Economic Costs of Diabetes in the U.S. in 2022

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ADA STATEMENT

OBJECTIVE

This study updates previous estimates of the economic burden of diagnosed diabetes, with calculation of the health resource use and indirect costs attributable to diabetes in 2022.

RESEARCH DESIGN AND METHODS

We combine the demographics of the U.S. population in 2022 with diabetes prevalence, from national survey data, epidemiological data, health care cost data, and economic data, into a Cost of Diabetes Economic Model to estimate the economic burden at the population and per capita levels. Health resource use and associated medical costs are analyzed by age, sex, race/ethnicity, comorbid condition, and health service category. Data sources include national surveys (2015–2020 or most recent available), Medicare standard analytic files (2020), and administrative claims data from 2018 to 2021 for a large commercially insured population in the U.S.

RESULTS

The total estimated cost of diagnosed diabetes in the U.S. in 2022 is $412.9 billion, including $306.6 billion in direct medical costs and $106.3 billion in indirect costs attributable to diabetes. For cost categories analyzed, care for people diagnosed with diabetes accounts for 1 in 4 health care dollars in the U.S., 61% of which are attributable to diabetes. On average people with diabetes incur annual medical expenditures of $19,736, of which approximately $12,022 is attributable to diabetes. People diagnosed with diabetes, on average, have medical expenditures 2.6 times higher than what would be expected without diabetes. Glucose-lowering medications and diabetes supplies account for ∼17% of the total direct medical costs attributable to diabetes. Major contributors to indirect costs are reduced employment due to disability ($28.3 billion), presenteeism ($35.8 billion), and lost productivity due to 338,526 premature deaths ($32.4 billion).

CONCLUSIONS

The inflation-adjusted direct medical costs of diabetes are estimated to rise 7% from 2017 and 35% from 2012 calculations (stated in 2022 dollars). Following decades of steadily increasing prevalence of diabetes, the overall estimated prevalence in 2022 remains relatively stable in comparison to 2017. However, the absolute number of people with diabetes has grown and contributes to increased health care expenditures, particularly per capita spending on inpatient hospital stays and prescription medications. The enormous economic toll of diabetes continues to burden society through direct medical and indirect costs.

Diabetes poses a substantial burden on society in the form of higher direct medical costs, lost productivity, premature mortality, and intangible costs in the form of reduced social connectivity and quality of life. The estimated economic burden of diabetes in 2017 was $327 billion in 2017 USD, including $237 billion in direct medical costs and

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$90 billion in reduced productivity (1). Furthermore, more than half of the total expenditure was directly attributable to diabetes and its complications. According to the Centers for Disease Control and Prevention (CDC), the prevalence of diagnosed diabetes among adults between 2017 and 2021 has remained relatively stable in the U.S. at 8.5% (2). Nevertheless, shifts in demographics of the population (3,4) with diabetes and changes in health care delivery, therapies, and technology affect the economic burden associated with diabetes. These factors all play a role in determining the burden of diabetes at a given point in time. In response to the health and economic impacts of diabetes, a variety of prevention programs and interventions have been introduced in the past decade, encompassing new care delivery models, policy measures, and community-based diabetes prevention lifestyle interventions (5,6) as well as therapeutic innovation such as incretin hormone receptor agonists, including glucagon-like peptide 1 and glucose-dependent insulinotropic polypeptide. This update estimates the economic burden of diabetes at the national and state levels in 2022. These data can help identify opportunities to decrease the financial burden on patients, families, employers, payors, and society. These data can also inform resource allocation for strategies designed to decrease diabetes prevalence, prevent complications, and mitigate the overall burden of this disease.

RESEARCH DESIGN AND METHODS

The methodology used is similar to that of previous studies on diabetes burden of illness sponsored by the American Diabetes Association (1,7–9), with updated data sources and modifications to refine the Cost of Diabetes Economic Model where appropriate. To estimate the 2022 economic cost of diabetes, we estimate prevalence of diagnosed diabetes, health care use, and costs at the state and national levels. National estimates are calculated by summing state-level estimates to reflect variation across states in demographics, clinical risk factors, health behavior, prices, and economic outcomes. All cost and use estimates are extrapolated to the U.S. population in 2022, with costs inflation adjusted to 2022 USD (10).

Data Sources

In this study we use both state-level and national-level data. State-level data sources include the 2020 American Community Survey (ACS), 2019–2020 Behavioral Risk Factor Surveillance System (BRFSS), and 2019 Medicare Current Beneficiary Survey (MCBS). National data sources include the 2021 Current Population Survey (CPS), 2017–2021 Optum de-identified Normative Health Information (dNHI) database, 2015–2019 Medical Expenditure Panel Survey (MEPS), 2015–2016 and 2018 National Ambulatory Medical Care Survey (NAMCS), 2017–2019 National Hospital Ambulatory Medical Care Survey (NHAMCS), 2019–2021 National Health Interview Survey (NHIS), 2019 National (Nationwide) Inpatient Sample (NIS), 2007 National Home and Hospice Care Survey (NHHCS), and 2020 Medicare 5% sample Standard Analytic Files (SAF). Generally, we use the latest data available from each source. However, in certain instances, we use an older data set, driven by quality concerns associated with the most recent file. (e.g., quality issues with the 2012–2017 NHAMCS Outpatient Department Data file necessitated using the 2009–2011 file) or where the survey was discontinued without an adequate replacement (e.g., NHHCS). Descriptions of these data sources and how they are used can be found in Table 1, and respective strengths and limitations are summarized in Supplementary Table 1 in Supplementary Appendix A.

Prevalence Estimates

To account for variation in demographics, we estimate prevalence of diagnosed diabetes for 336 strata defined by age-group (<18, 18–34, 35–44, 45–54, 55–64, 65–69, and ≥70 years of age), sex (male, female), race/ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic other, and Hispanic), insurance status (commercial, government [Medicare, Medicaid, Children's Health Insurance Program, Veterans Health Administration, and other government-sponsored coverage], and uninsured), and residence status (whether community dwelling or residing in a residential care or nursing home facility). Due to sample size limitations given the number of strata accounted for in our estimates, we are unable to examine prevalence by race/ethnicity with greater granularity.

To estimate the national prevalence of diagnosed diabetes by age-group, sex, race/ethnicity, insurance status, and residence status (whether residing in the community, a residential care facility, or a nursing home), we use 2019–2021 NHIS files and 2019 MCBS data. Similar to the United States Diabetes Surveillance System (11) and the CDC's National Diabetes Statistics Report, prevalence of diagnosed diabetes is based on respondents answering "yes" to the question, "Has a doctor or other health professional EVER told you that you had diabetes?" For individuals residing in the community, including children, we use NHIS files. These prevalence estimates exclude gestational diabetes mellitus and prediabetes. Additionally, we use 2019 MCBS data to estimate prevalence of diagnosed diabetes prevalence rate by age, sex, and race/ethnicity for individuals residing in residential care facilities or nursing homes. The diabetes status in the MCBS is based on clinical diagnosis.

We combine the national diabetes prevalence rate estimates with population estimates from ACS to obtain 2020 national diabetes prevalence by age, sex, race/ethnicity, insurance status, and residence status (community dwelling and those residing in residential care or nursing home facilities). To estimate national diabetes prevalence in 2022, we scale these 2020 diabetes prevalence estimates to arrive at 2022 prevalence based on population growth between 2020 and 2022 by demographic group.

To determine state-level diabetes prevalence, we use 2020 ACS data to calculate state-level population ratios by demographic factors such as age, sex, and race/ethnicity. These estimates are then combined with national diabetes prevalence rates for estimation of the 2022 state-level diabetes prevalence.

Direct Medical Costs Attributable to Diabetes

We estimate health resource use among the population with diabetes in excess of the resource use that would be expected in the absence of diabetes. Diabetes increases risk of developing neurological, peripheral vascular, cardiovascular, renal, endocrine/metabolic, ophthalmic, and other complications. (See Supplementary Appendix B for a more comprehensive list of medical conditions and respective ICD-10 codes.) Diabetes also increases the cost of treating other medical conditions that are not directly related to diabetes; therefore, only the relevant portion of health care

Table 1—Cost components and data sources

Cost component	Use	Expenditures and costs	Diabetes-attributable costs
Institutional care			
Hospital inpatient days	No. of days, from NIS (2019)	Average cost per day, from MEPS (2015–2019); facility charges, from NIS (2019)	Attributable risk fraction approach, using Optum dNHI (2020) and Medicare 5% SAF (2020)
Nursing/residential facility days	No. of days, from MCBS (2019)	Cost per day, from NHPCO survey (2021)	Attributable risk fraction approach, using Optum dNHI (2020) and Medicare 5% SAF (2020)
Hospice care days	No. of days, from NHHCS (2007)	Cost per day, from NHPCO Facts and Figures hospice care in America report (2021)	Imputed based on prevalence of diagnosed diabetes among hospice residents, from NHPCO (2021)
Outpatient care			
Outpatient and ER visits	No. of visits by age-sex-race stratum, from NHAMCS Outpatient Department Data file (2009–2011)* and ER file (2017–2019)	Average cost per visit, from MEPS (2015–2019)	Attributable risk approach, using Optum dNHI (2020) and Medicare 5% SAF (2020)
Office visits to physicians and other health providers	No. of visits by age-sex-race stratum, from NAMCS (2015–2016 and 2018)	Average cost per visit, from MEPS (2015–2019)	Attributable risk approach, using Optum dNHI (2020) and Medicare 5% SAF (2020)
Ambulance, home health, podiatry	—	Average annual expenditure by age-sex-race stratum, from MEPS (2015–2019)	Per capita use by diabetes status, using MEPS
Outpatient medication and supplies			
Insulin and noninsulin glucose-lowering medication prescriptions	Proportion using insulin and/or noninsulin medication, from NHIS (2019–2021)	Average cost per insulin and noninsulin (separately) Rx filled, from MEPS (2015–2019)	—
Other medication prescriptions	No. of Rx written, from NHAMCS (2009–2011*, 2017–2019) and NAMCS (2015–2015, 2018)	Average cost per (all other) Rx filled, from MEPS (2015–2019)	Attributable risk approach, using Optum Optum dNHI (2020) and Medicare 5% SAF (2020)
Diabetes supplies† and other equipment‡	—	Average annual expenditure by age-sex-race stratum, from MEPS (2015–2019)	Per capita use by diabetes status, using MEPS
Indirect costs			
Productivity loss	Work missed due to illness, from NHIS (2019)	Annual and daily earnings, from CPS (2020)	Population with and without diabetes, from NHIS
Inability to work due to disability	NHIS question about receipt of Social Security disability income (SSI) (2019)	Annual and daily earnings, from CPS (2020)§	Population with and without diabetes, from NHIS
Premature mortality	Life expectancy, from U.S. State Life Tables (2020); employment rates, from CPS (2020)	Annual and daily earnings, from CPS (2020)	CDC WONDER Mortality Multiple Cause File (2020)

