Health care spending on diabetes in the United States, 1996-2013

Ellen Squires

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Joe Dieleman, Chair

Herbie Duber

Irl Hirsch

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Abstract

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Ellen Squires

Chair of the Supervisory Committee:

Assistant Professor Joe Dieleman

Global Health

The mortality and morbidity attributable to diabetes in the United States has increased by 31% from 1990 to 2015 to become the second leading cause of disease burden. During this same time period, health care spending on diabetes has also increased. These spending increases have not been examined in detail, making it difficult to design policies to contain diabetes health care spending. This research seeks to describe health care spending on diabetes in the United States from 1996 through 2013, disaggregated by age and sex of the patient and by type of care, and to determine what factors are driving increases in diabetes spending.

Health spending estimates were extracted from the Disease Expenditure 2013 project database, produced by the Institute for Health Metrics and Evaluation. These estimates were made by synthesizing 183 data sources containing granular information on spending and utilization of health services across different types of care. Estimates were produced annually from 1996 to 2013, were adjusted for the presence of comorbid conditions, and were scaled to the official US Government spending records. Data on disease burden was extracted from the Global Burden of Disease 2015 study. We used demographic decomposition to measure the impact of population growth, population aging, diabetes prevalence, service utilization, and service price and intensity on diabetes health care spending.

Health spending on diabetes in the US increased from $37 (95% Uncertainty Interval: 32-42) billion in 1996 to $101 (97-107) billion in 2013. The greatest amount of health care spending on diabetes in 2013 occurred in prescribed retail pharmaceuticals ($58 [55-63] billion), followed by ambulatory care ($24 [22-26] billion), inpatient care ($9.6 [8.6-11] billion), and nursing facility care ($9.2 [8.1-10] billion). Spending patterns also varied by age. In particular, spending was greatest for ages 65 and older ($43 [41-46] billion), followed by ages 45 to 64 ($45 [42-48] billion) and ages 20 to 44 ($11 [10-13] billion). Service and price intensity was the biggest determinant of spending increases in pharmaceutical spending and inpatient care, and increases in disease prevalence were the biggest determinant of spending increases in ambulatory care and nursing facility care.

Knowing the types of care where spending increases are occurring can help policymakers attempting to control future spending on diabetes. In particular, growth in pharmaceutical spending reveals one important area of future focus.

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Acknowledgements

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Background

Diabetes burden in the US

The prevalence of diabetes in the United States has increased in the past several decades, rising from 7.7% in 1990 to 11.3% in 2015.[1] There are several types of diabetes, including Type 1 (T1D) and Type 2 (T2D), and T2D comprises an estimated 96% of diabetes cases in the US.[2] In addition to T1D and T2D, 86 million American adults over age 20 had prediabetes in 2012, up from 79 million in 2010.[2]

Diabetes comprises a significant portion of total disease burden in the US, and is associated with many complications, including hypertension, cardiovascular disease, blindness and eye problems, kidney disease, and stroke.[2] It was the ninth leading cause of death in 2015 and was the third leading cause of disability-adjusted life years (DALYs).[1] Furthermore, it is likely that the number of deaths attributable to diabetes is underestimated, as it is often not reported as an underlying cause of death when a patient presents with other conditions.[2–4]

Diabetes is not distributed evenly across the population. Prevalence is higher for American Indians and non-Hispanic blacks (15.9% and 13.2%, respectively) than for non-Hispanic whites (7.6%).[2] Prevalence is high among older adults, with an estimated 25.9% of Americans over age 65 living with diagnosed or undiagnosed diabetes.[2] Complication rates are also 2-4 times higher among African Americans than among non-Hispanic whites,[5–7] and there is some evidence underscoring the role of lower quality of care in driving these racial differences.[8]

As the obesity epidemic continues, the prevalence of diabetes is expected to rise. If current trends persist, diabetes prevalence is projected to increase to up to 33% of the U.S. population by 2050.[9] This is likely to have significant effects on the US health system, on health policy, and on domestic health care spending.

Diabetes management and treatment

To understand trends in diabetes spending, it is important to understand how diabetes is managed and treated. Importantly, a significant part of diabetes treatment involves the routine use of pharmaceuticals to regulate blood sugar. Ideal management of diabetes centers on maintaining normal or near-normal levels of glucose or hemoglobin A1c in the bloodstream. When these levels are above normal, medication may be needed to manage the condition.

Diabetes spending on pharmaceuticals is influenced in part by which drugs are selected for treatment. The main recommendations for drugs to be used in diabetes treatment are articulated in the American Diabetes Association (ADA) guidelines for managing diabetes, which are updated annually to reflect changes in treatment modalities over time.[10] Costs vary significantly by drug, and so the type of drug prescribed can affect overall spending. Metformin, which is recommended as the first-line drug, is relatively inexpensive.[11] If therapy with metformin is not effective in maintaining HbA1c levels during a three month period, however, a second oral agent may be prescribed, and these second-line drugs are typically more expensive than metformin.

Insulin is also used to manage all cases of T1D and some cases of T2D. Significantly, insulin use among T2D patients increased from 10% of T2D patients in 2000 to 15% in 2010.[12] This can have significant impacts on diabetes spending, as the cost of insulin has increased drastically in recent years.[13]

Health spending on diabetes

As diabetes prevalence has risen, there have also been substantial increases in health spending on diabetes. Notably, overall spending on diabetes rose from $37 billion in 1996 to $101 billion in 2013.[14]

Health spending on diabetes is an important area of research for several reasons. First, drastic increases in prevalence have led to the designation of diabetes as a pandemic.[15] With prevalence rising in the US and around the world, it is important to understand how these increases might impact health spending, a contentious issue in the US as health spending has continued to rise and currently accounts for 18% of GDP.[16] Second, it is important to understand how spending is distributed across types of care. In particular, pharmaceutical spending has emerged as a particularly important area of focus, as diabetes is treated with a complex and evolving array of drugs to manage blood glucose levels. One study found that 55% of spending increases between 1987 and 2010 were driven by prescription medications alone.[17] The rising costs of insulin have also been implicated in driving increased spending on diabetes.[13,18,19] Changes in pharmaceutical treatment patterns following several landmark studies,[20] as well as the development of new drugs,[21] will likely have important ramifications for future diabetes spending. Finally, diabetes affects health spending in complex ways, since complications associated with diabetes can result in greatly increased costs. Previous research has estimated that 72% of patients with diabetes possessed at least one complication,[22] and that 38% of excess spending on diabetes is attributable to related complications.[23] Furthermore, even after controlling for age and sex, people with diabetes incur health expenditures that are 2.3 times higher than people without diabetes.[24]

While trends in diabetes spending in aggregate have been widely reported, there are few studies that examine more granular spending trends. This research seeks to fill that gap by providing the most granular diabetes spending estimates to date, scaled to the official government estimates of health spending. This study draws on the Institute for Health Metrics and Evaluation's Disease Expenditure (DEX) project,[14] which synthesizes 183 individual data sources to produce granular and comprehensive estimates of health spending. Specifically, this study reports trends in diabetes spending disaggregated by type of care, age, and sex, for years 1996 through 2013.

