Original Investigation

Prevalence and Incidence Trends for Diagnosed Diabetes Among Adults Aged 20 to 79 Years, United States, 1980-2012

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IMPORTANCE Although the prevalence and incidence of diabetes have increased in the United States in recent decades, no studies have systematically examined long-term, national trends in the prevalence and incidence of diagnosed diabetes.

OBJECTIVE To examine long-term trends in the prevalence and incidence of diagnosed diabetes to determine whether there have been periods of acceleration or deceleration in rates.

DESIGN, SETTING, AND PARTICIPANTS We analyzed 1980-2012 data for 664 969 adults aged 20 to 79 years from the National Health Interview Survey (NHIS) to estimate incidence and prevalence rates for the overall civilian, noninstitutionalized, US population and by demographic subgroups (age group, sex, race/ethnicity, and educational level).

MAIN OUTCOMES AND MEASURES The annual percentage change (APC) in rates of the prevalence and incidence of diagnosed diabetes (type 1 and type 2 combined).

RESULTS The APC for age-adjusted prevalence and incidence of diagnosed diabetes did not change significantly during the 1980s, but each increased sharply each year during 1990-2008 before leveling off with no significant change during 2008-2012. The prevalence per 100 persons was 3.5 (95% CI, 3.2 to 3.9) in 1990, 7.9 (95% CI, 7.4 to 8.3) in 2008, and 8.3 (95% CI, 7.9 to 8.7) in 2012. The incidence per 1000 persons was 3.2 (95% CI, 2.2 to 4.1) in 1990, 8.8 (95% CI, 7.4 to 10.3) in 2008, and 7.1 (95% CI, 6.1 to 8.2) in 2012.

	1980s	1990-2008	2008-2012
Prevalence			
APC (95% CI), %	0.2 (−0.9 to 1.4)	4.5 (4.1 to 4.9)	0.6 (−1.9 to 3.0)
P value	.69	<.001	.64
Incidence			
APC (95% CI), %	−0.1 (−2.5 to 2.4)	4.7 (3.8 to 5.6)	−5.4 (−11.3 to 0.9)
P value	.93	<.001	.09

Trends in many demographic subpopulations were similar to these overall trends. However, incidence rates among non-Hispanic black and Hispanic adults continued to increase (for interaction, $P = .03$ for non-Hispanic black adults and $P = .01$ for Hispanic adults) at rates significantly greater than for non-Hispanic white adults. In addition, the rate of increase in prevalence was higher for adults who had a high school education or less compared with those who had more than a high school education (for interaction, $P = .006$ for <high school and $P < .001$ for high school).

CONCLUSIONS AND RELEVANCE Analyses of nationally representative data from 1980 to 2012 suggest a doubling of the incidence and prevalence of diabetes during 1990-2008, and a plateauing between 2008 and 2012. However, there appear to be continued increases in the prevalence or incidence of diabetes among subgroups, including non-Hispanic black and Hispanic subpopulations and those with a high school education or less.

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The prevalence and incidence of diabetes have increased during recent decades.[1-6] This may be caused by several factors, including improved rates of survival, demographic changes to the US population, enhanced case detection, changes to diagnostic criteria, and diverse environmental and behavioral factors that increase the risk of diabetes incidence. Obesity is a major risk factor for type 2 diabetes[6-10] (which accounts for 90%-95% of all diabetes), and increases in diabetes have paralleled increases in obesity.[11] However, recent reports suggest that the growth in obesity rates may have plateaued,[12,13] which could signify good news for diabetes trends. Because, to our knowledge, no recent studies have systematically examined long-term trends in the incidence and prevalence of diagnosed diabetes, we used nationally representative survey data to determine whether there have been periods of acceleration or deceleration in rates of diabetes prevalence and incidence over a more than 3-decade period.

Methods

Data Source

The Centers for Disease Control and Prevention (CDC) institutional review board approved data collection for the National Health Interview Survey (NHIS); the board ruled that this study, which used only publicly available data, was exempt from review.

We used cross-sectional data from the 1980-2012 NHIS to estimate and examine trends in the prevalence and incidence of diagnosed diabetes among the noninstitutionalized, civilian, US population aged 20 to 79 years. The NHIS is a multipurpose health survey that uses a multistage cluster sample design and is conducted by the National Center for Health Statistics, CDC.[14] In personal household interviews, the NHIS collects annual health and risk factor information that is used to monitor illness and disability and to track progress toward meeting national health objectives. The NHIS sample is redesigned about every 10 years and details on these designs are available.[14-17] Major revisions to the NHIS questionnaire occurred in 1982 and 1997.[18] NHIS household response rates ranged from 97% in 1980[19] to 78% in 2012.[20]

Measurements

Prevalence, Incidence, and Obesity

Self- or proxy report of a diabetes diagnosis was used to estimate prevalence (ie, percentage of the population with the disease) and a duration of diabetes for less than a year was used to estimate incidence (ie, rate of new cases in the past year). Because NHIS cannot distinguish between type of diabetes, cases included both type 1 and type 2 diabetes.

