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# Associations Between Trends in Race/Ethnicity, Aging, and Body Mass Index With Diabetes Prevalence in the United States

## A Series of Cross-sectional Studies

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**Background:** The increase in the prevalence of diabetes over the past few decades has coincided with an increase in certain risk factors for diabetes, such as a changing race/ethnicity distribution, an aging population, and a rising obesity prevalence.

**Objective:** To determine the extent to which the increase in diabetes prevalence is explained by changing distributions of race/ethnicity, age, and obesity prevalence in U.S. adults.

**Design:** Cross-sectional, using data from 5 NHANES (National Health and Nutrition Examination Surveys): NHANES II (1976–1980), NHANES III (1988–1994), and the continuous NHANES 1999–2002, 2003–2006, and 2007–2010.

**Setting:** Nationally representative samples of the U.S. noninstitutionalized civilian population.

**Patients:** 23 932 participants aged 20 to 74 years.

**Measurements:** Diabetes was defined as a self-reported diagnosis or fasting plasma glucose level of 7.0 mmol/L (126 mg/dL) or more.

**Results:** Between 1976 to 1980 and 2007 to 2010, diabetes prevalence increased from 4.7% to 11.2% in men and from 5.7% to 8.7% in women ($P$ for trends for both groups $< 0.001$). After adjustment for age, race/ethnicity, and body mass index, diabetes prevalence increased in men (6.2% to 9.6%; $P$ for trend $< 0.001$) but not women (7.6% to 7.5%; $P$ for trend $= 0.69$). Body mass index was the greatest contributor among the 3 covariates to the change in prevalence estimates after adjustment.

**Limitation:** Some possible risk factors, such as physical activity, waist circumference, and mortality, could not be studied because data on these variables were not collected in all surveys.

**Conclusion:** The increase in the prevalence of diabetes was greater in men than in women in the U.S. population between 1976 to 1980 and 2007 to 2010. After changes in age, race/ethnicity, and body mass index were controlled for, the increase in diabetes prevalence over time was approximately halved in men and diabetes prevalence was no longer increased in women.

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The increasing prevalence of diabetes over the past few decades (1–3) has made it one of the most common and costly chronic disorders in the United States. The nationwide prevalence of diagnosed diabetes more than doubled between 1976 to 1980 and 1999 to 2004 (3), and the prevalence of diagnosed and undiagnosed diabetes combined increased by 33% between 1988 to 1994 and 2005 to 2010 (1). The increase in diabetes prevalence has coincided with an increase in certain risk factors for diabetes. The most important modifiable risk factors for diabetes are obesity and overweight. The prevalence of adult obesity, defined as a body mass index (BMI) of 30 kg/m$^2$ or more, in national surveys was 22.3% from 1988 to 1994, 30.5% from 2000 to 2002, and 35.9% from 2009 to 2010, whereas the prevalence of overweight, defined as a BMI of 25.0 to 29.9 kg/m$^2$, was 32.6%, 34.0%, and 33.3% during these respective periods (4–6). Racial and ethnic groups at increased risk for diabetes (3) make up a growing proportion of the population. Non-Hispanic black and Hispanic persons represented 11.7% and 6.4% of the U.S. population, respectively, in 1980, and their numbers grew to 12.6% and 16.3%, respectively, in 2010 (7, 8). Risk for diabetes increases with age (9). Furthermore, the U.S. population is aging; in recent years, the median age has increased from 30.0 years in 1980 to 37.2 years in 2010 (10). How much of the increased prevalence of diabetes is explained by an increase in these known risk factors and how much is due to other factors is unclear. We sought to determine the extent to which this increase is explained by changing distributions of race/ethnicity, age, and obesity prevalence in U.S. adults. To do so, we analyzed data from several National Health and Nutrition Examination Surveys (NHANES). Each survey was designed to be representative of the U.S. population. The surveys have been conducted in waves from 1976 to 1980 (NHANES II) and 1988 to 1994 (NHANES III), as well as the continuous NHANES from 1999 to 2010. We limited the study sample to adults aged 20 to 74 years for consistency across surveys.

