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Assessing trends in medical expenditures and measuring the impact of health-related quality of life on medical expenditures for U.S. adults with diabetes associated chronic kidney disease using 2002–2016 medical expenditure panel survey data

Aditi A. Kharat[a], Jagannath Muzumdar[b], Monica Hwang[b] and Wenchen Wu[b]

[a]Department of Pharmacotherapy, University of Utah, Salt Lake City, UT, and [b]College of Pharmacy and Health Sciences, St. John's University, Jamaica, NY, USA

Abstract

Background Chronic Kidney Disease (CKD) is one of the most expensive comorbidities of diabetes. The changes in medical expenditures over the years and the latest economic burden of CKD among diabetes are unknown.

Objectives (1) To examine the trend and estimate the differences in medical expenditures between adults with diabetes-associated CKD and diabetes-no CKD from 2002 to 2016 using Medical Expenditure Panel Survey data (2) To study the impact of health-related quality of life (HRQOL) on medical expenditure for adults with diabetes-associated CKD.

Methods This is a retrospective cross-sectional study. Descriptive statistics were used for studying the trend in medical expenditures from 2002 to 2016. HRQOL was measured using physical and mental component summary (PCS, MCS). Two-part model was utilized for estimating the incremental medical expenditure for diabetes patients by CKD status.

Key findings A total of 35,112 diabetic adults were identified in the Medical Expenditure Panel Survey dataset. Among these, 3,489 individuals had CKD. The pooled mean expenditure for diabetes-associated CKD was $25,953 which was almost double of $12,170 for patients with diabetes and no CKD. Individuals with diabetes CKD had $12,109 higher adjusted direct incremental medical expenditure as compared to diabetes-no CKD. With respect to HRQOL, individuals in the highest quartile of PCS and MCS spent $18,076 and $10,307 lesser than those in the lowest quartile respectively.

Conclusions Medical expenditures associated with CKD are a significant contributor to the financial burden among diabetes adults. Improvements in HRQOL also lead to lower healthcare costs in diabetes-associated CKD patients.

Keywords diabetes and CKD; health-related quality of life; medical expenditures; Medical Expenditure Panel Survey; trends; two-part model

Introduction

Diabetes is the seventh leading cause of death in the United States (U.S.) and it continues to represent a growing concern across the world.[1] The prevalence of diabetes has increased substantially in the recent years. Among the U.S. adults, diabetes prevalence increased from 7.7% in 1999–2000 to 13.3% in 2015–2016[2] and globally, it has nearly doubled from 4.7% in 1980 to 8.5% in 2014.[3] In 2015, an estimated of 1.5 million new cases of diabetes were diagnosed among U.S. adults.[1] In 2017, a total of 424.9 million people were estimated to be living with diabetes worldwide.[4] According to a 2017 report on national diabetes statistics, more than 100 million U.S. adults are currently living with diabetes or prediabetes.[1,5] The global economic burden of diabetes in 2015 was $1.3 trillion and is estimated to increase to $2.2 trillion by 2030.[6] Average medical expenditure of people with diagnosed diabetes in 2017 was estimated to be $16,752 per year. People with diagnosed diabetes have medical expenditure of approximately 2.3

Correspondence:
Aditi A. Kharat, Department of Pharmacotherapy, University of Utah, Salt Lake City, UT 84112, USA.
E-mail: aditi.kharat@utah.edu

times higher than the expenditure of people without diabetes.[7] Patients suffering from diabetes are known to develop multiple health-related complications like hypertension, cardiovascular and renal conditions.[8,9] These comorbid complications majorly account for the significant portion of the costs of treatment of diabetes.[9] Moreover, the comorbid conditions associated with diabetes impact the Health-Related Quality of Life (HRQOL) of the patients.[10] The presence of complications deteriorates the HRQOL and in turn influences the medical expenditure of diabetes patients.

Chronic kidney disease (CKD) is one of the most alarming problems in diabetic patients and it poses a significant financial burden. Currently, about one in three adults with diabetes have CKD.[11] CKD is one of the most expensive comorbidities among diabetic patients. According to Brown et al. in 1999, CKD or advanced renal disorder is associated with approximately 195% increase ($6,012 versus $2,033) in diabetes treatment costs in comparison to diabetic patients with no renal conditions.[9] In 2011, the United States Renal Data System (USRDS) reported Medicare patients with diabetes-associated CKD (diabetes CKD) to have mean annual medical expenditure of $18,611 and estimated the economic burden to be $24.6 billion.[12] In 2014, Ozieh et al estimated medical expenditure for individuals with diabetes CKD to be $20,726 as compared to $9,689 for diabetes and no CKD.[11]

The increasing medical expenditures for diabetes and comorbid CKD over the years represent an enormous public and economic burden.[9,11,12] Therefore, it is important to understand the latest medical expenditures associated with diabetes CKD. Existing studies have analysed the trends in medical expenditure for diabetes population and CKD population alone.[13,14] However, there are no studies that have done a trend analysis of medical expenditures among diabetic adults with CKD.

