Thirty-Year Trends in Complications in U.S. Adults With Newly Diagnosed Type 2 Diabetes

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OBJECTIVE

To assess the prevalence of and trends in complications among U.S. adults with newly diagnosed diabetes.

RESEARCH DESIGN AND METHODS

We included 1,486 nonpregnant adults (aged ≥20 years) with newly diagnosed diabetes (diagnosed within the past 2 years) from the 1988–1994 and 1999–2018 National Health and Nutrition Examination Survey. We estimated trends in albuminuria (albumin-to-creatinine ratio ≥30 mg/g), reduced estimated glomerular filtration rate (eGFR <60 mL/min/1.73 m^2), retinopathy (any retinal microaneurysms or blot hemorrhages), and self-reported cardiovascular disease (history of congestive heart failure, heart attack, or stroke).

RESULTS

From 1988–1994 to 2011–2018, there was a significant decrease in the prevalence of albuminuria (38.9 to 18.7%, *P* for trend <0.001) but no change in the prevalence of reduced eGFR (7.5 to 9.9%, *P* for trend = 0.30), retinopathy (1988–1994 to 1999–2008 only; 13.2 to 12.1%, *P* for trend = 0.86), or self-reported cardiovascular disease (19.0 to 16.5%, *P* for trend = 0.64). There were improvements in glycemic, blood pressure, and lipid control in the population, and these partially explained the decline in albuminuria. Complications were more common at the time of diabetes diagnosis for adults who were older, lower income, less educated, and obese.

CONCLUSIONS

Over the past three decades, there have been encouraging reductions in albuminuria and risk factor control in adults with newly diagnosed diabetes. However, the overall burden of complications around the time of the diagnosis remains high.

Type 2 diabetes may be present in patients up to 12 years before its clinical diagnosis (1). During this latent period, hyperglycemia and cardiovascular risk factors are commonly present (2), contributing to a high burden of complications at the time of diagnosis (3).

Over the past three decades, there has been an increased focus on early diabetes detection in the U.S. (4), potentially reducing the time between disease onset and clinical diagnosis. In the late 1990s and early 2000s, expert groups increasingly emphasized regular diabetes screening for asymptomatic adults (5–9), contributing to a rise in testing, especially in high-risk populations (10,11). In 1997, the threshold for diagnosing diabetes was reduced from a fasting blood glucose of 140 mg/dL to

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126 mg/dL (6), and a sharp increase in the diagnosis of diabetes followed (12). In 2009, glycated hemoglobin ≥6.5% was first recommended for use in diagnosis (13).

The objective of our study was to assess the national prevalence of and trends in risk factors and microvascular and macrovascular complications among U.S. adults with newly diagnosed diabetes. To accomplish this, we analyzed three decades of data (1988–2018) from the National Health and Nutrition Examination Survey (NHANES).

RESEARCH DESIGN AND METHODS

Study Population

The NHANES is a nationally representative, cross-sectional survey designed to monitor the health of the U.S. population. During each survey cycle, a sample of participants is selected from the U.S. noninstitutionalized civilian population using a complex, stratified, multistage probability cluster sampling design. Data are collected from participants through in-home interviews and visits to a mobile examination center (14). The National Center for Health Statistics (NCHS) Institutional Review Board (Hyattsville, MD) approved study protocols, and all participants provided written informed consent. We analyzed data from the NHANES III (1988–1994) and the continuous NHANES (1999–2018).

All participants were asked whether they had ever been diagnosed with diabetes other than during pregnancy. Those reporting a diagnosis of diabetes were asked how old they were when they received their diagnosis. We calculated duration of diagnosed diabetes by subtracting participants' age of diabetes diagnosis from their age reported during the interview. We limited our analytic sample to nonpregnant adults aged ≥20 with newly diagnosed diabetes, defined as being diagnosed within the past 2 years (n = 1,486).