*See also:*

**Web-Only**
Supplements

## METHODS

### Data Collection

The NHANES is a series of stratified, multistage probability surveys designed to be representative of the U.S.

noninstitutionalized civilian population (11–13). Data were collected in an in-home interview and a subsequent visit to a mobile examination center. The response rate was 91% for the interview and 73% for the examination in NHANES II; respective response rates were 86% and 78% in NHANES III, 82% and 76% in 1999 to 2000, 84% and 80% in 2001 to 2002, 79% and 76% in 2003 to 2004, 80% and 77% in 2005 to 2006, 78% and 75% in 2007 to 2008, and 79% and 77% in 2009 to 2010. Each NHANES survey consisted of participants who were randomly selected to participate in a morning examination for which they were asked to fast or an afternoon or evening examination. We used data from the morning sessions, which were capable of independently producing national estimates. We excluded pregnant women from the analysis because pregnancy affects glucose and BMI measurements. Respective years and sample sizes from the NHANES series were 1976 to 1980 with 4343 participants, 1988 to 1994 with 7023 participants, 1999 to 2002 with 3848 participants, 2003 to 2006 with 3688 participants, and 2007 to 2010 with 5030 participants.

For NHANES III and NHANES 1999–2010, all participants gave written informed consent and the research ethics boards of the National Center for Health Statistics approved all protocols. The National Center for Health Statistics did an internal human subjects review in NHANES II, which did not consist of institutional review board approval using current standards.

A standardized questionnaire was used to collect demographic information, including age, race/ethnicity, and sex during an in-home interview, except race/ethnicity may have been determined on the basis of interviewer observation in NHANES II. Participants were also asked if they had ever been diagnosed with diabetes by a "doctor" (NHANES II and III) or a "doctor or other health professional" (NHANES 1999–2010). During the visit to the mobile examination center, height and weight were measured and BMI was calculated.

A trained phlebotomist obtained a blood sample according to a standardized protocol, and fasting glucose was measured in plasma by a hexokinase method. Fasting glucose was measured by using an Abbott ABA-100 analyzer in NHANES II, and the interassay coefficient of variation was not reported. Respective equipment and coefficients of variation in the NHANES series were the Roche Cobas Mira chemistry system with 1.6% to 3.7% in NHANES III, Roche Cobas Mira chemistry system with 1.3% to 3.0% in NHANES 1999–2002, Roche Cobas Mira chemistry system or Roche/Hitachi 911 glucose analyzer with 1.3% to 2.3% in NHANES 2003–2006, and Roche Modular P chemistry analyzer with 0.8% to 2.6% in NHANES 2007–2010. Although NHANES III and NHANES 1999–2004 used the same equipment and methods to measure fasting glucose, NHANES 2005–2010 used different equipment and was therefore calibrated to the earlier data; calibration of NHANES II data was not possible (14, 15). Diabetes was defined as a self-reported previous diagnosis of diabetes or a fasting plasma glucose level of 7.0 mmol/L (126 mg/dL) or more. Although fasting plasma glucose level was consistently measured in all of the NHANES surveys, 2-hour plasma glucose and hemoglobin $A_{1c}$ levels were not.

***Context***

The prevalence of diabetes has increased in the United States during the past several decades. The extent to which demographic changes and rising obesity rates have contributed to this increase is unknown.

***Contribution***

Data collected from nationally representative samples of men and women between 1976 and 2010 showed a greater increase in diabetes prevalence in men than in women. After adjustment for race/ethnicity, age, and body mass index, diabetes prevalence still increased in men but not women.

***Caution***

This study could not adjust for physical activity.

***Implication***

Body mass index is a substantial contributor to the observed increase in diabetes prevalence.

*—The Editors*

### Statistical Analysis

We calculated means or percentages of participant characteristics by survey year and diabetes status. We then used multivariable logistic regression models with diabetes as the outcome and terms for survey year, age, race/ethnicity, and BMI to find the adjusted prevalence of diabetes by survey period, for which we computed predicted margins (16). We fit an unadjusted logistic regression model with only a term for time (midpoint of survey year—the results are denoted as unadjusted estimates); models including covariates of age, race/ethnicity, or BMI; and a model with all 3 variables. We compared these models to determine the extent to which covariates explained the trend in diabetes over time. All tests for trend were computed by including the midpoint year for each survey period as a continuous variable in regression models. We initially included sex and a sex-by-time interaction term in all models and found the interaction to be significant. Therefore, we conducted all analyses separately by sex.

Appropriate sample weights were used to account for unequal probabilities of selection and nonresponse and thus provided estimates representative of the U.S. noninstitutionalized civilian population. Data were analyzed using SUDAAN (RTI International) and accounted for the NHANES-stratified, clustered sample design.

