Original Investigation

Prevalence of and Trends in Diabetes Among Adults in the United States, 1988-2012

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IMPORTANCE Previous studies have shown increasing prevalence of diabetes in the United States. New US data are available to estimate prevalence of and trends in diabetes.

OBJECTIVE To estimate the recent prevalence and update US trends in total diabetes, diagnosed diabetes, and undiagnosed diabetes using National Health and Nutrition Examination Survey (NHANES) data.

DESIGN, SETTING, AND PARTICIPANTS Cross-sectional surveys conducted between 1988-1994 and 1999-2012 of nationally representative samples of the civilian, noninstitutionalized US population; 2781 adults from 2011-2012 were used to estimate recent prevalence and an additional 23 634 adults from 1988-2010 were used to estimate trends.

MAIN OUTCOMES AND MEASURES The prevalence of diabetes was defined using a previous diagnosis of diabetes or, if diabetes was not previously diagnosed, by (1) a hemoglobin A_{1c} level of 6.5% or greater or a fasting plasma glucose (FPG) level of 126 mg/dL or greater (hemoglobin A_{1c} or FPG definition) or (2) additionally including 2-hour plasma glucose (2-hour PG) level of 200 mg/dL or greater (hemoglobin A_{1c}, FPG, or 2-hour PG definition). Prediabetes was defined as a hemoglobin A_{1c} level of 5.7% to 6.4%, an FPG level of 100 mg/dL to 125 mg/dL, or a 2-hour PG level of 140 mg/dL to 199 mg/dL.

RESULTS In the overall 2011-2012 population, the unadjusted prevalence (using the hemoglobin A_{1c}, FPG, or 2-hour PG definitions for diabetes and prediabetes) was 14.3% (95% CI, 12.2%-16.8%) for total diabetes, 9.1% (95% CI, 7.8%-10.6%) for diagnosed diabetes, 5.2% (95% CI, 4.0%-6.9%) for undiagnosed diabetes, and 38.0% (95% CI, 34.7%-41.3%) for prediabetes; among those with diabetes, 36.4% (95% CI, 30.5%-42.7%) were undiagnosed. The unadjusted prevalence of total diabetes (using the hemoglobin A_{1c} or FPG definition) was 12.3% (95% CI, 10.8%-14.1%); among those with diabetes, 25.2% (95% CI, 21.1%-29.8%) were undiagnosed. Compared with non-Hispanic white participants (11.3% [95% CI, 9.0%-14.1%]), the age-standardized prevalence of total diabetes (using the hemoglobin A_{1c}, FPG, or 2-hour PG definition) was higher among non-Hispanic black participants (21.8% [95% CI, 17.7%-26.7%]; $P < .001$), non-Hispanic Asian participants (20.6% [95% CI, 15.0%-27.6%]; $P = .007$), and Hispanic participants (22.6% [95% CI, 18.4%-27.5%]; $P < .001$). The age-standardized percentage of cases that were undiagnosed was higher among non-Hispanic Asian participants (50.9% [95% CI, 38.3%-63.4%]; $P = .004$) and Hispanic participants (49.0% [95% CI, 40.8%-57.2%]; $P = .02$) than all other racial/ethnic groups. The age-standardized prevalence of total diabetes (using the hemoglobin A_{1c} or FPG definition) increased from 9.8% (95% CI, 8.9%-10.6%) in 1988-1994 to 10.8% (95% CI, 9.5%-12.0%) in 2001-2002 to 12.4% (95% CI, 10.8%-14.2%) in 2011-2012 ($P < .001$ for trend) and increased significantly in every age group, in both sexes, in every racial/ethnic group, by all education levels, and in all poverty income ratio tertiles.

CONCLUSIONS AND RELEVANCE In 2011-2012, the estimated prevalence of diabetes was 12% to 14% among US adults, depending on the criteria used, with a higher prevalence among participants who were non-Hispanic black, non-Hispanic Asian, and Hispanic. Between 1988-1994 and 2011-2012, the prevalence of diabetes increased in the overall population and in all subgroups evaluated.

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Diabetes is a major cause of morbidity and mortality in the United States, costing an estimated $245 billion in 2012 due to increased use of health resources and lost productivity.[1] The recent prevalence and trends in diabetes can be estimated using US survey data with information on a previous diabetes diagnosis and measured glucose levels. Studies have shown that the prevalence of diagnosed diabetes,[2,3] total diabetes (diagnosed plus undiagnosed),[2,4] and type 1 diabetes[5] has increased in the US population during the past decades. Diagnosed diabetes increased from 3.5% in 1990 to 7.9% in 2008 before plateauing between 2008 and 2012.[3]

In addition, the prevalence of prediabetes (based on levels of hemoglobin A_{1c} and fasting plasma glucose [FPG]) increased between 1999 and 2010.[6] These diabetes trends are consistent with other studies showing that the prevalence of obesity has generally been increasing in the US population during the past few decades.[7,8] New US survey data are available to estimate total diabetes prevalence and trends.[2,4]

To estimate the prevalence and US trends in total, diagnosed, and undiagnosed diabetes and prediabetes, we used data collected in the 1988-1994 and the 1999-2000 to 2011-2012 National Health and Nutrition Examination Surveys (NHANES).

Methods

Data Collection

NHANES is a series of stratified, multistage probability surveys designed to be representative of the US civilian, noninstitutionalized population.[9,10] NHANES III collected data over 7 years during 1988-1994, whereas the current NHANES has continuously collected data in 2-year cycles since 1999. The data are collected via an in-home interview and a visit to a mobile examination center. We used data from the 2011-2012 NHANES to estimate recent trends in diabetes prevalence.

