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Burden of Subclinical Renal Impairment and Albuminuria in the Thar Desert: Survey-Weighted Community Screening Study with Geospatial Hotspot Analysis, India

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Abstract

Introduction: Chronic kidney disease (CKD) has increased globally, and population-based data from arid India is limited. In areas with limited resources, the urine albumin-to-creatinine ratio (ACR) may be a valuable screening tool for detecting undetected kidney damage.

Methods: The study was a community-based, stratified cluster survey of 14,050 participants in Bikaner and Jaisalmer from April 2022 to September 2023. Participants with ACR ≥30 mg/g had repeat serum creatinine and urine ACR tests at 3 months to assess chronicity. Gender- logistic regression, and survey-weighted analyses identified 3-month follow-up prevalence and risk factors for reduced eGFR and ACR 2-3 Stage. SPSS 28.0 conducted survey-weighted estimates and gender-adjusted logistic regression. R (v4.5.2) created AOR forest plots. ArcGIS Pro 2.9 assessed Getis–Ord Gi* hotspots.

Result: Out of 731 patients assessed for three-month urine ACR screening, 29.3% had chronic albuminuria (ACR ≥30 mg/g; A2+A3), 20.4% had moderately elevated (A2: 30–300 mg/g), and 8.9% had severely increased (A3: >300 mg/g). In 8.9% (95% CI:6.4–12.2%) of 632 individuals with serum creatinine, eGFR was <60 mL/min/1.73 m² at follow-up. A geospatial hotspot revealed clustering in Jaisalmer's Lunkaransar, eastern Bikaner, Pokaran, and northern Bhaniana. The most effective independent predictor of albuminuria was family history of renal disease (AOR 2.47; 95% CI:1.41–4.32; p=0.002), followed by 12-month prescription drug use (AOR 1.57; 95% CI:1.15–2.15). The duration of prescription drug use was associated with eGFR decline (AOR 4.19; 95% CI: 1.48–11.84; p=0.007).

Conclusion: This is the first comprehensive community-based urine-screening study to identify subclinical renal damage in the arid region, highlighting the disorder's incidence in this cohort. After screening, one in three inhabitants in this arid area had chronic albuminuria, revealing a significant kidney disease burden. Thus, in extreme-climate, resource-limited areas, spot urine ACR screening efficiently detects silent kidney disease.

Key words: Chronic kidney disease; Albuminuria; eGFR; Hypertension; Diabetes mellitus; Rajasthan, India

What is already known about this topic?

- Globally, CKD affects 14.2% of adults (GBD 2023), driven by hypertension, diabetes, and emerging environmental factors, including heat stress and dehydration.
- CKD affects 9.3% of India's population (128 million), however screening data from arid and semi-arid areas, where heat stress, chronic dehydration, and excessive dietary salt are prevalent, are lacking.
- Albuminuria, a sign of kidney damage, may be detected years before eGFR decline. The spot urine albumin-to-creatinine ratio (ACR) is a reliable, cost-effective screening method for large-scale population use.

What This Study Adds

- This survey-weighted research is the first to determine albuminuria prevalence and reduced eGFR in the Thar Desert, a severe climatic zone. Patients without any prior CKD diagnosis had a 29.3% prevalence of albuminuria (ACR ≥30 mg/g) and an 8.9% prevalence of progressively reduced eGFR (<60 mL/min/1.73 m²).
- Geospatial hotspot analysis (Getis-Ord Gi*) revealed significant kidney damage clustering in Lunkaransar, eastern Bikaner, southern Pokaran, and northern Bhaniana (Jaisalmer), identifying areas for targeted public health intervention.
- Evidence suggests that long-term prescription drug use (>12 months) is a significant risk factor for reduced eGFR (AOR 4.19; 95% CI: 1.48–11.84) and albuminuria (AOR 1.57; 95% CI: 1.15–2.15) in low-literacy, resource-limited desert communities.
- A family history of kidney disorders was the strongest indicator of albuminuria (AOR 2.47; 95% CI: 1.41–4.32), emphasising the cost-effectiveness of screening first-degree relatives for ACR screening in primary care.

Recommendations for policy:

What this study findings imply?

Our results recommend following public health response:

- Integrating spot urine ACR testing into ASHA and sub-centre screening programs in hotspot areas
- Primary care long-term analgesic and antihypertensive prescription assessments with essential creatinine monitoring for patients on drugs for >6 months
- First-degree relatives of all CKD family history should be screened since its strongly linked to albuminuria. These measures align with India's NCD action plan and feasible in primary healthcare system.
- The urine ACR screening method is cost-effective and feasible to detect silent kidney damage in extreme-climate LMIC areas. Policymakers in arid belt countries like India, Pakistan, the Middle East, and Sub-Saharan Africa need to emphasise ACR screening at primary health facilities.
- Geospatially targeted interventions, such as restricting over-the-counter nephrotoxic drugs, regulating hypertension, and encouraging family screening, could substantially reduce preclinical CKD in arid regions globally.

Introduction

In recent GBD (2023) reports, the global CKD prevalence in adults has reached 14.2% in 2023, representing a significant rise since 1990[1]. India data also suggests a CKD prevalence between 10.65% and 15.34%[2]. affecting 9.3% of India's population (128.0 million cases) in 2021[3], In Asian countries, South Korea's KNHANES found 13.7% CKD among urban civilians aged 35 and above [4]. Japan's prevalence has been estimated at 13%[5]. Singapore's latest health survey reports about 13.8% of adults with CKD [6]. Many African and Eastern European regions report even higher burdens, with North Africa and the Middle East at 18.0% [1] and Eastern and Central Europe at 12.8%[7].

The increasing prevalence of risk factors leading to impaired renal function, such as diabetes (7.1% in 2015-2016)[8] and hypertension (30.7%) [9][10][11][12], an ageing population (8.6% in 2011, projected to reach 19.5% by 2050)[13][14] [15][16], and environmental and lifestyle changes [17] [18] Unhealthy behavioural habits such as smoking and alcohol consumption, inappropriate medication use.

Meanwhile, end-stage renal disease (ESRD) requiring dialysis was still on the rise in India, with an incidence of 229 per million population [19], and the number of people progressing to ESRD annually was approximately 220000, leading to the global need for renal replacement therapy, with annual dialysis requirements of 34 million treatments [20]. However, population-based information on renal function in the dry, arid state of Rajasthan was limited. The majority of the Rajasthan-based studies on renal function are from urban or hospital settings, and there are limited comprehensive regional data, while rural areas are under-represented in CKD research in Rajasthan [21] [22].

To address a knowledge gap, this research implemented spot urine ACR screening in the community to estimate the prevalence of undiagnosed renal impairment and albuminuria. The dry areas of Jaisalmer and Bikaner are particularly vulnerable to severe weather and resource scarcity. Thus, in settings with limited resources, the two-step screening procedure to estimate albuminuria and a reliable biochemical analysis for early kidney disease screening were efficient and cost-effective.

Methodology

Study Area

Jaisalmer and Bikaner districts are situated in the western and north-western parts of Rajasthan and form part of the arid desert region. Jaisalmer covers about 38,401 km², while Bikaner spans nearly 27,244 km². Both districts experience very low rainfall (250.1-707.2 mm), high evapotranspiration, and extreme temperatures. Summers are intensely hot (25°C-50°C), winters can be cold (5°C-23.6°C), and strong winds during April to June cause shifting sand dunes.

Study Design

A community-based, stratified, multistage cluster survey was conducted across urban and rural strata in two districts (Bikaner and Jaisalmer) from April 2022 to September 2023. This manuscript's research design, analysis, and reporting follow STROBE cross-sectional and cohort reporting guidelines, and the urban/rural sample frame was used in the 2011 Rajasthan population census. The stratified multi-stage cluster sampling chose 30 urban (municipal wards) and 30 rural (villages) PSUs in each district. Urban wards and rural villages were PSUs.

Sample size:

Given India's 9% adult CKD prevalence, [23] At an 11% prevalence, 2 design effect, and 7% non-response rate in each district, the sample size was calculated to be 7200 [24] [25]. In 2 districts, 14,050 participants were targeted. Global data from LMICs indicate a 3% prevalence of CKD among 18-30-year-olds (17); thus, 1080 individuals must be included. According to the Census 2011, Rajasthan has an urban-rural population ratio of 1.3. After random selection from the CEB of each district, 30 urban PSUs would each recruit 300 eligible people. The districts were sampled proportionally depending on the number of blocks. Each district selected 30 rural primary sampling units (PSUs) choose for screening. Block in Bikaner from 7, and Jaisalmer from 4; PSU in Bikaner 210, and Jaisalmer 120. If the chosen PSU could not enrol enough people, the adjacent village considered to fulfil the sample size.

Participants: Inclusion: aged ≥18, irrespective of gender, from the outlined areas; Exclusion: Participants with self-reported CKD, dialysis, or renal transplant were excluded from biochemical screening, pregnant women and those near gestation, not willing to participate

Data collection and Measurement: The urine ACR from spot urine samples was a primary screening test, as it is a validated and recommended alternative to 24-hour urine protein quantification, a sensitive assessment for the early identification of renal dysfunction (refer to Figure 2). ACR adjusts for variations in urine concentration due to hydration

levels and is appropriate for population screening in a field survey. Urine samples were obtained in the early morning, whenever feasible, to reduce diurnal variation[26].
Field staff obtained written consent and shared the PIS in participants' language. Using a pre-structured questionnaire, demographics, medical history (hypertension, diabetes, cardiovascular disease, renal illness), medication usage (NSAIDs, herbal medicines), lifestyle factors (tobacco, food, physical activity), and other exposures were gathered Portable ERBA urine analysers were used for field screening. Serum creatinine analysis was limited to this subset to maximise laboratory resources and logistics in a broad community screening program since mass biochemical testing was not feasible. A non-stretchable measuring tape measured waist and hip circumferences, while a stadiometer and digital weighing scale recorded height and weight. Standardising field equipment to one model per parameter and utilising a standard method enhanced community measurement validity. A sitting rest was followed by three blood pressure readings at predefined intervals. Portable Accu-Chek Active glucometers detected random glucose.
The albumin-creatinine ratio (ACR) was estimated by collecting a 15-20 mL spot urine sample in a sterile container and transporting it to the lab under cold chain conditions. Morning urine samples were taken wherever feasible. Laura Smart urine analyser (Model EM-200) with MicroalbuPHAN measured albumin and creatinine. The analyser automatically computed ACR (mg/g) from urinary microalbumin (mg/L). Participants with ACR ≥30 mg/g who agreed to biochemical investigation had blood collected using sterile vacutainers. Thus, only individuals in a biochemically assessed subgroup with A2-A3 had their serum creatinine assessed. Prioritising biochemical evaluation for participants with A2/A3 albuminuria was done as a targeted resource-efficient strategy appropriate for large-scale community screening refer Figure 2. Field samples were transferred to the Biochemistry Laboratories at the Bikaner and Jaisalmer District Hospitals, where a strict cold chain was maintained at 2°C-8°C. The Erba E-200 fully automated biochemistry analyser evaluated serum after centrifugation and labelling cryovials. Serum creatinine, urea, and lipid profile parameters (total cholesterol, triglycerides, HDL-C, LDL-C) were analysed based on standard guidelines. Figure 3 shows the spatial distribution of chronic kidney disease (CKD) participants at the 3-month follow-up (FUP) who had an albumin-to-creatinine ratio (ACR) greater than 30 mg/g and an estimated glomerular filtration rate (eGFR) below 60 mL/min/1.73 m², as calculated using the CKD-EPI equation.