*Table 1.* **Baseline Characteristics of Men, by Diabetes Status and Survey Period, 1976–2010**

| Variable | No Diabetes | | | | | |
|---|---|---|---|---|---|---|
| | 1976–1980 (*n* = 1738) | 1988–1994 (*n* = 2750) | 1999–2002 (*n* = 1507) | 2003–2006 (*n* = 1446) | 2007–2010 (*n* = 1760) | *P* for Trend |
| Mean age (±SE), *y* | 41.8 ± 0.45 | 40.8 ± 0.44 | 42.0 ± 0.57 | 41.8 ± 0.47 | 42.3 ± 0.61 | 0.20 |
| Race/ethnicity (±SE), % | | | | | | |
| Non-Hispanic white | 78.4 ± 1.61 | 76.3 ± 1.73 | 71.0 ± 2.40 | 71.9 ± 2.32 | 68.1 ± 2.46 | <0.001 |
| Non-Hispanic black | 8.7 ± 1.45 | 10.2 ± 0.69 | 9.9 ± 1.26 | 10.1 ± 1.25 | 10.3 ± 1.15 | 0.44 |
| Mexican American | 2.8 ± 0.47 | 5.8 ± 0.57 | 8.2 ± 1.05 | 9.1 ± 1.36 | 9.8 ± 1.36 | <0.001 |
| Mean body mass index (±SE), *kg/m²* | 25.5 ± 0.13 | 26.5 ± 0.17 | 27.4 ± 0.18 | 28.3 ± 0.17 | 28.2 ± 0.19 | <0.001 |
| Mean fasting glucose level (±SE) | | | | | | |
| *mmol/L* | 5.2 ± 0.02 | 5.4 ± 0.02 | 5.4 ± 0.02 | 5.4 ± 0.03 | 5.4 ± 0.02 | <0.001 |
| *mg/dL* | 93.6 ± 0.29 | 97.2 ± 0.27 | 96.9 ± 0.36 | 97.1 ± 0.45 | 98.1 ± 0.32 | <0.001 |

* Relative SE >50%.


### Role of the Funding Source

The Centers for Disease Control and Prevention (CDC) and the National Institutes of Diabetes and Digestive and Kidney Diseases funded NHANES and oversaw its conduct and reporting with regard to diabetes-related data. As employees or contractors of the Centers for Disease Control and Prevention or National Institutes of Diabetes and Digestive and Kidney Diseases, the authors had a direct role in the design and interpretation of the secondary analysis and the decision to submit the manuscript for publication.


## RESULTS

Participant characteristics by diabetes status are presented for men (**Table 1**) and women (**Table 2**). The "no diabetes" group includes persons with both normal fasting glucose levels (<5.6 mmol/L [<100 mg/dL]) and impaired fasting glucose levels (5.6 to 6.9 mmol/L [100 to 125 mg/dL]). Our study population was limited to persons aged 20 to 74 years; within this age range, a significant increase in mean age over time was seen only in women without diabetes. The percentage of non-Hispanic white men and women without diabetes significantly decreased over time, but the decrease was not significant in those with diabetes. Both the percentage of Mexican Americans and mean BMI significantly increased over time in all subgroups. Mean fasting plasma glucose levels significantly increased over time in men and women without diabetes but not in those with diabetes. Mean fasting plasma glucose levels were generally higher in men than in women among people with and without diabetes.

The crude prevalence of diabetes increased between 1976 to 1980 and 2007 to 2010 for both men and women (both $P$ for trends $< 0.001$) (**Figure 1**) (**Supplement 1**, available at www.annals.org). After adjustment for age, race/ethnicity, and BMI, the prevalence of diabetes in men increased from 6.2% in 1976 to 1980 to 9.6% in 2007 to 2010 ($P$ for trend $< 0.001$) (**Figure 2**). After identical adjustment, the prevalence of diabetes in women was 7.6% in 1976 to 1980 and 7.5% in 2007 to 2010 ($P$ for trend = 0.69) (**Figure 2**).