Risk Factor Treatment and Control

Hemoglobin A_{1c} (HbA_{1c}) was measured using high-performance liquid chromatography methods. To account for changes in laboratory methods over time, we calibrated HbA_{1c} using an equipercentile equating approach (15). We examined the proportion of participants with an HbA_{1c} <7.0% (<53 mmol/mol) (16). We defined receiving diabetes treatment as the self-reported current use of blood glucose-lowering pills or insulin.

Blood pressure was measured up to three times with a mercury sphygmomanometer, and the mean of all available readings was used in the analysis. We defined hypertension as having elevated mean blood pressure (mean systolic/diastolic blood pressure ≥140/90 mmHg or ≥130/80 mmHg) or the self-reported current use of antihypertensive medication (17,18). We defined receiving treatment as the self-reported current use of antihypertensive medication, and blood pressure control as having a mean blood pressure <140/90 mmHg or <130/80 mmHg.

Serum total cholesterol was measured enzymatically, and measurements from fasting and nonfasting participants were included in the analysis. We defined hyperlipidemia as having elevated lipids (total cholesterol ≥240 mg/dL or ≥200 mg/dL) or the self-reported current use of lipid-lowering medication (19). We defined receiving treatment as the self-reported current use of lipid-lowering medication and lipid control as total cholesterol <240 mg/dL or <200 mg/dL.

Microvascular Complications

Serum creatinine was measured using the Jaffe method. All creatinine measurements were recalibrated to standardized creatinine measurements using recommended equations that minimize the effects of laboratory drift (20). We determined the estimated glomerular filtration rate (eGFR) using the Chronic Kidney Disease Epidemiology Collaboration formula (21). We defined reduced eGFR as having an eGFR <60 mL/min/1.73 m^2. Urine albumin and creatinine concentrations were measured in a random urine sample using fluorescent immunoassay and a modified Jaffe method, respectively. We defined albuminuria as an albumin-to-creatinine ratio ≥30 mg/g. We defined any chronic kidney disease as having reduced eGFR, albuminuria, or both (22).

Medication use was assessed through pill bottle examination review. We evaluated use of ACE inhibitors or angiotensin II receptor blockers among those with chronic kidney disease.

Participants aged ≥40 had film photographs taken of one randomly selected eye in the NHANES III (1988–1994) and digital photographs taken of both eyes in the 2005–2008 NHANES. Retinopathy was assessed by graders using the Early Treatment Diabetic Retinopathy Study (ETDRS) protocol (23). We defined diabetic retinopathy as having any retinal microaneurysms or blot hemorrhages, with or without more severe lesions (24).

Participants aged ≥40 participated in a lower-extremity examination during the 1999–2004 cycles of the continuous NHANES. These participants received monofilament testing on three sites on each foot. We defined peripheral neuropathy as having one or more insensate areas. Blood pressure measurements were taken at participants' ankles and right arm. We computed the ankle-brachial pressure index by dividing systolic blood pressure measured at each ankle by the systolic blood pressure measured at the arm. We defined peripheral artery disease as having an ankle-brachial pressure index of <0.9 for either ankle (25). Participants reported whether they ever had an ulcer or sore on their legs or feet that lasted >4 weeks. We defined any lower-extremity disease as having peripheral neuropathy, peripheral artery disease, or a history of ulcers (26).

Cardiovascular Disease

Participants reported whether they had ever been diagnosed with congestive heart failure, stroke, or heart attack. We defined any cardiovascular disease as having at least one of these conditions.

Sociodemographic Measures and BMI

Participants self-reported their age, sex (male/female), race/ethnicity (non-Hispanic White, non-Hispanic Black, Mexican American, other), education (high school or less, some college, college graduate or above), family income (income-to-poverty ratio <130%, 130–349%, ≥350%), health insurance status (uninsured, any health insurance), access to a usual source of care (has access, no access), and smoking status (current, former, never). We calculated BMI as measured weight in kilograms divided by height in meters squared and classified participants into three weight status groups (normal, BMI <25 kg/m^2; overweight, BMI 25–29.9 kg/m^2; obese, BMI ≥30 kg/m^2).