The DEX dataset is a particularly advantageous source to use to study diabetes health spending. First, because it is scaled to the official US government spending estimates, there is no double-counting of dollars spent on health. Having an envelope for spending ensures that the sum of spending on individual diseases does not exceed the total amount of spending in the country. Second, DEX uses a comparable estimation method across 18 years and six types of care, allowing for reliable comparisons between types of care and time. Third, the data is disaggregated by age and sex. This granularity makes the data uniquely valuable for policymakers seeking to target specific groups or types of care when attempting to contain costs. Finally, there is a systematic adjustment to account for comorbidities, which is especially important in the context of diabetes. The comorbidity adjustment ensures that spending estimates reflect spending on the *condition* rather than the primary diagnosis alone.

It is also important to understand the drivers of increased health spending on diabetes over time, and this is an area where more research is needed. We produce a dataset that incorporates both demographic, epidemiologic, health system, and spending data in order to analyze the relative contributions of five key drivers to increases in health spending: population growth, population aging, disease prevalence, service utilization, and service price and intensity. Understanding how these factors are contributing to increased spending over time can also guide future efforts to contain spending on diabetes.

Methods

Data overview

The primary data source for this study was the 2013 Disease Expenditure project (DEX), produced by the Institute for Health Metrics and Evaluation.[14] This database contains estimates of health spending and volume for 155 conditions, six types of care, and 38 age and sex groups from 1996 through 2013. The six types of care included in the DEX study are inpatient care, ambulatory care, emergency departments, nursing facility care, dental care, and prescribed retail pharmaceuticals. Final estimates are produced by synthesizing 183 different underlying data sources, which include household surveys, insurance claims, and administrative records. These data sources collectively contain 2.9 billion individual records. Table 1 lists the data sources used for estimating spending within each type of care.

Table 1. Primary data sources used in the Disease Expenditure project

Type of care	Macro spending data and years	Micro spending data and years	Micro volume data and years
Ambulatory	NHEA (1996 – 2013)*	MEPS (1996 – 2013); SAMHSA (1998, 2002, 2004, 2005, 2009); MarketScan (2000, 2010, 2012)	NAMCS (1996 – 2011); NHAMCS (1996 – 2011); MarketScan (2000, 2010, 2012)
Inpatient	NHEA (1996 – 2013)	NIS (1996 – 2012); MEPS (1996 – 2013), SAMHSA (1998, 2002, 2004, 2005, 2009); MarketScan (2000, 2010, 2012)	NIS (1996 – 2012); MarketScan (2000, 2010, 2012)
Emergency Department	NHEA (1996 – 2013)*	MEPS (1996 – 2013); MarketScan (2000, 2010, 2012)	NHAMCS (1996 – 2011); MarketScan (2000, 2010, 2012)
Nursing care	NHEA (1996 – 2013)	Medicare claims data (1999 – 2001, 2002, 2004, 2006, 2008, 2010, 2012); NNHS (1997, 1999, 2004); MCBS (1999-2011); MarketScan (2000, 2010, 2012), MCBS (1999 – 2011)	Medicare claims data (1999 – 2001, 2002, 2004, 2006, 2008, 2010, 2012); NNHS (1997, 1999, 2004); MCBS (1999-2011); MarketScan (2000, 2010, 2012)
Dental	NHEA (1996 – 2013)	MEPS (1996 – 2013)	MEPS (1996 – 2013)
Prescribed retail pharmaceuticals	NHEA (1996 – 2013)	MEPS (1996 – 2013)	MEPS (1996 – 2013)
Public Health	NHEA (1996 – 2013)	President's Budget Appendix (1996 – 2014); Congressional Reports (1997, 1998, 2000 – 2014); Agency Justification documents from the CDC, FDA, HRSA, and SAMHSA (2004 – 2014)	Not disaggregated
Other	NHEA (1996 – 2013)	Not disaggregated	Not disaggregated

The data used in the DEX project are health system encounter-level data, meaning that each record captures information about a single encounter with the medical system. The exact meaning of an encounter varies by type of care; for example, it is an admission in inpatient care, a visit in ambulatory care, and a prescription in a pharmaceutical setting. Each encounter record contains information on health spending, patient diagnoses, and demographic factors like age and sex. This information was used to group data by primary diagnosis, age, sex, and type of care.

The DEX project estimates both public and personal health care spending, but only personal health care spending is included in this study, since public health spending on diabetes is a distinct area of research. Personal health spending excludes public health activities, third-party investment in the health system, and administrative costs related to Medicare and Medicaid. The DEX study includes all personal health care spending regardless of payer; therefore private insurance, Medicare and Medicaid, and out-of-pocket spending are all captured in the data. As it is defined in this study, personal health spending accounted for 89.5% of total health care spending in the United States in 2013.[14] Personal health spending in the DEX project is divided into the six mutually-exclusive types of care: inpatient care, ambulatory care, emergency departments, nursing facility care, dental care, and prescribed retail pharmaceuticals. These six categories account for between 84.0% and 85.2% of personal health care spending. The remaining spending is incurred on over-the-counter pharmaceuticals, non-durable and durable medical devices, and home health care.

After undergoing a multi-step estimation process, outlined in Table 1 of the appendix, health spending estimates were scaled to the official government estimate of public health spending, reported in the National Health Expenditure Accounts. Using this data source as a final envelope avoids double-counting by ensuring that the sum of spending on individual conditions equals total national health spending. However, this scaling method also assumes that spending in our data sources reflects spending in the general U.S. population, which may introduce bias if some populations who are systematically excluded or underrepresented in the data exhibit different health care spending patterns.

To perform a decomposition analysis of health spending increases, epidemiologic and population data were combined with the DEX data described above to create a combined dataset. First, estimates of personal health care spending and volume on diabetes from 1996 through 2013 were extracted from the DEX database. Second, population data and epidemiologic data, including prevalence and incidence of diabetes for each age, sex, and year, were extracted from the 2015 Global Burden of Disease (GBD) study. This study estimates prevalence, incidence, and other metrics by age and sex for years 1990, 1995, 2000, 2005, 2010, and 2015. While the GBD study contains estimates for 289 conditions, only diabetes data was extracted. GBD data was matched by age, sex, cause, and year to DEX data to create a combined dataset to use in the decomposition analysis.

