Health Tech Asmnt Act. 9(4). doi: 10.18502/htaa.v9i4.20667

Research Article

Economic Burden of Diabetic Nephropathy in the Southwest of Iran

Saeed Bagheri Faradonbeh[1], Fatemeh Hayati[2], Homeira Rashidi[3], Amin Torabipour[4], Somayeh Loveimi[5*]

[1]Assistant Professor of Health Economics, Social Determinants of Health Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
[2]Assistant Professor of Nephrology, Department of Internal Medicine, Chronic Renal Failure Research Center, Imam Khomeini Hospital, School of Medicine, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
[3]Professor of Endocrinology and Metabolism, Department of Internal Medicine, Diabetes Research Center, Health Research Institute Imam Khomeini Hospital, School of Medicine, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
[4]Professor of Healthcare Services Management, Department of Healthcare Services Management, Social Determinants of Health Research Center, School of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
[5]MSc Student in Healthcare Services Management, Department of Healthcare Services Management, Social Determinants of Health Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

* Corresponding Author: Somayeh Loveimi, MSc Student in Healthcare Services Management, Department of Healthcare Services Management, Social Determinants of Health Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran. Email: somayeh96lovemi@gmail.com

Received 2025 May 14; Accepted 2025 September 8.

Abstract

Background: Diabetic nephropathy (DN) is a common complication of diabetes that, given the increasing prevalence of diabetes, imposes a serious economic burden on healthcare systems and societies. Therefore, this retrospective cross-sectional study aimed to estimate the economic burden of DN and identify factors influencing its cost in Iran.
Methods: Overall, 192 patients with DN were selected from Imam Khomeini and Golestan Hospitals in Ahvaz and then categorized into mild, moderate, and severe stages based on their glomerular filtration rate. Direct medical costs were obtained from hospital billing records, while non-medical and indirect costs were recorded through interviews with patients and their caregivers. Finally, the obtained data were analyzed by Microsoft Excel 2019 and Stata 16 using logistic regression models.
Results: The total cost of managing patients with DN was estimated at 839,083.88 PPP (current international dollars). Moreover, direct costs accounted for 88.2% of the total cost, of which 83.9% were medical, while 16.1% were non-medical. The logistic regression analysis demonstrated that education (odds ratio: 3.655, $P = 0.044$) and disability (odds ratio: 0.722, $P < 0.001$) were significantly associated with diabetes-related costs.
Conclusions: It was revealed that DN imposes a substantial economic burden on adults with type 2 diabetes. Thus, effective diabetes control and complication prevention strategies can help reduce these costs and alleviate the economic strain on both patients and the healthcare system.
Keywords: Economic Burden; Diabetic Nephropathy; Type 2 Diabetes; Iran

1. Background

Diabetes is one of the most prevalent chronic diseases globally, which is caused by a disorder in insulin secretion, insulin function, or both (1). While it is estimated that diabetes affects more than 8% of the world's population (over 350 million people), this number is expected to exceed 550 million by 2035 (2). Today, this disease is considered one of the most serious health, social, and economic problems worldwide (3-5). Demographic changes and cultural transitions in societies, along with the aging phenomenon in developing and developed countries, have turned diabetes into a global epidemic (6). According to the World Health Organization, approximately 422 million adults worldwide had diabetes in 2016, and this number is estimated to increase by about 48% by 2045 (7). In 2021, the national prevalence of diabetes was 14.15% among the Iranian population aged 20–79 based on fasting blood sugar levels. Khuzestan province in the southwest of Iran had a higher prevalence of 18.95% and ranked second in the country (8).

Diabetes is associated with short-term and long-term complications, many of which are irreversible (9). Diabetic nephropathy (DN) is regarded as one of the most critical microvascular complications in the diabetic population (10). This complication is a major cause of severe kidney disease or end-stage renal disease (ESRD), requiring dialysis or kidney transplantation. In the United States (US) alone, 42% of all ESRD cases were diagnosed with DN (11). The mortality rate in individuals with diabetic kidney disease (DKD) is nearly 30 times higher than that in diabetic patients without nephropathy and is associated with increased cardiovascular mortality (12). In fact, a report from the National Health and Nutrition Examination Survey revealed that the prevalence of DKD increased from 1988 to 2008, corresponding to an increase in diabetes prevalence (3). The results of the largest national study, 'Survey of Diabetes and Prediabetes Prevalence and Risk Factors in the Iranian Adult Population,' demonstrated that 15% of individuals had diabetes and 25% were in the prediabetes stage. The high prevalence of diabetes in Iran poses a serious challenge to the health system in the future. DN is one of the major complications of type 1 and type 2 diabetes (T1D and T2D), accounting for a significant portion of the advanced kidney failure patient population (8).

According to many epidemiological studies, persistent hyperglycemia and hypertension are modifiable risk factors for the onset of DN and its progression in susceptible individuals. Moreover, inflammation, metabolic hormones, oxidative stress, and vitamin D deficiency are the recently recognized factors (13-15). Likewise, other potential risk factors include glomerular hyperfiltration, smoking, dyslipidemia, proteinuria levels, and dietary factors, such as the amount and source of protein and fat in the diet (16). Similarly, genetic predisposition contributes to the development of DN in patients with T1D and T2D (17). Therefore, precise management of modifiable risk factors is essential for preventing and delaying kidney function decline (18). DN not only negatively impacts the patient's quality of life and social environment but also imposes a burden on national healthcare budgets (18). Additionally, loss of productivity, increased risk of disability, inability to work, or premature death due to this complication creates a serious economic burden on healthcare systems (19). This complication is one of the most expensive microvascular complications of diabetes mellitus (20). Nearly 20–30% of patients develop nephropathy during their diabetes course. It is a progressive disease that is associated with multiple comorbidities, major complications, and increased healthcare costs (21). In diabetic patients, nephropathy creates a critical economic burden in adults with T1D or T2D, and the overall annual costs per patient rapidly increase as the disease worsens (22). A study in the Michigan Health Maintenance Organization showed that end-stage kidney disease treated with dialysis had an 11-fold increase in costs compared to diabetic patients without complications (23). Recently, a study reported that symptoms of DN cause workers to lose approximately $3.65 billion annually in health-related lost productivity (24).