Prevalence | Before 1997, NHIS respondents were asked to report whether anyone in the family had diabetes in the past 12 months. Beginning in 1997, respondents were asked whether they had ever been told by a health professional that they had diabetes or sugar diabetes (other than during pregnancy for women). Prevalence was calculated as the number of people who had diabetes divided by the total number of adults in the sample.

Incidence | Before 1997, how long ago diabetes was diagnosed was ascertained for persons who had had diabetes in the previous 12 months. Persons with onset in the past year were considered incident cases. Beginning in 1997, respondents were asked whether they had ever been told by a health professional that they had diabetes or sugar diabetes (other than during pregnancy for women) and, if yes, at what age they were diagnosed. The number of years each person had diagnosed diabetes was calculated by subtracting their age at diagnosis from their age at the time of the interview. A value of 0 indicated that the disease was diagnosed within the previous year. To account for people who had a birthday during their first year of diabetes, it was assumed that half of those with a value of 1 also had the disease diagnosed within the previous year. This method has been previously used to calculate incidence.[3,21] Diabetes incidence was calculated as the number of incident cases divided by the total number of persons (excluding adults who had been diagnosed with diabetes for more than a year).

Obesity | Self- or proxy reports of height and weight were used to calculate body mass index (BMI; calculated as weight in kilograms divided by height in meters squared). We defined obesity as a BMI of 30 or higher and calculated obesity prevalence as the number of obese adults divided by the total number of adults. Because BMI based on self-reported height and weight is known to be underreported,[22] obesity estimates were also derived from prior studies[23,24] that used objective measurements of height and weight.

Demographic Variables

Demographic variables included age (grouped into 20-44, 45-64, and 65-79 years of age), sex, race/ethnicity (non-Hispanic white, non-Hispanic black, and Hispanic), and educational level (<high school, high school, and >high school). Race/ethnicities other than non-Hispanic white, non-Hispanic black, and Hispanic were included in total counts but not analyzed separately because of small sample sizes.

Statistical Analysis

We examined overall trends and trends by demographic subpopulations. Race/ethnicity analyses were restricted to 1997-2012 due to limited sample sizes for non-Hispanic black and Hispanic adults before 1997. To account for the complex sampling design of the NHIS, we used SUDAAN software, version 11.0.1 (Research Triangle Institute) to obtain estimates of incidence and prevalence and the standard errors on the basis of the Taylor series linearization method. Estimates were weighted to reflect the age, sex, and racial/ethnic distribution of the noninstitutionalized adult US population, and the 2000 US population was used as the standard population for age-adjustment. To analyze trends, we used Joinpoint Regression software, version 4.0.4 (National Cancer Institute). Briefly, Joinpoint regression analysis (also known as piecewise linear regression) uses statistical criteria to determine the minimum number of linear segments needed to describe a trend; the points at which a segment begins and ends; the annual percentage change (APC) for each segment; and whether the APC is significantly different from 0.[25] Two-sided tests with a P value less than .05 were considered statistically significant. Using pairwise z tests, we conducted post hoc comparisons of APCs between demographic subgroups for the most recent trend period.

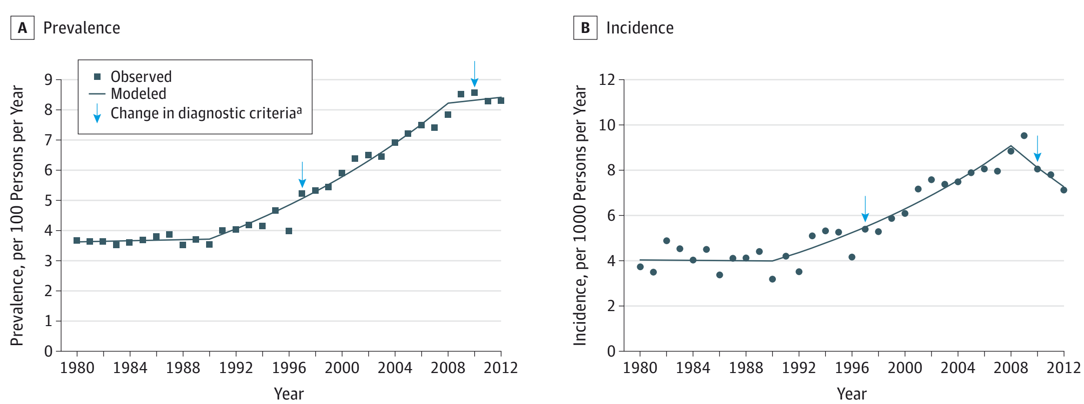
Table 1. Characteristics of US Adults Aged 20 to 79 Years[a]