The overall response rates ranged from 73% to 86% for the interview and 70% to 80% for the examination. Participants were randomly selected to participate in a morning examination or an afternoon or evening examination. We used data from the morning examination session (after an 8- to 24-hour fast) to include FPG level in diabetes definitions. We excluded women who were pregnant because pregnancy affects glucose measurements. All participants provided written informed consent and the research ethics boards of the National Center for Health Statistics (NCHS) approved all protocols.

A standardized questionnaire was used to collect information on age, race/ethnicity, sex, education level, and income level. Poverty income ratio (a measure of family income to poverty guidelines specific to the survey year) was categorized into tertiles. Participants were asked if they have ever been diagnosed with diabetes by a "doctor" (NHANES III) or a "doctor or other health professional" (NHANES 1999-2012).

During the examination, weight and height were measured and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. A phlebotomist obtained a blood sample from participants according to a standardized protocol. Hemoglobin A_{1c} level was measured; the interassay coefficient of variation was 0.7% to 3.1%.[9,10] Although different equipment was used over time, calibration of hemoglobin A_{1c} is not necessary according to NHANES recommendations.[10] Fasting plasma glucose was measured (to convert glucose to mmol/L, multiply by 0.0555); the interassay coefficient of variation was 0.8% to 3.7%.[9,10]

We calibrated FPG in NHANES 2005-2012 to the earlier NHANES surveys as recommended by the NCHS.[10] In NHANES III and the 2005-2012 NHANES, an oral glucose tolerance test was administered to participants using a calibrated dose (75 g) of glucose and a venipuncture 2 hours (±15 minutes) later (2-hour plasma glucose [PG]). Diagnosed diabetes was defined as a self-reported previous diagnosis of diabetes.

Definitions of Diabetes

Undiagnosed and Total

We used 2 definitions of undiagnosed and total diabetes in our study. The first defined undiagnosed diabetes as any participant who had a hemoglobin A_{1c} level of 6.5% or greater, an FPG level of 126 mg/dL or greater, or a 2-hour PG level of 200 mg/dL or greater and defined total diabetes as any participant who had either diagnosed diabetes or undiagnosed diabetes defined by hemoglobin A_{1c}, FPG, or 2-hour PG; this definition allows for a full accounting of diabetes. However, 2-hour PG levels were not available for all age groups and in all NHANES years. The second defined undiagnosed diabetes as any participant who had a hemoglobin A_{1c} level of 6.5% or greater or an FPG level of 126 mg/dL or greater and defined total diabetes as having either diagnosed diabetes or undiagnosed diabetes defined by hemoglobin A_{1c} or FPG; this definition is consistent across all NHANES study years. In addition, this definition is consistent with the methods used in the medical community in which 2-hour PG is used less frequently because it is relatively costly and burdensome for patients.

Prediabetes

We also used 2 definitions of prediabetes. The first defined prediabetes as any participant who did not have diabetes but who had a hemoglobin A_{1c} level of 5.7% to 6.4%, an FPG level of 100 mg/dL to 125 mg/dL, or a 2-hour PG level of 140 mg/dL to 199 mg/dL. The second defined prediabetes as any participant who did not have diabetes but who had a hemoglobin A_{1c} level of 5.7% to 6.4% or an FPG level of 100 mg/dL to 125 mg/dL. Because estimates based on the 2 definitions of diabetes used different subsets of NHANES data (ie, the FPG sample and the 2-hour PG sample), corresponding estimates of total and diagnosed diabetes and prediabetes may differ.

Statistical Analysis

We used NHANES 2011-2012 to calculate the prevalence of total diabetes, previously diagnosed diabetes, and undiagnosed diabetes as well as the percentage of total diabetes that was undiagnosed and the prevalence of prediabetes in the overall population, stratified by age, sex, and race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic Asian, Hispanic, and

Mexican American; other racial/ethnic groups were included in overall analyses and analyses stratified by other variables). We did this for the hemoglobin A_{1c}, FPG, or 2-hour PG definition for diabetes and prediabetes and for the hemoglobin A_{1c} or FPG definition for diabetes and prediabetes.

All stratified estimates were age standardized to the overall 2011-2012 NHANES interview population using age groups and weights (20-44 years, weight, 0.4561; 45-64 years, weight, 0.3673; and ≥65 years, weight, 0.1766) to allow comparisons by sex and race/ethnicity independent of age and then repeated the analysis without using age standardization. The *F* test was used to calculate *P* values for overall differences in prevalence by strata.

To investigate trends over time, we calculated the age-standardized prevalence of total diabetes based on the definition using hemoglobin A_{1c} or FPG overall and by age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, and Mexican American; other racial/ethnic groups were not available in all survey years), education level (<high school, high school, and >high school), and tertile of poverty income ratio. We repeated this analysis using the hemoglobin A_{1c}, FPG, or 2-hour PG definition for diabetes among people aged 40-74 years in NHANES III and the 2005-2012 NHANES (the age group and years in which all data were available).

Tests for trends were calculated by including the midpoint of each survey period as a continuous variable in a logistic regression model. Significance tests were 2-sided and *P* values <.05 were considered statistically significant; we did not adjust for multiple comparisons. When we added a quadratic term to test for a nonlinear change in diabetes prevalence over time, it was not significant in the overall population or in any subgroups, so we only included a linear test for trend in our analysis. We calculated the relative standard error for each estimate; any relative standard error greater than 30% indicates estimates with low precision.