The final combined dataset used for the decomposition consisted of five key variables stratified by age, sex, cause, type of care, and year. Population size, population fraction, and prevalence were drawn directly from the GBD study. Service price and intensity, representing spending per encounter, came directly from the DEX study, and service utilization was calculated by dividing the encounter volume (from the DEX study) by the number of prevalent cases (from the GBD study).

Disaggregating spending by age and sex

The DEX database contains spending estimates for 155 health conditions, but we only extracted diabetes spending estimates. Diabetes is estimated for each age and sex group and for five types of care, as dental care is not estimated for diabetes. While the DEX project produces data for 19 age groups, we report spending patterns by more aggregated groups: 0-19 years, 20-44 years, 45-64, and 65 years and older. All spending estimates are adjusted for inflation and are reported in 2015 US dollars.

Mapping data

During the estimation process, raw encounter-level data must eventually be assigned to a condition of health care spending. To do this, ICD-9 codes were assigned to conditions of health care events, injuries, or “garbage codes,” which are not valid causes of illness. These garbage codes are eventually reallocated to valid conditions using methods developed by the GBD study.[1] A primary diagnosis was then selected from the condition assigned, with a few rules and plausibility restrictions imposed. For example, injuries were prioritized when assigning primary diagnoses, and age restrictions were applied for conditions that are not expected to occur in given age ranges.

Data adjustments

The data underlying the estimates produced in the DEX project is subject to known limitations, and steps were taken in order to correct for some of these biases. First, patients often have comorbid conditions, and this can increase the cost of providing health care. If all spending for a patient with one or more comorbidities is allocated to the primary diagnosis, this will not accurately represent true spending. To account for the presence of comorbidities, a regression-based adjustment was used. After the adjustment, conditions with many comorbidities decreased in spending, while conditions that tend to be comorbidities increased in spending. This adjustment ensures that all spending reported is attributable to the condition itself, rather than the primary diagnosis.

Second, inpatient data that were reported in charges were adjusted to reflect payments rather than charges. This is necessary because actual payments made are often a small fraction of charges reported in inpatient spending records. Again, a regression-based adjustment was used in order to convert charge data to payment data. Third, a Bayesian hierarchical model was used to leverage the strength of multiple data sources when data on a particular condition was scarce. This model generates a complete time series of estimates, and enables a more granular estimation of spending.

Uncertainty

The encounter-level data was bootstrapped 1000 times, and this was used to generate uncertainty intervals. Spending estimation occurred for each bootstrapped sample, resulting in 1000 spending estimates for each age, sex, year, and type of care. Uncertainty intervals are built using the 2.5th and 97.5th percentiles, and they are used to indicate the degree of confidence in a given estimate.

Statistical analysis

The statistical analysis contained two main components: (1) an analysis of spending trends, and (2) a decomposition analysis to determine the impact of key drivers of health spending. To perform the first part of the analysis, spending estimates for diabetes were compared across ages, sexes, and types of care. Specifically, we report: (1) aggregated spending and spending by type of care, age, and sex in 2013; (2) changes in spending between 1996 and 2013; and (3) spending per prevalent case over time.

The second component of the statistical analysis was a demographic decomposition to estimate the relative contributions of five key drivers to increases in diabetes spending: population growth, population age structure, disease prevalence, service utilization, and service price and intensity.

Five specific variables were measured for each age and sex group and type of care: (i) the total US population, (ii) the share of the population living in each age and sex group, (iii) prevalence of diabetes,

(iv) service utilization, and (v) service price and intensity. Service utilization and service price and intensity are defined differently for different types of care. Within ambulatory and emergency department care, utilization is the average number of visits per prevalent case, and service price and intensity is the average spending per visit. Within inpatient and nursing facility care, utilization is the average number of bed-days per prevalent case, and service price and intensity is the average spending per bed day. Lastly, in pharmaceutical settings, utilization is the average number of prescriptions per case, and service price and intensity is the average amount spent per prescription.

The final dataset used in the decomposition analysis included estimates for all five drivers from 1996 through 2013. Epidemiologic and population data were logarithmically interpolated to fill in the years for which GBD data was not estimated. To do this, we assumed a logarithmic relationship in prevalence over time, and used this relationship to fill in the in-between years without estimates. Therefore, the final data contained a full time series for each driver used in the decomposition.

To perform the decomposition analysis, we expressed health spending as the product of the five drivers, as shown in Equation 1:

$$Spending_{a,s,c,t,y} \equiv Pop_y * \frac{Pop_{a,s,y}}{Pop_y} * \frac{Cases_{a,s,c,y}}{Pop_{a,s,y}} * \frac{Encounters_{a,s,c,t,y}}{Cases_{a,s,c,y}} * \frac{Spending_{a,s,c,t,y}}{Encounters_{a,s,c,t,y}}$$

Where a = age, s = sex, c = condition, t = type of care, and y = year. Because we only applied the decomposition to diabetes data, c is constant. To measure the impact of each driver, a decomposition method described by Prithwis Das Gupta in 1993 was used.[25] This method involves the calculation of standardized rates and factor effects for each driver. Specifically, it calculates the additive contributions of each driver to changes in health spending over time, and it does not result in any interactions or residuals. Therefore, the change in spending can be completely accounted for by summing the effects of the five drivers.

We calculate standardized rates for each factor by considering all possible combinations of other factors across time. For example, if only considering two factors, utilization (U) and price (P) and two years, 1996 and 2013, the price-standardized rate in each year would be:

$$1996\ Price\ standardized\ rate\text{:}\ \ \frac{P_{2013}+P_{1996}}{2} U_{1996}$$

$$2013\ Price\ standardized\ rate\text{:}\ \ \frac{P_{2013}+P_{1996}}{2} U_{2013}$$

The difference between the 1996 price-standardized rate and the 2013 price-standardized rate is the effect of utilization, or, the contribution of utilization to changes in the outcome between 1996 and 2013 (below equation).

$$Effect\ of\ Utilization = \frac{P_{2013}+P_{1996}}{2}(U_{2013}-U_{1996})$$

The decomposition for our purposes was performed using the expanded 5-factor equation with calculations adjusted to ensure internal consistency, as described elsewhere.[26]

The decomposition was conducted at the most granular level of data, by each individual age, sex, and type of care. The equation was calculated for every possible combination of years, which is needed as an input into a subsequent equation to calculate corrected effects that allow for internal consistency in estimates over time. For example, this method ensures that the effect of population on spending from 1996 to 1998 will equal the sum of the estimate for the effect of population from 1996 to 1997 and the effect of population from 1997 to 1998. The general form of the equation used to calculate corrected effects for internal consistency is depicted in Equation 2:

$$\alpha_{12.34\ldots N} = \alpha_{12} - \frac{\sum_{j=3}^{N}(\alpha_{12} + \alpha_{2j} - \alpha_{1j})}{N}$$

Where α is one of the five drivers, and 1, 2 … N are individual years. In this example, α_{12} is the effect of α between years 1 and 2. Using the equation above, we calculate α_{12} in the presence of all other years of data (3 through 18 in this study), which is the corrected effect.