Statistical Analyses

We calculated participant characteristics, the prevalence, treatment, and control of risk factors, and the prevalence of

microvascular and cardiovascular disease over time. Because of the limited sample sizes in the individual 2-year survey cycles, we pooled survey years into three time intervals (1988–1994, 1999–2008, and 2009–2018) to improve the precision of our estimates (14). We assessed trends using logistic (binary outcomes), linear (mean of continuous outcomes), or quantile (median of continuous outcomes) regression models. Following NCHS guidelines to test for trends, we modeled the midpoint of each survey period as a continuous, linear predictor in the regression models (27). We examined the distribution of risk factors and compared changes over time using χ^2 tests. For complications that changed significantly over time, we used multivariable logistic regression models to explore how changes in social demographic characteristics, diabetes risk factors, and weight status might explain the observed trends. We examined risk factors for complications by combining data from 1988 to 2018 and estimating age-, sex-, and race/ethnicity-adjusted logistic regression models.

In sensitivity analyses, we repeated our trend analyses *1*) adjusting for age, sex, and race/ethnicity using predictive margins (28); and *2*) defining newly diagnosed diabetes as being diagnosed in ≤1 year, a common cut point used in surveillance research (29,30). Because the approach to assessing retinopathy changed over time, we also performed a sensitivity analysis using a randomly selected fundus photograph from one eye (rather than both eyes) for the NHANES 2005–2008 cycles. Following past studies (24), we used photographs from the right eye to classify participants with an even study identification number and the left eye for those with an odd number.

All analyses were conducted using Stata version 16.0 (StataCorp). The recommended sample weights were used, making our results representative of the civilian, noninstitutionalized U.S. adult population with newly diagnosed diabetes. A two-sided *P* value of <0.05 was considered statistically significant.

RESULTS

The age and sex distribution of U.S. adults with newly diagnosed diabetes did not change significantly from 1988 to 2018 (Table 1), whereas the proportion who were non-White, college educated, or had obesity increased substantially over the 30-year period.

The proportion of adults with good glycemic control (HbA_{1c} <7% [<53 mmol/mol]) increased substantially (59.8 to 73.7%, *P* for trend = 0.002) (Table 2 and Supplementary Fig. 1). While the proportion receiving any glucose-lowering treatment was unchanged, the proportion using any insulin declined from 12.8 to 7.5% (*P* for trend = 0.03).

Adults with newly diagnosed diabetes achieving blood pressure control increased during the 30-year period (Supplementary Fig. 1), as did the use of blood pressure-lowering medication (Table 2). The overall prevalence of hypertension increased when defined as ≥140/90 mmHg. When defined as ≥130/80 mmHg, the prevalence of hypertension was unchanged. An increasing proportion of adults with hypertension were treated and controlled to <140/90 mmHg (47.8 to 65.9%, *P* for trend = 0.02) and <130/80 mmHg (9.0 to 36.8%, *P* for trend <0.001), respectively.

The proportion with cholesterol control increased (Supplementary Fig. 1). The use of lipid-lowering medication rose significantly (Table 2), and the prevalence of hyperlipidemia was stable. An increasing share of those with hyperlipidemia were treated and controlled to total cholesterol <240 mg/dL (17.1 to 71.2%, *P* for trend <0.001) or <200 mg/dL (9.4 to 52.4%, *P* for trend <0.001), respectively.

The prevalence of any chronic kidney disease declined from 40.4 to 25.5% (*P* for trend = 0.003) (Table 3). These gains were driven by declines in albuminuria (38.9 to 18.7%, *P* for trend <0.001). In contrast, reduced eGFR remained stable over time (7.5 to 9.9%, *P* = 0.30). The use of ACE inhibitors/angiotensin II receptor blockers increased substantially among those with low eGFR or albuminuria (Supplementary Table 1).

The prevalence of retinopathy among U.S. adults aged ≥40 with newly diagnosed diabetes was unchanged from 1988 to 2008 (13.2 to 12.1%) (Table 3). Results were similar in sensitivity analyses using one fundus photograph to classify participants in the 2005–2008 NHANES (results not shown).