Rx, prescriptions. *More recent NHAMCS Outpatient Department Data file not available due to quality issues. †Includes, but is not limited to, syringes, blood glucose monitor, glucose meter, insulin pumps, lancets, alcohol swabs, or control solution. ‡Includes, but is not limited to, eyewear, orthopedic items, hearing devices, prosthesis, bathroom aids, medical equipment, and disposable supplies. §SSI payments are not included in our cost estimates.

expenditures for these medical conditions is attributable to diabetes.

The approach to quantify excess health care resource use associated with diabetes is influenced by four data limitations: *1*) absence of a single data source for all estimates, *2*) small sample size for some data sources, *3*) correlation of both diabetes and its comorbidities with other factors such as age and obesity, and *4*) underreporting of diabetes and its comorbidities in certain data sources, such as NIS, NAMCS, and NHAMCS. Because of these limitations we estimate diabetes-attributable costs using one of two approaches for each cost component.

For estimation of the excess use of health care services that can be attributed to diabetes, the Cost of Diabetes Economic Model uses two approaches, dependent on complexity of data source. First, for cost components estimated solely from MEPS data (e.g., ambulance services, home health, podiatry, diabetes supplies, and other equipment and supplies), we can make a direct comparison of annual per capita health resource use for people with and without diabetes controlling for age, sex, and race/ethnicity. Second, for nursing/residential facility use (which is not captured by MEPS) and for cost components that rely on analysis of medical encounter data (e.g., hospital inpatient, emergency care, and ambulatory visits), we use an attributable risk methodology to estimate the proportion of health care costs that can be attributed to diabetes (12,13). The attributable risk fraction method estimates the excess use of health care services among the population with diagnosed diabetes relative to a similar population who do not have diabetes.

The attributable risk fraction approach combines the etiological fractions (ε) with total projected U.S. health service use (U) in 2022 for each age-group (a), sex (s), medical condition (c), and care delivery setting (H), which includes hospital inpatient, emergency room (ER), and ambulatory service (office visits and hospital outpatient/clinic visits):

$$\text{Attributed health resource use}_{\mathrm{H}} = \sum_{\text{age}} \sum_{\text{sex}} \sum_{\substack{\text{medical}\\ \text{condition}}} \varepsilon_{\mathrm{H,a,s,c}} \times \mathrm{U}_{\mathrm{H,a,s,c}}$$

The attributable risk fraction is calculated using the diagnosed diabetes prevalence (P) and the relative rate ratio for health care use of people with and without diabetes (R):

$$\varepsilon_{\mathrm{H,a,s,c}} = \frac{\mathrm{P_{a,s}} \times (\mathrm{R_{H,a,s,c}} - 1)}{\mathrm{P_{a,s}} \times (\mathrm{R_{H,a,s,c}} - 1) + 1}$$

The rate ratio for hospital inpatient days, emergency visits, and ambulatory visits represents how annual per capita health service use for the population with diabetes compares with that of the population without diagnosed diabetes:

$$\mathrm{R_{H,a,s,c}} = \frac{\text{annual per capita use for people with diabetes}_{\mathrm{a,s,c}}}{\text{annual per capita use for people without diabetes}_{\mathrm{a,s,c}}}$$

Diabetes and its comorbidities are correlated with other patient characteristics such as demographics and body weight. To mitigate bias caused by correlation, we estimate age-, sex-, and setting-specific etiological fractions for each comorbid condition. For calculation of the attributable risk fractions, we use the 2020 Optum dNHI database and the 2020 Medicare 5% sample SAF to capture the populations insured by commercial insurance and Medicare, respectively. The large size of these two claims databases enables the generation of age-, sex-, and setting-specific rate ratios for each medical condition that are more stable than the rates estimated with MEPS.

Unlike the MEPS data, the dNHI and the Medicare 5% SAF data lack information regarding race/ethnicity and certain patient characteristics that could influence both the health status of patients and their behaviors related to seeking health care. For the 10 comorbid conditions thought to be the largest contributors to the overall cost of diabetes (general medical condition, other chronic ischemic heart disease, myocardial infarction, heart failure, hypertension, conduction disorders and cardiac dysrhythmias, cellulitis, occlusion of cerebral arteries, end-stage renal disease, and kidney failure and its sequelae) we estimate two multivariate Poisson regressions using MEPS 2015–2019 to determine the extent to which controlling only for age and sex might bias the relative rate ratios for hospital inpatient days, emergency visits, and ambulatory visits. First, we estimate a naive model adjusting for age and sex only, and second, we estimate a full model that includes diabetes status as an independent variable as well as known predictors of health service use including age, sex, educational attainment, income, marital status, medical insurance status, and race/ethnicity as covariates.

For the full model, our focus is not on the relationship between health care use and the covariates (other than diabetes); instead, these covariates are included to control for patient characteristics not available in medical claims data that could be correlated with both medical conditions and health-seeking behavior. The full model omits indicators for presence of coexisting conditions or complications of diabetes (e.g., hypertension), since including such variables could downward bias the estimated relationship between diabetes and health care use for each of the 10 medical conditions. The rate ratio coefficients for the diabetes flag variable in the naive and full models are then compared. A comparison of the naive and fully adjusted model rate ratio coefficients suggests statistically significant overestimates of the rate ratios for emergency visits when using the naive model for six conditions. For inpatient days, we find significant overestimates in the rate ratios for seven conditions. For office visits, we find significant overestimates in the rate ratios for four conditions.

To minimize the risk of overestimation for these comorbid conditions, we scale the rates ratios estimated from the dNHI and Medicare 5% SAF using a scalar derived from the MEPS analysis described above (the full model rate ratio divided by the naive model rate ratio). For ER visits, claims-based rate ratios are scaled down for other chronic ischemic heart disease (scale = 0.79), myocardial infarction (0.84), heart failure (0.93), hypertension (0.70), cellulitis (0.76), and renal failure and its sequelae (0.87). For inpatient days, claims-based rate ratios are scaled down for other chronic ischemic heart disease (0.83), myocardial infarction (0.86), heart failure (0.91), hypertension (0.66), cellulitis (0.95), occlusion of cerebral arteries (0.94), and renal failure and its sequelae (0.73). Office visits are scaled down for heart failure (0.98), hypertension (0.86), occlusion of cerebral arteries (0.58), and kidney failure and its sequelae (0.57). We also downward adjust claims-based rate ratios for ER visits (0.63) and inpatient days (0.81) for the general condition group by applying a scalar calculated as the MEPS-based naive model rate ratio divided by the claims-based rate ratio.

To estimate the use of health care resources by age, sex, and race/ethnicity for each medical condition, we use a variety of data sources: for office visits, to increase sample size, we combine the most recent waves of data collection, the 2015–2016 and 2018 NAMCS and 2017–2019 NHAMCS emergency department data for ER visits and 2019 NIS data for inpatient visits. Due to data quality issues, the most recent NHAMCS Outpatient Department Data file from 2012–2017 will not be made available (14). Therefore, we use the 2009–2011 NHAMCS Outpatient Department Data file for age-sex-race strata-specific health care use and to adjust for changes over time we apply the rate of change in outpatient visits from the years 2009–2011 to 2017–2019 calculated from the MEPS outpatient data. The rate of change in outpatient health care use is calculated for each age-sex-race stratum to account for variations in outpatient visits in demographic factors.

Estimates of health resource use attributable to diabetes are combined with estimates of the average medical cost per unit of health care use, in 2022 USD, for computation of total medical costs attributable to diabetes. For hospital inpatient days, office visits, emergency visits, and outpatient visits, we use the average cost per visit/day specific to the medical conditions modeled. We pool the 2015–2019 MEPS files to estimate average cost per unit of health care used. Although MEPS contains information on both inpatient facility and professional expenditures and NIS contains only facility charges (which are converted to costs using hospital-specific cost-to-charge ratios), the NIS has a much larger sample size (*n* = ~7 million discharges sampled in 2019) and also contains 5-digit diagnosis codes. Therefore, we use the 2019 NIS to estimate inpatient facility costs and use the pooled 2015–2019 MEPS to estimate the cost for professional services.

