1, 0.5) mmHg per year; diastolic blood pressure: –0.6 (95% credible interval: –1.0, –0.03) mmHg per year). The proportion with high blood pressure decreased from 72% to 55%. Mean blood pressure declined from 146/86 mmHg to 134/72 mmHg (systolic blood pressure: –0.5 (95% credible interval: –1.1, 0.5) mmHg per year; diastolic blood pressure: –0.6 (95% credible interval: –1.0, –0.03) mmHg per year). The proportion with high blood pressure decreased from 64% to 37%, and smoking prevalence decreased from 32% to 17%. Although these trends are encouraging, still one of two people with diabetes has high cholesterol, one of three has high blood pressure, and one of six is a smoker.

blood pressure; cardiovascular diseases; cholesterol; diabetes mellitus; risk factors; smoking

Abbreviation: NHANES, National Health and Nutrition Examination Survey.

In most industrialized countries, mortality from heart disease has declined over the past 30 years but remains the leading cause of death (1, 2). Heart disease is also the most frequent cause of death among persons with diabetes (3, 4). A national study, however, found that heart disease mortality among men declined 36 percent among those without diabetes and only 13 percent among those who had diabetes (5). For women without diabetes, there was a decline in heart disease mortality of 27 percent, while for those with diabetes a nonsignificant increase of 23 percent was reported (5).

In the general population, reductions in serum cholesterol, blood pressure, and cigarette smoking may partly explain the decline in heart disease mortality (1, 6, 7). Among persons with diabetes, however, data on the national prevalence of these major risk factors for cardiovascular disease are scarce. Thus, we assembled data from the National Health and Nutrition Examination Survey (NHANES) I (1971–1974), NHANES II (1976–1980), NHANES III (1988–1994), and the first 2 years of continuous NHANES (1999–2000), allowing us to examine whether cardiovascular disease risk factors have improved in people with diabetes.

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MATERIALS AND METHODS

Design and data collection

The NHANES is a nationally representative survey using a stratified multistage probability design to sample the US civilian, noninstitutionalized population. Weights are assigned to reflect the probability of being sampled, adjusted for oversampling, noncoverage, and nonresponse (8–13). The study received human subject approval, and the participants were asked to sign an informed consent form.

Measures

Each NHANES consists of a detailed standardized medical examination in a mobile examination center and an interview to obtain information on sociodemographic variables. Weight and height are measured with standardized techniques and equipment in the mobile examination center and used to compute body mass index (kg/m²). For this analysis, participants were categorized as White or Black for NHANES I and NHANES II and as non-Hispanic White, non-Hispanic Black, or Mexican American for NHANES III and NHANES 1999–2000; other racial or ethnic groups, including “Hispanic other” in NHANES 1999–2000, were included in the White category. We excluded persons aged more than 74 years because persons in that age group were not sampled in the first two surveys. The response rates among adults for the four surveys were 70, 69, 77, and 76 percent, respectively.

Diagnosed diabetes was defined as a positive response to the question, “Have you ever been told by a doctor that you have diabetes or sugar diabetes?” In the NHANES III and NHANES 1999–2000, women who reported being diagnosed only during pregnancy were not considered to have diabetes; this information was not available for the earlier two surveys. Three cardiovascular disease risk factors were analyzed: serum total cholesterol concentration, systolic and diastolic blood pressure, and smoking status.

Cholesterol measurement

For the first three surveys, a detailed description of the procedures used for blood sample collection and measurement of total cholesterol has been published (14). For NHANES 1999–2000, a description of blood collection and measurement of total cholesterol is provided in the NHANES Laboratory/Medical Technologists Procedures Manual (12). The samples were frozen at −20°C and shipped weekly on dry ice to the laboratory conducting the lipid analyses. The NHANES I measurements were made in the Centers for Disease Control and Prevention lipid standardization laboratory (15). The NHANES II, NHANES III, and NHANES 1999–2000 cholesterol measurements were made in laboratories of lipid research clinics that were standardized for cholesterol measurements using the criteria of the Centers for Disease Control and Prevention-National Heart, Lung, and Blood Institute Lipid Standardization Program (16–20). In all surveys, serum total cholesterol was measured regardless of fasting status. Missing data for total cholesterol ranged from 11 percent to 1 percent. We defined high total cholesterol concentrations as serum total cholesterol of 5.17 mmol/liter or more (≥200 mg/dl), regardless of use of lipid-lowering medications.

