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Epidemiology and economic burden of end-stage kidney disease by age, gender, and province among Iranian Hajj pilgrims in 2012-22: a retrospective study of 469,581 participants

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Abstract

Introduction Annually, over 3.5 million Hajj pilgrims from approximately 180 countries worldwide travel to Mecca for Hajj rituals. End-stage kidney disease (ESKD) is a high-morbidity condition that necessitates high-cost and time-intensive care, the present study aims to investigate the prevalence and economic burden of ESKD among Iranian Hajj pilgrims during the last decade.

Methods All demographic information, risk factors, prevalence and Hospital costs of ESKD were extracted from the database and medical records of the Hajj Pilgrimage Medical Centre, Iranian Red Crescent Society through file reading. Also, the multiple logistic regression model was used.

Results In total, the study encompassed data on 469,581 Hajj pilgrims. According to the findings, the highest prevalence of ESKD was observed in pilgrims aged 70 years and above. Results show that for the gender variable, the odds of having ESKD among women is 0.523 times that of men, for the creatinine (Cr), for each unit increase in the level of blood creatinine, the odds of having ESKD will be 1.383 times, Additionally, in pilgrims with diabetes (1) and hypertension (HTN), the odds of ESKD are 2.33 and 3.345 times, respectively. Results show that the mean total hospital costs are $4178.4.

Conclusion The present study shows a significant difference in the prevalence of ESKD in age, gender, and distribution in different provinces. To reduce the mortality and morbidity of ESKD patients, appropriate medication

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prescriptions, on-time dialysis, lifestyle modifications, and the reduction of disease complications through consultation with a nephrologist are essential during Hajj.

Keywords Epidemiology, Economic burden, End-stage kidney disease, Hajj, Iran

Introduction

Hajj, the annual pilgrimage to Mecca in Saudi Arabia, is one of the world's largest mass gatherings, attracting two to three million Muslims from more than 180 countries each year. Nearly two-thirds of these pilgrims come from low- and middle-income countries, and about a quarter are elderly individuals over 65 years old, many of whom live with chronic health conditions. The physically demanding nature of Hajj rituals—which are performed over five days in confined spaces and often under extreme heat—creates significant challenges for participants, especially those with non-communicable diseases such as cardiovascular disease, diabetes, and chronic kidney disease. Disruptions to sleep, nutrition, and medication routines, combined with the risks of dehydration, heat stress, and infectious disease transmission due to close contact, can further exacerbate these health risks and increase the likelihood of hospitalization and mortality among pilgrims [1–3].

Chronic kidney disease, a leading cause of death among non-communicable diseases globally, is of particular concern during Hajj [4]. The condition is closely linked to other major health problems, including hypertension and diabetes, and is recognized as an independent risk factor for cardiovascular complications. The most advanced stage, end-stage kidney disease, requires intensive and costly treatments such as dialysis or kidney transplantation. These interventions, while life-saving, are not curative and impose a substantial economic burden on healthcare systems, especially in countries with limited resources. The global prevalence of chronic kidney disease has risen sharply in recent decades, now affecting approximately 700 million people. Between 1990 and 2017, the number of affected individuals increased by 33%, driven by aging populations and the growing incidence of diabetes and hypertension. Projections suggest that the number of people requiring kidney replacement therapy may double by 2030 [5, 6].

The burden of chronic kidney disease is especially pronounced in low- and middle-income countries, which account for nearly half the world's population but only a small fraction of those receiving advanced kidney care. Many individuals in these regions lack access to life-saving therapies and often die prematurely. Even in high-income countries, outcomes for patients starting dialysis remain poor, with significant mortality in the first year of treatment. The financial costs are considerable; annual expenses for hemodialysis and peritoneal dialysis can reach tens of thousands of dollars per patient, and the cost of kidney transplantation is even higher, particularly in the first year after surgery [5, 7].

Iran, which ranked fifth in the number of Hajj pilgrims in 2022 after Indonesia, India, Bangladesh, and Nigeria, faces a significant burden of chronic kidney disease [8]. Prevalence estimates in Iran range from 15% to nearly 19% in the general population, with risk factors including age, gender, obesity, hypertension, and dyslipidemia [9]. The challenges of managing chronic kidney disease are heightened during Hajj, where physical stress, extreme environmental conditions, and disruptions to daily routines can lead to serious complications. These factors highlight the importance of targeted interventions, such as pre-Hajj health screenings and educational initiatives, to identify at-risk individuals and allocate medical resources effectively.

Understanding the prevalence and risks of chronic kidney disease among Hajj pilgrims is essential for policymakers and healthcare providers. Early diagnosis and appropriate management of conditions like diabetes and hypertension can help prevent progression to end-stage kidney disease and reduce associated mortality. Given the limited data on the prevalence of ESKD among Iranian pilgrims and the importance of assessing and planning to provide appropriate and timely healthcare to these groups, the present study aims to investigate the prevalence of ESKD. It will evaluate the kidney services provided to these patients among Iranian Hajj pilgrims by gender, province, and year within the timeframe from 2012 to 2022. Considering the high mortality, morbidity, and economic burden of ESKD among the affected individuals, effective and timely care is necessary.