Appropriate published sample weights were used so that the sum of the sample weights for each analysis added to the total civilian, noninstitutionalized US population (for the hemoglobin A_{1c} or FPG diabetes definition, a combination of the interview, mobile examination center, and FPG weights were used; for the hemoglobin A_{1c}, FPG, or 2-hour PG diabetes definition, a combination of the interview, mobile examination center, FPG, and oral glucose tolerance test weights were used).[2]

Weights were used to account for unequal probabilities of selection and nonresponse and thus provide estimates representative of the civilian, noninstitutionalized US population.[9,10] Data were analyzed using SUDAAN version 10.0.1 (RTI International) accounting for the stratified, clustered sample design used by NHANES.

Results

Prevalence Using Hemoglobin A_{1c}, FPG, or 2-Hour PG

The unweighted analytic sample was 2781 for NHANES 2011-2012. The 2011-2012 prevalence of diabetes using the hemoglobin A_{1c}, FPG, or 2-hour PG definition appears in **Table 1**. In the overall population, the unadjusted prevalence was 14.3% (95% CI, 12.2%-16.8%) for total diabetes, 9.1% (95% CI, 7.8%-10.6%) for diagnosed diabetes, 5.2% (95% CI, 4.0%-6.9%) for undiagnosed diabetes, and 38.0% (95% CI, 34.7%-41.3%) for prediabetes; among those with diabetes, 36.4% (95% CI, 30.5%-42.7%) were undiagnosed.

The unadjusted prevalence of total diabetes was higher in those aged 65 years or older (33.0% [95% CI, 27.1%-39.4%]) compared with those aged 45-64 years (17.5% [95% CI, 14.4%-21.0%]) and those aged 45 years or younger (5.0% [95% CI, 3.8%-6.7%]; *P* < .001). The age-standardized prevalence of total diabetes was similar among men (15.4% [95% CI, 13.2%-17.9%]) and women (13.8% [95% CI, 11.4%-16.6%]; *P* = .20).

Compared with non-Hispanic white participants (11.3% [95% CI, 9.0%-14.1%]), the age-standardized prevalence of diabetes was higher in non-Hispanic black participants (21.8% [95% CI, 17.7%-26.7%]; *P* < .001), non-Hispanic Asian participants (20.6% [95% CI, 15.0%-27.6%]; *P* = .007), and Hispanic participants (22.6% [95% CI, 18.4%-27.5%]; *P* < .001). Compared with non-Hispanic white participants (mean BMI, 28.4 [95% CI, 27.8-29.0]), the age-standardized mean BMI was higher among non-Hispanic black participants (30.8 [95% CI, 30.2-31.3]; *P* < .001) and Hispanic participants (29.7 [95% CI, 29.2-30.1]; *P* = .003) and was lower among non-Hispanic Asian participants (24.6 [95% CI, 24.1-25.1]; *P* < .001).

The age-standardized percentage of people with diabetes who were undiagnosed was higher among non-Hispanic Asian participants (50.9% [95% CI, 38.3%-63.4%]; *P* = .004) and Hispanic participants (49.0% [95% CI, 40.8%-57.2%]; *P* = .02) than all other racial/ethnic groups. The age-standardized prevalence of prediabetes was higher among non-Hispanic black participants (39.6% [95% CI, 33.5%-46.0%]) than non-Hispanic Asian participants (32.2% [95% CI, 28.3%-36.4%]; *P* = .05). Differences by race/ethnicity were similar without age standardization (eTable 1 in the Supplement).

Prevalence Using Hemoglobin A_{1c} or FPG

The prevalence of diabetes based on the hemoglobin A_{1c} or FPG definition appears in **Table 2**. Because 2-hour PG is not included in the definition, there are generally fewer people with undiagnosed diabetes. In the overall population, the unadjusted prevalence was 12.3% (95% CI, 10.8%-14.1%) for total diabetes, 9.2% (95% CI, 8.0%-10.7%) for diagnosed diabetes, 3.1% (95% CI, 2.5%-3.9%) for undiagnosed diabetes, and 36.5% (95% CI, 33.2%-40.0%) for prediabetes; among those with diabetes, 25.2% (95% CI, 21.1%-29.8%) were undiagnosed. Age-standardized differences by age, sex, and racial/ethnic group were generally similar to those seen when using the hemoglobin A_{1c}, FPG, or 2-hour PG diabetes definition and similar without age standardization (eTable 2 in the Supplement).

Trends

The unweighted analytic sample was 8478 for NHANES III and between 2168 and 3118 for each 2-year cycle of the continuous NHANES. The age-standardized prevalence of diabetes using the hemoglobin A_{1c} or FPG definition increased from 9.8% (95% CI, 8.9%-10.6%) in 1988-1994 to 12.4% (95% CI, 10.8%-14.2%) in 2011-2012 (*P* < .001 for trend). However, the prevalence of diabetes remained similar from 2007-2008

Table 1. Weighted Diabetes Prevalence per 100 Adults Aged 20 Years or Older in the US General Population Using Hemoglobin A_{1c} Level, Fasting Plasma Glucose Level, or 2-Hour Plasma Glucose Level to Define Diabetes, 2011-2012