	1980		1990		2000		2010		2012	
	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)
Total										
Unweighted, No.	22 528	NA	13 253	NA	29 935	NA	24 940	NA	31 701	NA
Age group, y										
20-44	12 442	56.0 (55.0-56.9)	7561	58.2 (57.2-59.3)	15 792	54.0 (53.3-54.7)	11 914	48.5 (47.6-49.3)	14 530	47.6 (46.8-48.4)
45-64	6925	30.3 (29.6-31.0)	3800	27.7 (26.8-28.7)	9537	32.5 (31.9-33.2)	9127	38.0 (37.2-38.8)	11 853	38.0 (37.3-38.8)
65-79	3161	13.8 (13.2-14.4)	1892	14.0 (13.3-14.8)	4606	13.5 (13.0-14.0)	3899	13.5 (13.0-14.1)	5318	14.4 (13.9-15.0)
Women	11 999	52.6 (52.2-53.0)	7122	52.1 (51.5-52.7)	16 829	51.7 (51.1-52.4)	13 781	51.2 (50.4-52.0)	17 470	51.4 (50.7-52.1)
Race/ethnicity										
Non-Hispanic white	18 639	81.9 (81.0-82.8)	10 029	77.7 (76.3-79.0)	19 537	73.8 (73.0-74.5)	14 090	68.1 (67.1-69.1)	18 953	66.9 (66.1-67.8)
Non-Hispanic black	2147	10.3 (9.5-11.0)	1778	10.9 (9.8-12.1)	4267	11.4 (10.8-11.9)	4185	12.0 (11.3-12.7)	4901	11.9 (11.3-12.4)
Hispanic	1341	6.0 (5.5-6.5)	1047	8.1 (7.2-9.2)	5065	10.6 (10.1-11.2)	4863	14.2 (13.6-14.9)	5496	15.1 (14.4-15.8)
Other	401	1.9 (1.6-2.2)	399	3.3 (2.7-3.9)	1066	4.2 (3.9-4.6)	1802	5.7 (5.3-6.1)	2351	6.2 (5.8-6.5)
Education										
<High school	6423	28.6 (27.8-29.5)	2722	20.0 (19.1-21.0)	5803	16.3 (15.8-17.0)	4004	13.3 (12.7-13.9)	4710	13.0 (12.5-13.6)
High school	8580	38.6 (37.8-39.4)	5094	38.8 (37.7-39.9)	8662	30.4 (29.7-31.1)	6433	26.2 (25.5-26.9)	8031	25.6 (24.9-26.3)
>High school	7226	32.7 (31.9-33.6)	5307	41.2 (40.0-42.5)	15 181	53.2 (52.4-54.1)	14 404	60.5 (59.5-61.4)	18 833	61.4 (60.6-62.3)

Abbreviation: NA, not applicable.

[a] Data from the National Health Interview Survey; estimates were weighted.

Figure 1. Trends in Age-Adjusted Diagnosed Diabetes Prevalence and Incidence Among Adults Aged 20-79 Years, 1980-2012



Data are from the National Health Interview Survey. Joinpoint regression was conducted using the natural logarithm of the age-adjusted rate as the dependent variable and year as the independent variable.

[a] In 1997, the diabetes diagnostic criteria for fasting plasma glucose was lowered from 140 mg/dL or more to 126 mg/dL or more; in 2010, hemoglobin A_{1c} was adopted for the diagnosis of diabetes. To convert glucose to mmol/L, multiply by 0.0555.

Using the 1997-2012 NHIS data, we conducted logistic regression and calculated predictive margins to estimate incidence after controlling for risk factors (ie, age group, sex, race/ethnicity, educational level, and BMI). Predictive margins are a type of direct standardization, in which the predicted values from the logistic regression models are averaged over the covariate distribution in the population. We first built the base model for incidence as a function of survey year and age categorized in 10-year intervals. Next, we added BMI to the base model using BMI as a continuous variable. Then we further added other demographic variables, including sex, race/ethnicity, and educational level, to the model. The final model included age, race/ethnicity, educational level, BMI, BMI as a squared term and interaction terms for BMI by age, BMI by education, and race/ethnicity by education. Hosmer-Lemeshow goodness-of-fit was used to assess model fitting. Lastly, we conducted Joinpoint regression analyses on the trends in the predictive margins for incidence from each model to compare the changes in APC by adjusting additional risk factors. We tested for differences in APCs using *z* tests.