Methodology

Ethical considerations

This study originates from a project sanctioned under the Code of Ethics IR.RCS.REC.1401.022 by the Iranian Red Crescent Society (IRCS), carried out at the Research Center for Emergency and Disaster Resilience located in Tehran, Iran. The IRCS is responsible for overseeing the health and medical treatment of Hajj pilgrims. This includes conducting pre-Hajj health screenings and providing medical services throughout the pilgrimage. Given the prevalence of chronic diseases among pilgrims, such as ESKD, the organization prioritizes addressing these issues. As a policymaker in this field, it actively allocates financial resources, ensures service provision, and focuses on prevention and rehabilitation efforts. Consequently, the organization examines this matter from

multiple perspectives to enhance its effectiveness in safeguarding pilgrim health [3].

The analysis was conducted using pooled cross-sectional data in 2023. This study investigated the prevalence and economic burden of ESKD in Hajj pilgrims by gender, province, and year within the timeframe from 2012 to 2022. Additionally, all demographic information, risk factors, and the prevalence of ESKD were extracted by type and number from the database and medical records of the Hajj Pilgrimage Medical Centre through file reading.

Sampling and inclusion & exclusion criteria

In this study, sampling was not conducted, and all Hajj pilgrims in the provinces of Iran were examined in the period from 2012 to 2022. The IRCS conducts comprehensive medical evaluations for pilgrims prior to their departure. These evaluations include both clinical and para-clinical assessments to identify health issues such as cardiovascular diseases, hypertension, respiratory disorders, diabetes, and mental health conditions [3]. Pilgrims whose information was not fully recorded or had deficiencies in medical documents were excluded from the study.

Statistical analyses

We report ESKD prevalence rates (%) by sex, age, and province between 2012 and 2022. To investigate the effect of the risk factors considered in the study, such as Hypertension (high blood pressure), Diabetes Mellitus, Creatinine (Cr), age, and sex on the odds of ESKD in pilgrims, the multiple logistic regression model was used. Considering that the prevalence of pilgrims' ESKD disease varies in provinces, and pilgrims in the same province are more similar than those in other provinces' ESKD disease, we considered the province as a cluster and used Robust Standard Error to adjust the correlation between pilgrims in the same province. We conducted statistical analyses with a predetermined significance level of 5% ($\alpha = 0.05$). Direct medical costs included Visit Consultation, Drugs, Laboratory, Imaging, Nursing, Surgery, Hospital bed & ICU, and Dialysis. mean ± SD calculated for ESKD patients hospitalized during hajj 2022. All costs converted to USD 2022. The extracted data were analyzed using Excel software version 2019 and Stata software version 17. Visualizations were carried out with R (version 4.3.1).

Definitions

CKD Chronic kidney disease [4] is defined as the presence of kidney damage or an estimated glomerular filtration rate (eGFR) less than 60 ml/min/1.73 mt2, persisting for 3 months or more, irrespective of the cause [10].

ESKD End-stage Kidney disease is defined as a GFR of less than 15 mL/min [11]. ESKD symptoms generally appear in stages 4 and 5 when the GFR is less than 30 ml/min. Some patients with nephrotic syndrome and cystic kidney disease may present earlier. Depression is ubiquitous in patients with ESKD and should be screened for on presentation [12].

According to The Kidney Disease Improving Global Outcomes (KDIGO) 2012 clinical practice guideline, CKD is classified into five stages considering the GFR level:

"Stage 1: Kidney damage with normal GFR (greater than 90 ml/min).

Stage 2: Mild reduction in GFR (60–89 mL/min).

Stage 3a: Moderate reduction in GFR (45 to 59 mL/min).

Stage 3b: Moderate reduction in GFR (30 to 44 mL/min).

Stage 4: Severe reduction in GFR (15 to 29 mL/min).

Stage 5: ESKD (GFR less than 15 mL/min) [11]".

Prevalence In medical epidemiology, prevalence is defined as the proportion of the population with a condition at a specific point in time (point prevalence) or during a period of time (period prevalence) [13].

Results

In total, the study encompassed data on 469,581 Hajj pilgrims with a mean age of 55.48 years, comprising approximately 50% females and 50% males. Of the total pilgrims, 20.92% were hypertensive, and 13.55% had Diabetes Mellitus [14]. pilgrims were grouped into four age categories: under 15 years, 15–44 years, 45–69 years, and over 70 years old, respectively. The highest number of pilgrims, amounting to 89,492 individuals, belonged to the year 2019, and 73.25% were in the age group of 45–70 years (Table 1).

Prevalence of ESKD by sex and age

According to the findings, the prevalence of ESKD among pilgrims increases with age, so the highest prevalence of the disease was observed in pilgrims aged 70 years and above (Table 2). The highest prevalence of ESKD was in 2014, and the lowest prevalence was in 2017. The disease was also estimated to be twice as prevalent in men as in women.