The HRQOL for diabetes CKD patients is another important concern that needs to be investigated. Evidence suggests that self-reported health status measures are effective tools in capturing patient preferences for medical services. It helps understand resource utilization which is related to efficacy and desirability preference of individuals.[15,16] Moreover, self-reported measures of physical and mental health are significant predictors of medical expenditures.[16,17] Existing literature has assessed the impact of HRQOL on medical expenditures for diabetes patients only. In case of diabetes population, Campbell et al. reported a clear relationship between quality of life and medical expenditure, wherein improvements in the physical and mental quality of life components were related to decrease in medical expenditure.[18] The impact of HRQOL on medical expenditures for diabetes CKD patients is poorly understood at present and there is limited research documenting the same in literature.

Our study aims to (1) examine the trends in medical expenditure for diabetes-associated CKD in US adults from 2002 to 2016 using Medical Expenditure Panel Survey (MEPS) data, (2) estimate the differences in medical expenditures between adults with diabetes-associated CKD and diabetes without CKD and (3) study the impact of HRQOL on medical expenditure for adults with diabetes-associated CKD using 2002–2016 MEPS data.

Methods

This is a retrospective, cross-sectional study using MEPS, a nationally representative secondary dataset. The research data was analysed from 2002 to 2016 using SAS 9.4 (Cary, NC, USA).

Study variables

The dependent variable was 'total annual direct medical expenditure' which in MEPS is defined as 'the sum of direct payments, including out-of-pocket payments and payments by private insurance, Medicaid, Medicare and other sources'. Over-the-counter drug payments are not included as a part of this variable. Similarly, indirect payments not related to specific medical events, such as Medicaid Disproportionate Share and Medicare Direct Medical Education subsidies, are also not included.[19] The primary independent variable was the 'self-reported diabetes-associated CKD' measured as a yes/no response to the question, 'Have you ever been diagnosed with diabetes caused kidney problems?'. The independent variable of HRQOL was physical and mental component summary (PCS and MCS) score which are derived from short-form 12 version 2 (SF-12v2).[19] Additional covariates that were controlled for were age, sex, race, marital status, educational attainment, insurance coverage, region, income category and comorbid conditions such as high blood pressure, heart disease, stroke, emphysema, joint pain, arthritis and asthma. All covariates included in the analysis were based on self-report. The comorbid conditions that were controlled for in the model were obtained from priority conditions variables available in the MEPS full year consolidated data files (FYC-DF). The comorbidities were included as binary indicators based on a positive response to the question 'Have you ever been diagnosed with XYZ'. XYZ are the above listed comorbidities.

Selection criteria

MEPS survey participants with a self-reported diagnosis of diabetes were included in the study analysis and were identified using DIABDX. Participants were recorded as having diabetes if they responded 'yes' to the question 'Have you ever been told by a doctor or professional that you have diabetes?'. Individuals were further identified as having CKD, if they answered 'yes' to the question 'Has diabetes caused kidney problem?'. This was captured by the variable DSKIDN53. MEPS also provides a medical condition file which has the International Classification of Diseases – Ninth Revision (ICD-9) and Clinical Classification Codes (CC codes). These codes can be used to identify patients with diabetes or CKD independently. However, the design of MEPS limits us to identify individuals having CKD caused by diabetes through these ICD-9/CC codes. MEPS consolidates all of the sub-classifications within a condition

to a single three-digit value to maintain confidentiality. Hence, the self-reported variable DSKIDN53 was used.[20]

Study data

Full year consolidated data files from 2002 to 2016 was first imported and only the required variables were kept. Patients without diabetes were excluded from the study. Among patients with diabetes, subjects who were <18 years were excluded. The diabetic patients were further classified by CKD status, that is, diabetes – CKD and diabetes – no CKD (Figure 1). Next, the total expenditure for the dataset was adjusted to 2019- US dollar value using the consumer price index for medical care (CPI-M) obtained from the Bureau of Labor Statistics.[21] These steps were repeated for each FYC-DF. Finally, the resulting files from the process were combined into one final data file, which was used for analysis related to medical expenditures. MEPS survey consists of five rounds of interviews covering two calendar years. This design of MEPS provides individual-level data for selected variables like expenditure and health status.[22] Since MEPS is an overlapping panel survey, many individuals are in the sample for consecutive years. Thus, samples for each year are not unique and are not independent from year to year.