Use of prescription medication (excluding insulin and other glucose-lowering pharmacological agents) for each medical condition is estimated from data on medications prescribed during office visits, ER, and outpatient visits attributable to diabetes. Average number of medications prescribed during an office visit for each age-sex-race stratum is estimated using data from 2015–2016 and 2018 NAMCS along with 2017–2019 NHAMCS for ER visits and 2009–2011 NHAMCS for outpatient visits. As mentioned previously, the most recent NHAMCS Outpatient Department Data file will not be available due to quality issues (14); for methodological consistency, we use the next most recent file (2009–2011) for use rates of insulin and noninsulin therapies and apply those to the 2022 prevalence estimates. While we acknowledge that the therapeutic landscape has changed in the intervening years with a number of new therapies being approved for the treatment of diabetes, the proportions of patients using insulin and noninsulin, respectively, have not changed dramatically (15–18). A number of studies suggest that availability of new treatment did not change the rate of use as a whole or by insulin and noninsulin agents; rather, there may have been decreases in use of human insulin but overall insulin use was similar due to uptake of analog insulins; similarly, the use of sulfonylureas and thiazolidinediones decreased and at the same time increases in other noninsulin medications, such as sodium–glucose cotransporter 2 inhibitors and glucagon-like peptide 1 receptor agonists, were observed (15,16,18). We calculate the total number of people with diabetes who use insulin and other glucose-lowering pharmacological agents by combining diabetes prevalence and the rate of use for these glucose-lowering pharmacological agents obtained from the 2019–2021 NHIS. Average cost per prescription filled, yearly average cost per insulin user, and yearly average cost per oral agent and other glucose-lowering agent user were obtained from 2015–2019 MEPS. We combine the use of these medications with the average cost per prescription in 2015–2019 MEPS to estimate the cost by age, sex, race/ethnicity, and insurance status. Average per capita cost for diabetes supplies by age-sex-race stratum is calculated from MEPS (excluding over the counter medications owing to lack of data on whether diabetes is associated with increased use of such medications).

In the 2022 cost study we estimate prevalence of diagnosed diabetes among the population in nursing homes, by demographic, using the 2019 MCBS data. Among ~1 million nursing home residents (<0.48% of 65–69 year olds and 2.6% of ≥70 year olds), the estimated prevalence of diagnosed diabetes is 24.4%.

Nursing/residential facility use attributable to diabetes is estimated with an attributable risk approach where the prevalence of diabetes among residents is compared with the prevalence of diabetes among the overall population in the same age-sex stratum. The analysis is conducted separately for long-stay and residential facility residents for estimation of total days of care. Unlike the 2012 study and similar to the 2017 study, due to data unavailability there is no separate analysis done for short stays at nursing/residential facilities. Similar to the previous studies, cost per day per resident was obtained from a geographically representative cost of care survey for 2021 (19).

Hospice days attributable to diabetes represent a combination of length of stay and diabetes prevalence among hospice residents. We use the 2007 NHHCS data and adjust these based on more recent estimates available from the National Hospice and Palliative Care Organization (NHPCO) on diabetes prevalence among hospice residents (20) to impute the 2022 diabetes hospice use. Cost per hospice resident per day is based on the 2020 report from NHPCO (NHPCO Facts and Figures on hospice care in America) (20,21) and is combined with hospice days attributable to diabetes for estimation of total cost of hospice care attributable to diabetes.

The 2015–2019 MEPS files are pooled to increase sample size for analyzing use of relatively rare services such as home health, podiatry, ambulance services, and other equipment and supplies. These cost components are estimated by comparing annual per capita cost for people with and without diabetes, controlling for age. Due to small sample size, sex and race/ethnicity are not included as a stratum in calculating costs per capita for these categories of health services.

Estimating the Indirect Costs Attributable to Diabetes

The indirect costs associated with diabetes include costs from workdays missed due to health conditions (absenteeism), reduced work productivity while working due to health conditions (presenteeism), reduced workforce participation due to disability, and lost productivity for those not in the workforce and due to premature mortality. We estimate the cost and utility of the populations with and without diabetes in parallel. The approach mirrors that used in the 2012 and 2017 studies but with more recent data.

Absenteeism

Absenteeism is defined as the number of workdays missed due to poor health among the employed population. People with diabetes have higher rates of absenteeism than the population without diabetes (22–24). Analyzing 2019–2021 NHIS data and using a negative binomial regression to control for overdispersion in self-reported missed workdays, we estimate that people with diabetes have a higher number of missed workdays statistically—ranging from 0.5 to 3.9 additional days missed per year by demographic group, or 1.9 days on average—after controlling for age-group, sex, race/ethnicity, diagnosed hypertension status (yes/no), and body weight status (normal, overweight, obese, unknown). Diabetes is entered as a dichotomous variable (diagnosed diabetes = 1; otherwise = 0), and as an interaction term with age-group; sparse cell sizes did not allow for interaction terms with race/ethnicity. The NHIS data allow us to control for hypertension and body weight, thus producing more conservative estimates of the impact of diabetes on absenteeism, as comorbidities of diabetes are correlated with body weight status and a portion of hypertension is attributable to diabetes.

Presenteeism

Presenteeism is defined as reduced productivity while at work among the employed and is generally measured through worker responses to surveys. These surveys rely on the self-reported inputs on the number of reduced productivity hours incurred over a given time frame. Multiple recent studies report that individuals with diabetes display higher rates of presenteeism than their peers without diabetes (25–27). We model productivity loss associated with diabetes-attributable presenteeism using the estimate (6.6%) from the 2012 study—which is toward the lower end of the 1.8%–38.0% range reported in the literature (9).

Inability to Work

Inability to work associated with diabetes is estimated using a conservative approach that focuses on unemployment related to long-term disability. Logistic regression with 2019–2021 NHIS data suggests that people ages 18–65 years with diabetes are significantly less likely to be in the workforce than people without diabetes. The extent to which people with diabetes voluntarily leave the workforce or do so because of diabetes is unclear. Therefore, we use a conservative approach (which is likely to underestimate the cost associated with inability to work) to estimate the economic burden associated with reduced labor force participation. Using logistic regression, we estimate the relationship between diabetes and receipt of Supplemental Security Income (SSI) payments for disability—controlling for age-group, sex, race/ethnicity, hypertension status, and body weight status (normal, overweight, obese). We include diabetes status in the regression both as a separate variable and for interaction with age-group to provide age-specific impacts. The regression results suggest that people with diabetes have a 1.8 percentage point higher rate of being out of the workforce and receiving disability payments in comparison with their peers without diabetes. The diabetes effect increases with age and varies by demographic—ranging from 0.1 percentage points for non-Hispanic White male individuals aged ≥70 years to 9.7 percentage points for non-Hispanic Black female individuals aged 18–34 years (Supplementary Table 13 in Supplementary Appendix A). The average daily earnings estimated from the CPS for those in the workforce are used as a proxy for the economic impact of reduced employment due to chronic disability. SSI payments are considered transfer payments and therefore are not included in the cost estimates. While we strive to maintain consistency in our methods as much as possible, it should be noted that an important change was made in how receipt of SSI is captured in NHIS. This question was formerly included in the household questionnaire, which is no longer used; NHIS now includes this question in the individual questionnaire. This contextual change from family to individual may change the meaning of the results where past results reflected household status with regard to SSI and the current results reflect an individual's status; as a result, results should be interpreted with caution in comparisons with past estimates of disability.

Reduced Productivity for Those Not in the Workforce

Reduced productivity for those not in the workforce is included in our estimate of the national burden. This population includes all adults age <65 years who are not employed (including those voluntarily or involuntarily not in the workforce). The contribution of people not in the workforce to national productivity includes time spent providing childcare, household activities, and other activities such as volunteering in the community. We use per capita absenteeism estimates for the working population as a proxy for reduced productivity days among the nonemployed population in a similar demographic. Whereas each workday lost due to absenteeism is based on estimated average daily earnings, there is no readily available measure of the value of a day lost for those not in the workforce. In some studies minimum wage is used as a proxy for the value of time lost, but this may underestimate the value of time. We use the human capital approach to estimate value of work time lost, which is based on the years absent from the workforce, market wage, and workforce participation rate (28).

Premature Mortality

Premature mortality associated with diabetes reduces future productivity (and not just the current year productivity). Ideally, to model the value of lost productivity in 2022 associated with premature mortality one would calculate the number and characteristics of all people who would have been alive in 2022 but who died prior to 2022 because of diabetes. Data limitations prevent using this approach. Instead, we estimate the number of premature deaths associated with diabetes in 2022 and calculate the present value of those expected future earnings. To estimate the total number of deaths attributable to diabetes we analyzed the CDC's 2020 Mortality Multiple Cause File to obtain mortality data by age, sex, and race/ethnicity for cardiovascular disease, cerebrovascular disease, renal failure, and diabetes. Using etiologic fractions for ER use as a proxy for mortality etiologic fractions, we estimate that diabetes is responsible for 20% of cardiovascular deaths (excluding cerebrovascular deaths), 26% of deaths with cerebrovascular disease listed as the primary cause, and ∼45% of deaths with renal failure listed as the primary cause. To generate 2022 estimates, we grow the 2020 CDC mortality data using the annual population growth rate from 2020 to 2022 for each age, sex, and race/ethnicity stratum. While we strive to use the most up-to-date data wherever possible, data collected in 2020, particularly mortality data, must be used with caution. Diabetes was eventually recognized as a risk factor for severe illness and death from coronavirus disease 2019 (COVID-19); thus, mortality rates during this time may not be generalizable to future years. As more data become available, in future research diabetes-attributable mortality during the pandemic could be more closely examined.

Productivity loss associated with premature mortality is calculated by taking the net present value of future productivity for men and women by age and race/ethnicity and discounting it by a 3% yearly rate often used in health economic studies (29,30). We calculate present value of future productivity using life expectancy based on the U.S. State Life Tables, 2020, and employment rates for 2020. We combine average annual earnings from the CPS, expected mortality rates from the CDC, and employment rates from the CPS by age, sex, and race/ethnicity to calculate the net present value of future earnings of a person who dies prematurely.