Prevalence of ESKD by Province

According to the data in the graph (Fig. 1) and (Table 3), it can be seen that the lowest and highest prevalence rates of ESKD among pilgrims are observed in North Khorasan and Kurdistan provinces, respectively.

Table 1 Characteristics of Iranian Hajj pilgrims

Variables	(%)*N*
Sex	
Male	234,773 (49.99%)
Female	234,808 (50.01%)
Age (years)	
< 15	133 (0.02%)
15–44	75,063 (15.98%)
45–69	343,977 (73.25%)
≥ 70	50,408 (10.75%)
Year	
2012	61,456 (13.09%)
2013	61,364 (13.07%)
2014	61,853 (13.17%)
2016	71,053 (15.13%)
2017	85,416 (18.19%)
2019	89,492 (19.06%)
2022	38,947 (8.29%)
Diabetes Mellitus	
Yes	63,637 (13.55%)
No	405,944 (86.45%)
Hypertension	
Yes	98,264 (20.92%)
No	371,317 (79.08%)

Table 2 Prevalence of ESKD in Hajj pilgrims by age and sex

Age (years)	ESKD	
	No	Yes
< 15	133	0(0.0%)
15 ≤ age < 45	75,046	17 (0.02%)
45 ≤ age < 70	343,508	469(0.14%)
70≤	50,187	221(0.44%)
Sex		
Male	234,311	462(0.20%)
Female	234,563	245(0.10%)
Total	468,874	707(0.15%)

Factors associated with the prevalence of ESKD

The influence of demographic variables and risk factors on ESKD has been evaluated. Given that the presence of ESKD is a binary variable (ESKD = 0, ESKD = 1), a logistic regression model was utilized. As the data exhibited a clustered structure (individuals within a province may exhibit similarities in terms of certain environmental and genetic characteristics), and the study's objective was not to draw inferences about the provinces, robust standard errors were employed to adjust for this clustering to facilitate more accurate inferences. The results of fitting the logistic regression model with robust standard errors are presented in Table 4.

The Wald test statistic for the overall model was estimated to be 1095.816 (P-value < 0.001), indicating that the fitted model is significant. The null hypothesis, which posits that all independent variables in the model have no effect on the odds of developing ESKD, is rejected. This suggests that at least one of the independent variables in the model has a significant effect on the probability of having ESKD. The p-value for all independent variables included in the model was less than 0.05 (P-value < 0.001), indicating that all variables had a significant effect on the dependent variable.

Given the statistical significance of the model, the interpretation of the effect of all independent variables on the dependent variable (likelihood of having ESKD) is consistent. For instance, the effect of the age variable on the dependent variable is interpreted as follows: for each unit increase in the age of pilgrims (assuming other variables are constant), the odds of having ESKD increases by 0.05%. Similarly, for the gender variable, the odds of having ESKD among women is 0.523 times that of men (in other words, the likelihood of having ESKD among men is 1.91 times that of women (1/0.523 = 1.91)).

Likewise, for the blood creatinine (Cr) variable, for each unit increase in the level of pilgrims' blood creatinine, the likelihood of having ESKD will be 1.383 times. Additionally, in pilgrims with diabetes [14], the likelihood is 2.33 times that of non-diabetic individuals. The chance of developing ESKD in pilgrims with hypertension (HTN) is 3.345 times that of individuals without hypertension.

Healthcare delivery and economic burden

ESKD have been one of the most important diseases among Hajj pilgrims. ESKD can lead to an increase in the consumption of medical services and increased economic burden of disease (Direct cost + indirect cost).

The trend of providing dialysis services to Hajj pilgrims was also reported in 2014, 2017, 2019, 2022 and 2023. The highest rate of receiving dialysis was in 2023 with 503 dialysis cases and the lowest rate was in 2014 with 165 cases requiring dialysis treatment. Table 5 shows that out of 2544 hospitalizations of Hajj pilgrims in 2023, about 20% were for ESKD patients, which shows the clinical and economic importance of this group of patients (Fig. 2).

Table 6 represents costs itemized for ESKD patients. Results show that mean total hospital costs is $4178.4, that most percent of total costs are Hospital bed & ICU (50.45%), drugs (8.69%), Physiotherapy (7.11%) and Dialysis (5.79%), respectively.

Discussion

This study was designed to investigate the epidemiological status of kidney diseases among Iranian Hajj pilgrims, stratified by gender, province, and year, over the decade spanning 2012 to 2022. The study revealed that ESKD was most common in individuals over 70 years old, with key risk factors including male gender, elevated creatinine levels, diabetes, and hypertension. The average hospital cost was $4,178.4.