The prevalence of diabetes based on results of each of the logistic regression models is shown in **Table 3**. (The coefficients from the models are shown in **Supplement 2**, available at www.annals.org.) In unadjusted and adjusted models, the prevalence of diabetes increased in men more than in women between 1976 to 1980 and 2007 to 2010 (all interactions $P < 0.001$). For women, the prevalence of diabetes no longer increased over time after we adjusted for BMI ($P = 0.80$). For men, the increase in prevalence of

*Table 2.* **Baseline Characteristics of Women, by Diabetes Status and Survey Period, 1976–2010**

| Variable | No Diabetes | | | | | |
|---|---|---|---|---|---|---|
| | 1976–1980 (*n* = 1950) | 1988–1994 (*n* = 3039) | 1999–2002 (*n* = 1501) | 2003–2006 (*n* = 1357) | 2007–2010 (*n* = 1972) | *P* for Trend |
| Mean age (±SE), *y* | 42.7 ± 0.52 | 42.3 ± 0.52 | 43.7 ± 0.62 | 43.8 ± 0.51 | 43.9 ± 0.41 | 0.010 |
| Race/ethnicity (±SE), % | | | | | | |
| Non-Hispanic white | 74.5 ± 1.96 | 76.2 ± 1.22 | 72.7 ± 2.05 | 72.0 ± 2.21 | 69.0 ± 2.38 | 0.030 |
| Non-Hispanic black | 9.9 ± 1.48 | 11.5 ± 0.65 | 11.0 ± 1.57 | 11.6 ± 1.34 | 11.7 ± 1.15 | 0.37 |
| Mexican American | 2.4 ± 0.82 | 5.0 ± 0.45 | 6.3 ± 0.92 | 6.8 ± 1.13 | 7.5 ± 1.16 | <0.001 |
| Mean body mass index (±SE), *kg/m²* | 24.9 ± 0.16 | 26.0 ± 0.19 | 27.8 ± 0.22 | 28.2 ± 0.20 | 28.2 ± 0.17 | <0.001 |
| Mean fasting glucose level (±SE) | | | | | | |
| *mmol/L* | 5.0 ± 0.02 | 5.1 ± 0.01 | 5.2 ± 0.02 | 5.2 ± 0.02 | 5.2 ± 0.02 | <0.001 |
| *mg/dL* | 89.9 ± 0.34 | 92.7 ± 0.18 | 93.4 ± 0.37 | 93.1 ± 0.43 | 93.7 ± 0.34 | <0.001 |

*Table 1*—Continued

| Diabetes | | | | | |
|---|---|---|---|---|---|
| 1976–1980 (*n* = 286) | 1988–1994 (*n* = 553) | 1999–2002 (*n* = 438) | 2003–2006 (*n* = 455) | 2007–2010 (*n* = 672) | *P* for Trend |
| 56.7 ± 1.22 | 55.9 ± 0.96 | 54.7 ± 0.96 | 55.6 ± 1.01 | 55.5 ± 0.71 | 0.42 |
| | | | | | |
| 68.3 ± 3.90 | 76.7 ± 2.62 | 68.9 ± 3.27 | 66.8 ± 3.94 | 64.5 ± 2.88 | 0.052 |
| 14.0 ± 2.87 | 11.9 ± 1.43 | 10.8 ± 1.72 | 14.6 ± 1.58 | 14.1 ± 1.93 | 0.58 |
| 1.3 ± 1.29* | 6.0 ± 0.74 | 6.0 ± 1.14 | 8.6 ± 1.64 | 10.1 ± 1.81 | <0.001 |
| 27.5 ± 0.56 | 29.8 ± 0.32 | 32.2 ± 0.75 | 31.7 ± 0.40 | 32.1 ± 0.46 | <0.001 |
| | | | | | |
| 8.0 ± 0.23 | 9.7 ± 0.29 | 9.2 ± 0.22 | 8.8 ± 0.28 | 8.9 ± 0.24 | 0.80 |
| 143.3 ± 4.14 | 175.1 ± 5.24 | 165.8 ± 3.99 | 157.6 ± 5.02 | 159.5 ± 4.33 | 0.80 |

diabetes over time after adjustment for age, race/ethnicity, and BMI was approximately half of the increase over time in unadjusted models. As in women, after adjustment, BMI was the greatest contributor among the 3 covariates to the trend changes in men.