In the US, the total annual direct medical costs of diabetes in 2017 were estimated at $60 billion, representing 5.8% of all personal healthcare costs in the US during that year, with the cost of treating DN accounting for approximately 33% of this cost. The total annual cost of treating DN in the United Kingdom was approximately $1.2 billion (25), and baseline costs among patients with this disease who later progressed were considerably higher compared to those who did not progress (26). Therefore, healthcare resources and related medical costs are more frequently used for patients with diabetes and nephropathy than for patients without diabetes (27).

2. Objectives

A better understanding of the economic burden of diabetes and its related complications, especially nephropathy, is crucial not only for mobilizing the community and informing policymakers but also for helping to determine the cost-effectiveness of interventions for disease prevention and control. Given the limited resources to meet the healthcare needs of the community, diabetes is one of the health priorities globally and especially in Iran. Accordingly, this study seeks to evaluate the economic burden of DN with a focus on direct and indirect costs in the southwest of Iran in 2024.

3. Methods

1.3. Study Setting and Population

This cross-sectional study was conducted to estimate the cost of DN from a societal perspective. The cost of illness (COI) studies aim to identify and quantify all costs associated with a specific disease, thereby estimating its economic burden on society and highlighting the potential savings achievable through disease prevention or eradication. The required data for this study were collected from patients with T2D whose diagnosis of DN had been confirmed by specialist physicians. The inclusion criteria were based on the primary or secondary disease diagnosis codes recorded in patients' medical files, according to the International Classification of Diseases, tenth revision, specifically code 18N (kidney failure). Ahvaz, a city in southwest Iran with a population of approximately one million, has an estimated DN prevalence rate of 30%. Based on Morgan's , a sample size of 384 participants was determined, including 192 patients with DN and 192 patients with T2D without nephropathy. Patients were recruited from the dialysis clinics, diabetes clinics, and nephrology departments of Imam Khomeini and Golestan Hospitals in Ahvaz between April and September 2024. In general, 192 patients with DN were selected using a simple random sampling method. The exclusion criteria included patients with T1D, those with other T2D complications, and patients who had overlapping nephropathy and additional diabetic complications.

Patients were classified into three severity groups based on their glomerular filtration rate (GFR):

- **Mild (Stages 1–2):** Kidney damage with normal or mildly decreased GFR (> 60 mL/min/1.73 m^2)
- **Moderate (Stage 3):** Moderate decrease in GFR (30–59 mL/min/1.73 m^2)
- **Severe (Stages 4–5):** Severe decrease or kidney failure (GFR < 30 mL/min/1.73 m^2 or dialysis required)

2.3. Cost Classification and Definition (Data Extraction)

This study employed a prevalence-based perspective and the COI method based on the human capital approach. In COI studies, costs are generally classified into direct medical costs, direct non-medical costs, and indirect costs.

Direct medical costs refer to expenses incurred in the delivery of healthcare services, including hospitalization, laboratory and diagnostic tests, medications, and hoteling charges (e.g., bed tariffs, clothing, and linens) as listed in patients' discharge bills. The costs of services purchased from outside the hospital were included as well.

After obtaining informed consent, patients were enrolled in the study according to the inclusion and

exclusion criteria. Then, demographic and clinical data were recorded using a structured data entry form. Next, a cost estimation checklist was developed based on the research requirements. Information related to age, gender, disease stage, occupation, marital status, socioeconomic status, family history, risk factors, and comorbidities was extracted from medical records. In this study, demographic characteristics and treatment costs were compiled for each participant in 2024.

Direct non-medical costs represent expenditures that are not directly related to medical treatment but are necessary for accessing care (transportation, accommodation, and food expenses incurred by patients and their families during the treatment period). These costs were collected through an electronic questionnaire that included demographic information and detailed hospital billing data.

Indirect costs refer to productivity losses resulting from morbidity and mortality. These costs affect patients, their families, society, and employers. They include losses due to premature death, illness-related disability, absenteeism, and reduced work efficiency.

Direct medical costs were calculated according to the latest approved diagnostic and therapeutic service tariffs for 2024. Moreover, non-medical direct and indirect costs were estimated through interviews with patients and their companions.

To calculate indirect costs, the average number of workdays lost by patients and their caregivers due to illness was determined and multiplied by the average daily income. Likewise, the cost of job loss due to illness was estimated by multiplying the duration of job loss by the average annual income. Additionally, the cost of premature death was calculated by subtracting the age at death from the average life expectancy and multiplying the result by the average annual income. This prevalence-based approach considers all healthcare expenditures incurred during the year of analysis.

3.3. Cost Estimation

To measure the financial value of lost productivity in terms of PPP, the formula from the Centers for Disease Control and Prevention in the US was used as follows:

- The cost due to the days of absence from work for patients and their families was estimated based on formula (1):

$$M = (d) * (Y/y) \quad (1)$$

where M denotes the cost due to days of absence from work for the patient and their family members, and d is the average number of days of absence from work for the patient and their family members. In addition, Y and y represent the annual income and the number of days in a year, respectively.