	Total No.	No. With Diabetes[a]	Total Diabetes Prevalence, % (95% CI)[b,c]	P Value[d]	Diagnosed Diabetes Prevalence, % (95% CI)[b,e]	P Value[d]	Undiagnosed Diabetes[f]				Prediabetes Prevalence, % (95% CI)[b,g]	P Value[d]	Body Mass Index, Mean (95% CI)[b,h]	P Value[d]
							Prevalence, % (95% CI)[b]	P Value[d]	% of Total Diabetes Cases, (95% CI)[b]	P Value[d]				
Overall prevalence[i]	2623	971	14.3 (12.2-16.8)		9.1 (7.8-10.6)		5.2 (4.0-6.9)		36.4 (30.5-42.7)		38.0 (34.7-41.3)		28.7 (28.3-29.2)	
Age group, y														
20-44	998	139	5.0 (3.8-6.7)		2.7 (2.0-3.6)		2.4 (1.6-3.6)		47.0 (37.1-57.0)		28.2 (24.4-32.4)		28.1 (27.6-28.6)	
45-64	964	432	17.5 (14.4-21.0)	<.001	11.6 (9.5-14.0)	<.001	5.8 (4.0-8.5)	<.001	33.5 (25.0-43.3)	.08	44.9 (37.6-52.4)	<.001	29.5 (28.8-30.3)	.007
≥65	661	400	33.0 (27.1-39.4)		21.3 (18.1-24.9)		11.6 (8.3-16.1)		35.3 (28.8-42.4)		49.5 (43.4-55.6)		28.5 (27.7-29.2)	
Sex														
Male	1334	495	15.4 (13.2-17.9)	.20	9.9 (8.9-11.0)	.15	5.5 (3.8-7.9)	.69	41.3 (33.2-49.9)	.95	40.1 (35.6-44.8)	.13	28.5 (28.1-29.0)	.07
Female	1289	476	13.8 (11.4-16.6)		8.7 (7.1-10.8)		5.1 (3.7-6.9)		38.5 (29.0-49.1)		35.9 (32.0-39.9)		28.9 (28.4-29.4)	
Race/ethnicity[j]														
Non-Hispanic														
White	948	279	11.3 (9.0-14.1)		7.5 (6.2-9.1)		3.8 (2.3-6.1)		32.3 (22.0-44.8)		38.2 (33.6-42.9)		28.4 (27.8-29.0)	
Black	676	323	21.8 (17.7-26.7)	<.001	14.9 (13.0-17.0)	<.001	7.0 (4.6-10.5)	.004	36.8 (27.5-47.1)	.009	39.6 (33.5-46.0)	.18	30.8 (30.2-31.3)	<.001
Asian	369	125	20.6 (15.0-27.6)		10.0 (7.2-13.9)		10.6 (6.9-15.7)		50.9 (38.3-63.4)		32.2 (28.3-36.4)		24.6 (24.1-25.1)	
All Hispanic	561	219	22.6 (18.4-27.5)		12.5 (9.5-16.2)		10.1 (7.8-13.0)		49.0 (40.8-57.2)		36.8 (32.1-41.7)		29.7 (29.2-30.1)	
Mexican American	282	105	23.8 (19.1-29.2)		14.4 (10.7-19.2)		9.4 (6.9-12.7)		48.1 (42.6-53.6)		38.0 (30.7-46.0)		30.2 (29.4-31.0)	

[a] Unweighted total number of cases of diabetes.

[b] The overall total and age group results are unadjusted. The sex and race/ethnicity data were age standardized to the overall 2011-2012 National Health and Nutrition Examination Survey interview population using the age groups of 20-44 years, 45-64 years, and 65 years or older. The relative standard error for each estimate was less than 30%, indicating good precision.

[c] Includes both diagnosed and undiagnosed cases of diabetes.

[d] Calculated using the *F* test.

[e] Based on self-report of a previous diagnosis by a physician or other health professional.

[f] Based on level of hemoglobin A_{1c} of 6.5% or greater, fasting plasma glucose level of 126 mg/dL or greater, or 2-hour plasma glucose level of 200 mg/dL or greater.

[g] Based on level of hemoglobin A_{1c} of 5.7% to 6.4%, fasting plasma glucose level of 100 mg/dL to 125 mg/dL, or 2-hour plasma glucose level of 140 mg/dL to 199 mg/dL.

[h] Calculated as weight in kilograms divided by height in meters squared.

[i] Unless otherwise indicated.

[j] Sixty-nine participants self-reported as "other" and their data are not included for this variable; however, their data are included for the other variables.

Table 2. Weighted Diabetes Prevalence per 100 Adults Aged 20 Years or Older in the US General Population Using Hemoglobin A_{1c} Level or Fasting Plasma Glucose Level to Define Diabetes, 2011-2012