### Sensitivity Analysis

We conducted several sensitivity analyses. First, we repeated the logistic regression analyses and defined diabetes based only on fasting plasma glucose level without using data on previous diagnosis of diabetes or insulin use (**Supplement 2**). Second, we repeated the logistic regression analyses, excluding participants with probable type 1 diabetes (defined as those who received a diagnosis when they were younger than 30 years and who were receiving insulin, which they started within 1 year of diagnosis) (**Supplement 2**). Third, we repeated the logistic regression analyses with either diabetes or prediabetes as the outcome (that is, a self-reported previous diagnosis of diabetes or a fasting plasma glucose level ≥5.6 mmol/L [≥100 mg/dL]) (**Supplement 2**). Fourth, we repeated the logistic regression analyses with additional adjustment for calories consumed and the percentage of calories from saturated fat; nutrition data were ascertained using a 24-hour recall (2.5% of participants missing nutrition data were excluded) (**Supplement 2**). Fifth, we repeated the logistic regression analyses and adjusted for waist circumference instead of BMI in NHANES III and NHANES 1999–2010 (3.7% of participants missing waist circumference data were excluded) (**Supplement 3**, available at www.annals.org). Sixth, we repeated the logistic regression analyses defining diabetes based on previous diagnosis, a fasting plasma glucose level of 7.0 mmol/L (126 mg/dL) or more, or a hemoglobin $A_{1c}$ level of 6.5% or more in NHANES III and NHANES 1999–2010 (4.8% of participants missing hemoglobin $A_{1c}$ data were excluded) (**Supplement 3**). Seventh, we repeated the logistic regression analyses excluding NHANES II to provide a basis for comparison for the previous 2 sensitivity analyses because that survey did not have relevant data on waist circumference and hemoglobin $A_{1c}$ level (**Supplement 3**). The sensitivity analysis results were similar but the associations had a small difference in magnitude. Of note, when we excluded NHANES II, the adjusted increase in prevalence of diabetes in men over time was attenuated and not significant after adjustment for age, race/ethnicity, and BMI ($P = 0.071$) and was further attenuated when we adjusted for waist circumference instead of BMI ($P = 0.29$).

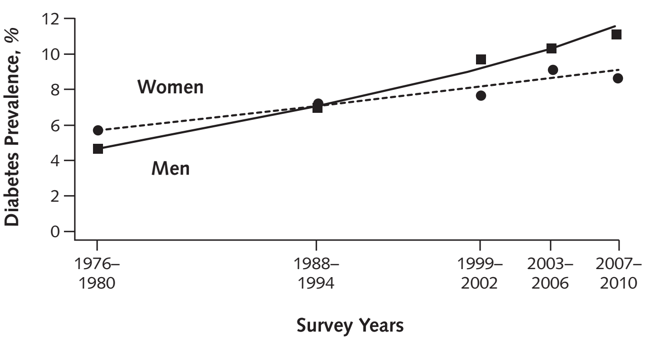
## Discussion

In a series of representative samples of U.S. men and women younger than 75 years, the prevalence of diabetes increased more in men than in women. After changes over

*Table 2*—Continued

| Diabetes | | | | | |
|---|---|---|---|---|---|
| 1976–1980 (*n* = 369) | 1988–1994 (*n* = 681) | 1999–2002 (*n* = 402) | 2003–2006 (*n* = 430) | 2007–2010 (*n* = 626) | *P* for Trend |
| 53.8 ± 1.01 | 56.1 ± 0.67 | 55.1 ± 1.04 | 56.1 ± 0.72 | 56.2 ± 0.53 | 0.069 |
| | | | | | |
| 60.9 ± 4.78 | 65.8 ± 3.28 | 53.5 ± 3.76 | 61.3 ± 4.40 | 53.3 ± 5.11 | 0.157 |
| 19.2 ± 4.03 | 18.8 ± 2.07 | 22.2 ± 3.40 | 17.7 ± 2.88 | 22.3 ± 3.17 | 0.63 |
| 4.1 ± 1.37 | 6.9 ± 0.91 | 7.8 ± 1.46 | 9.8 ± 2.34 | 10.2 ± 2.27 | 0.010 |
| 30.5 ± 0.84 | 32.2 ± 0.43 | 33.6 ± 0.47 | 34.2 ± 0.63 | 35.1 ± 0.40 | <0.001 |
| | | | | | |
| 7.9 ± 0.40 | 9.7 ± 0.40 | 8.9 ± 0.41 | 8.5 ± 0.30 | 8.2 ± 0.25 | 0.52 |
| 142.5 ± 7.14 | 175.0 ± 7.16 | 159.6 ± 7.40 | 152.3 ± 5.37 | 148.4 ± 4.45 | 0.52 |

*Figure 1.* **Crude and unadjusted prevalence of diabetes in men and women, 1976–2010.**




Points refer to crude prevalence, and lines refer to unadjusted prevalence (logistic regression–based).

time in age, race/ethnicity, and BMI were controlled for, the increase in diabetes prevalence was approximately halved among men and diabetes prevalence was no longer increased among women between 1976 to 1980 and 2007 to 2010. Change in BMI over time was the most important factor for the increase in diabetes prevalence in our study. Thus, decreasing the occurrence of overweight and obesity remains an important intervention to reduce the burden of diabetes.