The prevalence of any self-reported cardiovascular disease was stable from 1988 to 2018 (19.0 to 16.5%) (Table 3). The prevalence of lower-extremity diseases—peripheral neuropathy, peripheral arterial disease, or ulcers—in the 1999–2004 period was ~24%, 15%, 9%, and 6%, respectively (Supplementary Table 1). Limited data availability (1999–2004 only) precluded trend analyses of lower-extremity diseases.

We explored factors that might explain declines in the prevalence of albuminuria. Differences in albuminuria across time periods increased after adjusting for age, sex, and race/ethnicity but decreased after adjusting for education (Supplementary Table 2). Changes in HbA_{1c}, blood pressure, and total cholesterol partially accounted for the population-level improvements in albuminuria. Adjusting for weight status increased differences in albuminuria over time.

After adjusting for age, sex, and race/ethnicity, the prevalence of any complication for adults with newly diagnosed diabetes was higher among those who were older, lower income, less educated, current or former smokers, and obese (Table 4).

Trends in risk factors and complications were similar after adjusting for age, sex, and race/ethnicity (Supplementary Tables 3 and 4) and when defining newly diagnosed diabetes as being diagnosed within 1 year (Supplementary Tables 5 and 6).

CONCLUSIONS

From 1988 to 2018, there were marked improvements in the treatment and control of risk factors (HbA_{1c}, blood pressure, or cholesterol) and a substantial decline in the prevalence of albuminuria in U.S. adults with newly diagnosed type 2 diabetes. However, the burden of complications remained high. Approximately 26% had chronic kidney disease, 24% had lower-extremity disease, 12% had retinopathy, and 17% had a history of cardiovascular disease.

Our findings extend population research on the health status of adults with newly diagnosed type 2 diabetes. A prior U.S. population-based study using data from the National Health Interview Survey (NHIS) found that from 1997 to 2003 the prevalence of obesity rose among adults with newly diagnosed diabetes, while the prevalence of cardiovascular disease and hypertension was unchanged (31). However, data in the NHIS are entirely self-reported. When

Table 1—Characteristics of U.S. adults aged ≥20 years with newly diagnosed diabetes (diagnosed within the past 2 years), NHANES 1988–2018