Blood pressure measurement

As described previously (21), differences in protocol across the four surveys included the number of blood pressure measurements, the temporal sequence of blood pressure measurements within the entire examination, types of staff who performed the measurements, whether blood pressure was measured in both the seated and supine positions, and whether blood pressure measurements were performed in the home in addition to the mobile examination center. In our analysis, we used only blood pressure measurements conducted in the mobile examination center with subjects in a seated position. When more than one blood pressure measurement was available, we calculated a mean blood pressure. Our estimates of mean blood pressure are based on up to two blood pressure measurements for NHANES I and NHANES II, up to three blood pressure measurements in NHANES III, and up to four blood pressure measurements in NHANES 1999–2000. Because the accepted definition of high blood pressure changed across the years of the surveys (i.e., 1971–2000) (22–24), we defined high blood pressure levels as a mean systolic blood pressure of 140 mmHg or more and/or diastolic blood pressure of 90 mmHg or more regardless of self-reported history of hypertension and use of antihypertensive drugs.

Smoking behaviors

To determine current cigarette smoking, we asked respondents the questions, “Have you smoked at least 100 cigarettes in your entire life?” and “Do you smoke cigarettes now?”. Current smoking was defined by a positive answer to both questions. In NHANES I, data on smoking behaviors were collected for a sample of adults aged 25–74 years. For this reason, we restricted the analysis of smoking to the group aged 25–74 years for all four surveys. Missing data ranged from 4.0 percent to 1.7 percent.

Statistical analysis

Statistical analyses used SAS for Windows software (25) for data management, SUDAAN software (26) to obtain point estimates and standard errors, and WinBUGS software (27) to fit models. Sampling weights were used to produce national estimates that accounted for the complex survey design. For comparisons across surveys, data were age adjusted by the direct method to population totals from the 2000 US Census.

Trends in the age-adjusted estimates of cardiovascular disease risk factors were assessed using a normal hierarchical Bayesian model with noninformative prior distributions on model hyperparameters (28). A Bayesian approach to modeling was preferred because inference does not depend on asymptotic assumptions. In addition to accounting for variability within survey measurements, Bayesian hierarchical models account for variability


<table>
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<tr>
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<tbody>
<tr>
<td>20–59</td>
<td>51.9 (4.1)</td>
<td>53.4 (3.1)</td>
<td>53.3 (2.5)</td>
<td>53.1 (3.0)</td>
</tr>
<tr>
<td>60–74</td>
<td>48.1 (4.1)</td>
<td>46.6 (3.1)</td>
<td>46.7 (2.5)</td>
<td>46.9 (3.0)</td>
</tr>
<tr>
<td>Female (% (SE))</td>
<td>58.7 (3.7)</td>
<td>59.5 (2.8)</td>
<td>53.8 (2.8)</td>
<td>47.6 (3.4)</td>
</tr>
<tr>
<td>Race/ethnicity (% (SE))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White + other</td>
<td>87.1 (1.9)</td>
<td>83.5 (2.4)</td>
<td>83.7 (1.4)</td>
<td>N/A*</td>
</tr>
<tr>
<td>African American</td>
<td>12.9 (1.9)</td>
<td>16.5 (2.4)</td>
<td>16.3 (1.4)</td>
<td>N/A</td>
</tr>
<tr>
<td>Non-Hispanic White + other</td>
<td>N/A</td>
<td>N/A</td>
<td>77.9 (1.6)</td>
<td>75.8 (3.5)</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>N/A</td>
<td>N/A</td>
<td>15.8 (1.4)</td>
<td>17.6 (3.0)</td>
</tr>
<tr>
<td>Mexican American</td>
<td>N/A</td>
<td>N/A</td>
<td>6.2 (0.5)</td>
<td>6.6 (1.1)</td>
</tr>
<tr>
<td>High school degree or higher (% (SE))</td>
<td>48.8 (2.9)</td>
<td>50.4 (2.2)</td>
<td>59.0 (3.2)</td>
<td>59.7 (5.0)</td>
</tr>
<tr>
<td>Body mass index (kg/m²) (mean (SE))</td>
<td>27.3 (0.4)</td>
<td>27.9 (0.3)</td>
<td>30.9 (0.3)</td>
<td>33.0 (0.9)</td>
</tr>
</tbody>
</table>

* NHANES, National Health and Nutrition Examination Survey; SE, standard error; N/A, not applicable.

between surveys. Variability between surveys, such as methodological changes, is accounted for by incorporating random effect parameters into the model.