The strong temporal relationship between increases in BMI and diabetes prevalence is consistent with a previous study showing that both the prevalence of diabetes and obesity increased concurrently in the U.S. population, but that study did not stratify by sex (17). Furthermore, previous studies showed that BMI was the most important risk factor for type 2 diabetes. Among 74 970 participants of the Hawaii component of the multiethnic cohort, those with a BMI of 25 kg/m$^2$ or more had a partial population attributable risk of 49% for men and 50% for women, which was higher than any other factor studied (18). Among 72 627 participants of the 2000–2001 Canadian Community Health Survey, those with a BMI of 25 kg/m$^2$ or more had a population attributable risk of 44% for men and 53% for women (19). In a study of 8545 participants from the NHANES Epidemiologic Follow-up Study, those who gained 5 kg or more of body weight during 10 years of follow-up had a population attributable risk for diabetes of 27% for men and women combined (20). Moreover, lifestyle intervention targeting a modest 7% weight loss has been proven to dramatically reduce progression from prediabetes to type 2 diabetes (21, 22).

We found that the unadjusted increase in diabetes prevalence was greater in men than in women. However, the difference was not due to a greater corresponding increase in BMI in men. Physical activity is associated with a decreased risk for diabetes independent of BMI (23). The percentage of occupations with low physical activity increased by 83% between 1950 and 2000, but the extent to which men and women differ in the decrease in occupational physical activity over the past few decades remains unknown (24). In NHANES, questions about physical activity and exercise were not consistent across survey years (that is, different physical activities and periods). Consequently, we were not able to assess the effect of changing physical activity levels on diabetes prevalence. Another possible factor that may have affected prevalence between men and women is dietary changes. However, adjustment for calories consumed and the percentage of calories from saturated fat had minimal effect on the prevalence of diabetes among men and women in a sensitivity analysis in our study. Caution should be taken when interpreting these results because nutrition data were obtained using a 24-hour recall, and it is unclear how bias in the reporting of diet may have changed over time (25). Other possible factors that may have affected diabetes trends differently for men and women include changes in sun exposure and consequently vitamin D synthesis (26), shift work and decreased sleep time (27), psychological stress and depression (28), and environmental and occupational exposure to pollutants and toxins (29–35). Limited published research on the role of these factors in the development of diabetes makes it unclear how trends in exposure may have affected our analysis (34, 35).

Another important factor of the prevalence of diabetes is the mortality rate among persons with diabetes. A lower mortality rate will result in a higher prevalence of diabetes. Part of the difference by sex in our study may be due to a greater decrease in the overall mortality rate in men than in

*Table 3.* **Unadjusted and Adjusted Prevalence of Diabetes for Men and Women, by Survey Period, 1976–2010***

| Variable | Prevalence in Men (95% CI), % | | | | | |
|---|---|---|---|---|---|---|
| | 1976–1980 (*n* = 2024) | 1988–1994 (*n* = 3303) | 1999–2002 (*n* = 1945) | 2003–2006 (*n* = 1901) | 2007–2010 (*n* = 2432) | *P* for Trend |
| Unadjusted | 4.8 (4.1–5.5) | 7.0 (6.5–7.6) | 9.2 (8.6–9.8) | 11.5 (10.5–12.6) | 13.6 (12.0–15.1) | <0.001 |
| Age | 5.0 (4.3–5.7) | 7.2 (6.6–7.7) | 9.2 (8.6–9.8) | 11.3 (10.3–12.3) | 13.0 (11.6–14.5) | <0.001 |
| Race/ethnicity | 4.8 (4.1–5.5) | 7.1 (6.5–7.6) | 9.2 (8.6–9.8) | 11.5 (10.5–12.6) | 13.5 (11.9–15.1) | <0.001 |
| Body mass index | 6.1 (5.2–7.1) | 7.6 (7.0–8.2) | 8.9 (8.3–9.5) | 10.1 (9.1–11.0) | 11.1 (9.7–12.5) | <0.001 |
| All covariates | 6.6 (5.6–7.5) | 7.8 (7.2–8.4) | 8.9 (8.3–9.4) | 9.8 (8.9–10.8) | 10.6 (9.3–11.9) | <0.001 |