Quality Assurance

All fieldworkers at the study locations underwent collective training at the project's inception to ensure uniform protocol, along with periodic standardisation sessions held biannually. To ensure accuracy, anthropometric devices were calibrated before each examination. The Biochemistry Laboratories of the Government District Hospitals in Bikaner and Jaisalmer received accreditation under the National Accreditation Certificate for the External Quality Assessment (EQA) Programme, ensuring the quality assurance of all biochemical tests.

Definitions

Glomerular filtration rate was estimated using the creatinine-based CKD-EPI equation (2021) as recommended for standardised laboratory reporting [27] All positive findings (e.g. eGFR <60 or albuminuria ≥30 mg/g) were rechecked within 3 months to distinguish chronic CKD from acute or transient abnormalities, consistent with guideline definitions[28]. Chronic kidney disease (CKD) was defined according to current KDIGO criteria as abnormalities of kidney structure or function present for at least 3 months [28]. In practice, CKD was defined by either decreased eGFR (<60 mL/min/1.73 m²) persisting ≥3 months or markers of kidney damage (albuminuria or structural abnormalities) persisting≥3 months[28][27]. In our study, an eGFR <60 mL/min/1.73 m² was classified as CKD [27]. Albuminuria was defined by urine ACR: A2 (30–300 mg/g), and A3 (>300 mg/g)[28].

Statistical analysis

Statistical analyses were done using SPSS Statistics 28.0, R 4.5.2, and ArcGIS Pro 2.9. A set plan file in SPSS outlined a complex sampling design with district-level stratification and ward-level clustering, estimated survey-weighted proportions, and 95% confidence intervals. Analyses were conducted for (N=14,050), the serum creatinine follow-up subgroup (n=632), and the urine ACR subgroup (n=731).
Significant variations in baseline characteristics between individuals with and without follow-up data (Supplementary Table 1) suggest attrition bias. Survey-weighted analyses were used to adjust for different follow-up probabilities. The missing-at-random assumption was used to impute missing data (5 completely conditional imputations). Variance inflation factors (VIFs) and tolerance statistics analysed predictor multicollinearity (Supplementary Table 2). AORs with 95% CIs were estimated using survey-weighted multivariable logistic regression for a reduced eGFR (<60 ml/min/1.73 m²), ACR 2-3 stage using complex-sample logistic regression estimated models.
Sensitivity analysis (Supplementary Table 1, Fig. 1) evaluated complete-case, imputed, and unweighted models. Model discrimination was tested using ROC analysis (AUC = 0.777; 95% CI: 0.701–0.853). Getis–Ord Gi* hotspot analysis in ArcGIS Pro analysed spatial clustering of skewed ACR and reduced eGFR. AOR forest plots were created in R using ggplot2.
References: Key definitions and procedures followed international guidelines[28][27][23] as cited above.

Hotspot Analysis

The Getis–Ord Gi* hotspot analysis refer Figure 1. revealed statistically significant geographic clustering of elevated urine albumin–creatinine ratio (ACR2-3) and recurrent low eGFR in participants who underwent 3month- follow-up screenings. To evaluate renal dysfunction in the biochemically monitored subgroup, a new GIS layer was created using ACR classifications A2 (30-300 mg/g) and A3 (>300 mg/g) and eGFR values < 60 mL/min/1.73 m^2

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}\, x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2}{n-1}}}$$

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}$$

[29]

In the Getis–Ord Gi* statistic, $x_j$represents the attribute value of feature j, corresponding to locations with elevated ACR [A2 (30–300 mg/g) and A3 (>300 mg/g)] and reduced renal function (eGFR < 60 mL/min/1.73 m^2). The term w_{ij}denotes the spatial weight between features $i$and j, reflecting their spatial relationship, while $n$indicates the total number of locations with individuals who have abnormal ACR and/or eGFR < 60.

Hotspot analysis used z-scores and p-values to check if patterns were random. High positive scores indicated clusters of high kidney risk (hotspots), while negative scores indicated clusters of lower kidney risk (cold spots).

All abnormal ACR and low eGFR cases mapped with geographic coordinates and analyzed to see whether they are clustered, scattered, or random in Bikaner and Jaisalmer. ANN results guided Getis–Ord Gi* analysis to identify significant kidney disease hotspots and cold spots.

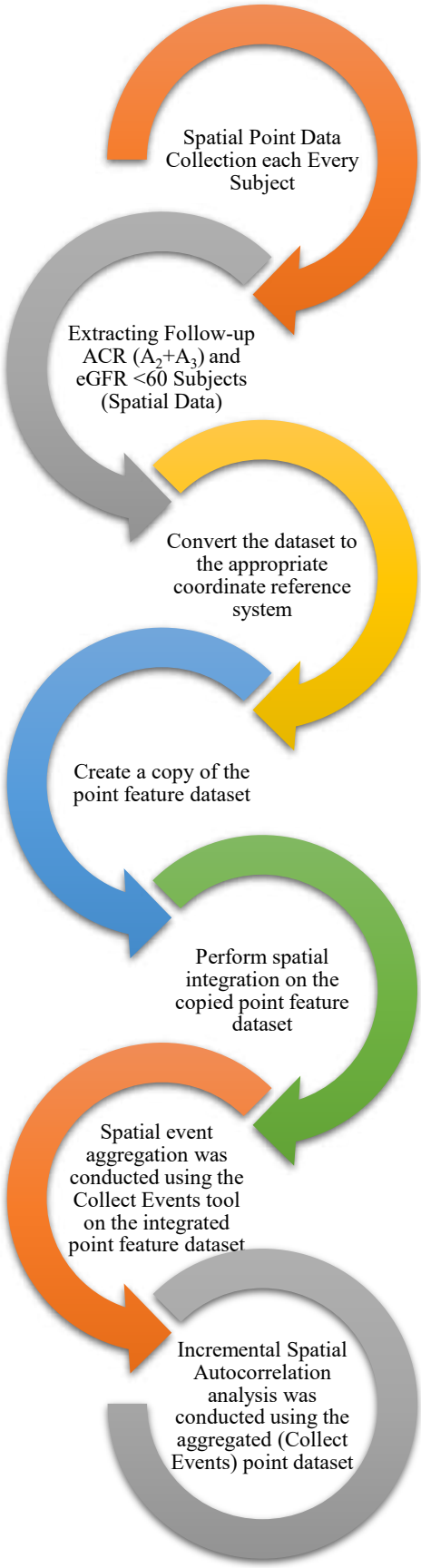
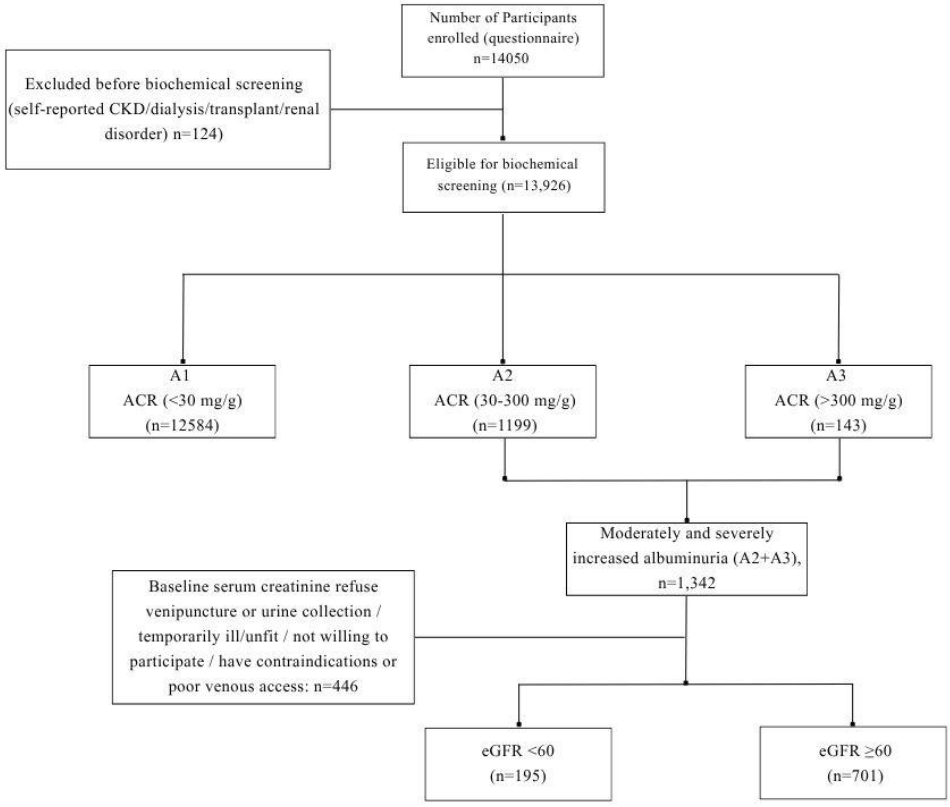