Our model has two levels. At the first level, we specify a probability distribution for the observed data. Letting \( \gamma_i \) denote the estimate for a cardiovascular disease risk factor determined from survey \( i \) and \( \sigma_i^2 \) denote the variance for \( \gamma_i \) estimated from SUDAAN software, we assume

\[
\gamma_i \sim N(\theta_i, \sigma_i^2).
\]

The survey means \( \theta_i \) are assumed to arise from a linear model

\[
\theta_i = \alpha + \beta(t_i - t_1) + Z_i,
\]

where \( t_i \) represents the midpoint year of survey \( i \), \( \alpha \) represents the mean value of the risk factor from the first survey (intercept), and \( \beta \) represents the annual change in the risk factor over time. The random effect \( Z_i \) represents the variability in \( \theta_i \), remaining after accounting for the linear trend, and it is assumed to be distributed \( N(0, \tau^2) \).

At the second level of our model, we assign probability distributions to each hyperparameter (\( \alpha, \beta, \tau \)). Normal priors with variances of 10,000 are assigned to \( \alpha \) and \( \beta \), while \( \tau \) is approximated with a \( \gamma(0.001, 0.001) \). Combining the prior probabilities specified at the second level with the probability distribution for the observed data specified at the first level, we express knowledge about model parameters through the posterior distribution derived using Bayes’ theorem. Random draws from this posterior distribution are generated through an iterative Markov chain Monte Carlo simulation known as the Gibbs sampler.

We simultaneously ran three Gibbs samplers and saved 50,000 of the 60,000 iterations from each. Model convergence was assessed visually by inspecting trace plots of sampled values versus iteration number and inspecting the Gelman-Rubin statistic for each iteration. We used the mean of the posterior distribution of \( \beta \) as our point estimate. Significant decreases in cardiovascular disease risk factors were defined by 95 percent Bayesian credible intervals for \( \beta \) that did not contain zero. In addition, we estimated the probability that \( \beta \) is negative. A significant decrease was defined as a probability greater than 97.5 percent. Because there is particular interest in recent declines in the prevalence of cardiovascular disease risk factors, we also obtained the Bayesian estimate for the probability of a decrease between the two most recent surveys (NHANES III and NHANES 1999–2000) for each factor. Separate Bayesian models were fit for the overall population, men, women, and persons aged 20–59 and 60–74 years.

RESULTS


Trends in total cholesterol

During the 30-year period, age-adjusted mean total cholesterol decreased –0.02 (95 percent credible interval: –0.03, –0.01) mmol/liter (–0.6 mg/dl), from 5.95 mmol/liter (230 mg/dl) to 5.48 mmol/liter (212 mg/dl). The probability that the mean total cholesterol concentration decreased over the 30-year period was 99.3 percent, and between the two most recent surveys it was 99.7 percent. This decline was of a greater magnitude in persons aged 60–74 years than in those aged 20–59 years (table 2). In addition, in both age groups most of the decrease occurred between NHANES III and
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In the whole population (aged 20–74 years), the proportion of those with total cholesterol values of ≥5.17 mmol/liter (200 mg/dl) decreased from 72 percent in 1971 to 55 percent in 2000 (figure 1), with a mean change per year of –0.6 (95 percent credible interval: –1.7, 0.6) percentage point and a probability of decrease of 91.8 percent. Between 1988–1994 and 1999–2000, the probability of a decline in the prevalence of high total cholesterol was 99.0 percent.

In men, total cholesterol concentrations declined by 0.62 mmol/liter (24 mg/dl), and the change from 1988–1994 to 1999–2000 was also significant (table 3). The yearly estimated decrease in the percentage of men with high total cholesterol was –0.7 percentage point (table 3).

Over the 30-year period, women experienced an annual decline in mean total cholesterol that was smaller than that for men (table 4). From 1988–1994 to 1999–2000, the probability of a decrease was 78.7 percent (table 4). The proportion of women with high total cholesterol was stable in the first three surveys but decreased significantly between the third and fourth (table 4).