After calculating the decomposition effects of each factor at the most granular level, the impact of each driver can then be aggregated to assess the impact of the driver within a given type of care, age, or sex group, or time period.

All analyses were conducted using Stata version 13.1 (StataCorp) and R version 3.3.1.

Results

2013 spending patterns

Total personal health care spending on diabetes in 2013 was $101.4 (96.7-106.5) billion. Figure 1 shows that this spending was not split evenly between the five types of care included in the study. The largest amount of money was spent on prescribed retail pharmaceuticals, which accounted for $58.4 (54.5-62.9) billion of total diabetes spending in 2013. Ambulatory care was the second biggest source of diabetes spending, with $23.8 (22.0-26.0) billion spent in that setting in 2013. Inpatient and long-term care each had a similar amount of spending ($9.6 [8.6-11.0] billion and $9.2 [8.1-10.3] billion, respectively), while a comparatively small amount of spending occurred in emergency departments ($0.4 [0.3-0.5] billion).

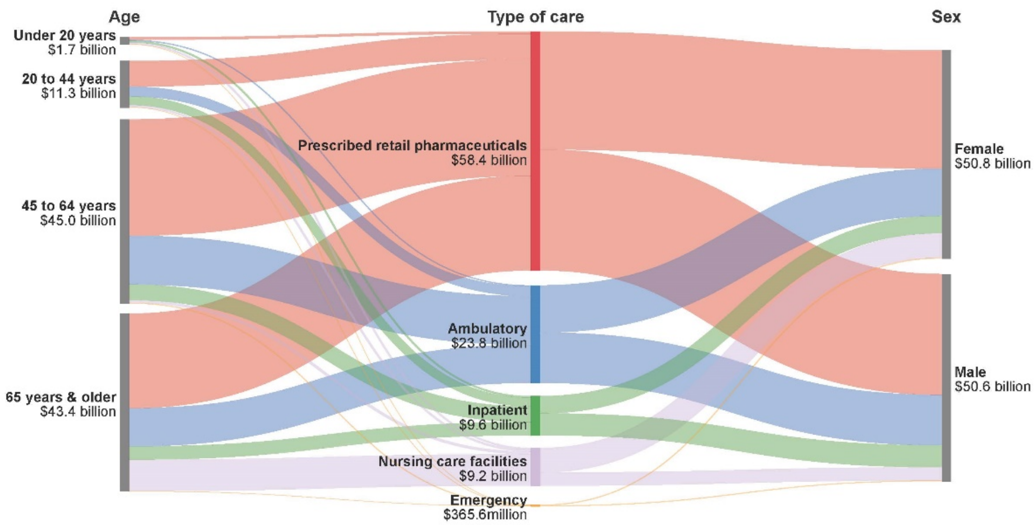

Figure 1: Spending on diabetes by age, type of care, and sex in 2013.

Spending was also not split evenly across age categories. Diabetes spending in 2013 was greatest among 45 to 64 year olds (44.4% [41.7-47.0%] of spending), followed by the 65 and older category (42.8% [40.3-45.4%] of spending). Spending in the younger age categories was much lower; spending among 20 to 44 year olds comprised 11.2% (10.3-12.3%) of total spending, and spending among those younger than

20 comprised 1.7% (1.4-1.9%) of total spending. When all ages are included together, females spent slightly more than males on diabetes in 2013 (50.1% [45.7-53.3%] of total spending for females, compared to 49.9% [46.4-53.8%] for males). Spending by type of care differed slightly by sex. Males spent more in ambulatory care, inpatient care, and pharmaceuticals. Females spent more on emergency department care and on nursing facility care, where female spending was almost twice as high as male spending.

Changes in spending

Total spending on diabetes in the US increased from $36.9 (32.3-41.6) billion in 1996 to $101.4 (96.7-106.6) billion in 2013, representing an 6.1% (5.3-7%) annualized rate of change over this time period. Figure 2 shows that spending on different types of care did not increase evenly. Spending on pharmaceuticals increased the fastest, with an 8.9% (7.1-10.6%) annualized rate of change. Pharmaceutical spending grew especially fast from 2008 to 2013, increasing at an annualized rate of 9.9% (6.2-12.9%), compared to an annualized rate of 8.4% (6.7-10.4%) from 1996 to 2008. Spending in emergency departments increased the second fastest, with a 5.2% (3.2-7.5%) annualized rate of change, followed by ambulatory care (5.0%, UI: 3.6-6.5%) and inpatient care (4.3%, UI: 3.3-5.8%). In terms of absolute increase, pharmaceuticals increased the most, growing by $44.4 (38.7-49.7) billion between 1996 and 2013.

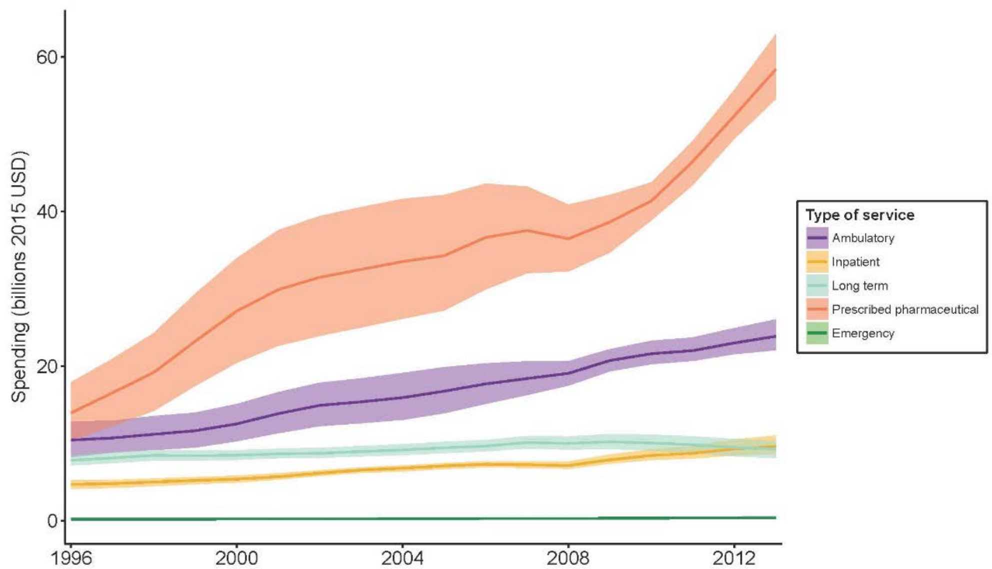

Figure 2: Spending by type of care over time, 1996-2013. Shaded portions represent 95% uncertainty intervals.