Figure 1. Flow Chart of Hotspot Analysis

Flow chart: Baseline screened Participants



Flow chart: 3-month Follow-up Participants

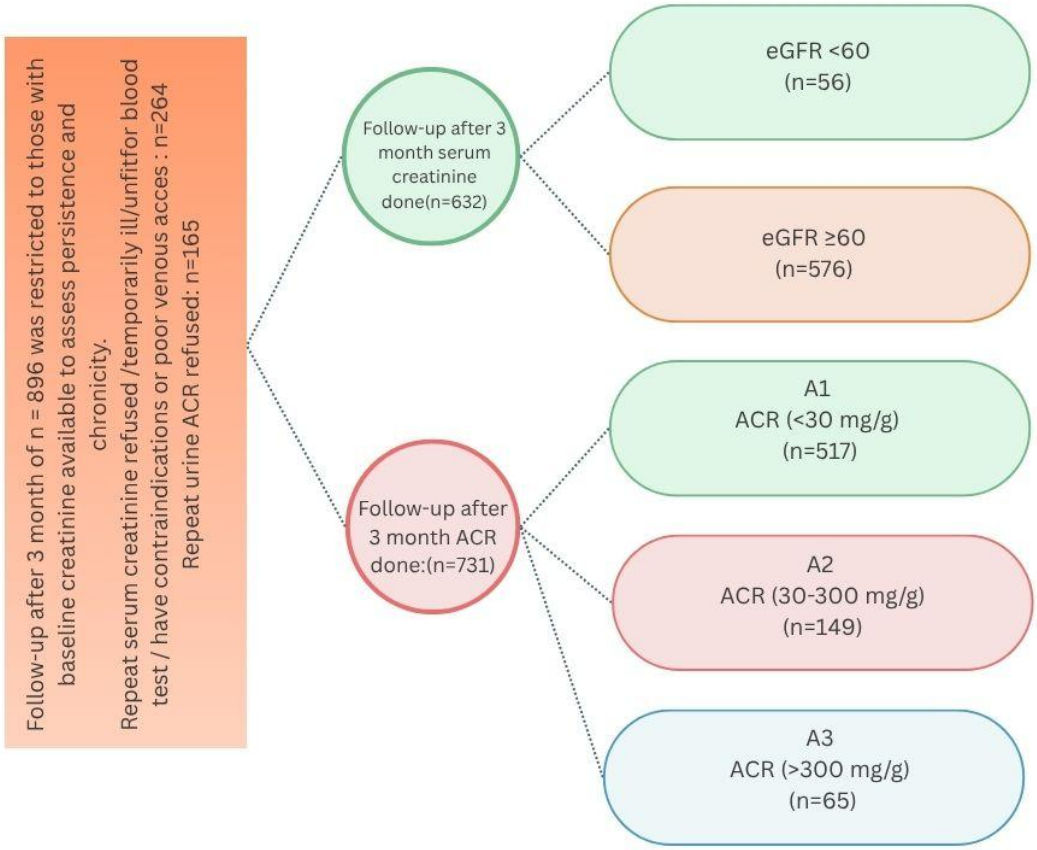


Figure 2. Flow chart of the screened Participants

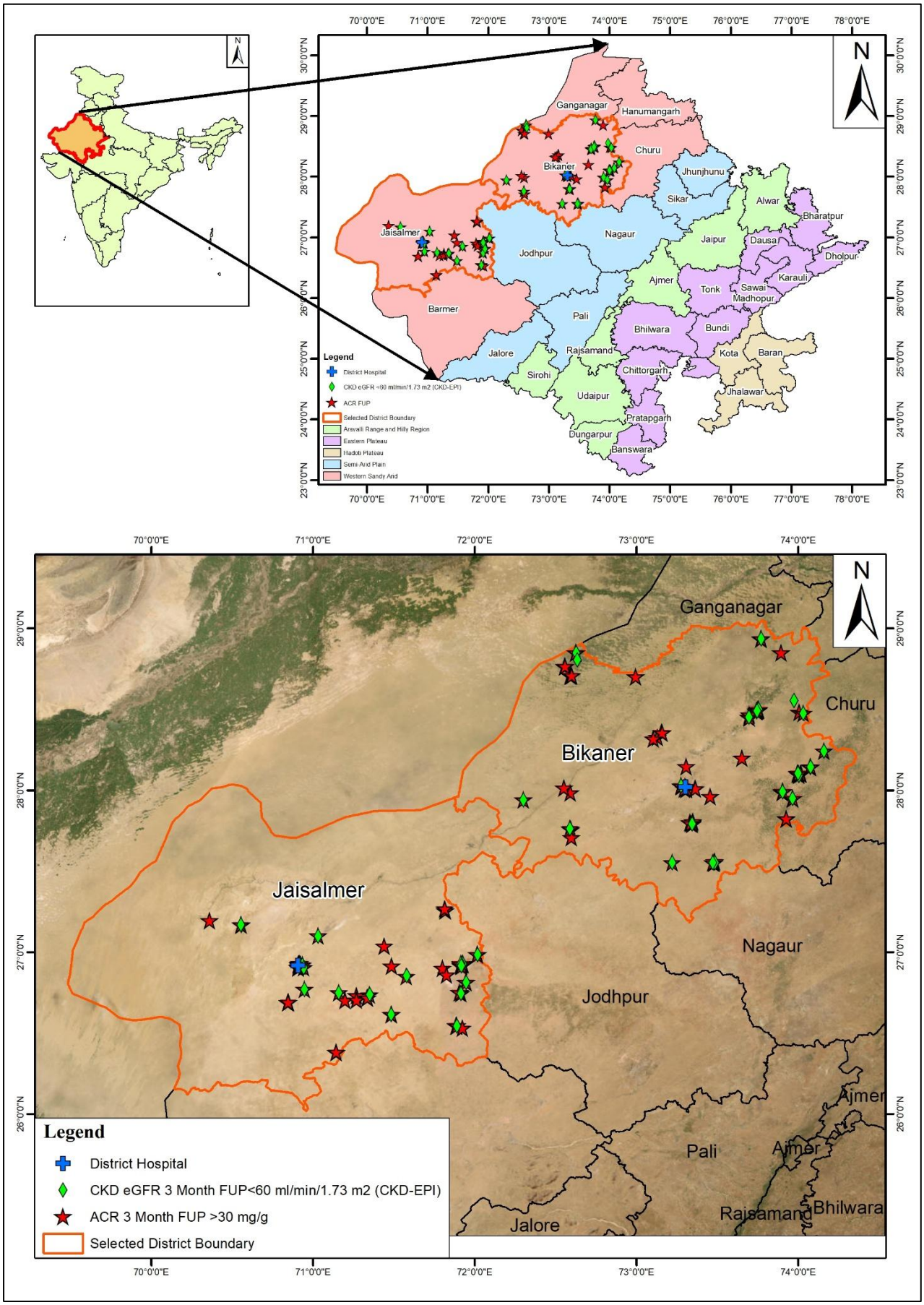


Figure 3. Map showing the spatial distribution of CKD participants at 3-month follow-up (FUP) with ACR >30 mg/g and eGFR <60 mL/min/1.73 m² (CKD-EPI)

Results

Table 1. Sociodemographic profile of the study population (N = 14,050) Complex samples analysis; estimates weighted to account for survey design. 95% CI = 95% confidence interval; SE = standard error.

Variable	Weighted n [A]	Weighted % (SE) [A]	95% CI	p value
AGE GROUP (YEARS)				
18–30	2,696	19.2% (0.6)	18.0–20.5	<0.001
31–40	2,980	21.2% (0.4)	20.4–22.0	
41–50	2,670	19.0% (0.3)	18.3–19.7	
51–60	2,328	16.6% (0.3)	15.9–17.2	
≥61	3,376	24.0% (0.7)	22.7–25.4	
GENDER				
Male	5,465	38.9% (0.8)	37.4–40.4	<0.001
Female	8,583	61.1% (0.8)	59.6–62.6	
EDUCATIONAL STATUS				
Illiterate	5,737	40.8% (1.1)	38.8–42.9	<0.001
Literate (no formal education)	1,978	14.1% (0.4)	13.3–14.9	
Primary (Class 1–5)	1,715	12.2% (0.5)	11.3–13.1	
Upper primary (Class 6–8)	1,538	10.9% (0.3)	10.4–11.5	
Secondary (Class 9–10)	1,056	7.5% (0.3)	6.9–8.2	
Senior secondary (Class 11–12)	786	5.6% (0.3)	5.0–6.2	
ITI / vocational	70	0.5% (0.1)	0.4–0.6	
Graduate	813	5.8% (0.3)	5.3–6.4	
Post-graduate	280	2.0% (0.1)	1.7–2.3	
Professional degree / diploma	56	0.4% (0.1)	0.3–0.5	
Others	21	0.1% (0.0)	0.1–0.2	
Occupation				
Professional	145	1.0% (0.1)	0.9–1.2	<0.001
Trained / semi-professional	546	3.9% (0.2)	3.5–4.3	
Skilled labour	1,838	13.1% (0.6)	12.0–14.2	

Semi-skilled labour	1,168	8.3% (0.5)	7.4–9.3	
Non-skilled labour	852	6.1% (0.4)	5.3–6.9	
Student	648	4.6% (0.3)	4.1–5.2	
Housewife	7,760	55.2% (0.7)	53.8–56.6	
Retired	206	1.5% (0.2)	1.2–1.8	
Unemployed	275	2.0% (0.2)	1.5–2.5	
Other	612	4.4% (0.3)	3.8–5.0	
Residence				
Urban	7,202	51.3% (3.2)	44.9–57.6	0.698
Rural	6,848	48.7% (3.2)	42.4–55.1	

A = Weighted percentages with 95% confidence intervals (CIs) estimated using Complex Samples analysis (CSAPLAN), incorporating stratification at the district level, clustering at the ward level (primary sampling unit), and assuming sampling with replacement.
CI = Confidence interval; % = Weighted percentage.