	1988–1994 (Unweighted N = 312)	1999–2008 (Unweighted N = 518)	2009–2018 (Unweighted N = 656)	P for trend
Age, %				
20–44 years	30.1 (20.8–41.3)	27.8 (23.1–33.2)	21.4 (17.6–25.8)	0.12
45–64 years	44.9 (35.5–54.7)	47.6 (42.0–53.3)	52.3 (47.4–57.2)	0.24
≥65 years	25.0 (19.3–31.7)	24.5 (20.1–29.7)	26.3 (21.8–31.3)	0.67
Age, mean, years	54.3 (51.9–56.8)	54.0 (52.3–55.7)	55.3 (53.8–56.7)	0.51
Race/ethnicity, %				
Non-Hispanic White	71.1 (62.5–78.4)	60.1 (53.3–66.7)	59.1 (53.4–64.6)	0.01
Mexican American	5.4 (3.8–7.6)	8.3 (5.8–11.7)	9.8 (7.4–12.9)	0.003
Non-Hispanic Black	13.4 (9.8–18.0)	18.1 (14.2–22.8)	13.6 (10.6–17.4)	0.85
Non-Hispanic Asian*	—	—	5.0 (3.8–6.6)	—
Other†	10.2 (5.0–19.5)	13.5 (9.4–18.9)	12.4 (9.2–16.4)	—
Sex, %				0.57
Female	51.8 (41.6–61.8)	51.9 (46.3–57.5)	49.2 (43.5–55.0)	
Male	48.2 (38.2–58.4)	48.1 (42.5–53.7)	50.8 (45.0–56.5)	
Educational level, %				
High school or less	74.2 (64.8–81.8)	52.4 (45.8–58.8)	47.0 (41.4–52.7)	<0.001
Some college	13.1 (7.8–21.2)	30.8 (25.0–37.4)	31.3 (26.0–37.3)	0.001
College graduate	12.7 (7.3–21.2)	16.8 (13.1–21.3)	21.6 (16.8–27.5)	0.05
Poverty-to-income ratio, %				
<130%	26.7 (19.9–34.9)	27.2 (21.7–33.4)	23.5 (19.6–28.0)	0.37
130–350%	49.6 (39.7–59.6)	37.3 (31.2–43.9)	41.5 (36.5–46.8)	0.13
≥350%	23.7 (16.2–33.2)	35.5 (29.6–41.8)	34.9 (29.5–40.8)	0.02
Usual source of care, %				0.47
No usual care	6.2 (2.7–13.4)	2.8 (1.7–4.7)	4.0 (2.6–6.0)	
Any usual care	93.8 (86.6–97.3)	97.2 (95.3–98.3)	96.0 (94.0–97.4)	
Health insurance status, %				0.97
Uninsured	11.7 (6.5–20.2)	15.5 (11.7–20.3)	12.7 (10.1–16.0)	
Any insurance	88.3 (79.8–93.5)	84.5 (79.7–88.3)	87.3 (84.0–89.9)	
BMI categories, %‡				
Normal weight	17.6 (11.8–25.4)	10.9 (8.2–14.3)	8.1 (5.6–11.6)	0.01
Overweight	34.3 (27.0–42.5)	28.5 (23.4–34.2)	23.3 (19.2–27.9)	0.01
Obese	48.1 (39.8–56.5)	60.6 (53.9–66.9)	68.6 (63.1–73.7)	<0.001
BMI, mean, kg/m^2	31.0 (30.0–32.0)	33.2 (32.2–34.2)	34.5 (33.5–35.6)	<0.001
Smoking, %				
Never smoker	37.1 (28.4–46.7)	50.2 (45.5–55.0)	47.3 (42.4–52.2)	0.09
Former smoker	39.7 (29.7–50.5)	26.6 (21.8–32.0)	34.5 (29.1–40.3)	0.47
Current smoker	23.2 (15.6–33.1)	23.2 (19.2–27.6)	18.2 (14.4–22.8)	0.29

Data are presented as percentages or means (with 95% CIs). *Representative information for non-Hispanic Asians only available in the 2011–2018 NHANES. †Trend not tested for "other" racial/ethnic group because of changing definition over survey years. ‡Normal weight defined as BMI <25 kg/m^2; overweight defined as BMI ≥25 and <30 kg/m^2; and obese defined as BMI ≥30 kg/m^2.

examining a broader range of objectively measured risk factors and comorbidities, we confirmed the increase in obesity but also found evidence of improvements in glycemic control and kidney health.

The reduction in albuminuria was likely related to major improvements in the detection of diabetes over the study period (4). This is consistent with research showing that the proportion of undiagnosed diabetes cases has decreased in the past two decades (2,32). Declines in albuminuria were especially pronounced from 1988–1994 to 1999–2008, corresponding to the reduction of the fasting blood glucose diagnostic threshold and increased emphasis on diabetes screening (5–9). We also found that declines in HbA_{1c}, blood pressure, and total cholesterol explained some of the decrease in albuminuria. Results for HbA_{1c} and blood pressure are consistent with landmark trials demonstrating the benefits of tight glycemic and blood pressure control (33,34), and findings for total cholesterol are congruent with research suggesting an association between dyslipidemia and kidney disease risk (35). Increasing educational attainment was another important contributor and suggests the fundamental importance of education in health. Growing awareness of the importance of albuminuria among clinicians, along with rising use of renin-angiotensin system blockers, were likely important factors as well.