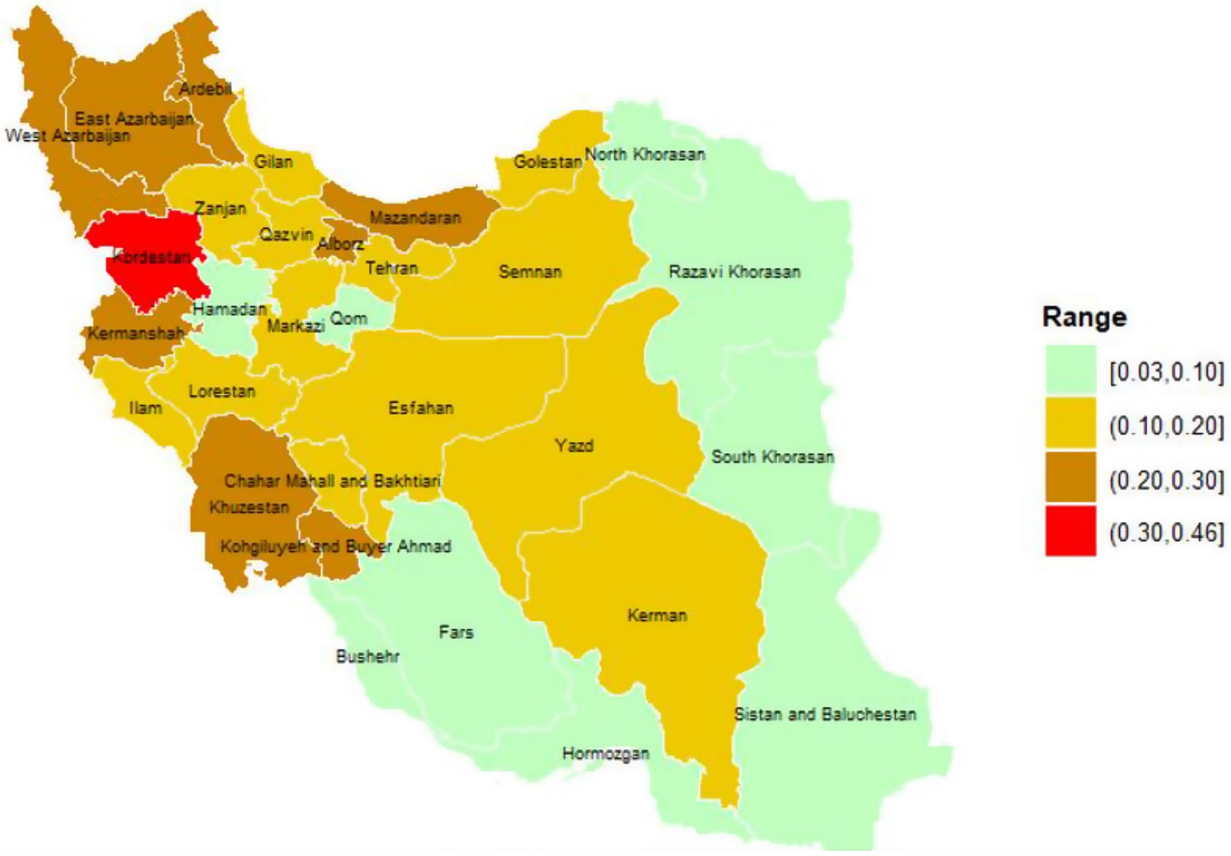


Fig. 1 Prevalence rate of ESKD by province

CKD refers to a persistent abnormality in kidney structure or function that lasts for more than three months. According to global statistics, 8 to 15% of the world's population suffers from this disease. In developed countries, CKD is predominantly attributed to diabetes and high blood pressure. However, less than 5% of affected patients are aware of their condition in the early stages of the disease. Generally, CKD is classified into five stages based on clinical symptoms, with stage 5 being chronic ESKD, where the glomerular filtration rate (GFR) is less than 15 and kidney function is significantly reduced. These patients should be under the care of a kidney specialist [15].

Research in the Saudi indicated that CKD affects approximately 11.7% of the Saudi Arabian population. This existing burden of kidney disease within Saudi Arabia, the host country for the Hajj pilgrimage, has implications for healthcare management during the annual event [16].

A systematic review of 33 population-based studies worldwide estimated the prevalence of CKD in individuals over 20 years old to be 10.4% in men and 11.8% in women, with a standardized global prevalence of CKD stages 3–5 in adults over 20 years estimated at 4.7% in men and 5.8% in women [17]. A systematic review and meta-analysis of 100 studies reported the prevalence of CKD was estimated to be 13.9% in stage 1, 7.6% in stage 2, 3.9% in stage 3, 0.4% in stage 4, and 0.1% in stage 5. These findings align with the results of the present study, which estimated the prevalence of ESKD in Iranian Hajj pilgrims over a ten-year period to be 0.2% in men and 0.1% in women [18].

The overall prevalence of CKD in Iran is estimated at 15.14%, with 10.38% in men and 18.80% in women [19]. Findings from the Golestan Cohort Study indicate that the prevalence of CKD in stages 4 and 5 is 0.4% and 0.1%, respectively. This aligns with our study, where the overall prevalence of stage 5 (ESKD) is 0.15% [20]. ESKD is a high morbidity condition that requires timely and expensive intensive health services in any situation, especially during a ceremony such as Hajj.