The final full year merged dataset was used to create another copy. This copy of merged dataset was utilized to perform HRQOL analysis, wherein we excluded subjects who had diabetes only. This final dataset was then used for HRQOL analysis.

Data analysis

Descriptive statistics were used to determine the characteristics of adults with diabetes, with and without CKD. Chi-square was used to compare the significance between the demographic characteristics of sample with diabetes by CKD status. Adjusted differences in mean medical expenditure for diabetes patients by CKD status and the incremental effect of HRQOL on medical expenditure was estimated using a two-part model, while adjusting for relevant confounders.

Two-part model

This model is specifically designed to deal with mixed discrete dependent variables.[23] It is commonly used when large number of patients have zero expenditure, and the data for positive expenditure are not normal, but highly right skewed.[24]

In the first part of the model, logistic regression was used to estimate the probability of observing zero or positive value for medical expenditure. Logistic regression is used to model binary outcome variables and estimate the probabilities of an outcome considering the independent variables which are appropriate for the model.[25] In the second part, conditional on having positive expenditure, general linear model (GLM) with gamma distribution and log link was used to estimate medical expenditures. This was used because the expenditure data is right skewed and not normally distributed. Using GLM in two parts improved the accuracy of our estimates as a significant number of individuals in our sample had zero expenditures. The estimated medical expenditure was adjusted to 2019- US dollar value. GLM has an advantage over ordinal least squares as it relaxes the normality and homoscedasticity assumptions and it avoids bias with retransforming the data to raw scale.[14,23,24]

For evaluating the relationship between HRQOL and medical expenditure, the continuous scores of PCS and MCS were converted into quartiles. Instead of just comparing the highest and the lowest score, quartiles helped us to determine the average costs for a range of scores and allow us to compare these costs for various PCS or MCS values. The quartiles were computed using the data for diabetes-associated CKD patients only. Mean medical expenditure was

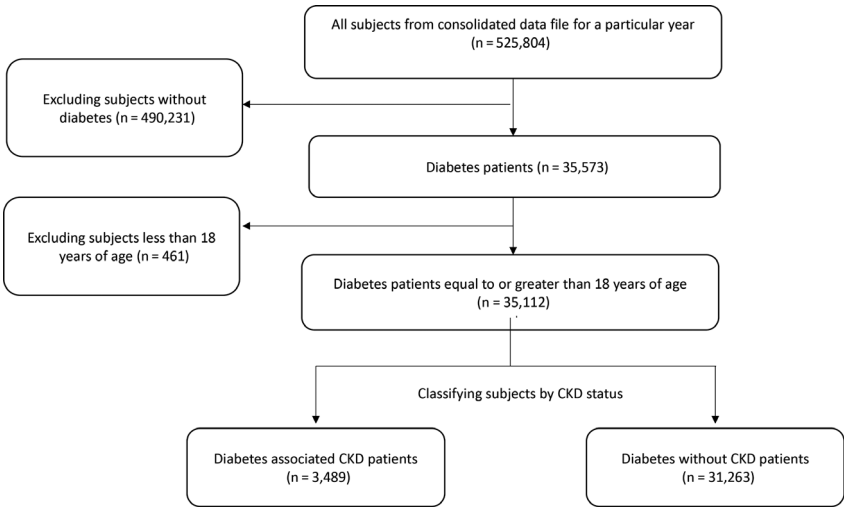

Figure 1 Flowchart depicting sample size and sample selection process.

then calculated for each quartile. These means were used to compare the medical expenditure for each of the quartiles for PCS and MCS. Then, a two-part model was used to determine the adjusted incremental total medical expenditures for the HRQOL quartiles.

Results

Full year consolidated file from 2002 to 2016 accounted for a total of 525,804 subjects (Figure 1). Among these individuals, a total of 35,573 were identified as having diabetes, of which 461 subjects were <18 years of age. These subjects were excluded as the interested population for our study are diabetic adults. 35,112 diabetic adults were identified from 2002 to 2016 MEPS combined dataset. From 35,112 diabetic adults, 31,263 subjects had diabetes – no CKD, and 3,489 subjects had diabetes-associated CKD. As shown in Table 1, significant differences were observed by CKD status among adults with diabetics. Diabetes-associated CKD was more likely among in the middle-income group, whereas diabetes – no CKD was more likely among high-income group. Both diabetes-associated CKD and diabetes – no CKD were more likely in age group of greater than or equal to 45 years, females, Non-Hispanic Blacks, married, high school education, insured individuals and Southern residents. All comorbid conditions were more likely among adults with diabetes-associated CKD as compared to individuals with diabetes – no CKD.