### Trends in blood pressure

From 1971 to 2000, the mean systolic blood pressure declined –0.5 (95 percent credible interval: –1.1, 0.5) mmHg annually (a probability of decrease of 93.5 percent) but showed little change between 1988 and 2000 (a probability of decrease of 17.4 percent). A similar pattern and magnitude of change in systolic blood pressure were seen for both sexes and age groups (tables 2, 3, and 4). From 1971 to 2000, the mean diastolic blood pressure declined –0.6 (95 percent credible interval: –1.0, –0.03) mmHg per year. The magnitude of change was similar among men and women but somewhat higher among persons aged 60–74 years than among those younger (tables 2, 3, and 4). Between the 1988

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**TABLE 2. Trends in total cholesterol, blood pressure, and smoking among persons with diabetes, by age, United States, 1971–2000.**

<table>
<thead>
<tr>
<th>Trend by age (years)</th>
<th>NHANES† (years)</th>
<th>Mean change per year from 1971 to 2000</th>
<th>Probability of decrease (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SE‡)</td>
<td>Mean (95% credible interval)</td>
<td>1971–2000</td>
</tr>
<tr>
<td></td>
<td>Total cholesterol (mmol/liter)</td>
<td>Probability of decrease (%)</td>
<td></td>
</tr>
<tr>
<td>20–59</td>
<td>5.81 (0.12)</td>
<td>5.80 (0.14)</td>
<td>–0.01</td>
</tr>
<tr>
<td>60–74</td>
<td>6.09 (0.09)</td>
<td>5.96 (0.07)</td>
<td>–0.02</td>
</tr>
<tr>
<td></td>
<td>Total cholesterol of ≥5.17 mmol/liter (%) (SE)</td>
<td>93.9 99.7§</td>
<td></td>
</tr>
<tr>
<td>20–59</td>
<td>67 (4.0)</td>
<td>67 (4.0)</td>
<td>–0.4</td>
</tr>
<tr>
<td>60–74</td>
<td>78 (3.0)</td>
<td>73 (3.0)</td>
<td>–0.6</td>
</tr>
<tr>
<td></td>
<td>Systolic blood pressure (mmHg) (mean (SE))</td>
<td>95.1 48.7</td>
<td></td>
</tr>
<tr>
<td>20–59</td>
<td>139.6 (2.2)</td>
<td>133.6 (2.2)</td>
<td>–0.4</td>
</tr>
<tr>
<td>60–74</td>
<td>152.9 (1.8)</td>
<td>147.7 (1.6)</td>
<td>–0.6</td>
</tr>
<tr>
<td></td>
<td>Diastolic blood pressure (mmHg) (mean (SE))</td>
<td>95.0 35.7</td>
<td></td>
</tr>
<tr>
<td>20–59</td>
<td>86.3 (1.3)</td>
<td>85.1 (1.4)</td>
<td>–0.5</td>
</tr>
<tr>
<td>60–74</td>
<td>86.1 (1.1)</td>
<td>83.1 (0.8)</td>
<td>–0.6</td>
</tr>
<tr>
<td></td>
<td>High blood pressure (% (SE))†</td>
<td>99.8§ 99.5§</td>
<td></td>
</tr>
<tr>
<td>20–59</td>
<td>52 (5.0)</td>
<td>46 (6.0)</td>
<td>–1.0</td>
</tr>
<tr>
<td>60–74</td>
<td>78 (4.0)</td>
<td>59 (3.0)</td>
<td>–1.4</td>
</tr>
<tr>
<td></td>
<td>Smoking (% (SE))</td>
<td>91.2 22.4</td>
<td></td>
</tr>
<tr>
<td>25–59</td>
<td>36 (6.0)</td>
<td>26 (4.0)</td>
<td>–0.4</td>
</tr>
<tr>
<td>60–74</td>
<td>27 (6.0)</td>
<td>17 (2.0)</td>
<td>–0.4</td>
</tr>
</tbody>
</table>

* To obtain mean total cholesterol concentrations in mg/dl, divide by 0.02586.
† Values for total cholesterol and blood pressures are age adjusted.
‡ NHANES, National Health and Nutrition Examination Survey; SE, standard error.
§ Significant decrease over time period.
¶ High blood pressure was defined as systolic blood pressure of ≥140 mmHg and/or diastolic blood pressure of ≥90 mmHg.