- The cost of lost productivity due to disability was calculated using formula (2):

$$L = (X) * Y \quad (2)$$

where L and X indicate the cost of lost productivity due to job loss and the average duration of job loss for patients and their family members, respectively. Moreover, Y denotes the annual income.

The total cost of a disease includes expenses that the patient and their family incur for treating the disease, encompassing both direct and indirect costs of DN.

3.4. Data Analysis

Initially, all estimated costs were calculated in Iranian Rials and then converted to US dollars based on the official exchange rate in October 2024 in order to facilitate the comparison of our results with those of other studies. The data were checked for completeness and consistency prior to analysis. The cleaned data were tabulated and analyzed using Microsoft Excel 2019 and Stata software (version 17). Descriptive statistics, including means and standard deviations (SD), were used to summarize the cost data. Furthermore, logistic regression analysis was performed to identify factors associated with the economic burden of DN. The model estimated the percentage change in the dependent variable (economic burden) relative to the percentage change in independent variables representing patient and disease characteristics. The logistic model for the present study was as follows:

$$\text{Log}\,(P / (1 - P)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta k Xk$$

where P is the probability of the economic burden variable and can take a value of 0 or 1. The dependent variable in this study was converted into two values, 0 (low economic burden) and 1 (high economic burden), based on the cut-off point, which is the 50th percentile of the total cost. Moreover, X_1 to Xk are the independent variables. Additionally, β_0 denotes the intercept, and β_1 to βk are their respective coefficients. A P-value less than 0.05 was considered statistically significant. This model was estimated using the maximum likelihood estimation method (29). All statistical analyses were performed using Stata, version 17.

4. Results

In general, 192 patients with DN participated in this study (1). Most patients were in the severe stage (49.7%), followed by the moderate stage (27.6%) and mild stage (20.7%). Among those in the severe stage, 56 patients with ESRD were undergoing hemodialysis, with a total of 100 dialysis sessions recorded.

The mean age of participants was 61.2 years, with the largest proportion (34.3%) belonging to the 46–60-year age group. Further, the majority of respondents were male (63.6%) and married (88.5%). In addition, more than half of the patients (54.6%) resided in urban areas, while the remaining patients (45.3%) lived in rural or neighboring villages.

Regarding educational status, 26.5% of patients had

Table 1. Clinical and Demographic Characteristics of Patients in Hospitals

Characteristics		Stage of nephropathy (GFR)			Total	Percent
		1-2	3	4-5		
Number of patients		**40 (20.7)**	**58 (27.6)**	**94 49.7()**	**192**	**100**
Age (y)	15-45	3	21	13	38	19.7
	46-60	11	20	35	66	34.3
	61-75	9	14	26	49	25.5
	76-90	13	3	17	33	17.1
	Up to 90	4	0	2	6	3.1
Gender	Female	8	21	41	70	36.4
	Male	32	37	53	122	63.6
Marital status	Marriage	40	48	82	170	88.5
	Single	0	10	12	22	11.5
Place of residence	Urban	35	50	20	105	54.6
	Rural	5	8	74	87	45.3
Education	Illiterate	4	6	7	17	8.8
	Elementary	4	7	18	29	15.1
	Middle/high school	10	14	27	51	26.5
	Bachelor's	11	15	21	47	24.4
	Postgraduate	11	16	21	48	25
Occupation	Employee/worker	21	40	44	105	54.6
	Housekeeper	6	13	24	43	22.3
	Retired	13	5	26	44	22.9
	Student	0	0	0	0	0
Insurance type	Health insurance	5	6	9	20	10.4
	Social security	30	44	61	135	70.3
	Oil/relief foundation	5	6	10	21	10.9
	Other	0	2	3	5	2.6
Insurance coverage	Yes	35	48	78	161	83.8
	No	5	10	16	31	16.2
Supplementary insurance	Yes	27	36	56	119	61.9
	No	13	22	38	73	38.1
History of diabetes	Yes	33	47	77	157	81.9
	No	7	11	17	35	18.1
Comorbidities Anemia	No underlying disease	4	7	6	17	8.8
	Cardiovascular	4	4	9	17	8.8
	Stroke/cardiac	11	19	31	61	31.7
	Blood pressure	6	6	6	55	28.6
	Hyperlipidemia obesity/overweight	3	4	6	13	6.7
	Anemia	2	2	6	10	5.2
	Depressions	0	0	0	0	0
	Other complications	0	0	0	0	0
	No underlying disease	10	16	29	18	9.3
Disability status	Healthy	40	58	94	192	100
	Disability	0	0	0		

Note. GFR: Glomerular filtration rate.

completed secondary school, 25% held postgraduate degrees, and 24.4% held bachelor's degrees. In terms of employment, 54.6%, 22.9%, and 22.3% were employed, retired, and housewives, respectively. Among patients' companions, most were employees (25%) or workers (20.8%).

Approximately 83.8% of patients had health insurance, of whom 70.3% were covered by social security insurance; furthermore, 61.9% had supplementary insurance.

As regards comorbidities, myocardial infarction (31.7%) was the most common condition, followed by hypertension (28.6%), cardiovascular disease (8.8%), hyperlipidemia (6.7%), and obesity (5.2%). Only 8.8% of patients reported no underlying disease. A family history of T2D was found in 81.9% of participants.

Concerning disability status, most patients were healthy (64.5%), while 35.4% reported partial disability due to DN.