Table 1 Sample demographics by chronic kidney disease (CKD) status among diabetic adults in the United States

Variables	Diabetes-no CKD (%)	Diabetes CKD (%)	*P*-value
***N* (*n*)**	**19 890 000 (31 623)**	**1 942 059 (3489)**	
Age (years)			
18–44	12.97	10.37	<.0001
45–64	46.31	41.06	
65–85	40.72	48.57	
Gender			
Male	49.08	48.77	<.0001
Female	50.92	51.23	
Race			
Hispanic	14.59	13.99	<.0001
Non-Hispanic Black	15.33	16.73	
Non-Hispanic Asian	4.50	2.56	
Other	65.58	66.71	
Marital status			
Married	58.52	53.07	<.0001
Widow/divorced/single	31.44	36.86	
Never married	10.04	10.06	
Education			
<High school	33.61	40.79	<.0001
High school	44.04	42.30	
College or more	22.35	16.91	
Insurance coverage			
Private	60.66	48.31	<.0001
Public	31.92	45.03	
Uninsured	7.41	6.63	
Region			
Northeast	17.93	15.03	<.0001
Midwest	21.38	19.38	
South	40.33	44.66	
West	20.36	20.93	
Poverty			
Poor	19.64	27.76	<.0001
Low income	16.14	19.78	
Middle income	30.04	28.39	
High income	34.18	24.06	
Chronic conditions			
Hypertension	73.32	85.81	<.0001
CVD	15.93	29.54	<.0001
Stroke	10.14	19.66	<.0001
Emphysema	4.59	7.03	<.0001
Joint pain	53.68	69.48	<.0001
Arthritis	48.57	64.35	<.0001
Asthma	13.20	17.17	<.0001

N, weighted sample size; *n*, unweighted sample size; Level of significance $P < 0.05$ for each category.

Analysis of medical expenditures

The pooled mean medical expenditure from 2002 to 2016 for diabetes-associated CKD patients was found to be $25,953 (95% CI: 24,618–27,289) which was almost double the mean medical expenditure of $12,170 (95% CI: 11,914–12,426) for diabetes without CKD patients (Table 2).

Between 2002 and 2016 the mean direct medical expenditure for diabetes-associated CKD increased from $13,031 to $23,345 (an increase of 79.15%) (Figure 2) as compared to $8,037–$11,306 (an increase of 40.67%) for diabetes without CKD (Figure 3). The mean medical expenditure for diabetes-associated CKD patients was 2.1 times that of diabetes without CKD patients. This gap was lowest in the year 2003 (1.5 times) and highest in the year 2015 (2.6 times).

Adjusted cost differences between diabetic individuals with and without CKD

Medical expenditure data are skewed and is not distributed normally (Figure 4). Approximately, 70% of the study population had zero expenditures. According to MEPS, there could be several reasons associated with respondents reporting zero expenditure for medical events. These include the following: (1) free care was provided, (2) a bad debt was incurred, (3) care could be covered under the flat fee arrangement and the current event was not the initial event of the bundle, and, (4) it could be a follow-up visit, provided without a separate charge.[26] The zero expenditure data cannot be ignored and needs to be accounted while predicting the differences in medical costs for diabetes patients with CKD and no CKD. Therefore, using a two-part model is the ideal approach to model expenditure data with a sizable portion of zero costs. Additionally, we have no information whether the zero expenditures were truly non-users of care or those that received free care, using the

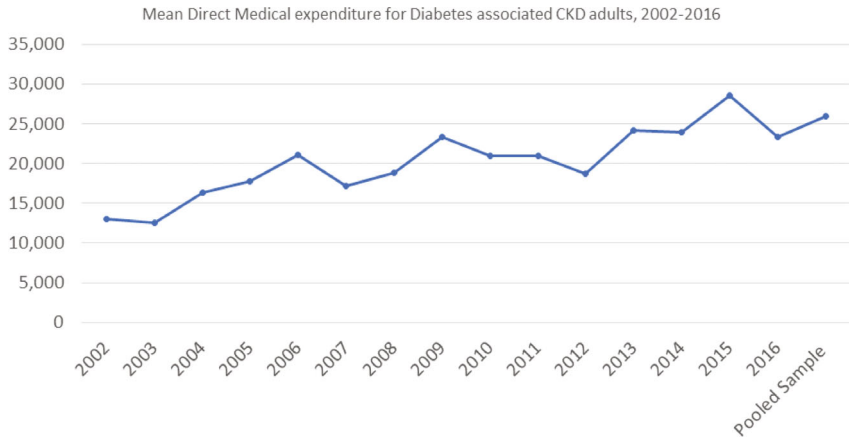

Figure 2 Mean direct medical expenditure for diabetes CKD, 2002–2016.