NHANES 1999–2000. In the whole population (aged 20–74 years), the proportion of those with total cholesterol values of ≥5.17 mmol/liter (200 mg/dl) decreased from 72 percent in 1971 to 55 percent in 2000 (figure 1), with a mean change per year of –0.6 (95 percent credible interval: –1.7, 0.6) percentage point and a probability of decrease of 91.8 percent. Between 1988–1994 and 1999–2000, the probability of a decline in the prevalence of high total cholesterol was 99.0 percent.

In men, total cholesterol concentrations declined by 0.62 mmol/liter (24 mg/dl), and the change from 1988–1994 to 1999–2000 was also significant (table 3). The yearly estimated decrease in the percentage of men with high total cholesterol was –0.7 percentage point (table 3).

Over the 30-year period, women experienced an annual decline in mean total cholesterol that was smaller than that for men (table 4). From 1988–1994 to 1999–2000, the probability of a decrease was 78.7 percent (table 4). The proportion of women with high total cholesterol was stable in the first three surveys but decreased significantly between the third and fourth (table 4).
and 2000 surveys, large probabilities of decrease in the mean diastolic blood pressure were seen only for persons aged 60–74 years (a probability of decrease of 99.5 percent) and among men (a probability of decrease of 99.2 percent).

From 1971 to 2000, the percentage of persons with high blood pressure decreased by 1 (95 percent credible interval: −2.7, 1.1) percentage point per year (a probability of decrease of 93.4 percent) (figure 1). The proportion of men with high

![Figure 1](https://academic.oup.com/aje/article-abstract/160/6/531/79246)

**FIGURE 1.** Trends in the age-adjusted prevalence of high total cholesterol concentrations (≥5.17 mmol/liter; triangles), high blood pressure (systolic blood pressure: ≥140 mmHg and/or diastolic blood pressure: ≥90 mmHg; squares), and current smoking (diamonds) among US adults with diabetes from 1971–1974 to 1999–2000. —, mean levels; – – –, 95% credible intervals.

**TABLE 3.** Trends in total cholesterol, blood pressure, and smoking among men aged 20–74 years with diabetes, United States, 1971–2000*†

<table>
<thead>
<tr>
<th>NHANES‡ (years)</th>
<th>Mean change per year from 1971 to 2000</th>
<th>Probability of decrease (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (95% credible interval)</td>
<td>1971–2000</td>
</tr>
<tr>
<td>Total cholesterol (mmol/liter) (mean (SE‡))</td>
<td>5.96 (0.12)</td>
<td>5.79 (0.10)</td>
</tr>
<tr>
<td>Total cholesterol of ≥5.17 mmol/liter (% (SE))</td>
<td>69 (4.0)</td>
<td>67 (4.0)</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg) (mean (SE))</td>
<td>140.7 (1.8)</td>
<td>141.8 (1.6)</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg) (mean (SE))</td>
<td>85.0 (1.0)</td>
<td>86.1 (1.1)</td>
</tr>
<tr>
<td>High blood pressure (% (SE)¶)</td>
<td>60 (5.0)</td>
<td>56 (4.0)</td>
</tr>
<tr>
<td>Smoking (% (SE))</td>
<td>41 (6.0)</td>
<td>25 (4.0)</td>
</tr>
</tbody>
</table>

* To obtain mean total cholesterol concentrations in mg/dl, divide by 0.02586.
† Values for total cholesterol and blood pressures are age adjusted.
‡ NHANES, National Health and Nutrition Examination Survey; SE, standard error.
§ Significant decrease over time period.
¶ High blood pressure was defined as systolic blood pressure of ≥140 mmHg and/or diastolic blood pressure of ≥90 mmHg.

*% 2004;160:531–539
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Blood pressure decreased from 60 percent to 31 percent (a probability of decrease of 95.0 percent), and the proportion of women with high blood pressure decreased from 67 percent to 43 percent (a probability of decrease of 89.4 percent). Between 1988 and 2000, little change was seen in the proportion of persons with high blood pressure for either sex or any age group.

Trends in smoking

The age-adjusted prevalence of cigarette smoking among persons with diabetes dropped 15 percent (figure 1), with a median annual change of –0.5 (95 percent credible interval: –1.4, 0.6) percentage point per year (a probability of decline of 89.5 percent). The magnitude of decrease was greatest for men, but it was limited to NHANES I through NHANES III (table 3). Among women, the decline occurred over all four surveys (table 4).