A study on the prevalence of emergency cases among Hajj pilgrims revealed that 3% of emergency cases were attributable to kidney diseases such as chronic ESKD, kidney stones, and urinary obstruction [21]. The results of a systematic review and meta-analysis of 26 papers indicate that eight of them reported the prevalence of kidney diseases among Hajj pilgrims. The prevalence varied from 0.03 to 2.5% among French pilgrims, 0.9% among Australian pilgrims, and 0.6% among pilgrims

Table 3 Prevalence of ESKD by Province among Hajj pilgrims

Province	ESKD		Total
	No	Yes	
Chahar Mahaal and Bakhtiari	2,493	4	2,497
	(99.84)	(0.16)	(100)
Kohgiluyeh and Boyer-Ahmad	853	2	855
	(99.77)	(0.23)	(100)
Alborz	7,981	17	7998
	(99.79)	(0.21)	(100)
Ardabil	4,050	11	4,061
	(99.73)	(0.27)	(100)
Bushehr	5,395	4	5,399
	(99.93)	(0.07)	(100)
East Azarbayjan	15,221	38	15,259
	(99.75)	(0.25)	(100)
Fars	22,158	19	22,177
	(99.91)	(0.09)	(100)
Gilan	3,745	5	3,750
	(99.87)	(0.13)	(100)
Golestan	21,706	28	21,734
	(99.87)	(0.13)	(100)
Hamadan	13,038	5	13,043
	(98.96)	(0.04)	(100)
Hormozgan	5,592	4	5,596
	(99.93)	(0.07)	(100)
Ilam	711	1	712
	(99.86)	(0.04)	(100)
Isfahan	44,010	62	44,072
	(99.86)	(0.14)	(100)
Kerman	17,525	23	17,548
	(99.87)	(0.13)	(100)
Kermanshah	5,447	13	5,460
	(99.76)	(0.24)	(100)
Khuzestan	24,252	70	24,322
	(99.71)	(0.29)	(100)
Kurdistan	8964	41	9,005
	(99.54)	(0.46)	(100)
Lorestan	7,110	9	7,119
	(99.87)	(0.13)	(100)
Markazi	9,236	13	9,249
	(99.86)	(0.14)	(100)
Mazandaran	21,216	48	21,264
	(99.77)	(0.23)	(100)
North Khorasan	7,193	2	7,195
	(99.97)	(0.03)	(100)
Qazvin	6,409	10	6,419
	(99.84)	(0.16)	(100)
Qom	13,368	12	13,380
	(99.91)	(0.09)	(100)
Razavi Khorasan	57,641	56	57,697
	(99.90)	(0.10)	(100)
Semnan	6,564	8	6,572
	(99.88)	(0.12)	(100)
Sistan and Baluchistan	9,263	6	9,269
	(99.94)	(0.06)	(100)

Table 3 (continued)

Province	ESKD		Total
	No	Yes	
South Khorasan	10,255	4	10,259
	(99.96)	(0.04)	(100)
Tehran	72,132	100	72,232
	(99.86)	(0.14)	(100)
West Azarbayjan	20,588	47	20,635
	(99.77)	(0.23)	(100)
Yazd	16,517	33	16,550
	(99.80)	(0.20)	(100)
Zanjan	8,241	12	8,253
	(99.85)	(0.15)	(100)
Total	468,874	707	469,581
	(99.85)	(0.15)	(100)

Table 4 Results of logistic regression analysis for factors influencing the prevalence of ESKD

CRF	Coef.	Robust. St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Age	1.05	.006	9.20	0	1.039	1.061	***
Sex	.523	.039	-8.73	0	.452	.605	***
Cr	1.383	.071	6.29	0	1.25	1.53	***
DM	2.33	.181	10.87	0	2	2.714	***
HTN	3.345	.346	11.66	0	2.731	4.097	***
Constant	0	0	-29.72	0	0	0	***

Mean dependent var	0.002	SD dependent var	0.039
Pseudo r-squared	0.109	Number of obs	469581
Chi-square	1095.816	Prob > chi2	0.000
Akaike crit. (AIC)	9461.312	Bayesian crit. (BIC)	9527.670

*** $p<.01$, ** $p<.05$, * $p<.1$

Table 5 Hospitalization during Hajj 2023

Type of Hospitalization	Emergency admissions	Women's internal ward admissions	Men's internal ward admissions	Coronary Care Unit Ward admissions	Dialysis of End Stage Kidney Disease	Total
Number	1438	229	367	510	503	2544