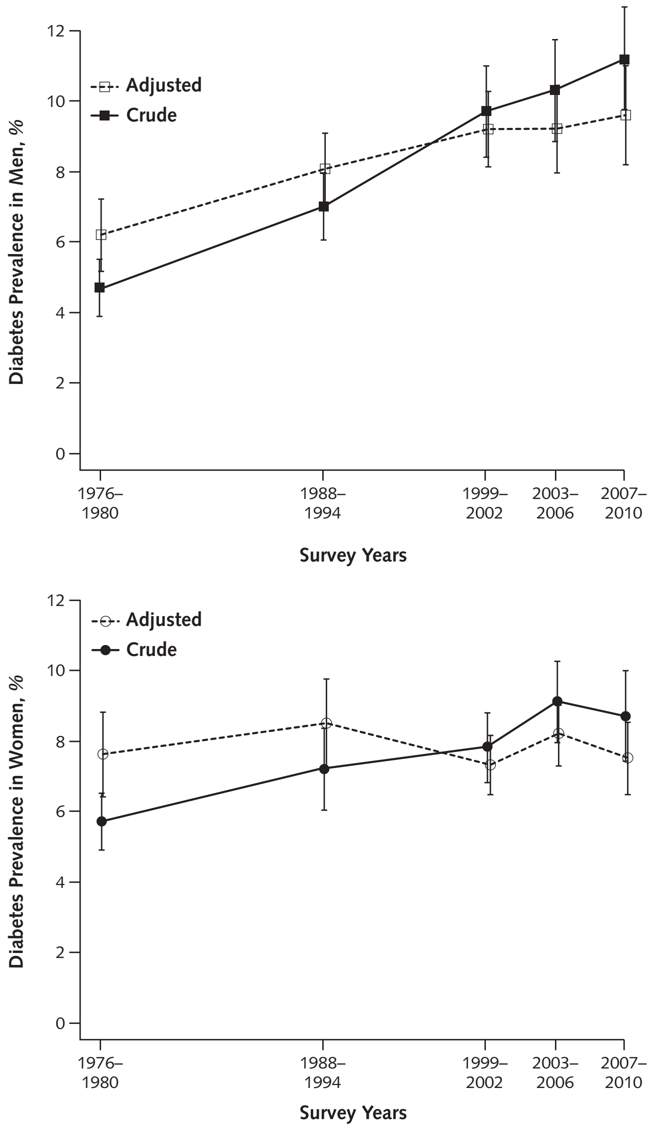
* Estimates based on logistic regression models with time modeled continuously by using the midpoint of the survey.

women with diabetes from 1976 to 2010. One study of 2059 diabetic adults aged 35 to 74 years found that men had a decrease in all-cause mortality from 1971 to 2000, whereas the corresponding mortality rate among women did not significantly change (36). However, in another study of 16 274 diabetic adults aged 18 years or older, men and women experienced a similar decrease in mortality from 1997 to 2006 (37). In the Framingham Heart Study, which had participants aged 45 to 74 years, the mortality rate decreased by 45% for men and 52% for women from 1976 to 2001 compared with 1950 to 1975 (38). Those studies of mortality rates encompassed different periods or participant age ranges than our study. In NHANES, mortality rates are unavailable both in the years preceding each prevalence estimate and for all periods after each prevalence estimate. Therefore, we were not able to include mortality in our analysis. Further research is needed to better characterize the mortality trends for diabetic persons over the past several decades; such research would help to determine how these trends affect the prevalence of diabetes.

Family history might be considered a potential explanatory factor for the increase in diabetes prevalence over time. However, genetic risk factors are unlikely to change over such a short period; therefore, any contribution of family history of diabetes to trends in diabetes prevalence would likely be due to increased rates of gestational diabetes, conferring increased risk to offspring or to lifestyle factors, such as exercise, diet, and obesity (39).