The study enrolled 14,050 respondents using a complex, multistage random sampling design. The majority of the sample (61.1%; 95% CI: 59.6–62.6%) was female, reflecting the household-based sampling frame. The gender distribution varied considerably across the main sample units ($p < 0.001$). Over 40% of the sample was illiterate, and 14% was literate without formal schooling. This is epidemiologically significant since inadequate health awareness is an independent risk factor for delayed CKD onset and adverse effects. Wide age distribution skewed toward older age groups, with >60 years the largest single group (24.0%) and the group with the greatest CKD risk. Urban and rural participants were nearly equally sampled (51.3% vs 48.7%), ($p = 0.698$), indicating that the complex sampling plan achieved geographic balance.

Table 2. Survey-weighted prevalence of repeat reduced eGFR among participants with repeat serum creatinine (n=632) and repeat albuminuria among participants with repeat urine ACR (n=731), estimated with complex sample analysis.

Variable [BC]	**Unweighted n** [B]	**Unweighted % of sub-sample** [B]	**Weighted N (estimate)** [A]	**Weighted % (95% CI)** [A]	**p value**
Reduced kidney function: eGFR <60 mL/min/1.73 m² (sub-sample with follow-up eGFR measured, n = 632)					
eGFR ≥60 (normal / mildly reduced)	576	91.1%	576	91.1 (87.8–93.6)	<0.001
eGFR <60 CKD criteria met	**56**	**8.9%**	**56**	**8.9 (6.4–12.2)**	
Total	632	100.0%	632	100.0	—
Albuminuria: Urine albumin-to-creatinine ratio (ACR) (sub-sample with follow-up ACR measured, n = 731)					
A1 — Normal (<30 mg/g)	517	70.7%	517	70.7 (67.3–73.9)	<0.001
A2 — Moderately increased (30–300 mg/g)	**149**	**20.4%**	**149**	**20.4 (17.7–23.3)**	
A3 — Severely increased (>300 mg/g)	**65**	**8.9%**	**65**	**8.9 (6.8–11.6)**	
A2 + A3 combined Albuminuria present	214	29.3%	214	29.3 (26.3–32.4)‡	
Total	731	100.0%	731	100.0	—

A = Weighted percentages with 95% confidence intervals (CIs) estimated using Complex Samples analysis (CSAPLAN), incorporating stratification at the district level, clustering at the ward level (primary sampling unit), and assuming sampling with replacement.

B = Unweighted n represents the observed sample size.
C = Estimated glomerular filtration rate (eGFR) calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation without race coefficient, expressed as mL/min/1.73 m².
CI = Confidence interval; % = Weighted percentage.
Urban/Rural N differs for eGFR and ACR due to availability of follow-up samples..

Using Complex Samples Crosstabs for stratification and district-level clustering, a survey-weighted estimate of the prevalence of 8.9% (95% CI: 6.4–12.2%) (p <0.001), repeated reduced eGFR (<60 mL/min/1.73 m²) among participants who underwent repeat serum creatinine testing at 3-month follow-up. Among 731 subjects with 3-month follow-up ACR data, 29.3% had clinically relevant albuminuria (ACR ≥30 mg/g; A2+A3 combined) with moderately elevated albuminuria (A2: 30–300 mg/g) was 20.4% (95% CI: 17.7–23.3%) and significantly increased albuminuria (A3: >300 mg/g) was 8.9%.

Table 3. Survey-weighted factors associated with reduced eGFR at 3-month follow-up (CKD stages G3–G5), ACR (Stage2-3) estimated using complex-samples plan gender-adjusted logistic regression with adjusted odds ratios (AORs), 95% confidence intervals (CIs), and p-values

Variable / Category	Gender-AOR	95% CI	p	Gender-AOR	95% CI	p
	Outcome 1: CKD Stages G3–G5 Survey-weighted Adjusted Odds Ratio (AOR)			**Outcome 2:** ACR Stage (2-3)		
Gender						
Male	1.564	0.889 – 2.753	0.120	1.274	0.940 – 1.727	0.117
Female (ref)	1.00	—	—	1.00	—	—
Hypertension (HTN) Duration						
Grade >11yrs	0.522	0.187 – 1.460	0.103	1.554	0.656 – 3.679	0.359
Grade 10–6yrs	1.913	0.361 – 3.437		1.979	0.771 – 5.080	
Grade 0–5yrs (ref)	1.00	—	—	1.00	—	—
Swelling (feet/ankles / wrists/face)						
Yes	1.692	1.019 – 2.810	0.042	1.233	0.883 – 1.723	0.217
No (ref)	1.00	—	—	1.00	—	—
Regular Intake of Prescription Drugs>12 months						
Yes	4.192	1.484 – 11.839	0.007	1.573	1.149 – 2.153	0.005
No (ref)	1.00	—	—	1.00	—	—
Salt Intake Excess >12 months						
Yes (group 1)	1.157	0.436 – 3.070	0.768	0.749	0.375 – 1.496	0.410
No / group 2 (ref)	1.00	—	—	1.00	—	—
Painkiller use regular >12 months						
Yes	—		—	0.765	0.423 – 1.386	0.375
No (ref)	—	—	—	1.00	—	—

Traditional medicine use >12 months						
Yes	—		—	0.962	0.466 – 1.986	0.916
No (ref)	—	—	—	1.00	—	—
Daily water intake						
Low water intake (1,2-3 L/day)	—		—	1.200	0.713 – 1.460	0.913
Adequate intake (3-4, 4 L/day)	—	—	—	1.00	—	—
Family history of kidney disease						
Yes	—		—	2.470	1.413 – 4.315	0.002
No (ref)	—	—	—	1.00	—	—

CI, confidence interval; AOR, adjusted odds ratio; ROC, receiver operating characteristic; AUC, area under the curve; VIF, variance inflation factor; MAR, missing at random; FCS, fully conditional specification; SRS, simple random sampling; GIS, geographic information system; Ref, reference category; p<0.05 indicates statistical significanc, , — = variable not retained for outcome 1 CKD Stages G3–G5 Survey-weighted Adjusted Odds Ratio (AOR) n=56

This survey utilised a complex-sample analysis using district as the stratification variable and ward/village as primary sampling unit (cluster), using sampling with replacement, to detect risk factors. Multiple imputation (Fully Conditional Specification) generated 5 imputed datasets for missing estimate data. Complex Samples Logistic Regression estimated design-adjusted correlations with reduced follow-up eGFR.

Two independent variables were significant in the survey-weighted logistic regression for impaired kidney function (eGFR <60 mL/min/1.73 m²). Regular prescription medication use for over 12 months was significant predictor (AOR 4.19; 95% CI: 1.48–11.84; p=0.007). Oedema (swelling of feet, ankles, wrists, or face) also indicated CKD (AOR 1.69; 95% CI: 1.02–2.81; p=0.042). Hypertension duration, salt consumption, and male sex had higher chances but were not statistically significant (p>0.05) in this population, albuminuria (ACR ≥30 mg/g; early kidney damage) was strongly associated with family history of renal disease (AOR 2.47; 95% CI: 1.41–4.32; p=0.002). Regular medication usage independently predicted albuminuria (AOR 1.57; 95% CI: 1.15–2.15; p=0.005). AOR forest plots generated in R (v4.5.2) refer Figure 4. Duration of hypertension, oedema, excess salt consumption, weak positive risk factor; painkiller usage, traditional medicine use, and daily water intake did not predict albuminuria (all p>0.05) in this study participant.

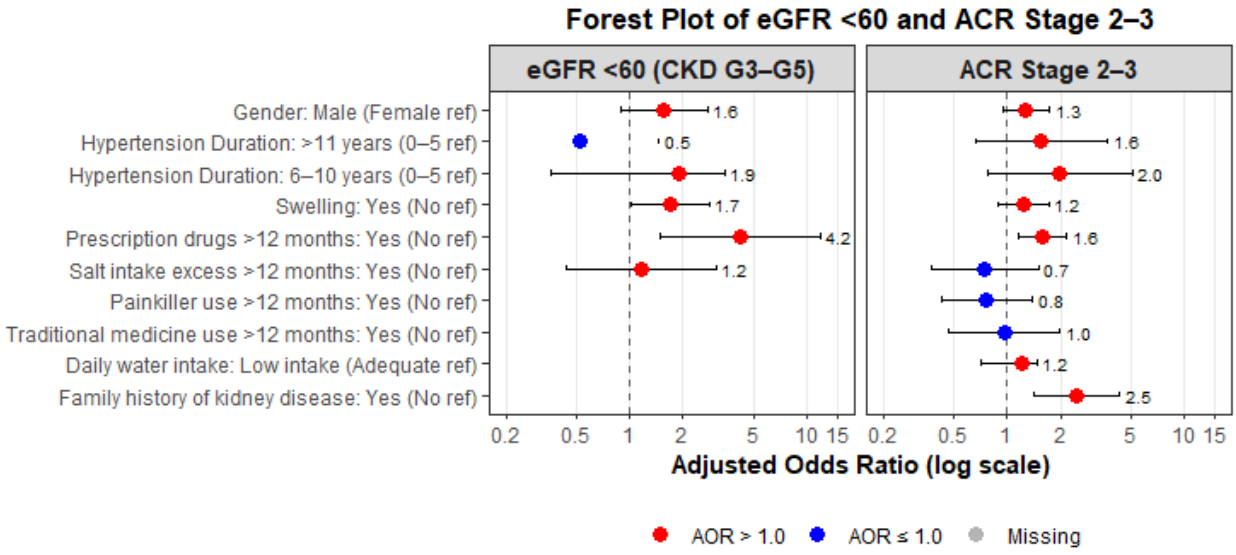


Figure 4. Forest plot of adjusted odds ratios (log scale) from a gender-adjusted survey logistic regression risk factor analysis (G3–G5 outcome), ACR Stage (2-3) using R version 4.5.2., illustrates a forest plot of gender-adjusted odds ratios (95% CI) for impaired kidney function (KDIGO G3-G5) at the 3-month follow-up.