Table 2 Mean of total medical expenditure by chronic kidney disease (CKD) status among diabetic adults in the United States, adjusted to 2019 – US dollar value

Year	Diabetes- no CKD Mean (95% CI)	Diabetes CKD Mean (95% CI)
2002	8037 (7393–8681)	13 031 (10 978–15 084)
2003	8450 (7795–9106)	12 515 (10 723–13089)
2004	8541 (7708–9373)	16 393 (13 716–19 071)
2005	9015 (8232–9799)	16 393 (14 590–20 861)
2006	8757 (8145–9370)	21 153 (17 379–24 927)
2007	9693 (8854–10 531)	17 160 (12 810–21 509)
2008	8774 (8142–9405)	18 895 (15 078–22 712)
2009	9481 (8828–10 113)	23 348 (19 275–27 421)
2010	8925 (8248–9602)	21 021 (17 543–24 498)
2011	8494 (7915–9073)	20 979 (16 562–25 396)
2012	8871 (8143–9599)	18 705 (15 340–22 070)
2013	9799 (9064–10 534)	24 240 (19 556–28 925)
2014	11 850 (10 918–12 783)	23 982 (19 387–28 578)
2015	10 910 (10 081–11 739)	28 626 (22 124–35 128)
2016	11 306 (10 566–12 046)	23 345 (19 790–26 900)
Pooled Sample	12 170 (11 914–12 426)	25 953 (24 618–27 289)

two-part model helped us to control for the possible selection bias.[18]

After adjusting for socio-demographics and comorbidities, diabetes CKD was associated with $12,109 higher direct total medical expenditure as compared to adults with diabetes without CKD (Table 3). The common comorbid condition of stroke was found to cause an additional highest medical expenditure of $9,578 (unadjusted medical expenditure for diabetes CKD with stroke: $39,217; 95% CI: $35,166–$43, 268) followed by cardiovascular diseases (CVD) with second highest medical expenditure of $8,314 (unadjusted medical expenditure for diabetes CKD with CVD: $35, 919; 95% CI: $32, 945–38, 892). Hypertension was found to be the least expensive comorbidity associated with diabetes CKD with an incremental adjusted medical expenditure of $1,689 (unadjusted medical expenditure for diabetes CKD with hypertension: $27,259; 95% CI: $25,868–$28,649). Non-Hispanic Black was the only demographic factor that was found to be non-statistically significant. Medical expenditure was found to increase with age. As compared to diabetes CKD patients in the 18–44 years age group, patients in the age groups of 45–64 and 65–85 had $884 and $1,008 additional medical care expenditure respectively. Females had a higher medical expenditure of $332 as compared to males. The financial burden of diabetes-associated CKD in the US population is approximately $50 billion, based on the average yearly estimates.

HRQOL and direct medical expenditure for diabetes-associated CKD patients

Quartile one had the lowest score range and quartile four had the highest score range, for both PCS and MCS (Table 4). The results of differences in medical expenditure between HRQOL quartiles among adults with diabetes-associated CKD are shown in Table 5. The mean direct medical expenditure of PCS and MCS decreased as the HRQOL increased. For MCS, medical expenditure decreased from $30,073 (95% CI: $27,355–$32,792) of quartile one to $21,566 (95% CI: $19,255–$23,856) for quartile four. The difference between the highest and the lowest quartile for total medical expenditure of MCS was found to be $8,507. In case of PCS, medical expenditure in quartile one was $34,742 (95% CI: $31,981–$37,502), which decreased to $14,636 (95% CI: $13,058–$16,214) in quartile four. The difference between the highest and the lowest quartile for total medical expenditure of PCS was found to be $20,106.

After adjusting for socio-demographic factors and comorbidities, the total mean medical expenditure for PCS quartile two was $5,012 lesser than that of quartile one (Table 6). For quartile three, the mean medical expenditure was $11,830 lesser than that of quartile one. Individuals in the highest quartile of PCS spent $18,076 lesser than those in the lowest quartile. It can be noted that as the PCS increased (i.e., increase in physical component of HRQOL), medical expenditure gradually decreased.