We do not count productivity loss for the population aged <18 years. While children constitute a small proportion of the population with diabetes, omitting productivity loss associated with diabetes among children could bias the cost estimates to be low. For example, the economic cost associated with parents who take time off from work to take their children to the doctor for diabetes-related visits is omitted from these cost estimates.

Sensitivity Analysis to Estimate Impact of COVID-19 Pandemic on Use Estimates

Our modeling approach to estimate direct medical costs in 2022 is intended to replicate the methods used in prior reports for valid comparisons over time. The COVID-19 pandemic had widespread impact on all aspects of health and health care. Furthermore, individuals managing chronic conditions, such as diabetes, were at increased risk of missed care, severe complications, worse outcomes, and mortality (31–33). At the same time, the pandemic also affected data collection for a number of surveys (34). To assess the magnitude of these pandemic-related impacts on our estimates of diabetes burden in 2022, we examine health care use patterns by setting (inpatient, ER, outpatient) for those with and without diabetes from 2017 to 2021 using the commercial claims data from Optum dNHI database. We apply the trends in prepandemic use to the pandemic era to get the expected use rates and then calculate the rates of change in pandemic and prepandemic inpatient, ER, and outpatient use, and we apply these rates of change to adjust Cost of Diabetes Economic Model estimates for the potential impact of the COVID-19 pandemic on health care use and costs.

RESULTS

For 2022, it is estimated that 25.5 million people in the U.S. had diagnosed diabetes, representing 7.6% of the total population. This represents a 3% increase in the total number of people with a diagnosis of diabetes from our 2017 estimates and a 14% increase from our 2012 estimates (1,9). Furthermore, 9.6% of the adult population had diabetes (Supplementary Table 2 in Supplementary Appendix A). The estimated national cost of diabetes in 2022 is $412.9 billion, of which $306.6 billion (74%) represents direct health care expenditures attributable to diabetes and $106.3 billion (26%) represents lost productivity from work-related absenteeism, reduced productivity at work and at home, unemployment from chronic disability, and premature mortality. Excess costs associated with medications constitute 44% of the total direct medical burden, including 7% for insulin, 9% for noninsulin glucose-lowering agents, and 28% for other prescription medications. In contrast, the costs associated with medications constituted 28.4% of the total direct medical burden, including 3.5% for insulin, 7% for noninsulin glucose-lowering agents, and 18% for other prescription medications in 2012 (9).

Health Resource Use Attributable to Diabetes

Table 2 shows estimates of health resource use attributable to diabetes and incurred by people with diabetes as a percentage of total national use. For example, of the projected 169 million hospital inpatient days in the U.S. in 2022, an estimated 48.6 million days (29%) are incurred by people with diabetes of which 32.4 million days are attributable to diabetes, an increase from 2017 estimates of 40.3 million days incurred by people with diabetes and 22.6 million attributed directly to diabetes (1). Approximately 26% of all nursing/residential facility days are incurred by people with diabetes, up slightly from 25% in 2017 (1). Consistent with 2017 estimates, more than half of all office visits, ER visits, hospital outpatient visits, and medication prescriptions (excluding insulin and other glucose-lowering agents) incurred by people with diabetes are attributed to their diabetes (Table 2). Of the nearly 1 billion office visits in the U.S., ∼21% are incurred by people with diabetes and 12% can be directly attributed to diabetes. Similarly, of 138 million outpatient hospital visits, 17% are incurred by people with diabetes and 14% can be directly attributed to diabetes. Health resource use by age, race/ethnicity, and medical condition can be found in Supplementary Tables 3–5 in Supplementary Appendix A).

Health Care Expenditures Attributable to Diabetes

Health care expenditures attributable to diabetes reflect the excess expenditures the nation incurs because of diabetes. This equates to the total health care expenditures for people with diabetes minus the projected level of expenditures that would have occurred for those people in the absence of diabetes. Table 3

Table 2—Health resource use in the U.S. by diabetes status and type of service—2022 estimates (in millions of units)

	Population with diabetes					
	Attributable to diabetes		Incurred by people with diabetes			
Health resource	Units	% of U.S. total	Units	% of U.S. total	Incurred by population without diabetes	U.S. total*
Institutional care						
Hospital inpatient days	32.4	19.1	48.6	28.7	120.9	169
Nursing/residential facility days	77.6	9.1	225.1	26.4	628.5	854
Hospice care days	0.3	0.3	13.7	12.7	94.7	108
Outpatient care						
Office visits	120.1	12.3	205.1	21.0	772.1	977
ER visits	9.7	5.6	19.3	13.2	127.1	146
Hospital outpatient visits	14.3	10.4	24.0	17.4	113.7	138
Home health visits	16.6	4.7	67.4	19.1	285.7	353
Medication prescriptions	671.9	16.3	1,097.7	26.6	3,033.4	4,131

Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020). *Numbers do not necessarily sum to totals due to rounding.

summarizes national expenditure for the cost components included accounting for nearly $2.0 trillion in projected expenditure for 2022. Approximately $503.4 billion of the total is incurred by people with diabetes, reflecting 1 in 4 (25%) of all health care dollars. Costs attributable to diabetes exceed $306.6 billion, or 61% of total medical costs incurred by people with diabetes. For the cost components included, 1 in every 7 health care dollars (15%) is attributable to diabetes, which is consistent with 2017 estimates (1).

The largest contributors to the cost of diabetes are higher use of prescription medications beyond glucose-lowering medications ($84.5 billion), higher use of hospital inpatient services ($96.2 billion), medications and supplies to directly treat diabetes ($51.3 billion), and office visits to physicians and other health providers ($33.6 billion) relative to the population without diabetes. Glucose-lowering medications and diabetes supplies account for ∼17% ($51.3 billion) of the total direct medical costs attributable to diabetes.

After adjustment for inflation, the total cost of insulin and other medications to control blood glucose increased by 26% from 2017 to 2022, to a total of $9.8 billion. The inflation-adjusted cost of insulin increased 24% during the same period. These increases are attributable to both the absolute number of people using insulin and the cost of the medications themselves. Cost of prescription medications for people with diabetes accounts for ∼37% of total medical expenditures incurred by people with diabetes. Medications to treat diabetes (e.g., insulin and noninsulin glucose lowering medications) account for only 10% of the total expenditures incurred by the people with diabetes; however, 100% of expenditures for these medications is attributable to diabetes.

Approximately 67% of all health care expenditures attributed to diabetes are for health resources used by the population aged ≥65 years, an increase from 61% in 2017 (1). Dividing total attributable health care expenditures by the number of people with diabetes, we estimate the average annual excess expenditures for the population aged <65 and ≥65 years, respectively, at $7,482 and $17,180 (Table 4). Health care expenditures attributed to diabetes increase with age and are slightly higher for female individuals (Table 5). Average costs are slightly higher in younger people (aged <18 years), as a higher proportion of these cases are type 1 versus type 2 diabetes.

Figure 1 summarizes the proportion of medical expenditures attributable to diabetes for each chronic complication over total U.S. health care expenditure combining expenditures for hospital inpatient, hospital outpatient, ER, and physician and other health care professional office visits and prescription medications. For people with diabetes who receive care for peripheral vascular conditions, 50% of these expenditures are attributable to diabetes, an increase from 39% attributable to diabetes in 2017 (1). For the neurological, cardiovascular, or renal issue categories, ∼30% of expenditures incurred by people with diabetes are attributable to

Table 3—Health care expenditures in the U.S. by diabetes status and type of service—2022 estimates (in millions, USD)

	Population with diabetes					
	Attributable to diabetes		Total incurred by people with diabetes			
Cost component	USD	% of U.S. total	USD	% of U.S. total	Population without diabetes	Total§
Institutional care						
Hospital inpatient days	96,182	19	144,538	29	354,857	499,395
Nursing/residential facility days	9,581	8	30,286	25	88,676	118,961
Hospice care days	57	0.3	2,852	13	19,672	22,525
Subtotal	105,820	17	177,676	28	463,205	640,881
Outpatient care						
Office visits	33,646	12	58,875	20	233,577	292,452
ER visits	11,821	7	23,451	13	154,856	178,308
Ambulance services	208	2	1,250	12	9,318	10,568
Hospital outpatient visits	12,114	8	22,033	15	121,260	143,296
Home health	5,591	5	22,680	19	96,153	118,834
Podiatry	363	10	767	22	2,800	3,567
Subtotal	63,742	9	129,057	17	617,967	747,023
Outpatient medications and supplies						
Insulin	22,389	100	22,389	100	0	22,389
Diabetes supplies*	4,232	100	4,232	100	0	4,232
Noninsulin glucose-lowering medications†	24,709	100	24,709	100	0	24,709
Other prescription medications	84,483	16	138,024	27	381,428	519,452
Other equipment and supplies‡	1,192	2	7,187	12	53,285	60,472
Subtotal	137,005	22	196,542	31	434,713	631,254
Total	306,568	15	503,274	25	1,515,885	2,019,159

Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020). *Includes, but is not limited to, syringes, blood glucose monitor, glucose meter, insulin pumps, lancets, alcohol swabs, or control solution. †Includes oral medications and noninsulin injectable glucose-lowering agents. ‡Includes, but is not limited to, eyewear, orthopedic items, hearing devices, prosthesis, bathroom aids, medical equipment, and disposable supplies. §Numbers do not necessarily sum to totals due to rounding.