Figure 3 depicts spending by age category over time. Spending increased the fastest in the 45-64 year old age group, with an annualized rate of change of 6.9% (5.9-7.8%) from 1996 through 2013. Spending increased the second fastest in the 20-44 year old age group, increasing at an annualized rate of 6% (5.1-7.1%) from 1996 through 2013. Spending increased more slowly in the 65 and older age group (5.6% [4.9-6.4%] annualized rate of change) and the 20 and younger age group (3.5% [2.6-4.5%] annualized rate of change). Finally, spending increased more quickly for men (6.9% [5.6-8.2%] annualized rate of change) than for women (5.5% [4.5-6.6%] annualized rate of change).

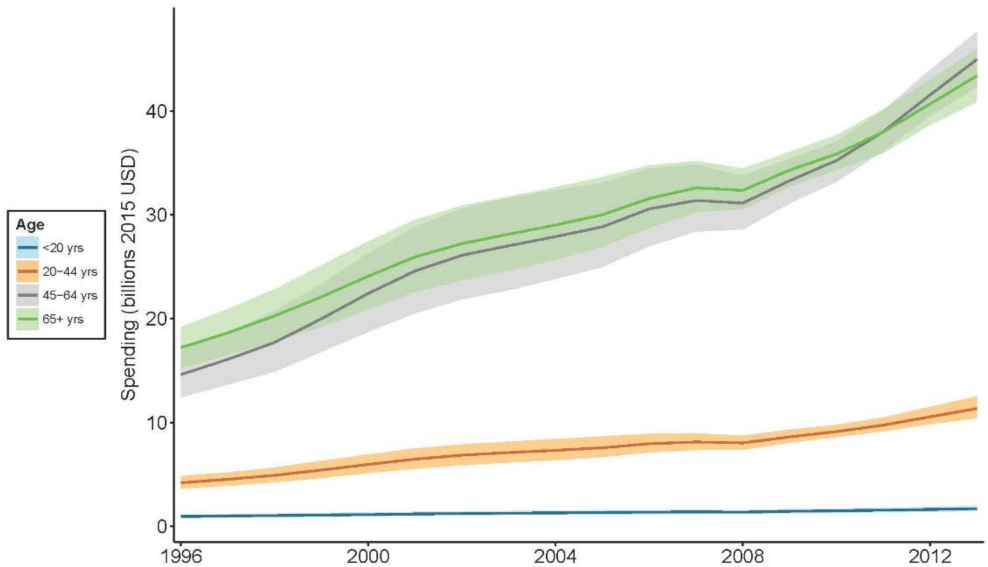

Figure 3: Spending by age category over time, 1996-2013. Shaded portions represent 95% uncertainty intervals

Spending per prevalent case

Spending per prevalent case increased at a rapid rate from 1996 to 2002, growing from $1130.8 (988.1-1274.7) per case in 1996 to $1879.6 (1610.8-2165.7) per case in 2002. Spending per case remained fairly constant from 2003 to 2008, before increasing during 2008 through 2013, growing from $2230.5 (2085.3-2386.0) per case in 2008 to $3103.4 (2959.1-3261.3) in 2013. Figure 4 shows that patterns in spending by prevalent case differed only slightly by age group. Specifically, spending per prevalent case on 65-year-olds decreased for a brief period in the late 2000s, and spending per prevalent case increased the most rapidly for 20-44 year olds after 2010.

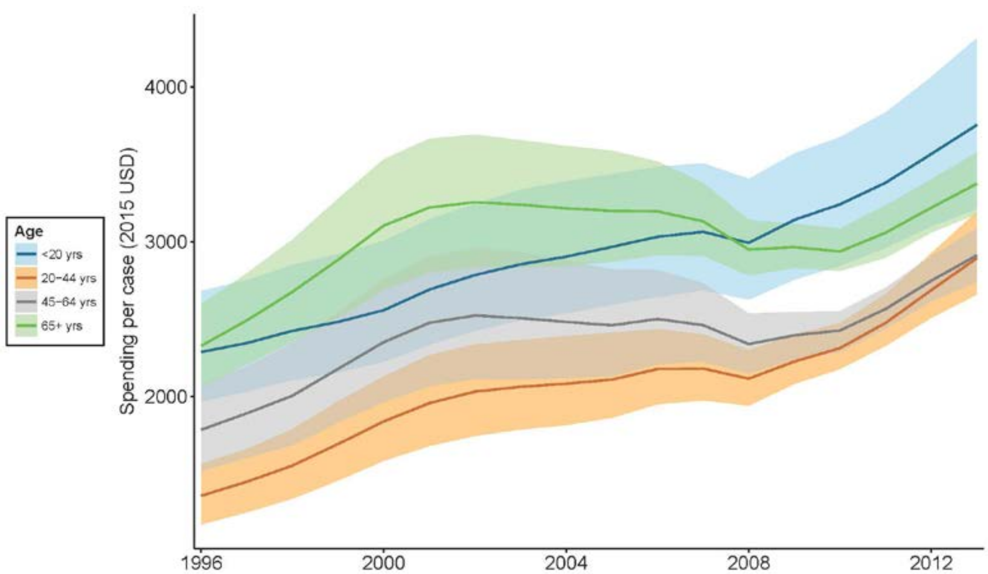

Figure 4: Spending per prevalent case by age group, 1996-2013

Decomposition of spending increases

Personal health spending on diabetes increased $64.4 (57.8-70.7) billion from 1996 to 2013, the greatest increase of any health condition estimated in the DEX study. The five-driver decomposition attributed this spending increase to five different factors: population size, population aging, disease prevalence, service utilization, and service price and intensity. When all types of care are aggregated together, increases in service price and intensity led to a 76.8% increase in spending between 1996 and 2013. Changes in disease prevalence, an aging population, and changes in population size led to spending increases of 40.3%, 29.8%, and 29.0%, respectively. Changes in service utilization was the smallest contributor to spending growth, increasing spending by only 1%. Together, these five fundamental drivers led to the 174.9% increase in diabetes spending between 1996 and 2013.