Hotspot Results

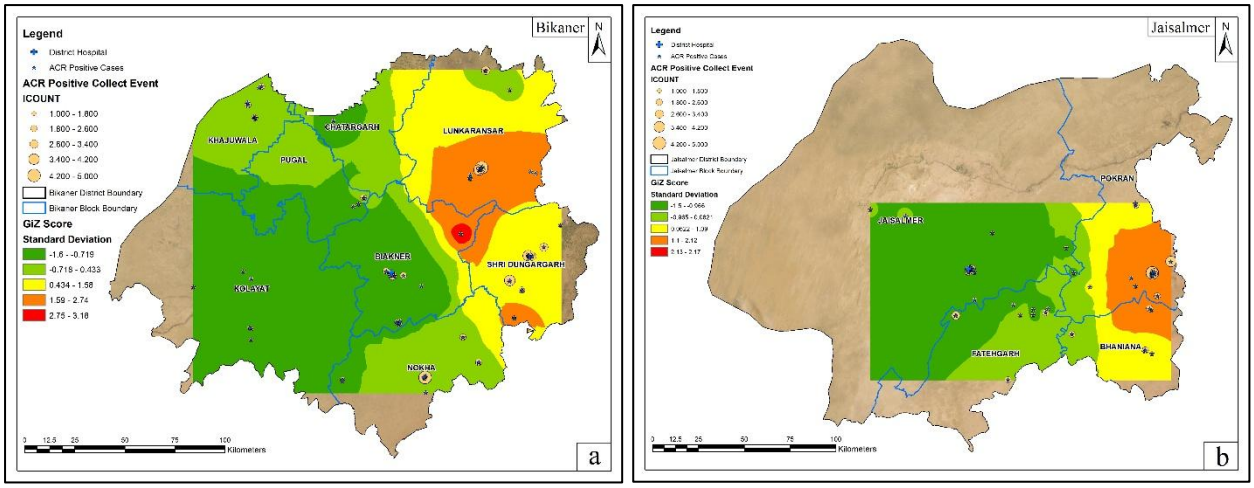


Figure 5 Abnormal ACR and Reduced Renal Function (eGFR < 60 mL/min/1.73 m²) Hotspot map of Bikaner (a) and Jaisalmer District (b)

In Bikaner district, a total of 137 cases of abnormal urinary albumin–creatinine ratio (ACR) was recorded, whereas Jaisalmer district reported 77 such cases. Notably, the burden of abnormal ACR in Bikaner was nearly twice that observed in Jaisalmer. In Bikaner district, 32 cases of reduced renal function (eGFR < 60 mL/min/1.73 m²) were identified, while Jaisalmer district reported 24 such cases. Bikaner exhibited a slightly higher burden of reduced renal function compared to Jaisalmer refer Figure 5.

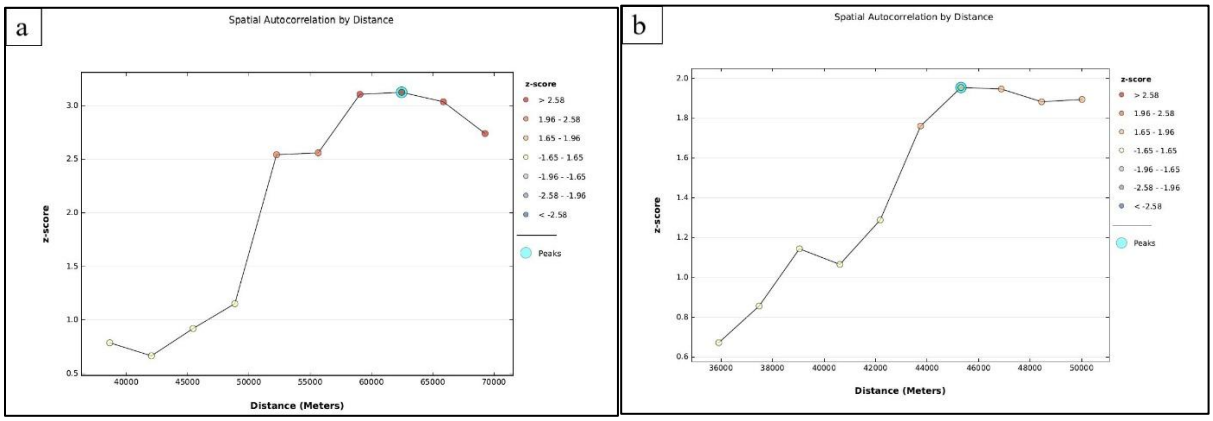


Figure 6 Abnormal ACR and Reduced Renal Function (eGFR < 60 mL/min/1.73 m²) Hotspot Peak of Bikaner (a) and Jaisalmer District (b)

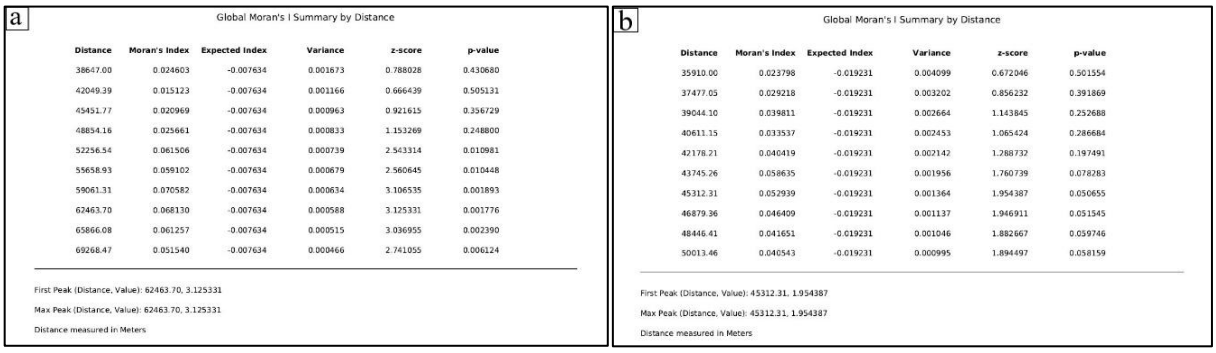


Figure 7. Spatial autocorrelation results at different distance thresholds using Moran's I index of Bikaner (a) and Jaisalmer District (b)

In Bikaner district, the spatial pattern of abnormal urinary albumin–creatinine ratio (ACR) and reduced kidney function (eGFR < 60 mL/min/1.73 m²) was examined using Global Moran's I. The highest Moran's I value in Figure 7 (0.070) indicated weak positive spatial clustering. Although this was statistically significant ($p < 0.01$), the low value suggests that the overall clustering was limited. The Getis–Ord Gi* local statistic can detect localised clustering that global autocorrelation measures can miss, making it the best tool for identifying actionable sub-district hotspots even when

district-wide clustering is limited. Global Moran's I values were modest (0.015–0.070), reflecting the predominantly dispersed distribution of cases across vast rural areas. However, specific hotspot areas were identified in the southern part of Lunkaransar block and the eastern part of Bikaner block. These hotspots showed z-scores between 1.96 and 3.28, with p-values ranging from 0.05 to 0.01, indicating 95% to 99% confidence refer Figure 6.

Similarly, in Jaisalmer district, the highest Moran's I value in Figure 7 (0.059) also showed weak positive spatial autocorrelation, while the lowest value (0.023) reflected very weak clustering. Overall, both districts demonstrated only slight spatial similarity among nearby villages, suggesting that most cases were dispersed rather than strongly clustered. In Jaisalmer, hotspot areas were identified in the southern part of Pokaran block and the northern part of Bhaniana block, with z-scores ranging from 1.96 to 2.17 and 90% to 95% statistical confidence refer Figure 6.

Discussion

The high burden of albuminuria despite preserved eGFR in this desert-dwelling cohort raises the possibility that a proportion of cases represent chronic kidney disease of unknown aetiology (CKDu) a phenotype increasingly attributed to occupational heat exposure, repetitive dehydration-mediated tubular injury, and heat-stress nephropathy. This entity, initially termed Mesoamerican Nephropathy, is now also designated CKD of nontraditional cause (CKDu) by the Pan American Health Organisation; epidemiological evidence points to repeated episodes of dehydration with electrolyte loss as the leading pathophysiological mechanism. Analogous CKDu epidemics have been documented in arid agricultural communities in Central America, Sri Lanka, and the Middle East [30][31]. Several such cases are now being reclassified as heat-stress nephropathy, an emerging global disorder driven by heat exposure, dehydration, and insufficient access to drinking water [32][33] Although causal attribution is precluded by the cross-sectional design, geographic clustering of cases in field-labour-intensive sub-districts such as Lunkaransar is consistent with an occupational aetiology. Future longitudinal research in Indian desert regions should incorporate standardised assessments of occupational heat exposure, tubular injury biomarkers (NGAL, KIM-1), and hydration status to evaluate this hypothesis formally.

Global guidelines (KDIGO, ADA) and recent studies on earlier CKD identification suggest that urine-based screening may detect "silent" renal impairment before clinical symptoms. Our finding addresses this gap and promotes a change from reactive late-stage disease treatment to preventive identification of CKD[34][35][28].

This research was a two-stage community-based screening approach, rather than a diagnostic population survey. The difficulties of venous blood collection, cold-chain transport, and participant refusal prevented serum creatinine testing for all screened participants in large-scale field surveys. Serum creatinine and repeat urine ACR were only measured in positive screeners who agreed to blood tests. To confirm CKD chronicity, albuminuria and eGFR were tested again at 3 months.

The outcome analysis included 632 of 14,050 initial screening participants who had full follow-up biochemical indicators (eGFR and ACR) at 3 months. The epidemiologically significant 29.3% burden of albuminuria (ACR 2-3 stage ≥30 mg/g), higher than the eGFR-based CKD prevalence. The albuminuria burden is three times higher than reduced eGFR at follow-up; this gap is predicted epidemiologically and clinically, as albuminuria precedes GFR reduction, a condition that may be reversible. The high prevalence of albuminuria in this arid area may be due to chronic dehydration, excessive heat stress, and a high dietary salt load, all of which indicate further study.

Strengths and Limitations

The study has several strengths. This weighted study is one of the first to estimate eGFR and ACR in rural and urban Rajasthan. The multistage probability sampling approach used for community analysis was based on KDIGO guidelines, with repeated eGFR measurements at 3-month follow-up, and creatinine and albumin-to-creatinine ratio assessments performed through an accredited laboratory to strengthen study reliability. Hotspot mapping and individual- and spatial-level epidemiology reveal clustering of CKD burden, helping policymakers identify high-burden locations and at-risk groups.