Results

Demographic Characteristics of Population

Based on analyses of data for 664 969 adults aged 20 to 79 years, the noninstitutionalized, civilian, US population became older and more racially diverse between 1980 and 2012 (**Table 1**). In addition, the educational level rose, and the proportion of the population with less than a high school education declined from 28.6% in 1980 to 13.0% in 2012.

Trends for Total Population

During 1980-2012, the trends in age-adjusted prevalence of diagnosed diabetes in the overall population were similar to those for age-adjusted incidence (**Figure 1**A and Figure 1B). The prevalence per 100 persons was 3.5 (95% CI, 3.2 to 3.9) in 1990, 7.9 (95% CI, 7.4 to 8.3) in 2008, and 8.3 (95% CI, 7.9

Table 2. Trends in Diagnosed Diabetes Prevalence (per 100 Persons per Year), United States, 1980-2012

					Trend 1[a]			Trend 2[a]			Trend 3[a]		
	Cases, No.	% (95% CI)	Cases, No.	% (95% CI)	Period	APC (95% CI)	P Value	Period	APC (95% CI)	P Value	Period	APC (95% CI)	P Value
	1980		2012										
Total													
Crude	812	3.6 (3.3 to 3.8)	3128	9.0 (8.6 to 9.4)	1980-1990	0.0 (−1.1 to 1.2)	.95	1990-2008	5.1 (4.6 to 5.5)	<.001	2008-2012	1.6 (−0.9 to 4.1)	.21
Age-adjusted[b]	812	3.7 (3.4 to 3.9)	3128	8.3 (7.9 to 8.7)	1980-1990	0.2 (−0.9 to 1.4)	.69	1990-2008	4.5 (4.1 to 4.9)	<.001	2008-2012	0.6 (−1.9 to 3.0)	.64
Age group, y													
20-44	131	1.1 (0.9 to 1.2)	392	2.5 (2.2 to 2.9)	1980-1984	−3.0 (−14.4 to 9.9)	.62	1984-2012	4.3 (3.8 to 4.9)	<.001			
45-64	364	5.4 (4.8 to 6.0)	1590	12.5 (11.8 to 13.3)	1980-1990	−0.3 (−1.7 to 1.1)	.63	1990-2008	4.4 (3.9 to 4.9)	<.001	2008-2012	1.3 (−1.6 to 4.3)	.36
65-79	317	9.8 (8.9 to 10.8)	1146	20.7 (19.3 to 22.1)	1980-1990	0.1 (−1.7 to 1.9)	.92	1990-2003	4.8 (3.7 to 6.0)	<.001	2003-2012	2.4 (1.3 to 3.6)	<.001
Sex[b]													
Men	352	3.5 (3.2 to 3.8)	1466	8.5 (8.1 to 9.0)	1980-1995	1.3 (0.4 to 2.2)	.01	1995-2001	8.7 (4.6 to 12.9)	<.001	2001-2012	2.6 (1.8 to 3.3)	<.001
Women	460	3.8 (3.5 to 4.2)	1662	8.1 (7.6 to 8.6)	1980-1989	−0.5 (−2.0 to 1.1)	.52	1989-2008	4.0 (3.6 to 4.5)	<.001	2008-2012	1.1 (−1.9 to 4.1)	.46
Education[b]													
<High school	433	5.1 (4.6 to 5.5)	686	12.2 (11.2 to 13.3)	1980-1987	0.8 (−2.2 to 3.9)	.61	1987-2012	3.8 (3.4 to 4.2)	<.001			
High school	219	3.0 (2.6 to 3.3)	962	9.6 (8.9 to 10.4)	1980-1988	1.5 (−1.7 to 6.2)	.35	1988-2012	4.7 (4.3 to 8.1)	<.001			
>High school	151	2.7 (2.2 to 3.2)	1467	6.9 (6.4 to 7.3)	1980-1994	1.3 (0.0 to 2.7)	.05	1994-2003	7.8 (5.7 to 9.9)	<.001	2003-2012	2.3 (1.3 to 3.3)	<.001
Race/ethnicity[b,c]	1997		2012										
Non-Hispanic white	1073	4.4 (4.1 to 4.7)	1699	7.2 (6.7 to 7.6)	1997-2005	5.1 (3.6 to 6.5)	<.001	2005-2012	1.9 (0.1 to 3.7)	.04			
Non-Hispanic black	417	9.7 (8.7 to 10.8)	675	12.6 (11.6 to 13.6)	1997-2012	2.2 (1.7 to 2.7)	<.001						
Hispanic	328	8.3 (6.9 to 9.6)	537	11.4 (10.2 to 12.7)	1997-2012	3.1 (2.4 to 3.7)	<.001						

Abbreviation: APC, annual percentage change.

[a] Joinpoint regression determines the number of linear segments needed to describe a trend and identifies points (ie, Joinpoints) in which linear trends change. The Joinpoint is included in each adjoining linear segment. Empty cells indicate no additional linear trend segment or Joinpoint.