The impact of these five drivers varied by type of care (Figure 5). Within prescribed retail pharmaceuticals, which led to the largest spending increase of all functions ($44.4 billion of the $64.4 billion total increase), service price and intensity increased spending by $20.2 billion between 1996 and 2013. The other drivers contributed fairly equally to spending increases in pharmaceuticals. Increases in disease prevalence increased pharmaceutical spending by $6.9 billion, followed by increases in service utilization ($6.1 billion), population aging ($5.9 billion), and population growth ($5.4 billion).

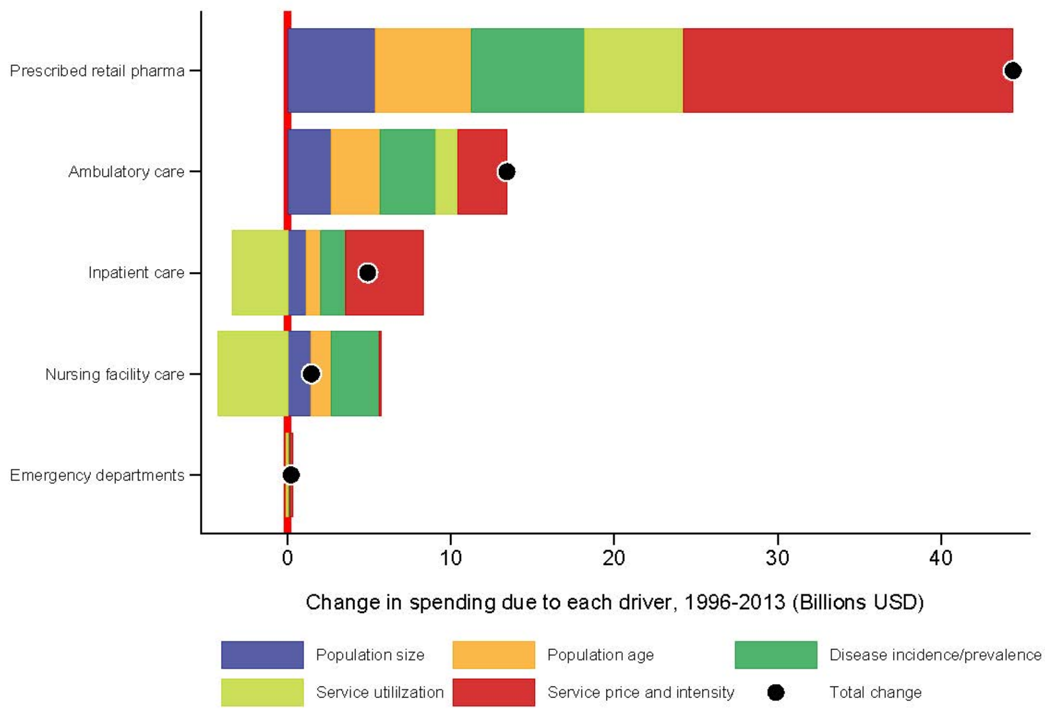

Figure 5: Decomposition of spending increases by type of care

Within ambulatory care, epidemiology increased spending the most ($3.4 billion), followed by service price and intensity ($3.0 billion), population aging ($3.0 billion), population growth ($2.7 billion), and service utilization ($1.3 billion). Service price and intensity was the biggest contributor to spending increases in inpatient care ($4.8 billion). Population growth, population aging, and epidemiology all modestly increased spending in inpatient care (by $1.1, $0.9, and $1.5 billion, respectively), while service utilization decreased inpatient care spending by $3.4 billion. Service utilization also decreased spending in nursing facility care, while epidemiology ($3.0 billion), population growth ($1.5 billion), population aging ($1.2 billion), and service price and intensity ($0.1 billion) all increased spending.

Spending did not increase evenly across the study time period (Figure 6). Spending increased the most from 2008 to 2013 ($28.5, UI: 20.4-35.0 billion), followed by 1996 to 2002 ($24.5, UI: 19.8-30.3 billion). Spending increased much less from 2002 to 008 ($11.5, UI: 5.2-17.5 billion). The impact of the five drivers changed within these three time periods. From 1996 to 2002 and from 2008 to 2013, the impact of the five drivers exhibited fairly similar trends by type of care. During both of these periods, increases in service price and intensity within prescribed retail pharmaceuticals increased spending the most (driving 36 and 49% of the total spending increase, respectively). Trends were significantly different from 2002 to 2008. Specifically, service price and intensity in pharmaceuticals was not a significant driver of spending increases. Additionally, service utilization decreased spending in each of the five types of care during the middle time period, a reversal of trends seen in the other two periods. Epidemiology had large positive impacts on spending within each type of care from 2002 to 2008, with the biggest increase in spending due to epidemiology occurring within pharmaceuticals.

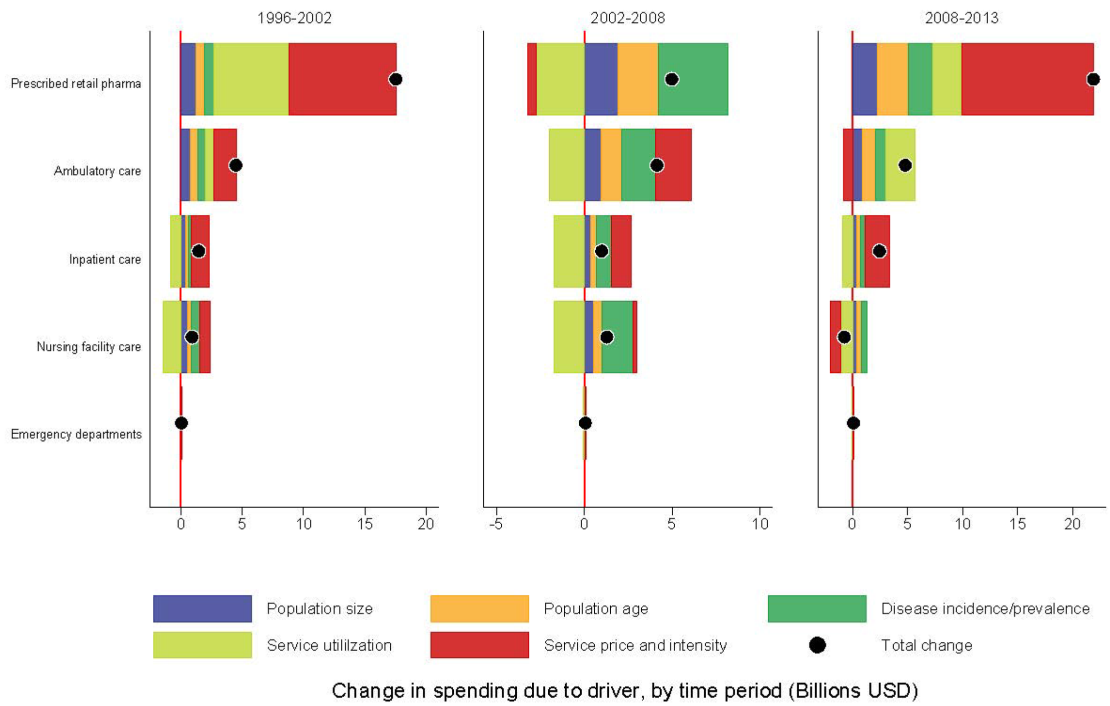

Figure 6: Decomposition of spending increase by function, for three different time periods