For MCS the mean medical expenditure for quartile two was $5,191 lesser than that of quartile one. For quartile three and quartile four, the mean medical expenditure was

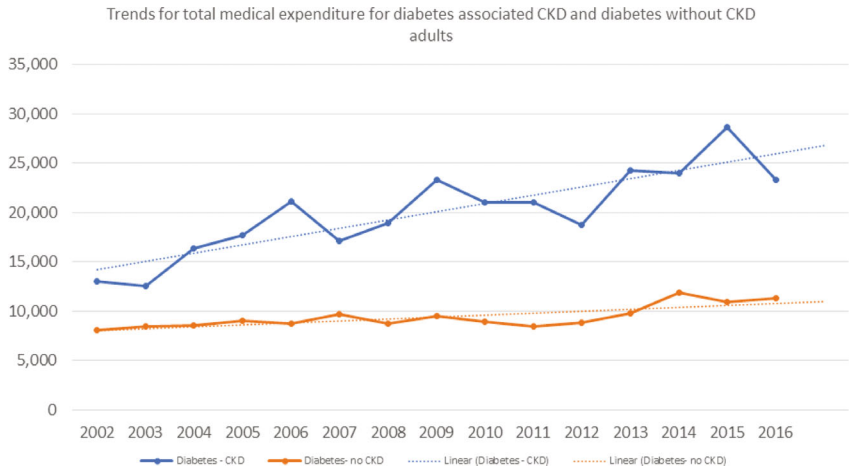

Figure 3 Trends for total medical expenditure for diabetes-associated CKD and diabetes without CKD.

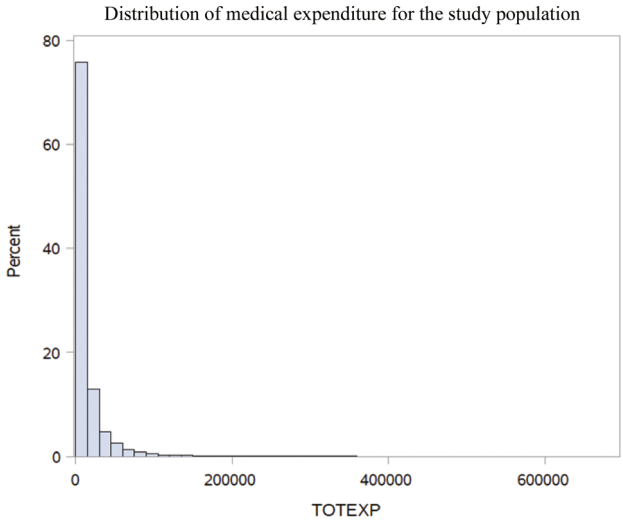

Figure 4 Distribution of medical expenditure for the study population.

$6,474 and $10,307 lesser than that of quartile one respectively. Individuals in the highest quartile of MCS spent $10,307 lesser than those in the lowest quartile. Similar to our observation for PCS scores, as the MCS score increased (i.e., increase in mental component of HRQOL), medical expenditure decreased. It can be collectively inferred that with an increase in HRQOL, the medical expenditure decreased for diabetes-associated CKD patients.

Discussions

Our study found diabetes-associated CKD patients to have almost two times higher mean direct medical expenditure as compared to diabetes without CKD patients. Comorbidities like stroke and CVD add to the medical expenditures among diabetes CKD patients. Additionally, our study showed increased HRQOL to be associated with decreased medical expenditure for diabetes CKD patients.

The trend of medical expenditures for diabetes CKD gradually increased over fifteen years. Higher medical expenditures were observed in all years compared to 2002 and 2003. The medical expenditure for diabetes CKD patients increased from 2004 to 2006 and we suspect this could be related with increased costs of other medical conditions and medications such as intravenous iron, erythropoiesis stimulating agents, vitamin D etc. in 2004.[27] In 2010-2011, the bundled cost implemented for dialysis treatment could be a plausible reason for the decrease in medical expenditures observed in the dataset.[28] The medical expenditure was observed to be the highest in 2015, which can be attributed to increase in cost of coverage under the affordable care act[29] and increase in the number of insured respondents.

Similar to our study results, previous studies have demonstrated higher medical expenditure associated with diabetes and CKD.[11,30] Ozieh et al. found the adjusted medical expenditure associated with diabetes CKD to be $8,473 higher than diabetes without CKD.[11] Similarly, Laliberte et al. estimated the total expenditure of $7,190 for CKD patients with diabetes and comorbid hypertension in a managed care population.[30] Our study estimates are slightly higher than the estimates of the previous studies. The most likely reason for the difference could be, that our study involved a larger sample size of 35,112 individuals and used fifteen years of data (2002–2016), whereas Ozieh et al. used a smaller sample size of 2,053 individuals and data for only one year (2011). Another reason for the difference could be that Laliberete et al. estimated the medical expenditure for patients in managed care setting, whereas we estimated it for the entire population and not for a specific healthcare setting.