However, significant limitations were noted. Body composition could affect CKD-EPI formula accuracy in this population. After 3 months, 632 of 14,050 baseline participants completed biochemical tests. Non-follow-up might result from migration, death, or blood sample collection challenges. Migration, employment mobility, and drought limited participant availability. This research may have missed reduced eGFR in non-albuminuric patients since serum creatinine was not measured. Our estimates likely underestimate CKD burden since participants with reduced eGFR but normal ACR were not detected. Our population-level CKD prevalence estimates are restricted due to a 4.5% biochemical follow-up rate. Consider the research a screening study for high-risk individuals rather than an epidemiological survey. Household surveys may underestimate male CKD due to selection bias. However, a comprehensive approach and larger sample size provide district-level CKD estimates, suggesting future study and intervention needs.

Comparison with Previous Research

Global and Indian studies were compared for prevalence, similar risk factors, and cases, as no relevant local research had been identified. At the 3-month follow-up, the weighted prevalence of eGFR <60 mL/min/1.73 m² was 8.9% (95% CI: 6.4–12.2%), which correlates with CKD rates of 6-17.2 % in India, [36] [37][38][39][2] 7-34.3% in Asia, [40] and 10.6% worldwide [41]. A meta-analysis of 18 community-based studies (2011–2023) indicated a CKD prevalence of 13.24% (10.52–16.22%), rising to 16.38% post-2018 in rural areas[42][43]

While clinically significant weighted prevalence of (ACR ≥30 mg/g), (A2: 30–300 mg/g) 20.4% (95% CI: 17.7–23.3%), and (A3: >300 mg/g) 8.9% (95% CI: 6.8–11.6%). This aligns with prior studies showing the predictive value of albuminuria in kidney damage, particularly in preserved eGFR [44][45][46][47][48][49][50][51][52][53] thus, arid regions with changing climate, dehydration, and heat-adjusted eGFR trends necessitate longitudinal studies and community-level regular eGFR-ACR screening[54][21][55].

The gender-adjusted logistic regression identified several renal risk factors that correlated with the Global Indian CKD studies' Hypertension duration of 6-10 years revealed a positive but non-significant shift to elevated risk of reduced eGFR (AOR 1.91; 95% CI: 0.36-3.44; p=0.103) and albuminuria (AOR 1.98; 95% CI: 0.77–5.08) indicating that further research need in hotspots on the cumulative impacts of hypertension on the kidneys. Failure to address hypertension and a sedentary lifestyle cause CKD worldwide[56][57][58][59].

Prolonged prescription medication usage (>12 months) lowered eGFR (AOR 4.19; 95% CI: 1.48–11.84; p=0.007). Despite gender correction and survey weighting, four-fold odds suggest nephrotoxic drug intake as a modifiable cause of CKD in this group. In both early and established kidney damage phenotypes, the same variable independently predicted albuminuria (AOR 1.57; 95% CI: 1.15–2.15; p=0.005). Unsupervised or over-the-counter use of analgesics, antihypertensives, and traditional formulations is frequent in low-literacy, resource-scarce settings, and poor renal monitoring increases cumulative nephrotoxic risk as seen in other studies thus, prioritising community-level pharmacovigilance and over-the-counter drug regulation is a public health imperative[60][61][62], aligning with findings from toxic nephropathy studies; thus, prioritising safety assessment and regulation is crucial [63][64][65][66][67]. This correlates with the analgesic nephropathy literature of long-term painkiller usage (AOR=3.068) and CKD risk; hence, over-the-counter NSAIDs availability must be monitored[68][69][70][71].

CKD clustering, including monogenic nephropathies and shared environmental exposures within households, was the strongest predictor of albuminuria in families with a history of kidney disease (AOR 2.47; 95% CI: 1.41–4.32; p=0.002)[72][73][74][75][76].

Podocyte destruction and glomerular permeability abnormalities precede genetic susceptibility and GFR decline. This supports targeted ACR screening of first-degree relatives of patients with renal disease as a cost-effective early-detection strategy.

Peripheral oedema was a significant clinical sign for lower eGFR detection in this community (AOR 1.69; 95% CI: 1.02–2.81; p=0.042) than ACR stage 2–3 (AOR 1.23; 0.88–1.72; p=0.217). In this cross-sectional study, oedema may reflect volume overload or nephrotic syndrome rather than early glomerular damage. In resource-limited dry areas, it may assist community triage as a visible sign for CKD[77][78][79][80][81][82].

High salt and low water intake were risk with reduced eGFR (AOR 1.16; 95% CI: 0.44–3.07; p=0.768 and 1.20), non-significantly similar to previous studies [83][84][85][86][87][88][89][90][91][92][93]. Due to a lower response rate, pain medication and traditional medicine usage were not statistically significant. These risk factors were identified in previous studies, warranting further investigation.

Conclusions

This research revealed a significant burden of early kidney disease that might be prevented in two dry Rajasthan districts: 29.3% of adults had chronic albuminuria in diagnostic tests. Biochemical follow-up shows 8.9% of screen-positive participants reduced eGFR. In extreme-climate LMICs, spot urine ACR screening may detect silent kidney disease before eGFR fall and is affordable. Geospatial hotspots were in Bikaner's Lunkaransar and Jaisalmer's Pokaran blocks. The main versatile and non-modifiable risk factors include long-term prescription drug usage and family history of renal failure. Climate change causes heat stress and water scarcity worldwide, so prospective surveillance integrating occupational heat exposure indicators with renal biomarkers such as NGAL, KIM-1, and serum uric acid is essential to assess the emerging impact of heat-stress nephropathy on the CKD burden in desert populations. Urgent and practical policy needs consist of ACR screening in primary care, regulation of over-the-counter nephrotoxic medications, and family-based CKD screening.

Author contributions

SY, PA, DS, TA, AM, and GT conceived and designed this study. The authors conducted field implementation and data collection together. PA and DS did the statistical analyses. The manuscript was first drafted by PA. SY and DS did critical

revision. TA, AM and GT reviewed and approved the final manuscript. All authors had full access to the study data and accept responsibility for the integrity of the data and the accuracy of the analysis. SY is the guarantor.

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Competing interests

All authors have completed the ICMJE disclosure form and declare: support from **ICMR–NIIRNCD** for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval

This study was approved by the Institutional Ethics Committee of the **ICMR–NIIRNCD, Jodhpur (IEC number: IEC/NIIRNCD/03/2020)** consistent with ICMJE guidelines**.** Written informed consent was obtained from all participants prior to enrolment.

Data availability statement

This study's datasets aren't publicly open due to confidentiality of participants and ICMR exchange of information terms, however anonymous compiled data may be provided upon reasonable request to author and institutional approval.

Transparency statement

The guarantor affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that all discrepancies from the study as planned have been disclosed.

PPI

The research involved a community survey in a resource-limited area, therefore patients or the public had no role in its design, conduct, or disclosure.

Dissemination statement

Study findings communicated to relevant government bodies through technical reports and policy briefs, and disseminated to the general population via digital media platforms, our institutional website, and mass media.

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Reference

[1] P. B. Mark *et al.*, "Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023," *The Lancet*, vol. 406, no. 10518, pp. 2461–2482, Nov. 2025, doi: 10.1016/S0140-6736(25)01853-7.

[2] R. Talukdar *et al.*, "Chronic Kidney Disease Prevalence in India: A Systematic Review and Meta-Analysis From Community-Based Representative Evidence Between 2011 to 2023," *Nephrology*, vol. 30, no. 1, Jan. 2025, doi: 10.1111/nep.14420.

[3] H. S. Meshram, S. Chauhan, and S. Puri, "Burden of Chronic Kidney Disease in India: Past, Present, and Future Projections to 2040 from the Global Burden of Disease 2021 Study," Nov. 01, 2025. doi: 10.21203/rs.3.rs-7858189/v1.

[4] J. I. Park, H. Baek, and H. H. Jung, "Prevalence of Chronic Kidney Disease in Korea: the Korean National Health and Nutritional Examination Survey 2011–2013," *J. Korean Med. Sci.*, vol. 31, no. 6, p. 915, 2016, doi: 10.3346/jkms.2016.31.6.915.

[5] T. Tanaka *et al.*, "Population characteristics and diagnosis rate of chronic kidney disease by eGFR and proteinuria in Japanese clinical practice: an observational database study," *Sci. Rep.*, vol. 14, no. 1, p. 5172, Mar. 2024, doi: 10.1038/s41598-024-55827-7.

[6] S. C. W. Ho, A. T. W. Ang, and A. R. K. Tng, "Stemming the tide of chronic kidney disease: A focus on primary care prevention," *Ann. Acad. Med. Singap.*, vol. 53, no. 10, pp. 591–593, Oct. 2024, doi: 10.47102/annals-acadmedsg.2024291.

[7] A. K. Bello *et al.*, "An update on the global disparities in kidney disease burden and care across world countries and regions," *Lancet Glob. Health*, vol. 12, no. 3, pp. e382–e395, Mar. 2024, doi: 10.1016/S2214-109X(23)00570-3.

[8] V. Vennu, T. A. Abdulrahman, and S. M. Bindawas, "The Prevalence of Overweight, Obesity, Hypertension, and Diabetes in India: Analysis of the 2015–2016 National Family Health Survey," *Int. J. Environ. Res. Public Health*, vol. 16, no. 20, p. 3987, Oct. 2019, doi: 10.3390/ijerph16203987.

[9] S. Ramakrishnan *et al.*, "Prevalence of hypertension among Indian adults: Results from the great India blood pressure survey," *Indian Heart J.*, vol. 71, no. 4, pp. 309–313, Jul. 2019, doi: 10.1016/j.ihj.2019.09.012.

[10] S. K. Agarwal, "Chronic kidney disease and its prevention in India," *Kidney Int.*, vol. 68, pp. S41–S45, Sep. 2005, doi: 10.1111/j.1523-1755.2005.09808.x.

[11] M. M. Rajapurkar *et al.*, "What do we know about chronic kidney disease in India: first report of the Indian CKD registry," *BMC Nephrol.*, vol. 13, no. 1, p. 10, Dec. 2012, doi: 10.1186/1471-2369-13-10.

[12] L. Wang *et al.*, "Global burden of chronic kidney disease and risk factors, 1990–2021: an update from the global burden of disease study 2021," *Front. Public Health*, vol. 13, Jul. 2025, doi: 10.3389/fpubh.2025.1542329.