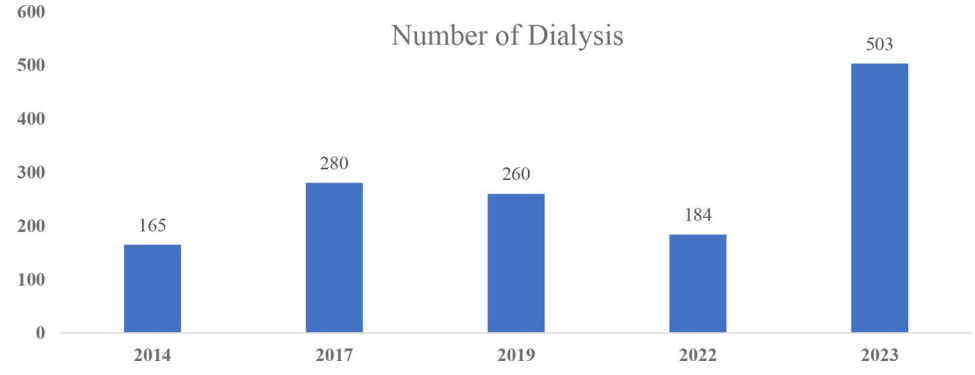


Fig. 2 Trend of Dialysis Healthcare delivery of ESKD

from five African and Asian countries [22]. The findings of this study are somewhat consistent with the results of the present study. One study demonstrated that 2% of Iranian pilgrims' admissions to hospitals in Saudi Arabia were due to kidney problems [23].

Research into the causes of mortality among hospitalized Hajj pilgrims between 2012 and 2017 revealed that 7.6% of all deaths were due to kidney problems [24]. Another finding of the present study is that the prevalence of CKD increases with age among pilgrims. A study on the epidemiology of CKD in adults in Iran indicates that the probability of developing CKD increases with age, so the chance of developing CKD in individuals aged over 70 is 13 times higher than that in individuals aged 15

Table 6 Costs items for specific diagnoses in ESKD

Type of Services	% As Total Cost
Visit	4.18
Consultation	0.68
Drugs	8.69
Laboratory	5.19
Imaging	2.13
Nursing	3.77
Surgery	1.72
Hospital bed & ICU	50.45
Dialysis	5.79
Physiotherapy	7.11
Other services	10.29
Total Cost	**100 (4178.4$)**

to 29 years old [25]. Similar findings regarding the relationship between age and the prevalence of kidney diseases have been reported in the United States [26] and China [27]. Generally, kidney function decreases with age, but it should be noted that the elderly population is heterogeneous, and some of them experience a decrease in Glomerular Filtration Rate (GFR) due to diseases such as arterial sclerosis accompanied by high blood pressure [28]. Additionally, the prevalence of ESKD among Hajj pilgrims was estimated to be twice as high in men compared to women. Globally, the age-adjusted prevalence of kidney diseases is higher in women than in men, but the ratio of dialysis and kidney transplantation is higher in men than in women [29]. Some studies have shown that from 2007 to 2012, the prevalence of CKD in women (15.1%) was higher than in men (12.1%), with a higher albumin-to-creatinine ratio and a lower GFR in women.

It is worth mentioning that gender is considered as a modifier in the GFR measurement equation, assuming that at a certain level of creatinine, men have a higher kidney function due to having more muscle mass and producing more creatinine compared to women [30]. Nevertheless, a GFR threshold of less than 60 for defining kidney disease can lead to overdiagnosis in women [31]. However, a meta-analysis of 30 studies that examined gender-stratified data showed that the progression of CKD is faster in men compared to women [32]. Another finding of the present study is that the prevalence of ESKD diseases among pilgrims varies significantly among different provinces, with the lowest and highest rates observed in North Khorasan and Kurdistan provinces, respectively. The results of a review study showed that the prevalence of CKD varies significantly among different provinces [19]. A large population-based study in Tehran estimated the age-adjusted prevalence of CKD (stages 3 to 5) at 14.9% [9]. Another study reported a prevalence of chronic kidney diseases in Yazd at roughly 27.5% [33]. In Khuzestan province, the prevalence of stage 3 kidney diseases for individuals aged 20 to 65 was estimated at 5.5%. Published data from the Golestan Cohort Study reported a prevalence of CKD at 23.7% (26.6% in women, 20.6% in men) [20].

Global estimates suggest that the number of recipients of kidney replacement therapies (KRT) will rise from 2.6 million in 2010 to 5.4 million in 2030, with Asia accounting for nearly 50% of cases [34]. Currently, over 678,000 Americans are living with ESKD, and projections indicate that the number of patients with this condition will surpass 2 million by 2023. The annual average medical costs of ESKD in the United States are estimated to exceed 32 billion dollars [35]. Countries respond to ESKD in various ways, such as effective prevention, case detection, protective care, kidney transplantation, and dialysis. Given the increasing demand for costly kidney replacement therapies through transplantation or dialysis and considering limited resources, ESKD should prioritize the prevention and treatment of chronic kidney diseases, acute kidney injuries, and other non-communicable diseases [36]. ESKD with unknown causes, predominantly affecting adults in their working years, often proves fatal due to the rapid progression of the disease and the lack of dialysis or kidney transplantation [37]. A study shows that in 2010, ESKD associated with diabetes and high blood pressure led to premature deaths of over 1.2 million people [38]. Furthermore, evidence suggests that most patients undergoing dialysis or kidney transplantation do not return to the workforce [39]. For instance, in the United States, approximately 71% of ESKD patients are unemployed, and the overall unemployment rate among patients under treatment is increasing [40]. On the other hand, the mortality risk in individuals with ESKD is 6 to 8 times higher than the general population, leading to productivity loss arising from premature deaths [41]. In Iran, the average annual costs of hemodialysis are estimated at $13,477, peritoneal dialysis at $12,865, and kidney transplantation costs around $16,450 [42]. Findings from a meta-analysis study indicate that the progression rate of chronic kidney diseases to ESKD is slower in women than in men. Additionally, the combination of end-stage kidney disease with diabetes is associated with an increased risk of cardiovascular diseases [43]. A domestic study conducted on Hajj pilgrims revealed that 1.76% of them had chronic kidney diseases, with 1.15% of these individuals undergoing dialysis, while 88.5% of the patients were unaware of their condition [44]. Nevertheless, the incidence of ESKD in many countries with long-term access to Renal Replacement Therapy (RRT) is stable or declining, likely due to increased success in preventing chronic kidney diseases or slowing their progression to prevent ESKD. Global survival in most ESKD patients undergoing home hemodialysis is low, but overall survival is improving, and in some Asian countries, it is the longest [45].