4.1. Direct Cost

From a societal perspective, the total direct cost for DN patients was estimated at 681,809.31 (PPP, current international $). 2 presents the medical and non-medical direct costs for the studied patients. The total direct medical cost for patients was 572,137.52 (PPP, current international $), accounting for 83.9% of the total direct cost. As expected, receiving dialysis was a significant factor in the costs. In total, the cost of dialysis for patients of subgroup three was reported to be 11,302 PPP. Among DN patients, the costs of admission (54,729.83 PPP), dietary supplements (43,312.99 PPP), hoteling (42,855.7 PPP), and prescribed medications (32,536.89 PPP) accounted for the highest proportion of medical costs. On the other hand, the costs of medical consultations and radiology imaging were the lowest among patients, at 3,311.32 PPP and 3,579.70 PPP, respectively.

The total non-medical direct cost for DN patients was 109,672.77 (PPP, current international $), constituting 13.07% of the total costs incurred by patients. Among the non-medical direct costs for patients, costs related to transportation, food and beverages, and accommodation for companions were 74,817.84 PPP, 18,823.86 PPP, and 7,302.27 PPP, respectively. Finally, telephone costs in the group were 144.94 PPP.

Table 2. Direct Costs for Nephropathy Diabetic Care and Treatment

Cost Items (PPP, Current International $)		SD	Mean
Total direct cost	681,809.31	127763464.4	219359538.9
Medical direct cost	572,137.52	116999496.2	187509884.5
Registration	35,136.1	17401299	16755393
Consultation	3,311.32	4752869	1579055
Hoteling	54,678.91	26671182	25780919
Consumables	55,158.15	26667393	25986471.4
Laboratories	31,368.81	15412732	14864202
Departmental medicine	35,857.73	18203541	16913903
Radiology	3,579.70	4561490	1707038
Surgery	21,689.18	27099022	10342815
Dialysis	11,302.5	13549366	5389792.2
Ultrasound	10,684.85	9007112.93	5095233.82
CT scan	10,472.26	10878619	4936109.82
ECG	9,765.57	5465727	4577490
Nursing services	46,881.60	21628601	22013913
Inpatient services	17,696.7	11197034	8438967
Vitamins/supplements	30,810.48	15999068	14856053
Prescription drugs	24,348.3	9165920	11631917
Medical equipment	16,139.3	19081833	7696281
Home care	7,004.73	15721738	3340314.2
Cardiologist	12,284.89	18660710	5858235.6
Non-medical direct cost	109,672.77	25910302.96	31849654.42
Food and drink	18,823.86	8971636	8924084
Transportation	74,817.84	15902579.16	19374345.58
Phone	144.9	33824.269	69026.1257
Accommodation	7,302.27	15756201.7	3482198.95

Note. SD: Standard deviation; CT: Computed tomography; ECG: Electrocardiography.

4.2. Indirect Cost

The results related to the indirect costs for the studied patients are presented in 3. Considering that the average hospitalization for each patient was 3.9 days, the number of days each patient was absent from work due to hospitalization was 1.6 days. Based on the monthly salary of each person in 2024, each patient had an approximate lost income of PPP 3,798.80. Additionally, the companions of the patients had a total of 3.9 days of work absence due to hospitalization, resulting in a lost income of approximately PPP 30,946.74 for the companions. In addition, the lost productivity due to the disability of patients was PPP 122,528.01. In total, the indirect cost for patients was 157,274.57 (PPP, current international $). Ultimately, the cost of lost productivity due to premature death was calculated as zero due to the absence of recorded deaths during the study period.

4.3. Total Cost

Based on the results (4), the total cost of managing DN patients was reported to be 839,083.88 (PPP, current

Table 3. Indirect Costs for Nephropathy Diabetic Care and Treatment

Indirect costs (PPP, current international $)		SD	Mean
Patients' income lost	3,798.80	3427818.591	1921465.969
Lost productivity from patient disability	122,528.01	88767253.2	58429319.37
Accompanying income lost	30,946.74	19157247.58	14706806.28
Indirect costs	157,274.57	89888564.21	75057591.62

Note. SD: Standard deviation.

Table 4. Total Costs for Nephropathy Diabetic Care and Treatment

Costs (PPP, current international $)		SD	Mean
Total direct cost	681,809.31	127763464.4	219359538.9
Medical direct cost	572,137.52	116999496.2	187509884.5
Non-medical direct cost	109,672.77	25910302.96	31849654.42
Indirect cost	157,274.57	89888564.21	75057591.62
Total cost	839,083.88	159186591.5	294417130.5

Note. SD: Standard deviation.

international $). Overall, the share of direct costs for patients accounted for 88.2% of the total cost. Among the studied patients, 83.9% of the total direct cost was direct medical costs, and 16.1% was non-medical direct costs.

4.4. Association of Patients' Characteristics and Economic Burden of Diabetic Nephropathy

In the logistic regression model analysis (5), education and disability in DN patients demonstrated a statistically significant association with the economic burden of DN. Patients with a bachelor's degree had a greater impact on economic burden compared to illiterate patients (odds ratio: 3.655, $P=0.044$). Additionally, patients with partial disabilities had a greater effect on the economic burden of DN compared to patients without disabilities (odds ratio: 6.722, $P=0.00$).

5. Discussion

The present study determined the economic burden of DN in patients attending diabetes clinics in Ahwaz in 2024. Overall, our findings revealed that the total estimated cost of treating DN was 839,083.88 (PPP, current international $), with the largest share of 68% related to direct medical costs and the smallest share associated with non-medical direct costs at 13% of the total costs. The total indirect cost of DN was also 157,274.57 (PPP, current international $), accounting for 34% of the total costs.