Table 4—Health care expenditures attributable to diabetes in the U.S., by age-group and type of service—2022 estimates

Cost component	Age (years)		
	<65, N = 13.6 million	≥65, N = 11.9 million	Total, N = 25.5 million§
Institutional care			
Hospital inpatient days	28,520 (30)	67,662 (70)	96,182
Nursing/residential facility days	3,217 (34)	6,363 (66)	9,581
Hospice care days	5 (9)	52 (91)	57
Subtotal	31,743 (30)	74,077 (70)	105,820
Outpatient care			
Office visits	8,023 (24)	25,622 (76)	33,646
ER visits	4,650 (39)	7,171 (61)	11,821
Ambulance services	59 (29)	148 (71)	208
Hospital outpatient visits	5,787 (48)	6,326 (52)	12,114
Home health	2,184 (39)	3,407 (61)	5,591
Podiatry	113 (31)	250 (69)	363
Subtotal	20,818 (33)	42,925 (67)	63,742
Outpatient medications and supplies			
Insulin	12,484 (56)	9,905 (44)	22,389
Diabetes supplies*	2,392 (57)	1,840 (43)	4,232
Noninsulin glucose-lowering medications†	12,637 (51)	12,073 (49)	24,709
Other prescription medications	20,564 (24)	63,919 (76)	84,483
Other equipment and supplies‡	826 (69)	366 (31)	1,192
Subtotal	48,903 (36)	88,102 (64)	137,005
Total	101,464 (33)	205,104 (67)	306,568
Average cost per person with diabetes (actual USD)	7,482	17,180	12,022

Unless otherwise indicated data are presented in millions, USD, with row percentages in parentheses. Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020). *Includes, but is not limited to, syringes, blood glucose monitor, glucose meter, insulin pumps, lancets, alcohol swabs, or control solution. †Includes oral medications and noninsulin injectable glucose-lowering agents. ‡Includes, but is not limited to, eyewear, orthopedic items, hearing devices, prosthesis, bathroom aids, medical equipment, and disposable supplies. §Numbers do not necessarily sum to totals due to rounding.

their diabetes. Health care expenditures attributable to diabetes by medical condition can be found in Supplementary Table 6 in Supplementary Appendix A).

Table 5—Health care expenditures attributable to diabetes in the U.S., by demographic

Characteristics	Prevalent diabetes (N)	Total direct cost (millions, USD)	Average cost per person with diabetes (actual USD)
Age (years)			
<18	300,000	2,271	7,581
18–34	1,110,000	7,056	6,352
35–44	1,890,000	12,345	6,532
45–54	3,860,000	28,648	7,427
55–59	2,910,000	24,419	8,381
60–64	3,490,000	26,725	7,656
65–69	3,570,000	54,753	15,354
≥70	8,370,000	150,351	17,958
Sex			
Male	12,970,000	151,453	11,680
Female	12,530,000	155,115	12,376
Race/ethnicity			
White, non-Hispanic	14,410,000	187,894	13,039
Black, non-Hispanic	4,060,000	53,480	13,169
Other, non-Hispanic	2,260,000	22,897	10,141
Hispanic	4,770,000	42,296	8,865

Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020).

When we compare expenditures for people with diabetes with expenditures for a population of similar age and sex, people with diabetes have health care expenditures that are 2.6 times higher ($19,736 vs. $7,714) than expenditures would be expected for this same population in the absence of diabetes (Table 6). This suggests that diabetes is responsible for an estimated $12,022 in excess health care expenditures per year per person with diabetes. This 2.6 multiple is a slight increase from the 2007 (8), 2012 (9), and 2017 estimates (1). Per capita health care expenditures by age and race/ethnicity can be found in Supplementary Tables 7 and 8, respectively, in Supplementary Appendix A.

Indirect Costs Attributable to Diabetes

The total indirect cost of diabetes in 2022 is estimated at $106.3 billion (Table 7). Major contributors to this burden are reduced employment ($28.3 billion), presenteeism ($35.8 billion), and premature mortality ($32.4 billion). Workdays absent ($5.4 billion) and reduced productivity for

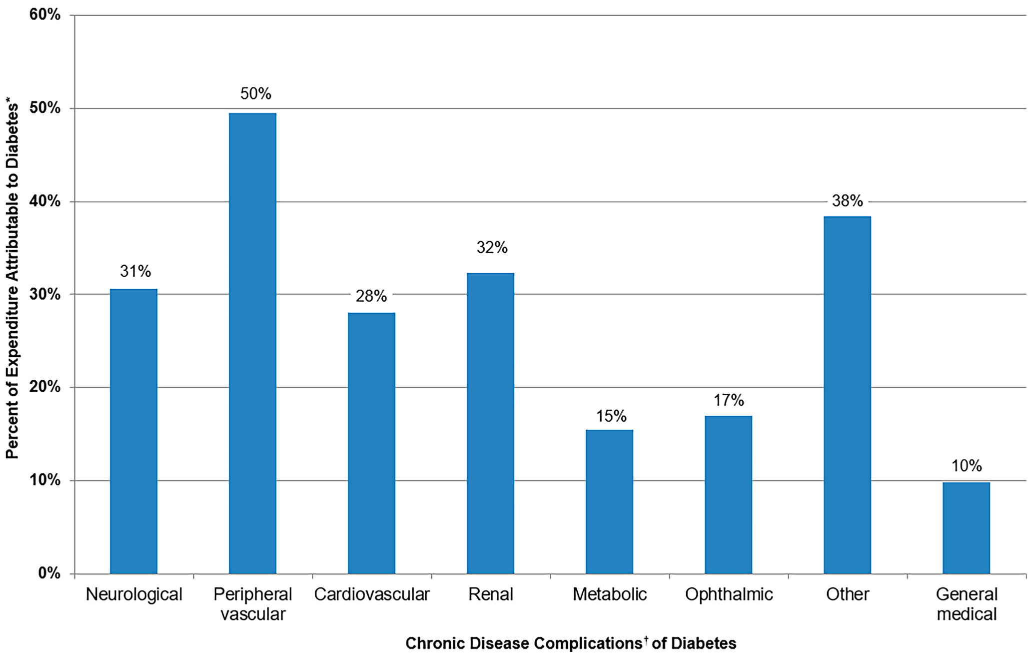

Figure 1—Percent of medical expenditures attributable to diabetes by chronic complication. *Using attributable fraction method. †Complications identified by diagnosis codes (see Supplementary Appendix B). Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020).

those not in the workforce ($4.4 billion) represent a relatively small portion of the total burden. Indirect costs by age and race/ethnicity can be found in Supplementary Tables 9 and 10, respectively, in Supplementary Appendix A.

Analysis of NHIS data suggests that of the estimated 25.5 million people with diagnosed diabetes, ∼8.2 million are in the workforce. If people with diabetes participated in the labor force at rates similar to their peers without diabetes, there would be ∼2 million additional people between the ages of 18 and 64 years in the workforce. However, using a more conservative approach where reduced labor force participation is associated with receiving disability payments, we estimate 447,000 fewer working-age adults in the workforce in 2022—equivalent to 107.2 million lost workdays. While disability payments themselves are a cost to the government, from a societal perspective they are considered transfer payments and thus not included in the burden estimates. Nevertheless, the projected number of lost workdays in 2022 is a marked decrease from 2017 (182 million), likely due to important changes to how information on disability status and receipt of disability payments is captured in NHIS from 2019 onward.

The cost of missed workdays due to absenteeism is estimated at $5.4 billion, representing 17.3 million days. If people not in the workforce had rates of days where they are unable to work due to poor health similar to the rates of their employed peers, this would equate to 15.5 million excess sick days with estimated productivity loss valued at $4.4 billion. Reduced performance at work (presenteeism) accounted for 34% of the indirect cost of diabetes. The estimate of a 6.6% annual decline in productivity attributed to diabetes equates to 113 million lost workdays per year.

The estimated number of deaths in 2022 attributable to diabetes is 339,000 (Table 8); for 107,000 deaths, diabetes is listed as the primary cause. Of the 777,000 deaths where cardiovascular disease is listed as the primary cause, ∼179,000 (23%) are attributable to diabetes, an increase from estimated 16% in 2017 (1). Approximately 25,000 cases (15%) where cerebrovascular disease is listed as the primary cause of death are attributable to diabetes and 28,000 cases (52%) where kidney disease is listed as the primary cause of death are attributable to diabetes. The average cost per premature death declines with age (reflecting fewer remaining expected working years) and across all premature deaths averaged approximately $95,658 per case.

Trends in Diabetes Costs, 2007–2022

After adjustment for inflation, we estimate that total direct medical costs associated with diabetes in the U.S. increased by 7.0% (from $287.0 billion to $306.6 billion in 2022 USD) between 2017 and 2022 and by 35% between 2012 and 2022 (Fig. 2). At the same time, after adjustment for both inflation and growth in diabetes prevalence, the excess medical cost per capita attributable to diabetes increased by 3.5% compared with the 2017 estimate (from $11,619 to $12,022 in 2022 USD) and 18% from the 2012 estimate (Fig. 3).

The indirect costs of diabetes decrease by 2.3% with adjustment for general inflation (Fig. 4), which on a per capita basis reflects 5.3% decline compared with 2017 estimates (from $4,403 to $4,169 per capita in 2022 dollars) (Fig. 3). This decrease in indirect costs is likely due to important changes to how information on disability status and receipt of disability payments is captured in NHIS from 2019 onward.