[b] Age-adjusted to the US 2000 population based on age groups 20 to 44 years, 45 to 64 years, and 65 to 79 years.

[c] Race/ethnicity analyses were restricted to using 1997-2012 data because of insufficient sample size for some racial/ethnicity groups in the preceding years.

Table 3. Trends in Diagnosed Diabetes Incidence (Rates per 1000 Persons per Year), United States, 1980-2012

	Cases	% (95% CI)	Cases	% (95% CI)	Trend 1[a] Period	Trend 1[a] APC (95% CI)	Trend 1[a] *P* Value	Trend 2[a] Period	Trend 2[a] APC (95% CI)	Trend 2[a] *P* Value	Trend 3[a] Period	Trend 3[a] APC (95% CI)	Trend 3[a] *P* Value
	1980		**2012**										
Total													
Crude	80	3.6 (2.7 to 4.5)	328	7.4 (6.3 to 8.5)	1980-1990	−0.3 (−2.7 to 2.1)	.80	1990-2008	5.2 (4.2 to 6.1)	<.001	2008-2012	−4.9 (−10.8 to 1.5)	.13
Age-adjusted[b]	80	3.7 (2.8 to 4.6)	328	7.1 (6.1 to 8.1)	1980-1990	−0.1 (−2.5 to 2.4)	.93	1990-2008	4.7 (3.8 to 5.6)	<.001	2008-2012	−5.4 (−11.3 to 0.9)	.09
Age group, y													
20-44	24	2.0 (1.2 to 2.9)	88	3.7 (2.7 to 4.7)	1980-2012	3.2 (2.3 to 4.1)	<.001						
45-64	33	4.6 (3.0 to 6.2)	177	12.1 (9.7 to 14.5)	1980-1992	−1.5 (−4.9 to 2.1)	.40	1992-2002	7.9 (3.4 to 12.6)	.01	2002-2012	0.4 (−2.0 to 2.9)	.73
65-79	23	8.4 (4.9 to 11.8)	63	8.7 (5.7 to 11.7)	1980-2012	2.2 (1.2 to 3.3)	<.001						
Sex[b]													
Men	33	3.4 (2.3 to 4.5)	125	5.9 (4.6 to 7.2)	1980-2008	4.0 (3.2 to 4.8)	<.001	2008-2012	−7.6 (−17.5 to 3.4)	.16			
Women	47	4.0 (2.8 to 5.2)	203	8.2 (6.7 to 9.8)	1980-2012	2.6 (2.0 to 3.2)	<.001						
Education[b]													
<High school	40	5.4 (3.4 to 7.4)	72	12.1 (8.4 to 15.8)	1980-2012	3.1 (2.2 to 4.1)	<.001						
High school	18	2.1 (1.1 to 3.1)	94	8.0 (5.7 to 10.3)	1980-2008	5.2 (4.1 to 6.2)	<.001	2008-2012	−6.3 (−18.7 to 8.1)	.36			
>High school	22	3.9 (2.1 to 5.8)	162	5.9 (4.8 to 7.1)	1980-2012	3.0 (2.4 to 3.7)	<.001						
Race/ethnicity[b,c]	**1997**		**2012**										
Non-Hispanic white	146	4.7 (3.8 to 5.6)	156	5.7 (4.5 to 6.8)	1997-2008	5.5 (3.6 to 7.4)	<.001	2008-2012	−8.0 (−16.8 to 1.6)	.09			
Non-Hispanic black	64	9.5 (6.7 to 12.4)	68	9.9 (6.8 to 13.0)	1997-2012	1.5 (0.1 to 2.9)	.04						
Hispanic	52	6.9 (4.2 to 9.6)	78	12.5 (8.8 to 16.2)	1997-2012	3.3 (1.7 to 4.9)	<.001						

Abbreviation: APC, annual percentage change.

[a] Joinpoint regression determines the number of linear segments needed to describe a trend and identifies points (ie, Joinpoints) where linear trends change. The Joinpoint is included in each adjoining linear segment. Empty cells indicate no additional linear trend segment or Joinpoint.

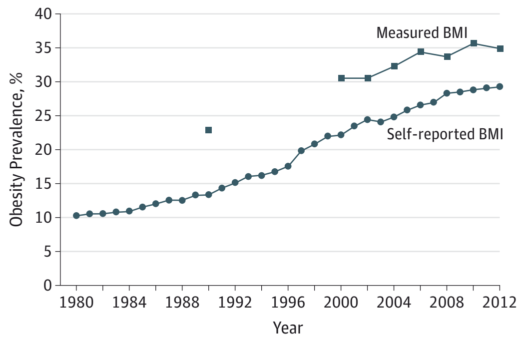
[b] Age-adjusted to the US 2000 population based on age groups 20 to 44 years, 45 to 64 years, and 65 to 79 years.