One finding of the research is that factors such as age, male gender, high blood creatinine, diabetes, and high blood pressure increase the risk of ESKD. A study on the causes of ESKD in hemodialysis patients in Fars province demonstrated that diabetes and high blood pressure are the most significant risk factors for these types of diseases [46]. Despite all clinical and laboratory findings, the risk factors for CKD and their etiology remain unknown, with environmental factors and low birth weight being responsible for these types of diseases [47]. A similar domestic study shows that age, female gender, high body mass index, high blood pressure, and diabetes are risk factors for chronic kidney diseases [9]. These findings are somewhat consistent with the results of our study. The Golestan Cohort Study findings indicate that female gender, older age, urban residence, a history of Cardiovascular Disease (CVD), high blood pressure or diabetes, a larger body mass index, and opium use are all associated with CKD [20]. Findings from a study in India show that older age, urban residence, overweight and obesity, diabetes and high blood pressure, cardiovascular diseases, and higher income are significantly associated with a higher likelihood of developing kidney diseases, and anthropometric measures (except height), blood pressure, random blood glucose, and fasting blood glucose were significantly correlated with Glomerular Filtration Rate (GFR) in the study group [48]. Many pilgrims, both elderly and young, suffer from non-communicable diseases such as diabetes, high blood pressure, arthritis, epilepsy, liver and kidney diseases, which can exacerbate the symptoms of kidney diseases due to the challenging conditions of the pilgrimage or neglect of regular medication [49]. Optimal management of CKD includes reducing the risk of cardiovascular diseases, such as controlling blood pressure, treating albuminuria, avoiding potential nephrotoxins, and adjusting the dosage of drugs such as antibiotics and blood sugar-lowering agents. Patients also need to be monitored for CKD-related complications such as hyperkalemia, metabolic acidosis, hyperphosphatemia, vitamin D deficiency, secondary hyperparathyroidism, and anemia. Individuals at high risk of CKD progression should be promptly referred to a nephrology specialist [50].

Chronic kidney diseases, when they reach the ESKD, create a significant economic burden on healthcare systems and society as they require dialysis or kidney transplantation [51]. The estimated direct healthcare costs of end-stage kidney disease in Canada reached $1.3 billion in 2000, which increases to $1.9 billion when including indirect costs [52]. A study in South Korea shows that the direct medical costs for CKD patients in stages 3, 4, and 5 are equivalent to €1205, €1963, and €8035 per year, respectively, and this amount increases to €68,798 for kidney transplantation. Additionally, the cost of lost productivity accounts for approximately 8 to 20% of the total costs [53]. Another study also indicates a significant difference in the costs of chronic kidney disease in the early stages compared to the costs in the dialysis stage, with these costs increasing sharply in the kidney transplant stage [54]. In Italy, the average social costs for individuals with CKD in stage 4 are estimated at €7422, and in stage 5 at € 8971. The total annual social costs of CKD in Italy are estimated to exceed €1.8 billion, equivalent to 0.11% of the gross domestic product [4]. The findings of a systematic review have shown that the progression of chronic kidney disease from stages 1–2 to stage 3a and 3b leads to an increase of 10 to 70% in annual healthcare costs per patient, and the progression from stage 3 to stages 4 and 5 results in a 30% to over 4-fold increase in costs. The highest cost is associated with end-stage ESKD, which incurs approximately $20,000 to $100,000 [51]. It is worth mentioning that the existing differences in CKD costs may be due to variations in data collection methods, study perspectives, and costing approaches.

Observed variations in ESKD prevalence across Iranian provinces suggest potential disparities in healthcare access and outcomes. The availability and distribution of nephrology services, including specialized care and dialysis facilities, likely influence these regional differences. Provinces with fewer resources may face challenges in timely diagnosis and effective management of chronic kidney disease, potentially leading to higher rates of ESKD. Furthermore, socioeconomic determinants, such as income levels and health literacy, could exacerbate these disparities [55]. Individuals with lower incomes may encounter obstacles in accessing preventative services and adhering to recommended treatment regimens, elevating their risk of progressing to ESKD [56]. Further investigation is warranted to elucidate the underlying factors contributing to these regional inequalities and to inform the development of targeted interventions aimed at improving kidney health across Iran.