Discussion

Spending on diabetes increased by $64.4 billion between 1996 and 2013, growing at an annualized rate of 6.1% to reach $101.4 billion in 2013. Among all conditions tracked in the DEX project, diabetes incurred the greatest amount of spending in 2013. This has been accompanied by drastic increases in prevalence, a trend which is expected to continue if current patterns persist.[9] It is important to evaluate how health spending changes in response to rising prevalence, as this could have ramifications for total health care spending in the US.

Pharmaceutical spending

One of the most striking patterns in health spending on diabetes is the rise in pharmaceutical spending. Increases in pharmaceutical spending constituted 69% of the increase in total spending between 1996 and 2013, and service price and intensity was the biggest contributor to the increase in pharmaceutical spending (45.4% of the $44.4 billion increase in pharmaceutical spending). The rate of increase in pharmaceutical spending was especially drastic from 2008 through 2013, and more recent research suggests that these upward trends have continued in more recent yeras.[16,27] Pharmaceutical spending is especially important in the context of diabetes, since the condition requires adherence to a steady drug regimen for effective management. Furthermore, drug development for diabetes is an actively evolving area; new drugs enter the market often, and treatment recommendations change. This can have real impacts on spending. For example, the ADA has moved towards an individualized treatment perspective for non-insulin anti-hyperglycemic drugs after metformin, the first line treatment.[28] This may open the market for several new, expensive drugs that might be considered as a second-line treatment, which might raise the overall cost of treating diabetes.

There are several emerging trends in pharmaceuticals for diabetes that have had and continue to have consequences for diabetes health spending. The requirement of a cardiac outcomes trial for all new therapies for diabetes, which began in 2008, is likely to raise the cost of bringing drugs to the market.[29] There have also been many new agents released to treat T2D following metformin, including empagliflozin and liraglutide, among others. Empagliflozin is an SGLT2 inhibitor that was approved in August 2014,[30] and Liralgutide is a GLP-1 receptor that was approved for the treatment of diabetes in 2010.[31] Both of these drugs are much more costly than metformin; while metformin's initial cost for a one-month supply was less than $20 in 2015, a one-month supply of empagliflozin was $340 and a one-month supply of liraglutide was $430.[32] Rising costs of insulin and high prices of Dipeptidyl Peptidase-4 (DPP4) inhibitors, which ranged from $310-$330 for a one month supply in 2015,[32] are also likely to have spending implications. Additionally, the price of insulin rose 197% from 2002 to 2013, and the price is unlikely to decline due to generic competition, because there are significant regulations and cost to market biosimilar insulins.[13] These trends corroborate our finding that increased service price and intensity within prescribed pharmaceuticals have been the biggest driver of spending increases over time.

Price growth for anti-hyperglycemic drugs may influence overall health care spending in other ways. If price increases lead to lower patient adherence, more costly complications could arise. This is especially problematic, given that only 50% of diabetic patients are currently able to achieve goals for HbA1c.[30] If medication costs increase, adherence could decrease even further due to cost concerns. Previous research has found that a $10 increase in out-of-pocket cost was associated with a 1.9% reduction in adherence, and a 10% reduction in adherence was associated with a 15% increase in per-patient hospital days.[33] When cost sharing was increased in this study, raising out-of-pocket costs to the patient, the overall cost of treating T2D patients increased, even as pharmaceutical spending decreased.[33] This finding is important in light of recent political developments that may restrict insurance coverage and increase out-of-pocket costs, while also eliminating or protracting diabetes prevention programs that were expanded as part of the Affordable Care Act.[34]

Diabetes and aging

Our analysis also revealed that a considerable amount of spending occurs among adults 65 and older. Around 40% of people with known diabetes in the US are over 65, and the number of people over 65 who have diabetes is expected to increase 4.5-fold between 2005 and 2050.[35] It is projected that many older adults will also eventually develop diabetes due to age effects on pancreas functioning.[36] Diabetes in older adults is also associated with higher mortality, decreased functional status, and a greater chance of both institutionalization and chronic complications.[37] This is important given the aging demographics of the US population. With the number of older adults increasing, a greater prevalence of diabetes in this population can have dramatic impacts on spending increases.

Spending by type of care

Finally, despite the relevance of pharmaceutical spending, it is important to not overlook spending in other types of care. Spending on diabetes in ambulatory care settings reached $24 billion in 2013, and spending in inpatient and nursing facility care also nearly reached $10 billion. Spending in ambulatory care is an important point of focus, as the number of office-based physician visits for patients with diabetes was estimated to be 2-3 times higher than patients without diabetes.[38] Importantly, service price and intensity was a positive contributor to increases in health care spending in both inpatient and ambulatory care settings. Understanding what is driving increased spending, and discerning how costs might be reduced in these care settings, is another important undertaking for health policymakers.

Policy importance

Our results demonstrate that health care spending on diabetes is significant and growing. For this and other reasons, strategies to contain spending on diabetes will likely be a part of the overall effort to bend the health care cost curve in the US. Several strategies and policies have been proposed that might be used to decrease spending on diabetes. These include disease management programs to improve the quality of care for chronic diseases in general,[39] which are supposed to decrease cost by reducing morbidity through improved care. Several other strategies emphasize prevention rather than treatment. Prevention strategies include lifestyle changes to reduce diabetes risk, and formal programs like the Diabetes Prevention Program, a randomized clinical trial that uses intensive lifestyle intervention to improve health outcomes and potentially reduce costs.[40,41] By reducing the number of people with diabetes, spending is likely to decrease. Other cost-containing strategies include medication adherence,[42] and the substitution of generic drugs for brand-name, when available.[42,43] Importantly, the two biggest drivers of spending increases identified in this analysis, service price and intensity and disease prevalence, should be a target in all efforts to contain spending.