[c] Race/ethnicity analyses were restricted to using 1997-2012 data because of insufficient sample size for some racial/ethnicity groups in the preceding years.

to 8.7) in 2012. The incidence per 1000 persons was 3.2 (95% CI, 2.2 to 4.1) in 1990, 8.8 (95% CI, 7.4 to 10.3) in 2008, and 7.1 (95% CI, 6.1 to 8.2) in 2012. The APC for neither prevalence nor incidence changed significantly during the 1980s (for prevalence, 0.2% [95% CI, −0.9% to 1.4%], $P = .69$; for incidence, −0.1% [95% CI, −2.5% to 2.4%], $P = .93$). However, both prevalence and incidence increased sharply during 1990-2008 (for prevalence, 4.5% [95% CI, 4.1% to 4.9%], $P < .001$; for incidence, 4.7% [95% CI, 3.8% to 5.6%], $P < .001$) before leveling off with no significant change during 2008-2012 (for prevalence, 0.6% [95% CI, −1.9% to 3.0%], $P = .64$; for incidence, −5.4% [95% CI, −11.3% to 0.9%], $P = .09$). Trends in crude diabetes prevalence and incidence were similar to trends in age-adjusted prevalence and incidence (**Table 2** and **Table 3**).

Based on self-reported height and weight, obesity increased between 1980 and 2012 (**Figure 2**). However, prior studies[23,24] reporting obesity estimates based on physical measurements found no significant change in obesity prevalence between 2003-2004 and 2011-2012.

Figure 2. Trends in Age-Adjusted Prevalence of Obesity Among Adults Aged 20 to 79 Years, 1980-2012



BMI indicates body mass index (calculated as weight in kilograms divided by height in meters squared). The prevalence of obesity was based on BMI derived from self-reported height and weight data from the National Health Interview Survey. Prevalence of obesity among adults aged 20 years or older was based on measured BMI from the National Health and Nutrition Examination Surveys (NHANES) from 1988 to 1994 (NHANES III) and 1999 to 2012 (continuous NHANES).[23] Line is not drawn through noncontiguous surveys.

Trends for Demographic Subpopulations

In many subpopulations, trends in the prevalence and incidence of diagnosed diabetes were similar to overall trends, with substantial increases beginning around 1990 that lasted 15 to 20 years before either leveling off or slowing in the rate of growth (**Figure 3**, Table 2, and Table 3). However, prevalence continued to increase at a significantly greater rate for young adults aged 20 to 44 years compared with those older (for interaction, $P = .04$ for those aged 45-64 years and $P = .003$ for those aged 65-79 years). In addition, the rate of increase in prevalence was higher for adults who had a high school education or less compared with those who had more than a high school education (for interaction, $P = .006$ for <high school and $P < .001$ for high school); and Hispanic adults compared with non-Hispanic black adults ($P = .01$ for interaction). Incidence rates continued to increase at a greater rate for adults aged 20 to 44 years compared with those aged 45 to 64 years ($P = .03$) and among non-Hispanic black and Hispanic adults than non-Hispanic white adults (for interaction, $P = .03$ for non-Hispanic black adults and $P = .01$ for Hispanic adults).

A change in trend was found in 2008 for all 3 models of incidence for years 1997-2012 (eFigure in the Supplement). The 1997-2008 APC for incidence controlling for age was 4.8% (95% CI, 3.4%-6.2%). Controlling for both age and BMI, BMI as a squared term, and age × BMI, attenuated the APC of incidence by about a third to 3.2% (95% CI, 2.0%-4.4%), and the difference between APCs was no longer statistically significant ($P = .06$). Additional adjustments for other risk factors and their interactions (ie, race/ethnicity, education, BMI by education, and race/ethnicity by education) had little effect on the APC (3.4% [95% CI, 2.2%-4.7%]), and the difference between it and the APC for the base age-adjusted model was not significant ($P = .14$). For the period of 2008-2012, the APCs in incidence for the 2 models controlling for selected risk factors did not significantly differ from the base age-adjusted model ($P = .90$ for both).