The high burden of complications suggests that timely detection of diabetes remains a challenge for some patients. In particular, we found that adults who were older, lower income, less educated, or obese had the highest prevalence of complications at the time of diagnosis. Approximately half of eligible U.S. adults receive recommended diabetes screenings, although uptake is significantly lower among certain high-risk groups, such as those who are low-income (11). More targeted screening programs for high-risk, underserved patients may thus

Table 2—Trends in the prevalence, treatment, and control of risk factors among U.S. adults with newly diagnosed diabetes (diagnosed within the past 2 years), NHANES 1988–2018

	1988–1994	1999–2008	2009–2018	*P* for trend
Glucose control				
HbA_{1c}, % points, median	6.3 (5.6–8.1)	6.2 (5.7–7.1)	6.2 (5.7–7.1)	0.24
HbA_{1c}, % points, mean	7.0 (6.6–7.3)	6.8 (6.5–7.1)	6.7 (6.5–6.8)	0.02
Treated, %				
Insulin or oral medication use	73.0 (65.1–79.6)	73.1 (67.6–78.1)	72.8 (67.3–77.6)	0.86
Oral medication use only	60.2 (51.8–68.0)	66.5 (60.8–71.9)	65.3 (59.3–70.8)	0.35
Any insulin use	12.8 (8.6–18.7)	6.6 (3.7–11.4)	7.5 (5.4–10.3)	0.03
HbA_{1c} <7.0%-points (<53 mmol/mol), %	59.8 (50.0–69.0)	69.9 (63.0–76.0)	73.7 (68.9–78.1)	0.002
Blood pressure				
Systolic, mmHg median	130.0 (119.0–137.0)	126.7 (118.0–137.3)	124.0 (114.0–135.3)	0.02
Diastolic, mmHg, median	78.0 (73.0–85.0)	72.7 (64.0–82.0)	72.0 (64.7–79.0)	<0.001
Systolic, mmHg, mean	130.1 (127.4–132.8)	129.2 (127.0–131.4)	126.0 (124.2–127.7)	0.02
Diastolic , mmHg, mean	77.5 (75.9–79.2)	72.0 (69.9–74.1)	72.1 (70.8–73.5)	<0.001
Treated, %	39.5 (30.4–49.5)	51.5 (45.4–57.5)	55.2 (49.3–61.0)	0.01
Hypertension (≥140/90 mmHg or med use), %	48.9 (40.3–57.5)	59.5 (53.2–65.4)	61.2 (55.2–67.0)	0.03
Treated*	81.4 (69.3–89.5)	86.0 (79.8–90.5)	90.1 (86.1–93.1)	0.08
Treated and controlled (blood pressure <140/90 mmHg)*	47.8 (35.8–60.0)	58.9 (51.3–66.2)	65.9 (58.7–72.3)	0.02
Hypertension (≥130/80 mmHg or med use), %	71.4 (61.0–79.9)	71.1 (65.5–76.2)	71.1 (65.0–76.5)	0.97
Treated*	55.6 (43.9–66.6)	71.9 (64.9–78.0)	77.6 (72.0–82.4)	0.001
Treated and controlled (blood pressure <130/80 mmHg)*	9.0 (4.6–17.0)	28.5 (23.0–34.8)	36.8 (30.7–43.4)	<0.001
Lipids				
Total cholesterol, mg/dL, median	212.0 (187.0–246.0)	192.0 (166.0–218.0)	181.0 (153.0–208.0)	<0.001
Total cholesterol, mg/dL, mean	219.4 (210.0–228.8)	198.4 (192.5–204.2)	182.4 (178.3–186.6)	<0.001
Treated, %	14.1 (8.3–22.9)	35.2 (29.1–41.7)	43.8 (37.8–49.9)	<0.001
Hyperlipidemia (total cholesterol ≥240 mg/dL or med use), %	40.3 (30.2–51.3)	45.4 (39.5–51.4)	49.8 (44.3–55.4)	0.14
Treated†	32.4 (20.5–47.2)	71.1 (62.7–78.2)	86.1 (81.1–90.0)	<0.001
Treated and controlled (total cholesterol <240 mg/dL)†	17.1 (7.6–34.1)	45.0 (34.5–55.9)	71.2 (63.9–77.6)	<0.001
Hyperlipidemia (total cholesterol ≥200 mg/dL or med use), %	71.6 (65.3–77.1)	65.1 (59.7–70.2)	66.3 (61.3–70.9)	0.14
Treated†	18.5 (11.0–29.4)	51.5 (43.8–59.1)	65.4 (58.4–71.8)	<0.001
Treated and controlled (total cholesterol <200 mg/dL)†	9.4 (4.2–19.7)	29.9 (22.2–39.0)	52.4 (45.1–59.5)	<0.001
All three risk factors controlled				
HbA_{1c} <7.0% (<53 mmol/mol) plus Blood pressure <130/80 mmHg, total cholesterol <200 mg/dL, %	9.4 (6.1–14.2)	18.1 (13.6–23.8)	33.0 (27.0–39.5)	<0.001
Blood pressure <140/90 mmHg, total cholesterol <240 mg/dL, %	31.6 (23.6–40.9)	47.8 (41.2–54.5)	56.2 (51.2–61.1)	<0.001