	Total No.	No. With Diabetes[a]	Total Diabetes Prevalence, % (95% CI)[b,c]	*P* Value[d]	Diagnosed Diabetes Prevalence, % (95% CI)[b,e]	*P* Value[d]	Undiagnosed Diabetes[f]				Prediabetes Prevalence, % (95% CI)[b,g]	*P* Value[d]	Body Mass Index, Mean (95% CI)[b,h]	*P* Value[d]
							Prevalence, % (95% CI)[b]	*P* Value[d]	% of Total Diabetes Cases, (95% CI)[b]	*P* Value[d]				
Overall prevalence[i]	2781	910	12.3 (10.8-14.1)		9.2 (8.0-10.7)		3.1 (2.5-3.9)		25.2 (21.1-29.8)		36.5 (33.2-40.0)		28.7 (28.3-29.2)	
Age group, y														
20-44	1078	132	4.5 (3.5-5.8)		2.7 (2.0-3.6)		1.8 (1.2-2.7)		40.2 (29.5-51.9)		25.1 (21.5-29.0)		28.1 (27.6-28.6)	
45-64	1003	414	16.2 (13.4-19.6)	<.001	11.9 (9.8-14.3)	<.001	4.4 (3.1-6.2)	.004	26.9 (21.0-33.9)	<.001	42.2 (36.3-48.4)	<.001	29.5 (28.8-30.3)	.007
≥65	700	364	24.7 (21.6-28.1)		20.9 (17.9-24.3)		3.8 (2.6-5.6)		15.5 (10.7-22.0)		54.6 (49.3-59.9)		28.5 (27.7-29.2)	
Sex														
Male	1393	469	13.6 (12.0-15.3)	.03	9.9 (8.9-11.0)	.16	3.6 (2.6-5.2)	.24	34.4 (26.6-43.2)	.38	39.1 (34.5-44.0)	.05	28.5 (28.1-29.0)	.07
Female	1388	441	11.4 (9.6-13.6)		8.8 (7.2-10.8)		2.6 (1.8-3.8)		27.4 (18.4-38.6)		33.8 (30.2-37.6)		28.9 (28.4-29.4)	
Race/ethnicity[j]														
Non-Hispanic														
White	1017	254	9.5 (8.0-11.2)		7.5 (6.3-9.0)		1.9 (1.3-2.8)		24.6 (16.5-35.0)		36.1 (31.7-40.7)		28.4 (27.8-29.0)	
Black	707	313	20.6 (16.9-24.8)	<.001	15.2 (13.2-17.5)	<.001	5.3 (3.4-8.4)	.001	32.8 (23.0-44.5)	.004	38.8 (33.2-44.7)	.17	30.8 (30.2-31.3)	<.001
Asian	395	115	16.5 (13.0-20.6)		10.0 (7.3-13.5)		6.5 (4.7-9.0)		39.7 (32.2-47.8)		31.7 (26.5-37.4)		24.6 (24.1-25.1)	
All Hispanic	589	203	18.7 (15.1-23.0)		12.5 (9.6-16.1)		6.2 (4.7-8.3)		36.8 (25.2-50.1)		37.5 (32.9-42.3)		29.7 (29.2-30.1)	
Mexican American	289	98	20.5 (16.3-25.4)		14.6 (10.8-19.4)		5.9 (4.7-7.5)		35.2 (22.9-49.8)		37.5 (30.8-44.7)		30.2 (29.4-31.0)	

[a] Unweighted total number of cases of diabetes.

[b] The overall total and age group results are unadjusted. The sex and race/ethnicity data were age standardized to the overall 2011-2012 National Health and Nutrition Examination Survey interview population using the age groups of 20-44 years, 45-64 years, and 65 years or older. The relative standard error for each estimate was less than 30%, indicating good precision.

[c] Includes both diagnosed and undiagnosed cases of diabetes.

[d] Calculated using the *F* test.

[e] Based on self-report of a previous diagnosis by a physician or other health professional.

[f] Based on level of hemoglobin A_{1c} of 6.5% or greater or fasting plasma glucose level of 126 mg/dL or greater.

[g] Based on level of hemoglobin A_{1c} of 5.7% to 6.4% or fasting plasma glucose level of 100 mg/dL to 125 mg/dL.

[h] Calculated as weight in kilograms divided by height in meters squared.

[i] Unless otherwise indicated.

[j] Seventy-three participants self-reported as "other" and their data are not included for this variable; however, their data are included for the other variables.

(12.5% [95% CI, 10.9%-14.2%]) to 2011-2012 (12.4% [95% CI, 10.8%-14.2%]) (**Table 3** and **Figure 1**).

Diabetes prevalence significantly increased over time in every age group, in both sexes, in every racial/ethnic group, by all education levels, and in all poverty income ratio tertiles. When stratified by BMI, diabetes only increased among people with a BMI of 30 or greater (18.0% [95% CI, 15.9%-20.0%] in 1988-1994 vs 20.1% [95% CI, 17.8%-22.4%] in 2011-2012; $P = .003$; **Figure 2**). Results were similar without age standardization (eTable 3 in the Supplement).

The increase in diabetes prevalence was due to an increase in diagnosed diabetes (Figure 1 and eTables 4 and 5 in the Supplement). Undiagnosed diabetes did not increase over time in the overall population; however, it did increase among Mexican American participants (from 5.6% [95% CI, 4.2%-7.1%] in 1988-1994 to 5.9% [95% CI, 4.6%-7.2%] in 2011-2012, $P = .01$; eTable 5 in the Supplement). The age-standardized percentage of total diabetes that was undiagnosed decreased from 40.3% (95% CI, 34.9%-45.7%) in 1988-1994 to 31.0% (95% CI, 25.2%-37.4%) in 2011-2012 ($P < .001$; eTable 6 in the Supplement). The percentage of total diabetes that was undiagnosed decreased in almost all age, sex, and racial/ethnic groups, except for the youngest age group and Mexican American participants.

The age-standardized prevalence of total diabetes using the hemoglobin A_{1c}, FPG, or 2-hour PG definition among people aged 40-74 years (the ages in which 2-hour PG was available for all study years) was 15.9% (95% CI, 14.5%-17.3%) in 1988-1994, 18.1% (95% CI, 15.1%-21.0%) in 2005-2006, and 18.0% (95% CI, 15.6%-20.4%) in 2011-2012 ($P = .01$ for trend). The prevalence increased among people aged 65-74 years (from 25.0% [95% CI, 22.0%-28.0%] in 1988-1994 to 26.9% [95% CI, 21.9%-32.0%] in 2011-2012; $P = .05$ for trend) and among men (from 16.9% [95% CI, 15.0%-18.8%] in 1988-1994 to 19.9% [95% CI, 16.8%-23.0%] in 2011-2012; $P = .03$ for trend) (eTable 7 in the Supplement). The increases among younger age groups and women were not statistically significant. Estimates of total diabetes without age standardization appear in eTable 8 and estimates of undiagnosed diabetes appear in eTable 9 in the Supplement.