[13] K. Nag, N. Karmakar, and A. Datta, "Importance of Geriatric Health Care in India during Covid 19 Pandemic," in *Update in Geriatrics*, IntechOpen, 2021. doi: 10.5772/intechopen.95500.

[14] National Disaster Management Authority Government of India, "National Disaster Management Authority," 2019. Accessed: Jan. 13, 2026. [Online]. Available: https://ndma.gov.in/sites/default/files/PDF/ndmp-2019.pdf

[15] N. B. Sastry, M. Vempadapu, and S. Sivananjiah, "Toward adapting the UN's healthy aging agenda for India: tailoring to unique historical context and traditions," *Front. Public Health*, vol. 11, Jan. 2024, doi: 10.3389/fpubh.2023.1346962.

[16] T. V. Sekher and S. Gupta, "Social Security Schemes for the Elderly in India," in *India Population Report*, Cambridge University Press, 2023, pp. 199–245. doi: 10.1017/9781009318846.008.

[17] U. Anandh, P. Meena, S. Karam, and V. Luyckx, "Social, political and legal determinants of kidney health: Perspectives from lower- and middle-income countries with a focus on India," *Frontiers in Nephrology*, vol. 2, Oct. 2022, doi: 10.3389/fneph.2022.1024667.

[18] P. , M. E. , & J. V. Jeemon, "Non-communicable diseases: A modern condition.," *nature india*, 2019, doi: https://doi.org/10.1038/nindia.2019.60.

[19] B. P. BEHERA, "COMPARATIVE STUDY OF LIPID PROFILE IN PATIENTS OF NON-DIABETIC CHRONIC KIDNEY DISEASE IN RELATION TO ITS SEVERITY," *Int. J. Pharm. Pharm. Sci.*, pp. 142–148, Jun. 2020, doi: 10.22159/ijpps.2020v12i8.38221.

[20] T. Hyodo *et al.*, "The status of dialysis patients in Asian countries under the coronavirus disease 2019 (COVID-19) disaster as of December 2019–June 2023: India," *Ren. Replace. Ther.*, vol. 10, no. 1, p. 64, Nov. 2024, doi: 10.1186/s41100-024-00583-7.

[21] R. Jhorawat *et al.*, "Demographic profile, spectrum, awareness, and cost of renal replacement therapy of chronic kidney disease patients in a public tertiary care center in Rajasthan, India," *Indian J. Med. Sci.*, vol. 76, p. 99, Feb. 2024, doi: 10.25259/IJMS_240_2023.

[22] T. H. Jafar *et al.*, "Access to CKD Care in Rural Communities of India: a qualitative study exploring the barriers and potential facilitators," *BMC Nephrol.*, vol. 21, no. 1, p. 26, Dec. 2020, doi: 10.1186/s12882-020-1702-6.

[23] S. Anand *et al.*, "Prevalence of chronic kidney disease in two major Indian cities and projections for associated cardiovascular disease," *Kidney Int.*, vol. 88, no. 1, pp. 178–185, Jul. 2015, doi: 10.1038/ki.2015.58.

[24] S. K. Ahmed, "How to choose a sampling technique and determine sample size for research: A simplified guide for researchers," *Oral Oncology Reports*, vol. 12, p. 100662, Dec. 2024, doi: 10.1016/j.oor.2024.100662.

[25] M. A. Bujang, "A Step-by-Step Process on Sample Size Determination for Medical Research," *Malaysian Journal of Medical Sciences*, vol. 28, no. 2, pp. 15–27, Apr. 2021, doi: 10.21315/mjms2021.28.2.2.

[26] National Kidney Foundation, "Urine albumin-to-creatinine ratio (ACR) testing," 2026. Accessed: Apr. 21, 2026. [Online]. Available: https://www.kidney.org/kidney-health/kidneydisease/siemens_hcp_acr

[27] S. R. , & A. N. R. Vaidya, *Chronic kidney disease.* StatPearls Publishing, 2024. Accessed: Jan. 13, 2026. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK535404/

[28] KDIGO 2024 Clinical practice guideline for the evaluation and management of chronic kidney disease, "Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group.," 2024.

[29] ESRI, "How Hot Spot Analysis (Getis-Ord Gi) works." Accessed: Feb. 20, 2026. [Online]. Available: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-how-hot-spot-analysis-getis-ord-gi-spatial-stati.htm

[30] R. Correa-Rotter, C. Wesseling, and R. J. Johnson, "CKD of Unknown Origin in Central America: The Case for a Mesoamerican Nephropathy," *American Journal of Kidney Diseases*, vol. 63, no. 3, pp. 506–520, Mar. 2014, doi: 10.1053/j.ajkd.2013.10.062.

[31] M. F. Valdivia Mazeyra, P. Muñoz Ramos, R. Serrano, M. Alonso Riaño, Y. Gil Giraldo, and B. Quiroga, "Nefropatía endémica mesoamericana: una enfermedad renal crónica de origen no tan desconocido," *Nefrología*, vol. 41, no. 6, pp. 612–619, Nov. 2021, doi: 10.1016/j.nefro.2021.03.005.

[32] G. Santra, "Heat Stress Nephropathy: An Emerging Epidemic of Global Warming," *Journal of The Association of Physicians of India*, vol. 72, no. 10, pp. 110–110, Oct. 2024, doi: 10.59556/japi.72.0686.

[33] C. Elinder, "Heat-induced kidney disease: Understanding the impact," *J. Intern. Med.*, vol. 297, no. 1, pp. 101–112, Jan. 2025, doi: 10.1111/joim.20037.

[34] Centers for Disease Control and Prevention, "Screening for chronic kidney disease," 2025, Accessed: Apr. 21, 2026. [Online]. Available: https://www.cdc.gov/kidney-disease/hcp/ckd-screening/index.html

[35] AJMC Contributor, "Global CKD burden nearly doubles since 1990, reaching 788 million adults worldwide.," 2025. Accessed: Apr. 21, 2026. [Online]. Available: https://www.ajmc.com/view/global-ckd-burden-nearly-doubles-since-1990-reaching-788-million-adults-worldwide

[36] M. Hasan, I. Sutradhar, R. Das Gupta, and M. Sarker, "Prevalence of chronic kidney disease in South Asia: a systematic review," *BMC Nephrol.*, vol. 19, no. 1, p. 291, Dec. 2018, doi: 10.1186/s12882-018-1072-5.

[37] V. Kumar *et al.*, "The Indian Chronic Kidney Disease (ICKD) study: baseline characteristics," *Clin. Kidney J.*, vol. 15, no. 1, pp. 60–69, Jan. 2022, doi: 10.1093/ckj/sfab149.

[38] C. O'Callaghan-Gordo *et al.*, "Prevalence of and risk factors for chronic kidney disease of unknown aetiology in India: secondary data analysis of three population-based cross-sectional studies," *BMJ Open*, vol. 9, no. 3, p. e023353, Mar. 2019, doi: 10.1136/bmjopen-2018-023353.

[39] A. K. Singh *et al.*, "Epidemiology and risk factors of chronic kidney disease in India – results from the SEEK (Screening and Early Evaluation of Kidney Disease) study," *BMC Nephrol.*, vol. 14, no. 1, p. 114, Dec. 2013, doi: 10.1186/1471-2369-14-114.

[40] T. Liyanage *et al.*, "Prevalence of chronic kidney disease in Asia: a systematic review and analysis," *BMJ Glob. Health*, vol. 7, no. 1, p. e007525, Jan. 2022, doi: 10.1136/bmjgh-2021-007525.

[41] N. R. Hill *et al.*, “Global Prevalence of Chronic Kidney Disease – A Systematic Review and Meta-Analysis,” *PLoS One*, vol. 11, no. 7, p. e0158765, Jul. 2016, doi: 10.1371/journal.pone.0158765.

[42] R. Talukdar *et al.*, “Chronic Kidney Disease Prevalence in India: A Systematic Review and Meta-Analysis From Community-Based Representative Evidence Between 2011 to 2023,” *Nephrology*, vol. 30, no. 1, Jan. 2025, doi: 10.1111/nep.14420.

[43] R. Jhorawat, P. Beniwal, A. Mittal, S. Godhara, and M. Chaturvedy, “Nephrology in Rajasthan,” *Indian J. Nephrol.*, vol. 0, p. 1, Oct. 2024, doi: 10.25259/IJN_339_2024.

[44] T. Cheng, X. Wang, Y. Han, J. Hao, H. Hu, and L. Hao, “The level of serum albumin is associated with renal prognosis and renal function decline in patients with chronic kidney disease,” *BMC Nephrol.*, vol. 24, no. 1, p. 57, Mar. 2023, doi: 10.1186/s12882-023-03110-8.

[45] P. Dash *et al.*, “Serum Biochemical Changes among Chronic Kidney Disease Patients in a Rural Cohort of Odisha, India: A Cross-sectional Study,” *JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH*, 2023, doi: 10.7860/JCDR/2023/57859.18829.

[46] V. Lezaic, “Albuminuria as a Biomarker of the Renal Disease,” in *Biomarkers in Kidney Disease*, Dordrecht: Springer Netherlands, 2015, pp. 1–18. doi: 10.1007/978-94-007-7743-9_31-1.

[47] D. Liu *et al.*, “Association of albumin, globulin and albumin/globulin ratio with renal injury in type 2 diabetic nephropathy patients,” *Int. J. Diabetes Dev. Ctries.*, vol. 44, no. 1, pp. 99–105, Mar. 2024, doi: 10.1007/s13410-023-01211-6.

[48] Y. Lu *et al.*, “Risk factor mining and prediction of urine protein progression in chronic kidney disease: a machine learning- based study,” *BMC Med. Inform. Decis. Mak.*, vol. 23, no. 1, p. 173, Aug. 2023, doi: 10.1186/s12911-023-02269-2.

[49] K. Manna, “Evaluation of Urinary Albumin Level in Newly Diagnosed Hypertensive Patients for Early Digonosis of Renal Diseases in Rural Area of Rajasthan,” *journal of medical science and clinical research*, vol. 5, no. 9, Sep. 2017, doi: 10.18535/jmscr/v5i9.47.

[50] B. A. Molitoris, R. M. Sandoval, S. P. S. Yadav, and M. C. Wagner, “Albumin uptake and processing by the proximal tubule: physiological, pathological, and therapeutic implications,” *Physiol. Rev.*, vol. 102, no. 4, pp. 1625–1667, Oct. 2022, doi: 10.1152/physrev.00014.2021.