Trends in multiple risk factors

The age-adjusted percentages of persons with diabetes and at least one, at least two, or all three cardiovascular disease risk factors (high total cholesterol, high blood pressure, or current smoking) were also estimated. Over the study period, the proportion of persons with diabetes who had at least one risk factor decreased from 92 percent to 74 percent (a probability of decrease of 96.6 percent) (data not shown). The percentage of those with two risk factors also decreased steadily from 1971–1974 to 1999–2000, with a median change of –1.0 (95 percent credible interval: –2.1, 0.1) percentage point (data not shown). The percentage of persons with all three risk factors was 15 percent in NHANES I but fell to 3 percent in NHANES III and NHANES 1999–2000 (data not shown).

DISCUSSION

In the US adult population with diabetes, the prevalence of high total cholesterol, high blood pressure levels, and smoking declined by 17, 27, and 15 percentage points, respectively, over three decades. Reductions in mean total cholesterol tended to be greater among men than women and in older (60–74 years) than younger (20–59 years) adults. Declines in mean blood pressure levels were similar across sex and age, but improvement tended to stop after 1988–1994. Smoking prevalence also decreased in both men and women, but these reductions were mainly in earlier decades among men (1970s and 1980s) and in the most recent decade among women (1990s). Taken as a whole, these findings are encouraging, as successful control of these risk factors has been associated with considerable reductions in the cardiovascular and microvascular complications of diabetes (3, 29–31).

Recent data for the US general population have indicated a reduction in the temporal declines in mean cholesterol concentrations for both men and women (32, 33). In contrast, we found that, among people with diabetes, total cholesterol continued to decline from 1988–1994 to 1999–2000, especially in men and in younger as well as older adults. In women, cholesterol values were stable up to 1988–1994 and then declined. The overall improvement in recent years may reflect the aggressive promotion of lipid control in persons with diabetes, following the results of clinical trials of lipid-lowering drugs published in the 1990s and the effort of the National Cholesterol Education Program (29, 34–38).

| TABLE 4. Trends in total cholesterol, blood pressure, and smoking among women aged 20–74 years with diabetes, United States, 1971–2000*† |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| NHANES‡ (years) | Mean change per year from 1971 to 2000 | Probability of decrease (%) |
| Total cholesterol (mmol/liter) (mean (SE‡)) | 5.93 (0.09) | 5.93 (0.12) | 6.08 (0.07) | 5.65 (0.16) | –0.003 | –0.03, 0.02 | 57.0 | 78.7 |
| Total cholesterol of ≥5.17 mmol/liter (% (SE)) | 75 (3.0) | 71 (4.0) | 76 (3.0) | 59 (6.0) | –0.4 | –2.0, 1.4 | 78.7 | 98.4§ |
| Systolic blood pressure (mmHg) (mean (SE)) | 149.8 (2.0) | 139.0 (1.7) | 132.9 (1.2) | 137.7 (2.6) | –0.4 | –1.5, 1.3 | 86.3 | 9.8 |
| Diastolic blood pressure (mmHg) (mean (SE)) | 87.1 (1.2) | 82.8 (1.1) | 70.4 (0.6) | 71.5 (2.0) | –0.7 | –1.3, 0.2 | 96.4 | 50.8 |
| High blood pressure (% (SE))¶ | 67 (4.0) | 49 (4.0) | 36 (3.0) | 43 (6.0) | –0.9 | –2.8, 1.7 | 89.4 | 28.1 |
| Smoking (% (SE)) | 26 (5.0) | 22 (3.0) | 21 (3.0) | 13 (3.0) | –0.4 | –1.4, 0.6 | 87.3 | 96.8 |

* To obtain mean total cholesterol concentrations in mg/dl, divide by 0.02586.
† Values for total cholesterol and blood pressures are age adjusted.
‡ NHANES, National Health and Nutrition Examination Survey; SE, standard error.
§ Significant decrease over time period.
¶ High blood pressure was defined as systolic blood pressure of ≥140 mmHg and/or diastolic blood pressure of ≥90 mmHg.
In 1999–2000, half of the adults with diabetes had total cholesterol concentrations above the level recommended by the National Cholesterol Education Program (5.17 mmol/liter or 200 mg/dl) (38). Our results underscore the need to enforce current recommendations to consider diabetes a risk factor for heart disease and to aggressively treat lipid abnormalities in people who have diabetes. We note that, even if the decline in the proportion of adults with diabetes having high total cholesterol levels would continue at 0.6 percentage point per year (the annual decrease we found for the entire study period), 49 percent of people with diabetes will still have high cholesterol levels in 2010.