Discussion

In a representative sample of US adults in 2011-2012, the weighted prevalence of diabetes was high (12%-14% in the overall population and >10% in all sex and racial/ethnic groups). The age-standardized prevalence was higher among minority populations, including non-Hispanic black, non-Hispanic Asian, and Hispanic populations. More than 1 in 3 people with diabetes were previously undiagnosed using the hemoglobin A_{1c}, FPG, or 2-hour PG definition and this number was particularly high in non-Hispanic Asian and Hispanic participants.

Between 1988-1994 and 2011-2012, the prevalence of diabetes increased significantly among the overall population and among each age group, both sexes, every racial/ethnic group, every education level, and every income level, with a particularly rapid increase among non-Hispanic black and Mexican American participants. The proportion of people who had undiagnosed diabetes significantly decreased.

The increase in prevalence of diabetes is consistent with previous findings. A study using NHANES data showed that the prevalence of diagnosed diabetes increased from 1988-1994 to 2005-2006; however, undiagnosed diabetes did not increase during that period.[2] Another study using NHANES data showed total diabetes prevalence increased from 1988-1994 to 2005-2010.[4] Prediabetes prevalence also increased in the United States between 1999-2002 and 2007-2010.[6]

In our study, we found a linear increase between 1988-1994 and 2011-2012, but prevalence estimates changed little between 2007-2008 and 2011-2012 using both diabetes definitions to estimate total diabetes prevalence. This is consistent with a study using National Health Interview Survey data that found diagnosed diabetes prevalence increased between 1990 and 2008, but remained steady between 2008 and 2012.[3] This plateauing of diabetes prevalence is consistent with obesity trends in the United States showing a leveling off around the same period.[11]

To our knowledge, our study provides the first estimates of the prevalence of total diabetes, undiagnosed diabetes, and prediabetes among Asian participants in the United States. More than half of non-Hispanic Asian participants had not been previously diagnosed and therefore were not aware of having diabetes. In all, 10.6% of non-Hispanic Asian participants were estimated to have had undiagnosed diabetes using the hemoglobin A_{1c}, FPG, or 2-hour PG definition, which was higher than any other racial/ethnic group. This may partly be due to less frequent screening for diabetes because non-Hispanic Asian individuals on average have lower BMIs.

Compared with people of other races, Asian individuals may have a higher percentage of body fat and higher risk of developing diabetes at a given BMI.[12-14] As a result, the World Health Organization has suggested lower BMI cut points for defining overweight and obesity in Asian individuals.[15] In the United States, the frequency of screening for diabetes in clinical practice may not reflect the greater risk for diabetes that Asian individuals have at a given BMI. The Asian population was oversampled in NHANES for the first time in 2011-2012 and further years of oversampling may provide additional information about specific Asian subgroups and trends over time.

Previous studies found a higher prevalence of diabetes among non-Hispanic black and Mexican American participants than non-Hispanic white participants,[2] which is consistent with our findings. Furthermore, we found the proportion of people with diabetes who were undiagnosed was higher in Hispanic participants than among non-Hispanic white or non-Hispanic black participants, and it did not decrease over time like other racial/ethnic groups.

The decreasing proportion of diabetes that was undiagnosed in the overall population may be due to a combination of better screening for diabetes and better survival among people with diagnosed diabetes. Similar improvements may not have occurred among Hispanic individuals and younger people with diabetes due to a lower percentage with health insurance,[16] resulting in lower access to health care.[17]

Table 3. Age-Standardized Weighted Total Diabetes Prevalence per 100 Adults Aged 20 Years or Older in the US General Population Using Hemoglobin A_{1c} Level or Fasting Plasma Glucose Level to Define Diabetes, 1988-2012