Based on demographic results, almost half of the patients undergoing treatment for DN were in the final stages of the disease, indicating that hospital management and intervention policies should focus on these stages to achieve the best outcomes. Koye et al concluded that DN is one of the most common and severe long-term complications of diabetes, with approximately 20–40% of patients with T2DM eventually developing DKD (30). Unlike our results, the findings of Chen et al demonstrated that the prevalence of the disease in stages 1 and 2 was usually higher than that in other stages, which may be due to the inadequate screening of suspected patients in these stages (31). DN naturally gradually progresses, and late diagnosis and increased risk factors cause the disease to be undetected in its early stages. Therefore, active prevention may noticeably reduce healthcare resource consumption and costs.

The medical records showed that a family history of diabetes and underlying conditions, such as hypertension, hyperlipidemia, and significant comorbidities, including cardiovascular complications, were present in more than 80% of the patients. Jankowski et al found that high blood pressure and increased incidence and prevalence of cardiovascular events in patients with early stages (stages 1-3) compared to those

Table 5. Association of Nephropathy Diabetic Costs With Patients' Characteristics

Variable		Odds ratio	*P* Value	SE	z	*P*>z	(95% confidence interval)
Age (RC: 15-45 years)	46-60	0.597	0.328	0.03	-0.98	0.32	0.21-1.67
	61-75	1.2267	0.723	0.70	0.35	0.72	0.39-3.80
	76-90	2.6020	0.195	1.92	1.29	0.19	0.61-11.06
	Up to 90	2.8017	0.367	3.20	0.90	0.36	0.29-26.2
Marital status (RC: Married)		0.8471	0.764	0.46	-0.30	0.76	0.28-2.49
Gender (RC: Male)		1.7635	0.254	0.87	1.14	0.25	0.66-2.49
Place of residence (RC: Urban)		0.7678	0.577	0.36	-0.56	0.57	0.30-1.94
Education (RC: illiterate)	Elementary	3.522	0.096	2.66	1.67	0.09	0.80-15.5
	Middle/high school	1.5814	0.669	1.05	0.69	0.49	0.42-5.8
	Bachelor's	3.6556	0.044	2.55	1.86	0.06	0.92-14.3
	Postgraduate	1.8592	0.330	1.18	0.97	0.33	0.53-6.4
Occupation (RC: Worker)		0.6566	0.165	0.25	-1.39	0.16	0.15-1.37
		0.6986	0.563	0.43	-0.58	0.56	0.20-2.3
Insurance (RC: Yes)		0.9229	0.861	0.42	-0.18	0.86	0.37-2.25
Supplementary insurance (RC: Yes)		0.9366	0.862	0.352	-0.17	0.86	0.44-1.95
History of diabetes (RC: Yes)		0.0509	0.136	0.23	-1.49	0.13	0.21-1.23
Comorbidities (RC: No underlying disease)	Cardiovascular	.5172	0.851	1.14	0.55	0.58	0.34-6.66
	Blood pressure	0.4256	0.149	0.25	-1.44	0.14	0.13-1.35
	Hyperlipidemia obesity/overweight	0.4582	0.307	0.34	-1.02	0.30	0.10-2.04
	Anemia	1.5293	0.620	1.31	0.50	0.62	0.28-8.20
	Other complications	2.0128	0.487	2.04	0.70	0.48	0.28-14.4
	Cardiovascular	0.5252	0.278	0.31	-1.08	0.27	0.16-1.6
Degree of disability (RC: Without disability)		6.722	0.00	2.70	4.74	0.00	3.05-14.79

Note. SE: Standard error; RC: Reference category.

with advanced stages (stages 4-5) pose a significant risk (32), which is in line with the results of our study. Zoccali et al also reported that cardiovascular complications are the most common causes of death in patients with kidney failure (stage G5) undergoing regular dialysis (33). According to the observations of the study, genetics, family history, and lack of control of underlying diseases increase the mortality rate due to cardiovascular disease in most patients with nephropathy. Therefore, patients with multiple comorbidities should be treated with a comprehensive strategy to reduce the risk of disease progression and various lifestyle interventions.

The findings of the current study confirmed that the direct medical costs for nephropathy patients were estimated at 681,809.31 (PPP, current international $), accounting for 81.2% of the total nephropathy costs. Among the direct medical costs, the largest share was related to consumable materials, while the smallest share was associated with medical consultation costs. Gülümsek and Keşkek also concluded that the average cost for a patient with DKD was $603, while the average cost for a diabetic patient without complications was $222. In contrast to our results, the highest costs for patients with DKD compared to those without complications were related to medical hospitalization (34). Zhou et al reported that the annual treatment costs for microalbuminuria and macroalbuminuria stages were $3,580 and $12,830 higher than those for the normoalbuminuric stage, respectively. Treatment costs for nephropathy significantly increased with the severity of the disease (35). Gordois et al calculated the total annual medical costs for managing DN to be $1.9 billion for T1D and approximately $15 billion for T2D (36). Likewise, Gandjour et al found that hospitalization was the main cost driver in stages 3 and 4 of DKD, accounting for more than 50% of the total costs (37). Prasad et al showed that the costs of doctor visits and prescribed medications were higher for patients at high risk of progressing to kidney failure compared to those at low risk (38), which contradicts our findings. McQueen et al concluded that the average annual treatment costs for patients on medication alone and for those on hemodialysis plus medication were $386 and $3,181, respectively (39). It can be stated that a significant portion of the costs incurred for disease management includes direct medical costs and costs incurred in hospital treatment centers for the final stages of the disease. Therefore, hospital dialysis centers should pay more attention to their capital resources, such as dialysis beds and consumables used regularly by patients, and patients exposed to extensive challenges, including difficulty accessing healthcare systems and medications, optimal diabetes management, and complication prevention. Accordingly, it is necessary to find cost-reduction solutions, especially in southwestern Iran, which, according to the Atlas of Non-Communicable Diseases, is among the provinces with a high prevalence of diabetes and its complications.