The prevalence of prediabetes is higher in men than in women, but in 1999 to 2010, the prevalence of prediabetes based on fasting plasma glucose and $A_{1c}$ levels increased faster in women than in men after adjustment for age, race/ethnicity, BMI, and income (40). It is unclear whether risk factors contribute the same way to diabetes and prediabetes. In a sensitivity analysis in which the outcome was diabetes or prediabetes, results were consistent with our main analysis—that is, the increase in BMI explained the largest percentage of change in the prevalence of diabetes and prediabetes, and BMI explained a larger percentage of change in women than in men. However, the percentage of change in both disorders explained by the increase in BMI was lower for both sexes than the percent-

*Figure 2.* **Crude and adjusted prevalence of diabetes in men and women, 1976–2010.**




Adjustment included age, race/ethnicity, and body mass index. Error bars represent 95% CIs.

*Table 3*—**Continued**

| Prevalence in Women (95% CI), % | | | | | |
|---|---|---|---|---|---|
| 1976–1980 (*n* = 2319) | 1988–1994 (*n* = 3720) | 1999–2002 (*n* = 1903) | 2003–2006 (*n* = 1787) | 2007–2010 (*n* = 2598) | *P* for Trend |
| 5.8 (5.0–6.6) | 7.0 (6.5–7.6) | 8.1 (7.5–8.6) | 9.1 (8.2–9.9) | 9.9 (8.7–11.1) | <0.001 |
| 6.1 (5.2–6.9) | 7.2 (6.6–7.7) | 8.0 (7.5–8.6) | 8.9 (8.0–9.7) | 9.5 (8.4–10.7) | <0.001 |
| 6.0 (5.2–6.8) | 7.1 (6.6–7.7) | 8.1 (7.5–8.6) | 8.9 (8.1–9.8) | 9.6 (8.4–10.8) | <0.001 |
| 7.9 (6.9–8.9) | 7.8 (7.2–8.4) | 7.8 (7.2–8.3) | 7.7 (7.0–8.4) | 7.7 (6.8–8.6) | 0.80 |
| 8.0 (6.9–9.1) | 7.9 (7.3–8.5) | 7.8 (7.2–8.3) | 7.7 (7.0–8.4) | 7.6 (6.7–8.5) | 0.69 |

age explained in our main analysis when only diabetes was the outcome.

Although diagnostic criteria and screening practices may have changed over time, NHANES measured fasting plasma glucose level. Further, we included undiagnosed diabetes defined as concentrations of 7.0 mmol/L (126 mg/dL) or more in our definition of diabetes (along with a self-reported diagnosis). Therefore, we were able to consistently define diabetes over the entire period based on this definition. The NHANES does not determine whether a participant has type 1 or type 2 diabetes. We excluded participants who probably had type 1 diabetes in a sensitivity analysis, and results were markedly similar because the proportion of all persons with diabetes who have type 1 diabetes is probably too small to have a meaningful effect on our results. Another potential limitation is the use of BMI to measure adiposity; BMI is a measure of general adiposity and does not take distribution of adiposity into account. In addition, muscle mass increases BMI. Other measures of adiposity, such as waist circumference, may be more strongly associated with diabetes (41), but BMI was the only measure of adiposity available in the NHANES surveys. In a sensitivity analysis excluding NHANES II, adjustment for waist circumference changed diabetes prevalence estimates more than adjustment for BMI. However, when combined in the model with age and race/ethnicity, whether BMI or waist circumference was included made little difference in men or women.

In conclusion, in a series of large, nationally representative samples of U.S. adults, adjustment for changes in BMI over time eliminated approximately half the increase in diabetes prevalence in men and the entire increase in women between 1976 to 1980 and 2007 to 2010. Considering the increasing prevalence of diabetes, which cost the United States an estimated $245 billion in 2012 (42), our findings have 2 important implications. First, the substantial contribution of BMI to the prevalence of diabetes in both men and women supports ongoing public health efforts to address obesity, including developing effective interventions aimed at reducing obesity. Second, our finding that nearly half of the diabetes increase in men remains unexplained gives urgency to research investigating what additional factors may contribute to the faster rise in diabetes in men than in women.

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**Reproducible Research Statement:** *Study protocol*: Available at www.cdc.gov/nchs/nhanes/about_nhanes.htm. *Statistical code*: Available from Dr. Menke (e-mail, amenke@s-3.com). *Data set*: Available at www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm.

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