	Total Diabetes Prevalence, % (95% CI)[a]								
	1988-1994 (n = 8478)	1999-2000 (n = 2168)	2001-2002 (n = 2479)	2003-2004 (n = 2299)	2005-2006 (n = 2191)	2007-2008 (n = 2901)	2009-2010 (n = 3118)	2011-2012 (n = 2781)	*P* for Trend[b]
No. with diabetes[c]	2136	606	669	676	635	991	955	910	
Overall prevalence	9.8 (8.9-10.6)	9.8 (8.5-11.0)	10.8 (9.5-12.0)	11.7 (10.3-13.0)	10.8 (9.5-12.2)	12.5 (10.9-14.2)	12.1 (10.3-13.9)	12.4 (10.8-14.2)	<.001
Age group, y									
20-44	2.7 (2.1-3.4)	2.9 (1.4-4.4)	3.8 (2.6-5.0)	3.5 (2.4-4.6)	4.2 (3.2-5.2)	3.7 (2.7-4.6)	3.3 (2.6-4.1)	4.5 (3.5-5.8)	.01
45-64	13.3 (11.9-14.8)	13.1 (10.8-15.4)	12.6 (9.9-15.2)	14.6 (12.3-16.8)	12.9 (10.1-15.7)	15.5 (12.0-19.0)	15.8 (12.0-19.6)	16.2 (13.4-19.6)	.02
≥65	20.5 (18.3-22.6)	20.6 (16.7-24.5)	25.1 (22.3-27.8)	26.7 (21.6-31.8)	23.7 (19.6-27.8)	29.3 (26.2-32.4)	27.0 (23.4-30.5)	24.7 (21.6-28.1)	<.001
Sex									
Male	10.3 (9.4-11.3)	10.5 (8.9-12.0)	12.3 (10.6-14.1)	12.8 (11.2-14.5)	11.2 (9.2-13.1)	13.7 (11.9-15.5)	14.4 (11.3-17.4)	13.6 (12.0-15.3)	<.001
Female	9.3 (8.2-10.4)	9.1 (7.7-10.6)	9.4 (8.0-10.7)	10.7 (9.4-11.9)	10.5 (8.7-12.3)	11.6 (9.7-13.5)	10.1 (8.9-11.2)	11.4 (9.6-13.6)	.005
Race/ethnicity[d]									
Non-Hispanic									
White	8.6 (7.7-9.5)	8.3 (7.1-9.5)	8.9 (7.7-10.1)	10.2 (8.7-11.7)	8.9 (7.4-10.4)	10.6 (8.3-12.9)	10.0 (7.8-12.2)	9.5 (8.0-11.2)	.04
Black	16.3 (14.6-18.0)	17.1 (13.5-20.8)	16.9 (13.9-20.0)	16.0 (13.5-18.4)	18.8 (15.8-21.8)	22.6 (19.3-26.0)	18.6 (16.6-20.6)	20.6 (16.9-24.8)	.003
Mexican American	17.5 (15.6-19.3)	13.2 (11.1-15.3)	16.1 (13.9-18.4)	16.6 (13.8-19.3)	18.5 (15.9-21.2)	18.1 (16.3-20.0)	20.8 (17.5-24.2)	20.5 (16.3-25.4)	<.001
Education level									
<High school	14.1 (12.7-15.5)	15.1 (12.2-17.9)	16.2 (14.4-18.1)	17.0 (15.2-18.7)	16.6 (13.0-20.2)	17.8 (15.1-20.5)	17.0 (14.6-19.3)	18.6 (14.7-22.5)	<.001
High school graduate	9.6 (8.2-10.9)	10.5 (8.6-12.4)	10.4 (8.1-12.7)	10.5 (8.7-12.3)	12.1 (9.4-14.8)	14.0 (10.6-17.4)	11.8 (8.2-15.4)	15.0 (12.0-17.9)	<.001
>High school	6.8 (5.8-7.8)	6.1 (4.6-7.6)	8.6 (7.0-10.3)	10.4 (8.5-12.3)	8.7 (7.0-10.4)	9.7 (8.0-11.4)	10.5 (8.4-12.7)	9.7 (7.9-11.5)	<.001
Poverty income ratio tertile									
Lowest	13.0 (11.7-14.4)	13.2 (11.1-15.4)	14.7 (12.0-17.3)	14.6 (12.3-16.9)	15.3 (12.5-18.1)	18.0 (15.6-20.4)	14.7 (12.1-17.3)	17.8 (15.1-20.5)	<.001
Middle	9.1 (8.0-10.3)	10.6 (7.9-13.4)	10.6 (9.4-11.8)	11.1 (9.0-13.3)	10.8 (7.3-14.2)	10.8 (8.9-12.7)	12.3 (9.8-14.9)	11.5 (9.1-13.8)	.01
Highest	7.5 (6.2-8.8)	5.1 (3.6-6.6)	7.1 (5.4-8.8)	9.2 (7.2-11.2)	6.8 (5.6-8.1)	9.9 (7.3-12.6)	9.0 (6.5-11.5)	8.0 (5.3-10.7)	.06

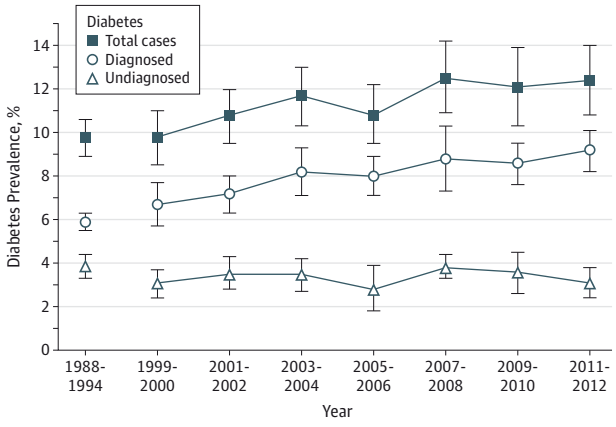
[a] All estimates were age standardized to the overall 2011-2012 National Health and Nutrition Examination Survey interview population using the age groups of 20-44 years, 45-64 years, and 65 years or older. Presence of diabetes is based on previous diagnosis, level of hemoglobin A_{1c} of 6.5% or greater, or fasting plasma glucose level of 126 mg/dL or greater. The relative standard error for each estimate was less than 30%, indicating good precision.

[b] Calculated using logistic regression models with the midpoint of each survey modeled as a continuous variable.

[c] Unweighted total number of cases of diabetes.

[d] There were 2740 participants who self-reported as "other" and their data are not included for this variable; however, their data are included for the other variables.