Combined, the inflation-adjusted total economic burden of diabetes increased from $395.7 billion in 2017 to $412.9 billion in 2022 (or 4.3% growth), a slight plateau compared with the 25% growth estimated from 2012 to 2017 (1) (Fig. 5). Adjusted for inflation and growth in diabetes prevalence,

Table 6—Annual per capita health care costs in the U.S. by diabetes status, 2022 (in actual USD)

		Unadjusted		Adjusted for age and sex		
Cost component	With diabetes	Without diabetes	Ratio, with to without diabetes	Without diabetes	Ratio, with to without diabetes	Attributable to diabetes
Institutional care						
Hospital inpatient days	5,668	1,138	5.0	1,896	3.0	3,772
Nursing/residential facility days	1,188	284	4.2	812	1.5	376
Hospice care days	112	63	1.8	110	1.0	2
Subtotal	6,968	1,485	4.7	2,818	2.5	4,150
Outpatient care						
Office visits	2,309	749	3.1	989	2.3	1,319
ER visits	920	497	1.9	456	2.0	464
Ambulance services	49	30	1.6	41	1.2	8
Hospital outpatient visits	864	389	2.2	389	2.2	475
Home health	889	308	2.9	670	1.3	219
Podiatry	30	9	3.3	16	1.9	14
Subtotal	5,061	1,982	2.6	2,561	2.0	2,500
Outpatient medications and supplies						
Insulin	878	NA	NA	NA	NA	878
Diabetes supplies*	166	NA	NA	NA	NA	166
Noninsulin glucose-lowering medications†	969	NA	NA	NA	NA	969
Other prescription medications	5,413	1,223	4.4	2,100	2.6	3,313
Other equipment and supplies‡	282	171	1.6	235	1.2	47
Subtotal	7,707	1,394	5.5	2,335	2.6	5,373
Total§	19,736	4,861	4.1	7,714	2.6	12,022

Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), Medicare 5% SAF (2020), and U.S. Census Bureau (2020). NA, not applicable. *Includes, but is not limited to, syringes, blood glucose monitor, glucose meter, insulin pumps, lancets, alcohol swabs, or control solution. †Includes oral medications and noninsulin injectable glucose-lowering agents. ‡Includes, but is not limited to, eyewear, orthopedic items, hearing devices, prosthesis, bathroom aids, medical equipment, and disposable supplies. §Numbers do not necessarily sum to totals due to rounding.

the average economic cost per capita associated with diabetes inclusive of direct medical and indirect costs is virtually unchanged, from $16,022 to $16,191 (in 2022 dollars), a 1.1% growth (Fig. 3) compared with 2017 estimates. There was a 14% increase from 2012 estimate.

COVID-19

We take advantage of national survey data to assess diabetes status and health care resource use over time; a great strength of these data sources is consistent methodology over time. The COVID-19 pandemic disrupted routine data collection for some, but not all, of the surveys used for these updates (34). Even when data collection was not disrupted, health care–seeking behavior patterns that may have been disrupted by the pandemic may alter the reliability of the data. To assess the potential impact of the pandemic on our projections for costs of diabetes in 2022, we examined health care claims in the years prior to and during the pandemic. The purpose of these analyses was twofold: *1*) to assess the degree to which health care use postpandemic may still be impacted by changes in health care–seeking behavior and *2*) to adjust the estimates from the Cost of Diabetes Economic Model to reflect this potential discrepancy.

Analysis of adult enrollees in the commercial insurance administrative claims database to assess the impact of the COVID-19 pandemic on health care use

Table 7—Indirect burden of diabetes in the U.S.—2022 estimates (in billions, USD)

Cost component	Productivity loss	Total cost attributable to diabetes	Proportion of indirect costs (%)*
Workdays absent	17.3 million days	5.4	5.1
Reduced performance at work	112.7 million days	35.8	33.7
Reduced productivity days for those not in labor force	15.5 million days	4.4	4.1
Reduced labor force participation due to disability	107.2 million days	28.3	26.6
Mortality	339,000 deaths	32.4	30.5
Total		106.3	100

Data sources (year): NHIS (2019–2021), CPS (2020), CDC WONDER Mortality Multiple Cause File (2020), and U.S. Census Bureau population estimates for 2020. *Numbers do not necessarily sum to totals because of rounding.

Table 8—Mortality costs attributable to diabetes, 2022

		Deaths attributable to diabetes		
Primary cause of death	Total U.S. deaths (thousands)*	Deaths (thousands)	% of U.S. deaths in category	Value of lost productivity (billions of dollars)
Diabetes	107	107	100	13.8
Kidney disease	54	28	52	1.8
Cerebrovascular disease	169	25	15	1.4
Cardiovascular disease	777	179	23	15.4
Total	NA	339	NA	32.4

*Total deaths in 2020 from CDC Mortality Multiple Cause File by primary cause of death, scaled to 2022 using the annual diabetes population growth rate from 2020 to 2022 for each age, sex, and race/ethnicity strata. NA, not applicable.

can be found in Supplementary Figs. 2–10 in Supplementary Appendix A. In general, a slight decrease in all types of in-person health care encounters is observed in 2020 and expected levels are generally recovered in 2021. However, telehealth visits increase by 35% from 2019 to 2020, from $<$1 per 1,000 patients per year in 2019 to $>$25 per 1,000 patients per year in 2020 and 2021.

After adjustment of our Cost of Diabetes Economic Model's estimates of 2022 medical costs to account for the relative difference between observed and expected use rates, the direct medical costs attributed to diabetes show a change of $<$5% (Table 9). Hospital inpatient expenditures rise by 2%, totaling $98.1 million and $3,848 per capita. Both office visit and hospital outpatient expenditures show an increase of 4.6%. Conversely, ER expenditures decrease by 3%, moving from $11.8 million to $11.5 million.

DISCUSSION

From our study we estimate that in 2022, approximately 25.5 million individuals, or roughly 7.6% of the U.S. population, had diagnosed diabetes. This constitutes a 3% increase in the total number of people with a diagnosis of diabetes from our 2017 estimates and a 14% increase from our 2012 estimates (1,9). Although prevalence rate has remained relatively stable in recent years, the estimated direct and indirect costs linked to diabetes persistently rise. Furthermore, the national economic burden of diabetes is estimated at $412.9 billion, comprising $306.6 billion (74%) in direct medical costs and $106.3 billion (26%) in indirect costs. After adjustment for age and sex, the projected annual per capita health care expenditures for people with diabetes are 2.6 times higher than those for people without diabetes, which is a slight increase from 2.3 in 2017 and 2012 (1,9). This is similar to other observational studies comparing costs for people with diabetes relative to those without (25,35). Notably, chronic complications such as cardiovascular, renal, and ophthalmic conditions constitute a significant portion of the medical costs associated with diabetes.

Despite a long-term trend of increasing diabetes prevalence, the overall estimated prevalence in 2022 remains relatively stable. This stability reflects demographic shifts, the aging U.S. population, and a slight decrease in incidence rates (2). The prevalence of diabetes in individuals aged ≥65 years shows a slight rise compared with 2017, while

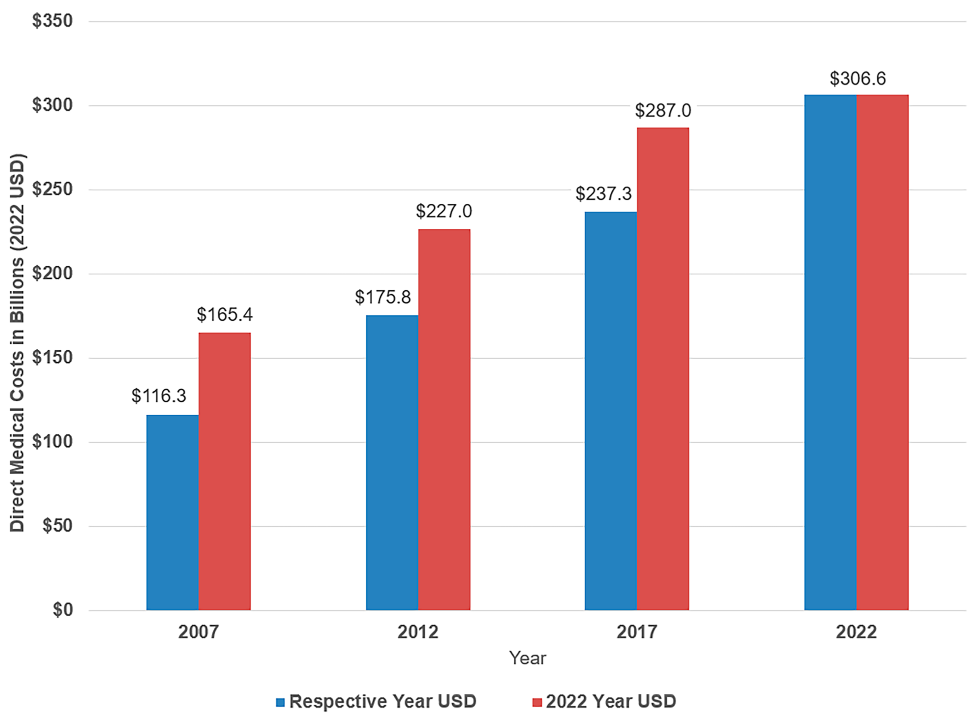

Figure 2—Total direct medical costs of diagnosed diabetes, 2007–2022. Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020).