Data are presented as percentages or as means (with 95% CIs) or median (with interquartile range). *Computed for those with hypertension. †Computed for those with hyperlipidemia.

reduce complications at diagnosis. Our findings also indicate that more aggressive treatment of risk factors immediately after diagnosis may be needed. In particular, we found that control of hypertension or hyperlipidemia failed in up to 63% and 48% of adults with newly diagnosed diabetes, respectively, highlighting the need to prioritize blood pressure and lipid management.

We observed a nonsignificant increase in the prevalence of reduced eGFR from 1988–1994 to 1999–2008, followed by little change in 2009–2018. These trends are consistent with trends in the total population of adults with diabetes. In U.S. adults with diabetes, the prevalence of reduced eGFR increased in 1988–1994 to 2003–2004 before subsequently leveling off in 2011–2012 (36). Prior studies speculate that rising blood pressure treatment and control may account for some of the increase in reduced eGFR in adults with diabetes due to their hemodynamic effects (37,38). Consistent with this suggestion, we found that trends in blood pressure-lowering medication use followed trends in reduced eGFR, rising from 1988–1994 to 1999–2008 and leveling off in 2009–2018.

We also did not observe any major improvements in the prevalence of retinopathy or cardiovascular disease in adults with newly diagnosed diabetes over this 30-year period. However, these findings must be viewed in light of some methodological limitations. The NHANES III (1988–1994) used film photography to assess retinopathy, whereas the NHANES 2005–2008 used higher-quality digital photography. Detection of retinopathy may therefore have been more sensitive in the later survey years, potentially affecting the comparability of estimates across years (24). Likewise, we likely underestimate the true prevalence of cardiovascular disease, because this information is self-reported in NHANES. In particular, subclinical cardiovascular disease is common in older adults and those with diabetes (39). Trends will also reflect

Table 3—Trends in the prevalence of complications among U.S. adults with newly diagnosed diabetes (diagnosed within the past 2 years), NHANES 1988–2018

	1988–1994	1999–2008	2009–2018	*P* for trend
Any chronic kidney disease	40.4 (31.8–49.5)	28.0 (23.8–32.7)	25.5 (21.7–29.7)	0.003
Albuminuria (albumin-to-creatine ratio ≥30 mg/g)	38.9 (30.7–47.9)	21.0 (17.2–25.3)	18.7 (15.6–22.3)	<0.001
Reduced eGFR (<60 mL/min/1.73 m^2)	7.5 (4.4–12.5)	10.2 (7.4–13.9)	9.9 (7.3–13.3)	0.30
Retinopathy*	13.2 (6.7–24.3)	12.1 (6.8–20.4)	—	0.86
Any self-reported cardiovascular disease	19.0 (13.5–26.1)	14.8 (11.6–18.6)	16.5 (12.6–21.3)	0.64
History of congestive heart failure	6.9 (3.9–11.8)	6.4 (4.3–9.5)	5.1 (3.2–7.8)	0.35
History of stroke	6.8 (3.7–12.2)	6.4 (4.4–9.1)	6.4 (4.5–9.1)	0.95
History of heart attack	10.2 (6.1–16.4)	6.6 (4.8–9.1)	9.4 (6.3–13.7)	0.90

Data are presented as percentages (with 95% CIs). *Retinopathy was defined as ≥1 retinal microaneurysms or blot hemorrhages. Data were only available for adults aged ≥40 during the 1988–1994 and 2005–2008 NHANES survey cycles.

improvements in detection and survival; studies of the general population with diabetes have found steady declines in cardiovascular complications and all-cause and cardiovascular mortality (40–42).