On the other hand, Pelletier and colleagues found that patients with type 2 diabetes mellitus and both microvascular and macrovascular complications to have a medical expenditure of $14,414, which was higher than the estimates of our study.[31] Since this study accounts for additional complications other than CKD, there are differences in the estimates of results.

Table 3 Two-part regression model: Incremental effects of medical expenditures by chronic kidney disease (CKD) status among diabetic adults accounting for relevant covariates (adjusted to 2019 – US dollar value)

	Adjusted mean expenditure	95% confidence interval	*P*-value
Diabetes without CKD (ref)	–	–	–
Diabetes associated CKD	$12,109	$11,998, $12,220	<0.0001
Age (years)			
18–44 (ref)	–	–	–
45–64	$884	$774, $993	<0.0001
65–85	$1008	$888, $1129	<0.0001
Gender			
Male (ref)	–	–	–
Female	$332	$263, $400	<0.0001
Race			
Hispanic (ref)	–	–	–
Non-Hispanic Black	$229	$105, $353	0.0003
Non-Hispanic Asian	−$1799	−$1981, −$1618	<0.0001
Other	$2128	$2026, $2230	<0.0001
Marital status			
Married (ref)	–	–	–
Widow/divorced/single	$1421	$1344, $1499	<0.0001
Never married	$1598	$1481, $1716	<0.0001
Education			
<High school (ref)	–	–	–
High school	$637	$561, $713	<0.0001
College or more	$1411	$1307, $1515	<0.0001
Insurance coverage			
Private (ref)	–	–	–
Public	$780	$696, $863	<0.0001
Uninsured	−$7069	−$7203, −$6934	<0.0001
Region			
Northeast (ref)	–	–	–
Midwest	−$731	−$836, −$625	<0.0001
South	−$2503	−$2596, −$2409	<0.0001
West	−$2764	−$2872, −$2656	<0.0001
Income/Poverty status			
Poor (ref)	–	–	–
Low income	−$1794	−$1903, −$1685	<0.0001
Middle income	−$2522	−$2623, −$2422	<0.0001
High income	−$1956	−$2065, −$1848	<0.0001
Chronic conditions			
Hypertension	$1689	$1609, $1768	<0.0001
CVD	$8314	$8223, $8404	<0.0001
Stroke	$9578	$9471, $9685	<0.0001
Emphysema	$6635	$6478, $6793	<0.0001
Joint pain	$1998	$1924, $2072	<0.0001
Arthritis	$2731	$2653, $2808	<0.0001
Asthma	$2849	$2750, $2949	<0.0001

Our study estimates the adjusted medical expenditure for diabetes-associated CKD to be $50 billion for the US population. Whereas, USRDS estimates only the Medicare spending for CKD to be more than $79 billion.[32] The possible reason for the differences could be that, USRDS includes all the patients mainly with severe end-stage renal disease, regardless of their age.[11] Whereas, MEPS uses ICD-9 codes from self-reported presence of kidney disease. This causes USRDS to consist of higher proportion of sicker population, which is responsible for the difference in the estimates.[11]

Increase in HRQOL was found to be significantly associated with decrease in medical expenditure for diabetes CKD patients. Although the impact of HRQOL on medical expenditure for diabetes CKD population has not been previously reported, our study findings are consistent with findings of Campbell et al. which reported increased quality of life to be associated with decreased medical expenditure for diabetes patients.[18] The possible explanation for this finding could be attributed to severity of diabetes CKD. Increased disease severity is associated with increased health resource utilization and increased medical expenditure.[33] In the past studies, HRQOL has been found to decrease with an increase in disease severity.[34] Also, poor HRQOL is associated with higher healthcare resource utilization and in turn leading to higher medical

Table 4 Quartile range of HRQOL categories (PCS and MCS) for diabetes associated chronic kidney disease adults

Variable	Quartile range
PCS	
Quartile 1	05.90–23.99
Quartile 2	24.00–32.04
Quartile 3	32.05–41.65
Quartile 4	41.66–62.39
MCS	
Quartile 1	08.83–36.15
Quartile 2	36.16–44.94
Quartile 3	44.95–53.80
Quartile 4	53.81–74.21

expenditures.[33,34] In our study, patients in the lowest quartiles of HRQOL may have high disease severity which may have led to higher healthcare costs.