Findings from randomized trials have demonstrated the benefits of tight blood pressure control to protect against renal disease and cardiovascular events in patients with diabetes (30, 39, 40). For this reason, more stringent criteria for blood pressure control have been suggested for this group (24, 41). Even so, we found that the proportion of persons with blood pressure above 140/90 mmHg did not decrease between 1988–1994 and 1999–2000 and, at the last survey, a substantial proportion of US adults with diabetes still had a blood pressure measurement above 140/90 mmHg. More recently, the recommended blood pressure for people with diabetes has been lowered to 130/80 mmHg (41); on the basis of this new criterion, an even greater proportion of persons with diabetes will be candidates for intervention.

The favorable changes in the major cardiovascular disease risk factors among adults with diabetes have occurred along- side a dramatic increase in mean body mass index. Like diabetes, obesity is associated with insulin resistance, hyper- tension, lipid abnormalities (42), and cardiovascular disease mortality (43). Thus, one would have expected results the opposite of what we obtained. It is possible that the shift in body mass index reflects an increase in detecting undiag- nosed diabetes, because people are at an earlier stage and have less severe disease. Similarly, changes in the diagnostic criteria for diabetes in the most recent years and increased screening may help to identify individuals with a less severe form of the disease, who would likely have a better cardio- vascular disease risk profile. If true, this could in part explain the downward trend in risk factors.

Despite the favorable trends in the three major risk factors for cardiovascular disease, a national study found that heart disease mortality had declined to a lesser degree among adults with diabetes than in the US general population (5). There are a few potential explanations for this. First, many risk factors other than the three we studied are associated with cardiovascular disease mortality in people with diabetes. For example, low high-density lipoprotein choles- terol, high triglycerides, abnormal low density lipoprotein particle size, hyperinsulinemia and insulin resistance, coagulation abnormalities, inflammation, and physical inactivity all can increase susceptibility to atherosclerosis in diabetes (44). Second, it may require additional time before a decline in cardiovascular disease risk factors is reflected in changes in cardiovascular disease mortality. Finally, people with diabetes may derive less benefit from the medical treatment of cardiovascular disease. For example, they experience worse outcomes of coronary revascularization than do persons without diabetes (45) and have an adverse long-term prognosis after myocardial infarction (46). Moreover, among patients with coronary artery disease, those with diabetes are less often tested or treated for dislipidemia (47).

Our study had some limitations. First, the sample size of people with diabetes, especially in the most recent survey, limited the number of stratified subgroup analyses that we could conduct. Second, differences in participation rates by race/ethnicity may have varied over time, which may have influenced the findings. We were unable to examine this in our analyses, because of the fact that the number of people with diabetes and non-White race was too small to provide reliable or meaningful inferences and because information on race/ethnicity was not collected uniformly across the four surveys. However, we conducted follow-up sensitivity analy- ses in which we estimated cardiovascular disease risk factor levels across the four surveys only in non-White partici- pants. We found that trends among non-Whites were of similar magnitude to that observed in the overall sample, but the standard errors were very large because of the small sample size. Third, given the lack of data from the earliest survey, we could not assess temporal trends in high density lipoprotein cholesterol, low density lipoprotein cholesterol, and triglycerides. Fourth, some of the methodological changes that occurred across the four surveys may have influenced our estimates, especially for blood pressure levels. Our choice of analytical approach reduces the effect of these changes on our estimates; thus, we believe that most of the observed decline in cardiovascular disease risk factors is real.

In conclusion, between 1971 and 2000, cardiovascular disease risk factors among people with diabetes declined. The biggest declines were among men and older people. Although we have strong evidence that control of blood pressure, lipids, and smoking can reduce cardiovascular disease mortality among people with diabetes, one of two people with diabetes still has a total cholesterol concentra- tion above the recommended targets, one of three has high blood pressure, and one of six is a smoker. Considerable opportunity to tackle cardiovascular disease risk in people with diabetes still exists.

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