Our study has several additional limitations. First, there may be misclassification of incident diabetes cases, because our definition relies on participants accurately reporting their diabetes status and age of diagnosis. However, prior research indicates that these measures are highly specific and reliable (43,44). Second, because of sample size limitations, we may have lacked the power to detect small changes in complications over time. Third, retinopathy and lower-extremity disease assessments were only performed in those aged ≥40 years. Thus, we were not able to draw conclusions regarding these outcomes in younger individuals. Fourth, our study was cross-sectional, and we cannot determine the temporality of the observed associations.

Strengths of the study include the contemporary, nationally representative sample of U.S. adults with newly diagnosed diabetes spanning 30 years. With the exception of cardiovascular disease, the assessment of risk factors and complications was based on objective, rigorous, and systematic measurement.

Over the past three decades, there were significant reductions in albuminuria and improvements in the treatment and control of HbA_{1c}, blood pressure, and cholesterol in adults with newly diagnosed type 2 diabetes. These results suggest that there have been improvements in diabetes

Table 4—Adjusted odds ratios (95% CIs) for the associations of risk factors with complications in U.S. adults with newly diagnosed diabetes (diagnosed within the past 2 years), NHANES 1988–2018*

	Any complication†	Any microvascular complication	Any self-reported cardiovascular disease
Age			
20–44 years (ref)	1	1	1
45–64 years	1.56 (0.93–2.62)	1.25 (0.69–2.26)	2.68 (1.02–7.03)
65 years	2.86 (1.66–4.94)	2.14 (1.21–3.79)	8.28 (3.41–20.15)
Race/ethnicity			
Non-Hispanic White (ref)	1	1	1
Mexican American	0.67 (0.45–1.01)	0.83 (0.56–1.23)	0.48 (0.25–0.91)
Non-Hispanic Black	0.90 (0.63–1.28)	0.88 (0.62–1.26)	1.09 (0.67–1.78)
Sex			
Female (ref)	1	1	1
Male	1.31 (0.90–1.91)	1.06 (0.73–1.54)	1.50 (0.94–2.40)
Income-to-poverty ratio			
≥350% (ref)	1	1	1
130–350%	1.98 (1.22–3.23)	1.58 (0.97–2.58)	1.82 (0.96–3.42)
<130%	1.81 (1.11–2.97)	1.49 (0.91–2.44)	2.04 (1.03–4.01)
Education level			
College graduate (ref)	1	1	1
Some college	1.63 (0.88–3.02)	1.14 (0.60–2.18)	2.13 (0.94–4.82)
≥ High school	2.31 (1.36–3.92)	1.68 (0.97–2.93)	2.43 (1.16–5.08)
Smoking status			
Never (ref)	1	1	1
Former	1.69 (1.09–2.61)	1.22 (0.78–1.93)	1.81 (1.07–3.08)
Current	1.80 (1.10–2.95)	1.48 (0.90–2.42)	2.46 (1.29–4.67)
Obese (BMI ≥30 kg/m^2)			
No (ref)	1	1	1
Yes	1.50 (1.04–2.18)	1.23 (0.85–1.77)	1.56 (0.99–2.45)

Ref, reference. *Odds ratios were adjusted for age, sex, and race/ethnicity. †Defined as any microvascular complication (chronic kidney disease, retinopathy, or lower-extremity disease) or any self-reported cardiovascular disease (history of congestive heart failure, heart attack, or stroke).

screening and that we are diagnosing cases earlier in the disease process. Nevertheless, the overall burden of complications and uncontrolled risk factors remains high. Targeted screening of high-risk populations and aggressive risk factor treatment immediately following diagnosis are important strategies for sustaining progress moving forward.

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