In our study, the non-medical direct costs for the studied patients were estimated at 109,672.77 (PPP, current international $), accounting for 13.07% of the total disease cost. In contrast, Wyld et al reported that the indirect costs for DKD patients were more than double those for patients without DKD. Additionally, there was a significant difference in the annual direct healthcare and non-healthcare costs per person based on the disease status and stage (40). Comparing these studies demonstrates that direct non-medical costs can vary depending on the type of disease and the economic and social conditions. However, a common point in all these studies is that direct non-medical costs play an important role in the overall financial burden of diseases and require special attention from policymakers and researchers.

Overall, the total indirect costs for patients in our study were 157,274.57 (PPP, current international $), with an average of 1.6 days of work absence and 3.9 days of hospital stay per individual. Khan et al found that the high costs of this disease are mainly due to prolonged hospitalizations (41). Similarly, Zawudie et al reported that the monthly work absence for patients and their companions for diabetes treatment was two days (42). Given that nearly half of the participants were retired or homemakers, the days of work absence in our study were lower than those in other studies. Although indirect costs constitute a smaller percentage of the total costs, they represent a significant economic burden. Productivity loss due to work absence and disability affects not only the patients but also has broader implications for their families and employers. This aspect of the economic burden is frequently overlooked but is crucial for a comprehensive understanding of the impact of DN.

In our study area, education and disability represented a statistically significant relationship with the increasing economic burden for patients with DN. Patients with a bachelor's degree and partial disability incurred higher costs for diabetes care and treatment. Zawudie et al, in their study on the economic burden of diabetes in Ethiopia, concluded that the total disease cost was associated with residence, family size, presence of comorbidities, and history of permanent treatments (42). Contrary to our study, Aoun et al reported that diabetes and coronary artery disease were significantly associated with the total cost of nephropathy, with a significant percentage of patients paying out-of-pocket (43). Ahlawat et al identified that employer/insurance funding, dialysis, lower socioeconomic status, lower education, comorbidities, and rural residential areas had a major impact on the costs of chronic kidney disease (44). Patients with higher education levels incurred higher costs, possibly indicating better access to healthcare services and a higher likelihood of receiving comprehensive treatment. Conversely, disabled patients had higher overall costs compared to those without disability, possibly due to greater use of preventive and therapeutic services.

To the best of our knowledge, our study is one of the pioneering studies in determining the costs and

economic burden of DN in recent years in Iran. Given the increasing prevalence of diabetes and its complications in Iran over the years, it can help highlight the importance of appropriate resource allocation in the field of non-communicable, chronic, and kidney diseases. It is worth mentioning that during the research, we faced several limitations, such as inadequate recording of costs in hospital electronic systems and difficulties in disease detection in stage 1.

6. Conclusion

The findings revealed that DN imposes a serious economic burden on patients' health, the healthcare system, and the overall economy. Healthcare costs uniformly increase with the higher stages of DN. Our findings can provide valuable insights for healthcare providers and policymakers in optimizing care and resource allocation for patients with DN. Based on our results, the total estimated cost of treating DN, given the widespread prevalence of T2D, was 839,083.88 (PPP, current international $), with the largest and smallest shares of 68% and 13% related to direct medical costs and non-medical direct costs, respectively. Overall, the indirect cost for patients was 157,274.57 (PPP, current international $). The total cost of managing DN patients was reported to be 839,083.88 (PPP, current international $).

Acknowledgments

The authors would like to express sincere thanks to all individuals who contributed to the completion of the present research.

Authors' Contribution

Conceptualization: Somayeh Loveimi, Saeed Bagheri Faradonbeh, and Amin Torabipour.
Data curation: F.H and Somayeh Loveimi.
Formal analysis: Saeed Bagheri Faradonbeh and Amin Torabipour.
Funding acquisition: Saeed Bagheri Faradonbeh.
Investigation: Somayeh Loveimi, Saeed Bagheri Faradonbeh, Amin Torabipour, Fatemeh Hayati, Homeira Rashidi.
Methodology: Somayeh Loveimi, Saeed Bagheri Faradonbeh, and Amin Torabipour.
Project administration: Saeed Bagheri Faradonbeh.
Software: Somayeh Loveimi.
Supervision: Amin Torabipour.
Validation: Saeed Bagheri Faradonbeh and Homeira Rashidi.
Visualization: Fatemeh Hayati and Homeira Rashidi.
Writing–original draft: Somayeh Loveimi.
Writing–review and editing: Somayeh Loveimi, Saeed Bagheri Faradonbeh, Amin Torabipour, Fatemeh Hayati, Homeira Rashidi.

Competing Interests: The authors declare they have no competing interests.