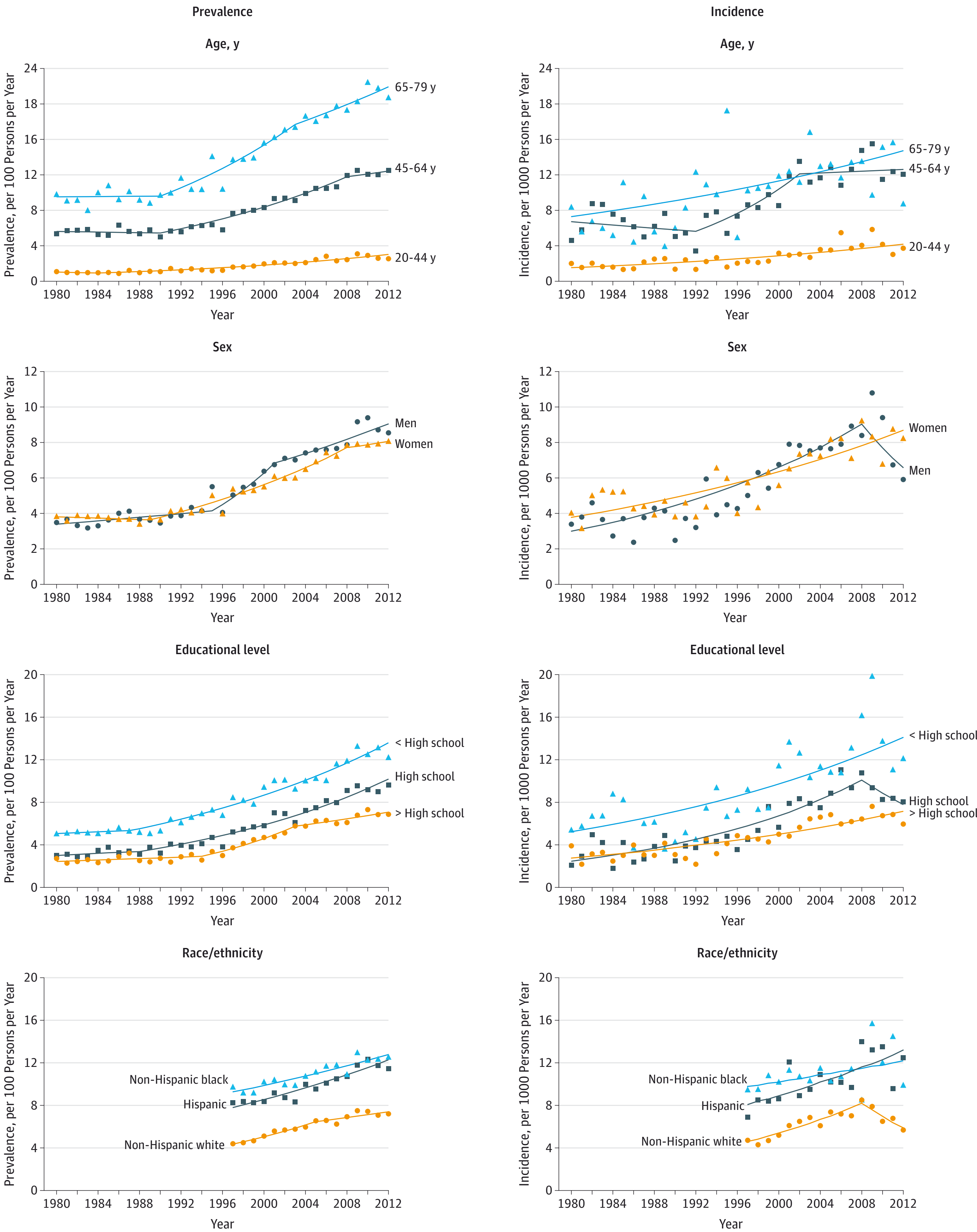
Discussion

Following a doubling of the incidence and prevalence of diagnosed diabetes during 1990-2008, our nationally representative data suggest a potential slowing in the diabetes epidemic. Incidence and prevalence ceased growing or leveled off in many population subgroups. However, incidence continued to increase in Hispanic and non-Hispanic black adults and prevalence continued to grow among those with a high school education or less. This threatens to exacerbate racial/ethnic and socioeconomic disparities in diabetes prevalence and incidence. Furthermore, in light of the well-known excess risk of amputation, blindness, end-stage renal disease, disability, mortality, and health care costs associated with diabetes, the doubling of diabetes incidence and prevalence ensures that diabetes will remain a major public health problem that demands effective prevention and management programs.

Reasons for the potential slowing of the increase in diabetes prevalence and incidence are difficult to determine from these serial cross-sectional surveillance data. Recent studies suggest that the rate of increase in obesity, a major risk factor for type 2 diabetes, may be slowing in the United States,[12,13] with no change in the prevalence of obesity among US adults since 2003-2004. This slowing in the growth of obesity and diabetes appears to be concurrent with declines in overall caloric intake, food purchases, and energy intake.[26,27] The recent slowing in diabetes prevalence and incidence could also reflect the adoption of hemoglobin A_{1c} (HbA_{1c}) for the diagnosis of diabetes.[28] This may be particularly so for diabetes incidence changes in the latter part of the period. Prior studies have suggested that the HbA_{1c} test threshold identifies fewer cases of hyperglycemia than the fasting plasma glucose (FPG) test.[29-33] However, although there are trade-offs among the different tests used for diagnosing diabetes, the degree to which the various tests are used alone or in combination is not clear, leaving future trends in diabetes uncertain. If adopting HbA_{1c} as the preferred test for the diagnosis of diabetes is having a major effect on magnitude of incidence rates, it is possible that a new baseline for monitoring future trends in diabetes incidence and prevalence will be established.