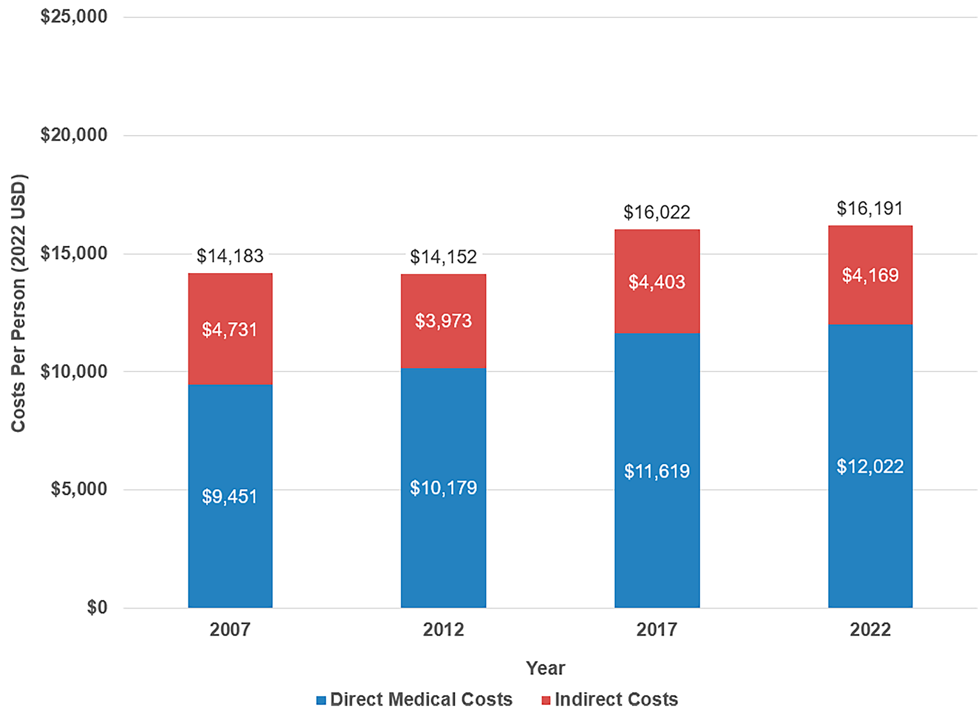

Figure 3—Average per capita cost (direct medical and indirect) of diagnosed diabetes, 2007–2022 (in 2022 USD). Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020), CPS (2020), CDC WONDER Mortality Multiple Cause File (2020), and U.S. Census Bureau population estimates for 2020.

the prevalence rates for most other age-groups are lower, which may reflect improved diabetes prevention efforts. The decline in incidence of diabetes has previously been reported (36) and may reflect prevention efforts.

After adjustment for inflation, overall medical costs are estimated to be slightly higher (∼7%) in 2022 in comparison with

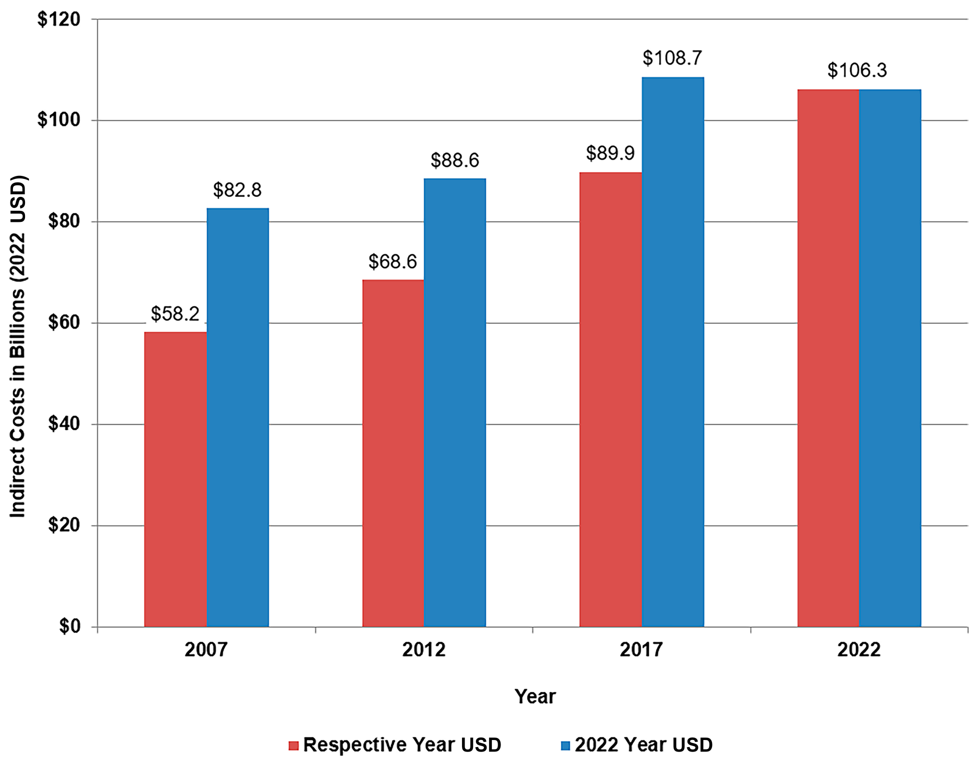

Figure 4—Total indirect cost of diagnosed diabetes, 2007–2022 (in 2022 USD). Data sources (years): NIS (2019), CPS (2020), CDC WONDER Mortality Multiple Cause File (2020), and U.S. Census Bureau population estimates for 2020.

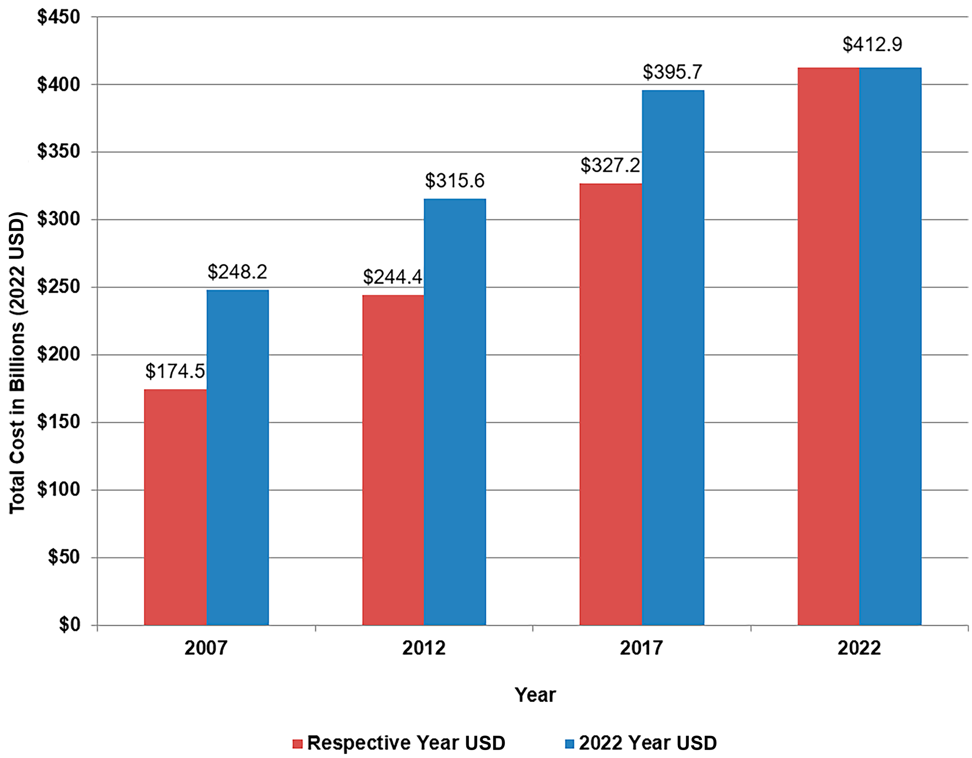

Figure 5—Total economic cost (direct medical and indirect) of diagnosed diabetes, 2007–2022 (in 2022 USD). Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017-2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2020), MCBS (2019), and Medicare 5% SAF (2020), CPS (2020), CDC WONDER Mortality Multiple Cause File (2020), and U.S. Census Bureau population estimates for 2020.

2017 estimates (in constant 2022 USD)—this is in contrast to much steeper increases of 37% from 2007 to 2012 (9) and 26% from 2012 to 2017 (1), is largely a reflection of relative stability in prevalence over recent years, and aligns with slight slowdown in year-over-year growth in health care spending (37). For 2022 it is estimated that 25% of U.S. health care expenditures were incurred by people with diabetes and 15% can be directly attributed to diabetes; this is 1 percentage point higher than the 2017 estimate. Similar to costs for the population without diabetes, health care costs are largely driven by inpatient use and prescription medications. Despite a relative stability in diabetes prevalence, the absolute number of people with diabetes has grown, which contributes to increased health care expenditures. Concurrently, there is an escalation in per capita spending, particularly for inpatient hospital stays and prescription medications. We estimate that between 2017 and 2022 the average cost per capita of prescriptions for insulin and glucose-lowering agents increased by 20% and 25%, respectively. These marked increases align with findings from retrospective studies of trends in glucose-lowering agent costs (38–40).