Moreover, our study estimated diabetes CKD patients in the highest quartile of PCS to have $18,076 and MCS to have $10,307 lesser total medical expenditure than those in the lowest quartile. These estimates are slightly higher than the estimates of Campbell et al., who found diabetes patients in the highest quartile of PCS and MCS to have $7,499 and $3,262 lower total medical expenditure than those in the lowest quartile.[18] The higher average expenditure observed in our study as compared to Campbell et al, who only included patients with diabetes, could be attributed to the comorbid CKD studied in diabetes patients.

The findings of this study are strengthened by using the two-part methodology for estimating the medical expenditure. This novel method accounts for zero expenditures and the skewed distribution of the expenditure data. To the best of our knowledge, this is the first study that examined the trends in medical expenditure for individuals with diabetes-associated CKD with fifteen years of data using a nationally representative survey. Examining the trends provide a detailed comparison of changes in the expenditure over the years for diabetes CKD as compared to diabetes without CKD patients. Also, the study involved a large sample of non-institutionalized individuals obtained from multi-year MEPS data, which is a nationally representative dataset. This ensured the high generalizability of our study.

These research findings should be interpreted with the following limitations. This study was not able to estimate CKD costs among diabetes patients by the CKD stage/severity, that is, dialysis versus non-dialysis. This is because, MEPS lacks laboratory data (estimated glomerular filtration rate and albumin creatinine ratios) to identify CKD stages and severity. Also, MEPS collapses the ICD-9 and procedure codes for CKD such as dialysis to protect the confidentiality of respondents, and thus, the link between disease severity and medical expenditure could not be studied. Our study is also limited due to it's cross-sectional nature. A statistically significant result in the study may be because of the large sample size. Moreover, because individuals with diabetes CKD were identified based on self-report, the response could have been subject to bias. Lastly, our study included diabetic patients who could have several comorbidities and it can affect the medical expenditure estimates.

Table 6 Two-part regression model: Incremental effect of medical expenditures by HRQOL categories among adults with diabetes associated chronic kidney disease (as per 2019 – US dollar value)

Direct total expenditure	Adjusted incremental medical expenditure	95% CI	*P*-value
PCS			
Quartile 1 (reference)	–	–	
Quartile 2	−$5012	−$5648 −$4377	<0.0001
Quartile 3	−$11,830	−$12,471 −$11,189	<0.0001
Quartile 4	−$18,076	−$18,768, −$17,383	<0.0001
MCS			
Quartile 1 (reference)	–	–	
Quartile 2	−$5191	−$5870 −$4512	<0.0001
Quartile 3	−$6474	−$7139 −$5809	<0.0001
Quartile 4	−$10,307	−$10,983 −$9630	<0.0001

Primary outcome variable in this model is total medical expenditure controlled for age, gender, race, marital status, education level, insurance coverage, region, poverty status, hypertension, CVD, stroke, emphysema, joint pain, arthritis and asthma.
Level of significance $P < 0.05$ for each category.

Conclusions

Diabetes-associated CKD patients have significantly higher direct medical expenditure as compared to diabetes patients without CKD. CKD is an important contributor to the financial burden of the US healthcare system. Therefore, early diagnosis of the disease and its complication is important to avoid increases in medical costs and worsening of HRQOL.

Table 5 Mean and 95% CI for total medical expenditure by HRQOL categories (PCS and MCS) among diabetic adults with chronic kidney disease (adjusted to 2019- US dollar value)

Total expenditure	Quartile 1	Quartile 2	Quartile 3	Quartile 4
PCS	$34,742	$29,218	$24,403	$14,636
95% CI	$31,981–$37,502	$26,617–$31,818	$21,565–$27,240	$13,058–$16,214
MCS	$30,073	$26,368	$25,143	$21,556
95% CI	$27,355–$32,792	$23,567–$29,169	$22,847–$27,439	$19,255–$23,856

HRQOL has a significant impact on the medical expenditure for diabetes-associated CKD patients. The medical expenditure was found to decrease with an increase in HRQOL. In order to decrease the medical expenditure and improve HRQOL among diabetes-associated CKD patients, policy makers and health plan providers should provide incentives for preventive care and early diagnosis of the disease. Also, health care professional should encourage regular checkups to assess treatment effectiveness, ensuring proper medical care and improved HRQOL. The national estimates provided by our study can be used by researchers as a point of reference for future studies. Performing longitudinal studies in the future to assess the long-term financial impact of CKD on diabetes patients will be helpful. Moreover, future researchers can expand on our study by evaluating the different stages of CKD among individuals with diabetes and link them to medical expenditure.

Declarations

Conflict of interest

The Author(s) declare(s) that they have no conflicts of interest to disclose.

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Authors' contributions

All the authors have equal contribution towards designing the study, data analysis and drafting manuscript.

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