This study's findings provide essential insights into the epidemiology and economic implications of end-stage kidney disease (ESKD) among Iranian pilgrims participating in the Hajj, thereby underscoring the necessity for proactive interventions to mitigate ESKD's impact on this vulnerable population and enhance healthcare resource efficiency during the pilgrimage.

To that end, policy development should be geared toward several key areas. First, robust pre-Hajj screening initiatives should be implemented for all Iranian pilgrims, emphasizing early detection of chronic kidney disease [4] and assessment of ESKD risk factors through blood pressure checks, urine albumin-to-creatinine ratio testing, and serum creatinine measurements, particularly for those with diabetes, hypertension, or a family history of kidney disease.

Second, accessibility to specialized nephrology services should be augmented, ensuring equitable access to specialist consultations, dialysis provisions, and pharmaceuticals via collaborative partnerships between the Iranian Ministry of Health, the Iranian Red Crescent Society, and Saudi Arabian healthcare entities, potentially incorporating telemedicine platforms and mobile dialysis facilities to reach remote pilgrims.

Third, strategic healthcare resource allocation should prioritize cost-effective strategies like medication adherence programs, dietary guidance, and patient education to curtail disease progression, while also negotiating favorable pricing for dialysis and medications with Saudi Arabian providers.

Finally, the pre-Hajj ESKD risk assessments, access to affordable services, enhanced care coordination, increased ESKD awareness, and investment in telemedicine infrastructure are some of the policy changes that should be implemented based on study findings regarding public health and ESKD.

This study, while offering valuable information, is not without limitations that should be considered when interpreting the findings. First, resource constraints and the nature of available data restricted the scope of economic analysis. The cost data are confined to direct in-hospital expenditures during the 2022 Hajj and lack a complete picture of pre-existing healthcare costs, extended follow-up expenses, and indirect costs like productivity losses. The cost figures presented thus offer a partial perspective on the economic impact, highlighting the need for dedicated economic evaluations in future research to enable comprehensive cost-effectiveness analyses and inform resource allocation strategies.

Second, the study's reliance on retrospective data from medical records carries inherent risks of data quality variations and potential selection biases. Diagnostic precision, coding practices, and the completeness of records may vary among different healthcare settings and geographical regions, potentially influencing the precision of prevalence estimates and the strength of risk factor associations. Furthermore, data limitations constrained our ability to explore more nuanced relationships and confounding factors, preventing the application of more sophisticated statistical methods. For example, granular data on ESKD severity, specific treatment protocols, and socioeconomic variables were unavailable. This restricted our ability to implement advanced modeling techniques like time-to-event analyses or causal inference methods, which could have provided a more refined understanding of the progression and drivers of ESKD in this specific population.

Due to the lack of access to detailed individual-level financial data, patient-level costs could not be stratified. Additionally, no sensitivity analysis was feasible because the dataset did not contain sufficient variability or parameter information required for such analysis. These constraints may affect the depth and robustness of the economic findings presented.

Despite these limitations, this study contributes important evidence to the limited knowledge base on ESKD among Hajj pilgrims and offers actionable insights for public health planning and resource allocation strategies. Future research should prioritize addressing the identified data gaps, employing prospective study designs where feasible, and conducting comparative analyses across diverse populations to enhance the robustness and broader applicability of findings.

Conclusion

ESKD is a condition with high morbidity that necessitates costly and time-intensive care. The significance of this issue is amplified during the Hajj pilgrimage due to the specific temporal and spatial conditions. The present study shows a significant difference in the prevalence of ESKD in age, gender, and distribution in different provinces. To reduce the mortality and morbidity of ESKD patients, appropriate medication prescriptions, on-time dialysis, lifestyle modifications, and the reduction of disease complications through consultation with a nephrologist are essential during Hajj.

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Author contributions

PK, PS, SA and AM contributed to the conception of the study. SA, SR, FK, MKK and AP contributed to the Data curation. AP and SR contributed in Data Analysis. PS, SA, BR, FK and MB contributed to the Writing of the study. SR, HS, TD and SJE contributed in review and editing.

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Data availability

The datasets used and/or analyzed during the current study are available (First Author: Samadazari1010@gmail.com).

Declarations

Ethics approval and consent to participate

This study was conducted under the ethical approval granted by the Institutional Review Board (IRB) of the Iranian Red Crescent Society (IRCS), with the approval code IR.RCS.REC.1401.022. The research utilized anonymized, pooled data extracted from routine medical records held in the IRCS database. As the study did not involve any direct contact or intervention with participants, and only used de-identified secondary data, the Ethics Committee of the Iranian Red Crescent Society (IRCS) waived the requirement for obtaining informed consent from individual participants in accordance with national regulations and IRCS policies. Furthermore, this study was conducted in full compliance with the ethical principles of the Declaration of Helsinki, ensuring that all research involving human data adhered to internationally recognized ethical standards.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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