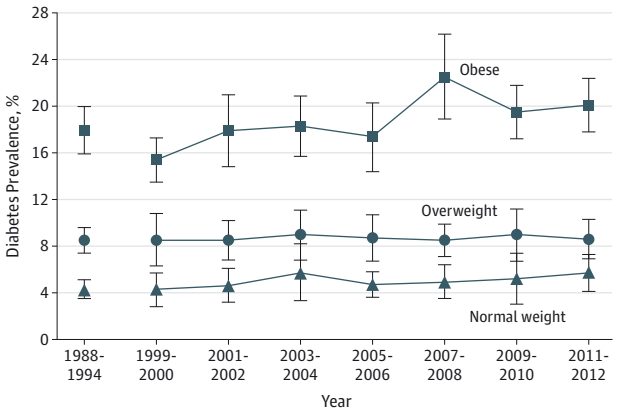
Figure 1. US Trends in Diabetes Prevalence per 100 Adults Aged 20 Years or Older



No. of participants	8478	2168	2479	2299	2191	2901	3118	2781

Both diagnosed and undiagnosed cases of diabetes are included in the total cases. Diagnosed diabetes is based on self-report of a previous diagnosis by a physician or other health professional. Undiagnosed diabetes is based on a hemoglobin A_{1c} level of 6.5% or greater or fasting plasma glucose level of 126 mg/dL or greater. All estimates were age standardized to the overall 2011-2012 National Health and Nutrition Examination Survey interview population using the age groups of 20-44 years, 45-64 years, and 65 years or older. Error bars indicate 95% confidence intervals.

Figure 2. US Trends in Diabetes Prevalence per 100 Adults Aged 20 Years or Older by BMI Category



No. of participants								
Obese	2324	727	732	815	820	1137	1302	1075
Overweight	2942	724	878	784	694	949	1009	852
Normal weight	3025	645	699	624	604	726	762	785

Normal weight includes participants with a body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) of less than 25, overweight includes those with a BMI of 25 to 29.9, and obese includes those with a BMI of 30 or greater. Presence of diabetes is based on a previous diabetes diagnosis, hemoglobin A_{1c} level of 6.5% or greater, or fasting plasma glucose level of 126 mg/dL or greater. All estimates were age standardized to the overall 2011-2012 National Health and Nutrition Examination Survey interview population using the age groups of 20-44 years, 45-64 years, and 65 years or older. Error bars indicate 95% confidence intervals.

The worldwide prevalence of diabetes has been increasing over the past few decades.[18] The rapid increase in diagnosed diabetes along with no change in undiagnosed diabetes may suggest improved detection in non-Hispanic black individuals between 1988-1994 and 2011-2012. The increase in total diabetes may be due to an increase in obesity, the most important risk factor for type 2 diabetes.[7] It may also be due to shifting demographics and an older population in more recent years, although the increase over time persisted after age standardization. A difference in the risk of mortality among non-Hispanic black individuals with diabetes would also affect trend estimates; however, previous studies have found that the decrease in mortality was similar among racial/ethnic groups between 1997-1998 and 2003-2004.[19]

We found the prevalence of prediabetes was 37% to 38% in the overall population, and consequently 49% to 52% of the population was estimated to have either diabetes or prediabetes. The prevalence of prediabetes was greater than 30% in all sex and racial/ethnic categories, and generally highest among non-Hispanic white individuals and non-Hispanic black individuals. In a previous study of NHANES data, prediabetes using level of hemoglobin A_{1c} or FPG increased from 29% in 1999-2002 to 36% in 2007-2010.[6]

The definitions of diabetes we used in our study included previously diagnosed diabetes and undiagnosed diabetes using level of hemoglobin A_{1c}, FPG, or 2-hour PG.[20] Previous diabetes diagnosis was based on self-report and was not verified by medical records. In addition, the American Diabetes Association recommends a repeat measurement after a single hemoglobin A_{1c}, FPG, or 2-hour PG diabetes-positive test result, which we could not do because most participants had only 1 study visit in NHANES; therefore, some participants without diabetes may have been misclassified as having diabetes in our study and it is unclear how frequently this occurred.[21,22]

Including 2-hour PG level in a definition of diabetes allowed for a more thorough accounting, which is why the prevalence of undiagnosed diabetes is higher when using the he-

moglobin A_{1c}, FPG, or 2-hour PG definition than when using the hemoglobin A_{1c} or FPG definition and the other prior definitions used.[6,18] Although the diagnostic criteria and screening practices changed over time, we included undiagnosed diabetes when investigating diabetes trends. As a result, we defined diabetes consistently over all NHANES surveys included in our study. NHANES does not have more precise data on Asian subgroups, so we were unable to explore differences by Asian heritage (eg, East Asian vs South Asian).[23] Trends in poverty income ratio should be interpreted with caution because the methods used in calculating this variable changed over time.[9,10]

Despite these limitations, our study maintains important strengths including use of NHANES data, which were designed to be representative of the US noninstitutionalized, civilian population. The NHANES data were collected using a rigorous study protocol, including extensive quality-control procedures and the use of technicians trained and certified in data collection. The large sample size allowed us to estimate the prevalence of diabetes with high levels of precision and among important subgroups, including the first estimates of total diabetes among non-Hispanic Asian participants.

Conclusions

In 2011-2012, the estimated prevalence of diabetes was 12% to 14% among US adults, depending on the criteria used, with a higher prevalence among participants who were non-Hispanic black, non-Hispanic Asian, and Hispanic. Between 1988-1994 and 2011-2012, the prevalence of diabetes increased in the overall population and in all subgroups evaluated.

ARTICLE INFORMATION

Author Contributions: Dr Cowie had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Menke, Cowie.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Menke.
Critical revision of the manuscript for important intellectual content: Casagrande, Geiss, Cowie.
Statistical analysis: Menke, Cowie.
Obtained funding: Cowie.
Administrative, technical, or material support: Geiss, Cowie.
Study supervision: Cowie.

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