The COVID-19 pandemic has left a deep imprint on the health care system, with lockdown measures causing lapses in medical care and shifts in service use patterns (41–43). Given that our study

Table 9—Health care resource use and expenditures and per capita costs by type of service with adjustment for observed COVID-19 care use patterns

	Unadjusted (Table 2)			Adjusted*		
Type of service	Health resource use, millions	Health care expenditures, millions (USD)	Per capita costs (USD)	Health resource use, millions	Health care expenditures, millions (USD)	Per capita costs (USD)
Hospital inpatient days	32.4	96,182	3,772	33.0	98,116	3,848
Office visits	120.1	33,646	1,319	125.9	35,270	1,383
ER visits	9.7	11,821	464	9.4	11,482	450
Hospital outpatient visits	14.3	12,114	475	15.0	12,699	498
Medication prescriptions	671.9	84,483	3,313	701.9	88,263	3,461

Data sources (years): NIS (2019), NAMCS (2015–2016 and 2018), NHAMCS (2009–2011 and 2017–2019), MEPS (2015–2019), NHIS (2019–2021), Optum dNHI (2017–2021), MCBS (2019), and Medicare 5% SAF (2020). *Adjusted for difference in observed vs expected use rates for pandemic years 2020.

heavily depends on prepandemic health care use data, it is crucial to acknowledge how these projections may overstate or underestimate 2022 use rates. Consistent with other reports, this analysis of real-world evidence suggests that postpandemic use rates are returning to expected levels (44,45). While some of these shifts, such as adoption of telehealth, appear to persist to some degree, other types of use have nearly returned to expected rates. Furthermore, despite the sizable increase in its use, use of telehealth remains a very small proportion of health resource use. It is important to note that this subanalysis is constrained by its reliance on a database of commercially insured individuals, which may not yield a representative sample, especially during the pandemic's early phase when insurance coverage dipped (46,47). Nonetheless, these declines in employer-sponsored insurance were observed through 2021, even amid decreasing unemployment rates (48). Furthermore, our examination of the impact of the pandemic does not account for indirect costs, specifically, the costs of absenteeism and/or presenteeism. Future research could include investigation of the differential impact for the population with diagnosed diabetes.

Diabetes accounts for a large proportion of health care spending in the U.S., and these costs primarily fall on insurers and people with diabetes. However, reduced productivity attributable to diabetes costs employers as well. After adjustment for inflation, the estimated total indirect burden of diabetes is similar to the 2017 estimate ($106.3 billion and $108.7 billion, respectively). While we observe increases in estimated productivity loss due to workdays absent and those not in the labor force as well as premature mortality, at the same time we see a marked decrease in the proportion of productivity loss due to inability to work (41.7% in 2017 [1] compared with 30.8% in 2022 [Table 7]), despite a small decrease in the size of the working-age adult population (13,600,000 in 2017 and 13,263,000 in 2022: a decrease of 2.5%). We calculate reduced labor force participation as the inability to work due to disability using questions about Social Security income from the NHIS, which was redesigned in 2019. The redesign eliminated the family questionnaire, and questions about Social Security income are now part of the individual questionnaire. This may mean that 2022 estimates of reduced labor force participation due to disability are more accurate than previous estimates, where this information was captured at the household level and thus could have potentially included misclassification of disability status of the individual of record. These costs are passed along to all of society in the form of higher insurance premiums and taxes, reduced earnings, and reduced standard of living. Our estimate for productivity loss per capita is slightly lower than that of another study where more robust employer data were used from payroll and disability claims (25). Regardless, the costs of presenteeism call for policies and practices that support flexible working environments to allow people living with diabetes to contribute optimally to the workplace.

Comparing our estimates for cost of diabetes in 2022 with the existing literature is not straightforward due to variations in source data, study populations (e.g., inclusion of both type 1 and type 2 diabetes, undiagnosed diabetes, and/or gestational diabetes mellitus in prevalence estimates), relevant time period, methods and modeling approach, and the dynamic nature of certain assumptions that underlie estimating future incidence and prevalence. For instance, the International Diabetes Federation prevalence estimates for the adult population with diabetes were standardized using the age structure of the United Nations world population data (49,50), while our estimates include children and are standardized based on age-, race-, sex-, and insurance-specific strata derived from ACS 2020. Some older studies projected higher prevalence based on modeling constraints that did not allow for variation in incidence rates over time (51). Our Cost of Diabetes Economic Model estimates are based on the most recent data available on incidence and prevalence in the U.S. Similarly, economic growth, particularly in the health sector, fluctuates over time (52). These dynamic forces warrant recurrent updates to cost estimates over time.

Limitations

Due to data limitations, we omitted the potential increases in the use of over the counter medications and optometry, dental, and mental health services from this analysis. This is consistent with methodology used in our previous reports (1,7–9) allowing for valid comparison. Diabetes increases the risk of periodontal disease, so one would expect dental costs to be higher for people with diabetes. Small sample size in MEPS data prevented meaningful analysis of these cost components. We also omitted expenditures for prevention programs targeted to people with diabetes, research activities, and health administration costs. With these omissions the full medical costs associated with diabetes are underestimated. Future cost estimates could include use of optometry, dental, and mental health services.

Without data on household structure and caregiver roles, we are unable to account for lost productivity associated with care for diabetes of family members or caregivers (e.g., time off from work to care for a child or an elderly parent with diabetes). The value of informal care and personal aides is excluded from our cost estimate. Time and costs associated with traveling to health care visits and other medical emergencies are omitted. This may result in underestimation of the indirect costs associated with diabetes. Additionally, we are unable to account for the intangible costs of diabetes such as pain, suffering, and reduced quality of life in our economic burden estimates. Further, we do not count productivity loss for the population aged <18 years, which may bias costs estimates to be lower; however, children constitute a small proportion of the population with diabetes.

A complicating factor in estimating costs attributable to diabetes is that health behavior, such as tobacco use or physical inactivity, which affects both the presence of diabetes and the presence of other comorbidities, unless controlled for, could result in an overestimate of the link between diabetes and use of health resources. Controlling for demographics helps to control for this correlation. In addition, for the top 10 cost drivers we conducted additional analysis controlling for other important explanatory variables using MEPS data, and based on the results we reduced the etiological fractions for several diabetes complications and for the general medical conditions group—depending on care delivery setting. Confounding by health behaviors can also affect the indirect cost estimates attributed to diabetes, especially the estimated productivity loss due to absenteeism or presenteeism. This can lead to an overestimation of these costs.

Other study limitations include small sample size for some data sources used, the use of a data source (dNHI) that overrepresents the commercially insured population for the population aged <65 years, and the need to use different approaches to model different cost components because of data limitations. Another limitation common to claims-based analysis is the possibility of inaccurate diagnosis codes on medical claims, as the presence of a single code could be used for ruling out disease rather than diagnosis (53–55). Claims data tend to be less accurate than medical records in identifying patients with specific conditions for reasons such as rule-out diagnosis, coding error, etc., which could result in slight overestimation of disease prevalence (53). The direction of such bias on our risk ratio calculations is unknown, although it is anticipated to be small as there is no reason to believe that the coding of comorbidities would be significantly different for people with and without diabetes. While other reporting systems, such as United States Diabetes Surveillance System and CDC's National Diabetes Statistics Report, focus on robust prevalence estimates, the primary focus of this report is to update estimates of the economic cost of diabetes; therefore, we are limited by sample sizes in the data sources we rely on for medical costs (e.g., MEPS). Due to the number of strata (age-group, sex, race/ethnicity, and insurance status) our ability to distinguish race within the "Other" category is limited; for instance, to have sufficient sample size to estimate medical costs for each stratum we combined multiple years of MEPS data.

An important limitation with regard to how disability status was captured was a change in the NHIS (56). Compared with 2017 estimates, the proportion of the population receiving SSI payment (being disabled) decreased by ∼50%. This is largely due to the redesign of the NHIS questionnaire. Specifically, the question about receipt of SSI payments was asked in the family survey prior to 2019; as such, the responses included the status of all family/household members and potentially overestimated the proportion receiving SSI payments. In 2019, the family survey was eliminated and the question about receipt of SSI payments was asked in the adult questionnaires; thus, the response might only reflect to that person's situation rather than that of the entire family. To assess the likelihood of being on disability as demonstrated by receipt of SSI payments, we compared likelihood of being on disability for the population with diabetes with that of the population without diabetes using a logistic regression adjusted for age-group, sex, race/ethnicity, diagnosed hypertension status (yes/no), and body weight status (normal, overweight, obese, unknown) and found that the population with diabetes has a 1.8 percentage point higher rate of being out of the labor force and receiving disability payments compared with the population without diabetes. This is much lower than what was reported in 2017 (3.1 percentage points).

Lack of updated data or discontinuation of data collection stream presents challenges in capturing some cost components. In most cases, we replicate our methods from prior reports using the most recent data available from a given survey. However, in two instances we use an alternative approach. First, in prior reports we used the NHAMCS Outpatient Department Data files to estimate outpatient health care use. The most recent NHAMCS data were not available due to quality issues (14), so we rely on the 2009–2011 Outpatient Department Data file for our estimates. To assess robustness of this alternative approach, we also assessed the rate of change in outpatient care use from the same period, 2009–2011 to 2017–2019, in the MEPS data and observed a small (3.3%) decrease. This small decrease may be due to shifts in site of service over time. The second instance where we use an alternative approach was for estimating care use in nursing home and hospice settings. The survey used to estimate hospice use in 2017 (NHHCS) was last fielded in 2007 (57). We apply a method similar to that used in 2017 and adjust the hospice use found in the most recent study.

National health-related expenditures are projected to exceed $4.4 trillion in 2022 (58), but slightly less than half of these expenditures are included in our analysis. These cost estimates omit national expenditures (and any portion of such expenditures that might be attributable to diabetes) for administering government health and private insurance programs, investment in research, overhead and infrastructure, policy efforts and diabetes-related quality measure reporting, over the counter medications, disease management and wellness programs through private insurance or community based, and office visits to nonphysician providers other than podiatrists (e.g., dentists and optometrists).

Nevertheless, using a methodology that is largely consistent with our previous studies conducted in 2012 and 2017, and with updated national survey and claims data sources, we estimate the total burden of diabetes in 2022. Despite a plateau in the prevalence of diabetes in recent years, direct medical costs and productivity losses attributable to diabetes increase. The estimates presented here show that diabetes continues to place an enormous burden on society—both in the economic terms presented here and in reduced quality of life. Future research should include exploration of the costs and benefits of new therapies, devices, and intervention modalities that can potentially prevent complications and severity of diabetes and have the potential to mitigate indirect costs and productivity losses.

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