Ethical Approval: This study was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (reference No. IR.AJUMS.REC.1402.683). Moreover, ethical considerations were observed at all stages of the research. All participants were informed about the purpose of the study and assured of their confidentiality and anonymity. Additionally, written informed consent was obtained from each participant before the commencement of the study. All methods were performed in accordance with relevant guidelines and regulations.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Ahmad E, Lim S, Lamptey R, Webb DR, Davies MJ. Type 2 diabetes. Lancet. 2022;400(10365):1803-20. doi: 10.1016/s0140-6736(22)01655-5.
2. Gheith O, Farouk N, Nampoory N, Halim MA, Al-Otaibi T. Diabetic kidney disease: world-wide difference of prevalence and risk factors. J Nephropharmacol. 2016;5(1):49-56.
3. Fain JA. National standards for diabetes self-management education and support: updated and revised 2012. Diabetes Educ. 2012;38(5):595. doi: 10.1177/0145721712460840.
4. Ong-Artborirak P, Seangpraw K, Boonyathee S, Auttama N, Winaiprasert P. Health literacy, self-efficacy, self-care behaviors, and glycemic control among older adults with type 2 diabetes mellitus: a cross-sectional study in Thai communities. BMC Geriatr. 2023;23(1):297. doi: 10.1186/s12877-023-04010-0.
5. Tripathy D, Chavez AO. Defects in insulin secretion and action in the pathogenesis of type 2 diabetes mellitus. Curr Diab Rep. 2010;10(3):184-91. doi: 10.1007/s11892-010-0115-5.
6. Hashim SA, Barakatun-Nisak MY, Abu Saad H, Ismail S, Hamdy O, Mansour AA. Association of health literacy and nutritional status assessment with glycemic control in adults with type 2 diabetes mellitus. Nutrients. 2020;12(10):3152. doi: 10.3390/nu12103152.
7. Roglic G. WHO Global report on diabetes: a summary. Int J Noncommun Dis. 2016;1(1):3-8. doi: 10.4103/2468-8827.184853.
8. Azadnajafabad S, Mohammadi E, Aminorroaya A, Fattahi N, Rezaei S, Haghshenas R, et al. Non-communicable diseases' risk factors in Iran; a review of the present status and action plans. J Diabetes Metab Disord. 2021;23(2):1-9. doi: 10.1007/s40200-020-00709-8.
9. Gerstein HC, Sattar N, Rosenstock J, Ramasundarahettige C, Pratley R, Lopes RD, et al. Cardiovascular and renal outcomes with efpeglenatide in type 2 diabetes. N Engl J Med. 2021;385(10):896-907. doi: 10.1056/NEJMoa2108269.
10. Shamiri S, Pourasmail V, Najarzadeh Sam. Evaluation of the relationship between vitamin D, sodium and potassium with nephropathy and its severity in patients with type 2 diabetes.2022;5(65):2008-2023.
11. Magee C, Grieve DJ, Watson CJ, Brazil DP. Diabetic nephropathy: a tangled web to unweave. Cardiovasc Drugs Ther. 2017;31(5-6):579-92. doi: 10.1007/s10557-017-6755-9.
12. Brugnara L, Novials A, Ortega R, De Rivas B. Clinical characteristics, complications and management of patients with type 2 diabetes with and without diabetic kidney disease (DKD): a comparison of data from a clinical database. Endocrinol Diabetes Nutr (Engl Ed). 2018;65(1):30-8. doi: 10.1016/j.endinu.2017.10.004.
13. Gross JL, de Azevedo MJ, Silveiro SP, Canani LH, Caramori ML, Zelmanovitz T. Diabetic nephropathy: diagnosis, prevention, and treatment. Diabetes Care. 2005;28(1):164-76. doi: 10.2337/diacare.28.1.164.
14. Bonakdaran S, Armanpour P. Evaluation of risk factors of renal involvement in patients with type 2 diabetes. Med J Mashhad Univ Med Sci. 2016;59(4):211-24. doi: 10.22038/mjms.2016.8481.
15. Al-Rubeaan K, Youssef AM, Subhani SN, Ahmad NA, Al-Sharqawi AH, Al-Mutlaq HM, et al. Diabetic nephropathy and its risk factors in a society with a type 2 diabetes epidemic: a Saudi National Diabetes Registry-based study. PLoS One. 2014;9(2):e88956. doi: 10.1371/journal.