The doubling of the prevalence and incidence of diagnosed diabetes during 1990-2008 has been attributed to multiple factors, including aging of the population, improved survival rates, growth of minority populations at increased risk, and increased risk factors such as obesity and sedentary lifestyle. The increase in obesity prevalence has been attributed to numerous factors, ranging from changes in total dietary intake and portion sizes to qualitative changes in the diet over recent decades (eg, refined carbohydrates, added sugar, etc). Although the contribution of each factor to increasing diabetes incidence cannot be discerned, the increase in diabetes prevalence coincides with the increase in obesity in the United States.[34,35] Furthermore, our results lend support to the finding of other population-based studies[6] indicating that increasing adiposity is a large, though not sole, factor in increasing diabetes incidence.

Figure 3. Prevalence and Incidence of Diagnosed Diabetes Among Adults Aged 20 to 79 Years by Demographic Variables, 1980-2012



Data are from National Health Interview Survey. Race/ethnicity analyses were restricted to 1997-2012 due to sample size for some race/ethnicity groups.

Another factor that may have increased diabetes incidence is the 1997 change to the diagnostic criteria of diabetes,[36] which lowered FPG from 140 mg/dL or more to 126 mg/dL or more and encouraged a shift from the oral glucose tolerance test to fasting plasma glucose (to convert glucose to mmol/L, multiply by 0.0555). Given that incidence began to increase in 1990 (7 years prior to the 1997 diagnostic change, with no dramatic shifts after 1997), this diagnostic criteria change alone probably does not explain the increase.

Determining the role of increased detection of undiagnosed diabetes on trends in diabetes rates is complex and unknown for several reasons: diagnostic criteria for diabetes have changed over time; the magnitude of undiagnosed diabetes varies by diagnostic criteria; little is known about which tests or criteria clinicians actually use to diagnose diabetes; whether screening has increased is unknown; and the degree to which the use of results from casual or opportunistic screening (eg, fasting or random glucose on chemistry panels collected for other purposes) has increased is also unknown. Although increased detection of undiagnosed diabetes may have contributed to the increases in diabetes prevalence and incidence, it is unlikely that this factor alone could account fully for a strong and steady 15- to 20-year increase in diabetes prevalence and incidence.

The major strengths of this study are that the data are representative of the civilian, noninstitutionalized, US population and covered more than 3 decades. However, there are several limitations. First, although self-report of diabetes is a sensitive and highly specific measure of diagnosed diabetes,[37,38] about 28% of all diabetes is undiagnosed.[39] Because the NHIS does not identify undiagnosed disease, our study likely underestimates diabetes incidence and prevalence rates. Second, although diabetes incidence was calculated from a large, nationally representative survey, there may have been insufficient power to detect changes in trend for some population subgroups, and data were not sufficient to examine trends by race/ethnicity for the entire period. Third, the NHIS does not include data on institutionalized persons, for whom prevalence and incidence rates may differ from those in the general population. Fourth, during the more than 30 years studied, there were changes in the conduct of NHIS, including changes to sample design, the use of proxy respondents, and changes to the questionnaire. However, none of these changes coincided with or could explain observed trend changes in diabetes incidence and prevalence. Furthermore, NHIS household response rates, although remaining relatively high, declined in later years. The extent of any bias introduced by nonresponse or the use of proxy respondents is unknown, as well as how any bias has changed over time. Finally, NHIS data cannot distinguish between type 1 and type 2 diabetes. However, because type 2 diabetes accounts for about 95% of all diabetes, our findings are likely more representative of type 2 diabetes.

Conclusions

Analyses of nationally representative data from 1980 to 2012 suggest an overall plateauing of prevalence and incidence of diagnosed diabetes since 2008. However, there are continued increases in the prevalence or incidence of diabetes among some population subgroups, including non-Hispanic black and Hispanic subpopulations and those with a high school education or less.

ARTICLE INFORMATION

Author Contributions: Mss Geiss and Wang had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Geiss, Gregg.
Acquisition, analysis, or interpretation of data: Geiss, Wang, Cheng, Thompson, Barker, Li, Albright.
Drafting of the manuscript: Geiss.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Geiss, Wang, Cheng, Thompson, Barker, Li.
Administrative, technical, or material support: Geiss, Cheng, Gregg.
Study supervision: Geiss, Albright, Gregg.

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