This research can be used to inform the cost reduction strategies described above, in addition to other policy conversations regarding diabetes spending. It adds to the existing literature about diabetes in the US by presenting the most granular picture of health spending to date. While previous studies have presented total spending on diabetes in the US, we disaggregate spending by useful categories. Analyzing spending patterns by age, sex, and type of care can provide policymakers with information needed to devise well-informed policies to contain spending. The comprehensive methodology employed by the DEX study also results in the most accurate spending estimates. Specifically, by accounting for comorbidities and by scaling to the official US government estimate of spending, we ensure that spending estimates reflect true spending on diabetes, in the context of other conditions. Finally, this study includes a novel decomposition analysis in order to discern the drivers of spending increases over time. Knowing which factors are driving increases can provide valuable direction for health policy.

Limitations

Despite the strengths of this study, there are some limitations. First, the DEX database itself is subject to known limitations. Some of the underlying data used in producing the DEX estimates is survey data, and it was necessary to assume that these surveys were representative of the general US population. If this assumption is not accurate, estimates may be biased. Additionally, the underlying data was sometimes reported in charges rather than payments, and a method had to be developed to convert charge data to payment data, which could introduce additional bias. However, this was true only for nursing facility and inpatient care. Finally, data on prescribed retail pharmaceuticals, which is a crucial component of diabetes spending, are an incomplete representation of total pharmaceutical spending. The only data source used for estimating pharmaceutical spending was the Medical Expenditure Panel Survey, which does not capture drugs that are not distributed via retail outlets.

The DEX data also did not contain certain pieces of information that would add additional richness to the analysis. Specifically, DEX is not stratified by geography, race, payer, or income, as this information was not available in the primary data sources used in the study. The estimates also extend only through 2013 due to data availability. More recent estimates that are stratified by geography, primary payer, and other key variables could improve the usefulness of spending estimates for policymakers.

Lastly, there are certain limitations specific to diabetes data. Diabetes is associated with numerous health complications, and it is difficult to split spending between the condition itself and its associated complications. Similarly, there are several comorbidities associated with diabetes, and it can be difficult to assign spending to diabetes versus a resulting comorbidity. The regression-based comorbidity adjustment used in the DEX study, however, reduces the impact of this methodological complication. Therefore, these results are a reflection of true spending on diabetes, rather than spending on all associated comorbidities. Including these would likely result in even higher estimates for diabetes spending.

Despite these limitations, this study provides estimates of diabetes spending over time, as well as the impact of key drivers on spending increases. With the prevalence of diabetes drastically increasing in the US, it is even more important to have a thorough, granular understanding of spending patterns. This information can be used to project how the health care system might be affected by future increases in diabetes and diabetes spending.

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Appendix

Table 1. Overview of steps in the estimation process of the DEX study

Step	Types of care	Motivation	Effect
Format data	Ambulatory, inpatient, emergency department, nursing care, dental, prescribed retail pharmaceuticals	To enable all data sources to go through same statistical machinery	All data were structured in the same manner, and variable names and variable formats were systematized across all data sources used
Bootstrap	Ambulatory, inpatient, emergency department, nursing care, dental, prescribed retail pharmaceuticals	To obtain 1,000 bootstrap samples upon which all other steps could be run independently, in order to quantify uncertainty	1,000 samples were created for analysis based on survey adjusted bootstrapping methods
De-truncation	Ambulatory (spending data only), emergency department (spending data only), prescribed retail pharmaceuticals	To estimate more detailed four- and five-digit ICD-9 diagnoses from the three-digit diagnoses recorded in Medical Expenditure Panel Survey (MEPS)	Variation within each bootstrap draw and across draws for data from MEPS was increased
Redistribution	Ambulatory, inpatient, emergency department, nursing care, prescribed retail pharmaceuticals	To attribute all spending and volumes to causes that represent the true underlying reason for a health care encounter	Spending and volume originally attributed to ICD-9 codes that do not map to GBD causes were assigned to GBD causes based on redistribution packages developed by the IHME GBD research. This redistributions was designed to take into account age and sex. While each cause is impacted differently by the redistribution process, spending per cause, measured at the age, sex, type, and year level goes up or stays the same, while spending attributed to “garbage codes” is removed

Mapping	Ambulatory, inpatient, emergency department, nursing care, dental, prescribed retail pharmaceuticals	To divide spending into 158 medically important and policy-relevant categories	Causes were aggregated from ICD-9 codes to 158 GBD causes, leading to more data for each cause-, year-, age-, sex-, type-combination
Injury adjustment	Ambulatory, inpatient, emergency department, nursing care, prescribed retail pharmaceuticals	To have all spending and volume due to injuries be defined by external cause of injury codes, rather than less actionable nature of injury codes	All spending attributed to injuries were defined by the external cause of injury
Comorbidity adjustment	Ambulatory, inpatient, emergency department, nursing care	To redistribute resources toward the underlying cause of the health care spending, rather than merely the primary diagnosis	Spending was moved from some causes to others, based on whether, on average, the cause leads to excess spending (as comorbidity) or is a primary diagnosis that has spending increased by excess spending on comorbidities
Age-splitting	Nursing care	To have Medicare nursing care claims data be consistent with all other data sources, as Medicare aggregates younger ages to ensure patient privacy	Charges captured in Medicare claims were split up from larger age bins into the age bins used in the study
Inpatient charges-to-payments adjustment	Inpatient	To estimate total inpatient spending from the inpatient facility charges report in the National Inpatient Sample	Inpatient spending estimates were made smaller than originally reported in National Inpatient Sample, based on cause, year, payer specific payment to charge ratios

Completing the series	Ambulatory, inpatient, emergency department, nursing care, dental, prescribed retail pharmaceuticals	To have estimates for years in which data does not exist, to obtain estimates for spending that are missed due to survey designs, and to have estimates that are appropriately consistent across age and time	Multiple data sources were combined to leverage strengths across data sources, such that every type-, age-, year-, cause-, and sex-combination was estimated and "smooth" series were produced
Nursing-care adjustment	Nursing care	To estimate nationally representative spending and volume estimates for short- and long-term stays at nursing homes	Three data sources were leveraged together, two using linear regression, to create nationally representative spending and volume estimates for short-term and long-term nursing facility care
Mental health adjustment	Ambulatory, inpatient	To address the under sampling of mental health and substance abuse specialty facilities and create mental health and substance abuse health care spending aggregates that are commensurate with official US government estimates.	Spending and volume on mental illnesses were increased, relative to non-mental illness causes, for the ambulatory and inpatient types of care
Scaling	Ambulatory, inpatient, emergency department, nursing care, dental, prescribed retail pharmaceuticals	To match spending estimates that reflect the official US government numbers, as no data source offers complete census of health care spending	Estimates for spending were increased or decreased depending on type of care