pone.0088956.
16. Lim A. Diabetic nephropathy - complications and treatment. Int J Nephrol Renovasc Dis. 2014;7:361-81. doi: 10.2147/ijnrd.S40172.
17. Samsu N. Diabetic nephropathy: challenges in pathogenesis, diagnosis, and treatment. Biomed Res Int. 2021;2021:1497449. doi: 10.1155/2021/1497449.
18. Tziomalos K, Athyros VG. Diabetic nephropathy: new risk factors and improvements in diagnosis. Rev Diabet Stud. 2015;12(1-2):110-8. doi: 10.1900/rds.2015.12.110.
19. John S. Complication in diabetic nephropathy. Diabetes Metab Syndr. 2016;10(4):247-9. doi: 10.1016/j.dsx.2016.06.005.
20. Leśniowska J, Schubert A, Wojna M, Skrzekowska-Baran I, Fedyna M. Costs of diabetes and its complications in Poland. Eur J Health Econ. 2014;15(6):653-60. doi: 10.1007/s10198-013-0513-0.
21. Helou N, Talhouedec D, Shaha M, Zanchi A. The impact of a multidisciplinary self-care management program on quality of life, self-care, adherence to anti-hypertensive therapy, glycemic control, and renal function in diabetic kidney disease: a cross-over study protocol. BMC Nephrol. 2016;17(1):88. doi: 10.1186/s12882-016-0279-6.
22. Wang V, Vilme H, Maciejewski ML, Boulware LE. The economic burden of chronic kidney disease and end-stage renal disease. Semin Nephrol. 2016;36(4):319-30. doi: 10.1016/j.semnephrol.2016.05.008.
23. Jose JV, Jose M, Devi P, Satish R. Pharmacoeconomic evaluation of diabetic nephropathic patients attending nephrology department in a tertiary care hospital. J Postgrad Med. 2017;63(1):24-8. doi: 10.4103/0022-3859.194199.
24. Karugu CH, Agyemang C, Ilboudo PG, Boachie MK, Mburu L, Wanjohi M, et al. The economic burden of type 2 diabetes on the public healthcare system in Kenya: a cost of illness study. BMC Health Serv Res. 2024;24(1):1228. doi: 10.1186/s12913-024-11700-x.
25. Alicic RZ, Rooney MT, Tuttle KR. Diabetic kidney disease: challenges, progress, and possibilities. Clin J Am Soc Nephrol. 2017;12(12):2032-45. doi: 10.2215/cjn.11491116.
26. Nichols GA, Vupputuri S, Lau H. Medical care costs associated with progression of diabetic nephropathy. Diabetes Care. 2011;34(11):2374-8. doi: 10.2337/dc11-0475.
27. American Diabetes Association Professional Practice Committee. 11. Chronic kidney disease and risk management: standards of care in diabetes-2024. Diabetes Care. 2024;47(Suppl 1):S219-30. doi: 10.2337/dc24-S011.
28. Yousefi M, Assari Arani A, Sahabi B, Kazemnejad A, Fazaeli S. Household health costs: direct, indirect and intangible. Iran J Public Health. 2014;43(2):202-9.
29. Su TT, Kouyaté B, Flessa S. Catastrophic household expenditure for health care in a low-income society: a study from Nouna district, Burkina Faso. Bull World Health Organ. 2006;84(1):21-7. doi: 10.2471/blt.05.023739.
30. Koye DN, Magliano DJ, Nelson RG, Pavkov ME. The global epidemiology of diabetes and kidney disease. Adv Chronic Kidney Dis. 2018;25(2):121-32. doi: 10.1053/j.ackd.2017.10.011.
31. Chen Y, Lee K, Ni Z, He JC. Diabetic kidney disease: challenges, advances, and opportunities. Kidney Dis (Basel). 2020;6(4):215-25. doi: 10.1159/000506634.
32. Jankowski J, Floege J, Fliser D, Böhm M, Marx N. Cardiovascular disease in chronic kidney disease: pathophysiological insights and therapeutic options. Circulation. 2021;143(11):1157-72. doi: 10.1161/circulationaha.120.050686.
33. Zoccali C, Mallamaci F, Adamczak M, de Oliveira RB, Massy ZA, Sarafidis P, et al. Cardiovascular complications in chronic kidney disease: a review from the European Renal and Cardiovascular Medicine Working Group of the European Renal Association. Cardiovasc Res. 2023;119(11):2017-32. doi: 10.1093/cvr/cvad083.
34. Gülümsek E, Keşkek Ş. Direct medical cost of nephropathy in patients with type 2 diabetes. Int Urol Nephrol. 2022;54(6):1383-9. doi: 10.1007/s11255-021-03012-4.
35. Zhou Z, Chaudhari P, Yang H, Fang AP, Zhao J, Law EH, et al. Healthcare resource use, costs, and disease progression associated with diabetic nephropathy in adults with type 2 diabetes: a retrospective observational study. Diabetes Ther. 2017;8(3):555-71. doi: 10.1007/s13300-017-0256-5.
36. Gordois A, Scuffham P, Shearer A, Oglesby A. The health care costs of diabetic nephropathy in the United States and the United Kingdom. J Diabetes Complications. 2004;18(1):18-26. doi: 10.1016/s1056-8727(03)00035-7.
37. Gandjour A, Armsen W, Wehmeyer W, Multmeier J, Tschulena U. Costs of patients with chronic kidney disease in Germany. PLoS One. 2020;15(4):e0231375. doi: 10.1371/journal.pone.0231375.
38. Prasad B, Osman M, Jafari M, Gordon L, Tangri N, Ferguson TW, et al. Kidney failure risk equation and cost of care in patients with chronic kidney disease. Clin J Am Soc Nephrol. 2022;17(1):17-26. doi: 10.2215/cjn.06770521.
39. McQueen RB, Farahbakhshian S, Bell KF, Nair KV, Saseen JJ. Economic burden of moderate chronic kidney disease in type 2 diabetes. Value Health. 2016;19(3):A14. doi: 10.1016/j.jval.2016.03.278.
40. Wyld ML, Lee CM, Zhuo X, White S, Shaw JE, Morton RL, et al. Cost to government and society of chronic kidney disease stage 1-5: a national cohort study. Intern Med J. 2015;45(7):741-7. doi: 10.1111/imj.12797.
41. Khan S, Amedia CA Jr. Economic burden of chronic kidney disease. J Eval Clin Pract. 2008;14(3):422-34. doi: 10.1111/j.1365-2753.2007.00883.x.
42. Zawudie AB, Daka DW, Teshome D, Ergiba MS. Economic burden of diabetic mellitus among patients on follow-up care in hospitals of Southwest Shewa Zone, Central Ethiopia. BMC Health Serv Res. 2022;22(1):1398. doi: 10.1186/s12913-022-08819-0.
43. Aoun M, Helou E, Sleilaty G, Zeenny RM, Chelala D. Cost of illness of chronic kidney disease in Lebanon: from the societal and third-party payer perspectives. BMC Health Serv Res. 2022;22(1):586. doi: 10.1186/s12913-022-07936-0.
44. Ahlawat R, Tiwari P, D'Cruz S. Cost of illness and the factors affecting it in the patients of chronic kidney disease at a public tertiary care hospital. Value Health. 2015;18(3):A187-8. doi: 10.1016/j.jval.2015.03.1086.