[51] P. C. Pafundi *et al.*, “Role of Albuminuria in Detecting Cardio-Renal Risk and Outcome in Diabetic Subjects,” *Diagnostics*, vol. 11, no. 2, p. 290, Feb. 2021, doi: 10.3390/diagnostics11020290.

[52] G. Romero-González *et al.*, “Albuminuria, Forgotten No More: Underlining the Emerging Role in CardioRenal Crosstalk,” *J. Clin. Med.*, vol. 13, no. 3, p. 777, Jan. 2024, doi: 10.3390/jcm13030777.

[53] R. M. M. M. H. K. K. S. R. S. Mitharwal, “A prospective study of acute kidney injury in outborn neonates admitted in a tertiary care center in western rajasthan.,” *Asian Journal of Pediatric Nephrology*, vol. 3, no. 2, pp. 58–63, 2020.

[54] M. Goyal, Y. Yadav, L. Sharma, and K. Yadav, “A study of correlation between hepatic and renal dysfunction in malarial patients in Rajasthan, India,” *Int. J. Contemp. Pediatrics*, pp. 1278–1283, 2016, doi: 10.18203/2349-3291.ijcp20163660.

[55] D. , G. M. , M. S. , & S. P. Yadav, “Reference Interval for Renal Profile parameters in North Indian Population from Rajasthan,” *International Journal of Advances in Scientific Research*, vol. 1, pp. 233–238, 2015.

[56] Y. J. Anupama, S. N. Hegde, G. Uma, and M. Patil, “Hypertension is an important risk determinant for chronic kidney disease: results from a cross-sectional, observational study from a rural population in South India,” *J. Hum. Hypertens.*, vol. 31, no. 5, pp. 327–332, May 2017, doi: 10.1038/jhh.2016.81.

[57] A. Gupta, S. P. Nagaraju, M. V. Bhojaraja, S. M. Swaminathan, and P. B. Mohan, “Hypertension in Chronic Kidney Disease: An Update on Diagnosis and Management,” *South. Med. J.*, vol. 116, no. 2, pp. 237–244, Feb. 2023, doi: 10.14423/SMJ.0000000000001516.

[58] Y. Liu *et al.*, “Global incidence and death estimates of chronic kidney disease due to hypertension from 1990 to 2019, an ecological analysis of the global burden of diseases 2019 study,” *BMC Nephrol.*, vol. 24, no. 1, p. 352, Nov. 2023, doi: 10.1186/s12882-023-03391-z.

[59] D. Nagata and E. Hishida, “Elucidating the complex interplay between chronic kidney disease and hypertension,” *Hypertension Research*, vol. 47, no. 12, pp. 3409–3422, Dec. 2024, doi: 10.1038/s41440-024-01937-8.

[60] T. Eichhorn, H. J. Greten, and T. Efferth, “Self-medication with nutritional supplements and herbal over-thecounter products,” *Nat. Prod. Bioprospect.*, vol. 1, no. 2, pp. 62–70, Oct. 2011, doi: 10.1007/s13659-011-0029-1.

[61] Y. Kondo *et al.*, “Knowledge and awareness of nonpharmacist salespersons regarding over-the-counter drug use in patients with chronic kidney disease in Japan,” *PLoS One*, vol. 14, no. 3, p. e0213763, Mar. 2019, doi: 10.1371/journal.pone.0213763.

[62] M. Mulka-Gierek, N. Krata, B. Foroncewicz, L. Pączek, and K. Mucha, “The Different Patterns of Over-the-Counter Nonsteroidal Anti-Inflammatory Drugs or Analgesics Use in Patients with Chronic Kidney Disease and the General Population,” *Healthcare*, vol. 10, no. 10, p. 2035, Oct. 2022, doi: 10.3390/healthcare10102035.

[63] M. M. AlAhmad, Y. Al Namer, S. Palaian, and M. J. Alomar, “A nephrological perspective of herbal remedies on the progression of chronic kidney disease: A systematic review,” *J. Appl. Pharm. Sci.*, 2024, doi: 10.7324/JAPS.2024.148539.

[64] M. S. Figueredo, F. M. Schroeder, R. V. Soares, and C. M. de B. Helou, “Adverse effects of medicinal herbs on the human kidney,” *Rev. Med. (Rio. J).*, vol. 97, no. 1, pp. 51–58, Mar. 2018, doi: 10.11606/issn.1679-9836.v97i1p51-58.

[65] V. JHA, “Herbal medicines and chronic kidney disease,” *Nephrology*, vol. 15, no. s2, pp. 10–17, Jun. 2010, doi: 10.1111/j.1440-1797.2010.01305.x.

[66] A. A. Maiyegun, M. D. Akangoziri, B. A. Grema, Y. B. Mutalub, and F. B. Ibrahim, “Renal Profile of Herbal Medicine Users versus Non-users: an Exploratory Cross-sectional Study in a Family Medicine Clinic in Nigeria,” Feb. 03, 2024. doi: 10.1101/2024.01.30.24301915.

[67] N. Touiti, T. S. Houssaini, and S. Achour, “Overview on pharmacovigilance of nephrotoxic herbal medicines used worldwide,” *Clinical Phytoscience*, vol. 7, no. 1, p. 9, Dec. 2021, doi: 10.1186/s40816-021-00248-6.

[68] S. Harirforoosh, W. Asghar, and F. Jamali, “Adverse Effects of Nonsteroidal Antiinflammatory Drugs: An Update of Gastrointestinal, Cardiovascular and Renal Complications,” *Journal of Pharmacy & Pharmaceutical Sciences*, vol. 16, no. 5, p. 821, Jan. 2014, doi: 10.18433/J3VW2F.

[69] K. Hayashi, K. Miki, H. Kajiyama, T. Ikemoto, and M. Yukioka, “Impact of Non-steroidal Anti-inflammatory Drug Administration for 12 Months on Renal Function,” *Frontiers in Pain Research*, vol. 2, May 2021, doi: 10.3389/fpain.2021.644391.

[70] T. Katsuno *et al.*, “Burden of Renal Events Associated with Nonsteroidal Anti-inflammatory Drugs in Patients with Osteoarthritis and Chronic Low Back Pain: A Retrospective Database Study,” *Pain Ther.*, vol. 10, no. 1, pp. 443–455, Jun. 2021, doi: 10.1007/s40122-020-00233-w.

[71] J. M. LaForge *et al.*, “Non-steroidal Anti-inflammatory Drugs: Clinical Implications, Renal Impairment Risks, and AKI,” *Adv. Ther.*, vol. 40, no. 5, pp. 2082–2096, May 2023, doi: 10.1007/s12325-023-02481-6.

[72] R. Abbas, T. Elahi, S. Manan, and Suraj, “The prevalence and risk factors of kidney disease in first degree relatives of patients with ESRD treatment – single center study,” *J. Pak. Med. Assoc.*, vol. 73, no. 12, pp. 2397–2402, Nov. 2023, doi: 10.47391/JPMA.10927.

[73] J. L. Bragg-Gresham, S. Annadanam, B. Gillespie, Y. Li, N. R. Powe, and R. Saran, “Using Risk Assessment to Improve Screening for Albuminuria among US Adults without Diabetes,” *J. Gen. Intern. Med.*, vol. 40, no. 13, pp. 3159–3169, Sep. 2025, doi: 10.1007/s11606-024-09185-9.

[74] J. Jefferis *et al.*, “Monogenic and polygenic concepts in chronic kidney disease (CKD),” *J. Nephrol.*, vol. 37, no. 1, pp. 7–21, Jan. 2024, doi: 10.1007/s40620-023-01804-8.

[75] S. S. A. Khamis, R. H. El Edel, A. M. Zahran, M. A. Ibrahim, and K. M. A. El Zorkany, “Prevalence of Chronic Kidney Disease in Relatives of Chronic Hemodialysis Patients,” *Open J. Nephrol.*, vol. 10, no. 04, pp. 274–281, 2020, doi: 10.4236/ojneph.2020.104027.

[76] J. Y. Kim, S. Chun, H. Lim, and T. I. Chang, “Association between familial aggregation of chronic kidney disease and its incidence and progression,” *Sci. Rep.*, vol. 13, no. 1, p. 5131, Mar. 2023, doi: 10.1038/s41598-023-32362-5.

[77] I. Bobkova, N. Chebotareva, L. Kozlovskaya, and E. Shilov, “Edema in Renal Diseases – Current View on Pathogenesis,” *Nephrology @ Point of Care*, vol. 2, no. 1, Jan. 2016, doi: 10.5301/pocj.5000204.

[78] D. Ellis, “Pathophysiology, Evaluation, and Management of Edema in Childhood Nephrotic Syndrome,” *Front. Pediatr.*, vol. 3, Jan. 2016, doi: 10.3389/fped.2015.00111.

[79] R. P. Hull and D. J. A. Goldsmith, “Nephrotic syndrome in adults,” *BMJ*, vol. 336, no. 7654, pp. 1185–1189, May 2008, doi: 10.1136/bmj.39576.709711.80.

[80] E. C. Siddall and J. Radhakrishnan, “The pathophysiology of edema formation in the nephrotic syndrome,” *Kidney Int.*, vol. 82, no. 6, pp. 635–642, Sep. 2012, doi: 10.1038/ki.2012.180.

[81] R. Takase *et al.*, “The Relationship Between Edema and Body Functions in Patients With Chronic Kidney Disease: A Preliminary Study,” *Cureus*, Jul. 2022, doi: 10.7759/cureus.27118.

[82] U. PK, A. AO, T. MU, A. OF, N. CI, and O. TA, “Kidney Volume in Kidney Function Assessment: Determinants and Clinical Correlates in Systemic Hypertension and Chronic Kidney Disease in Southwestern, Nigeria,” *Open J. Nephrol.*, vol. 10, no. 04, pp. 298–310, 2020, doi: 10.4236/ojneph.2020.104030.

[83] S. Borrelli *et al.*, “Sodium Intake and Chronic Kidney Disease,” *Int. J. Mol. Sci.*, vol. 21, no. 13, p. 4744, Jul. 2020, doi: 10.3390/ijms21134744.

[84] N. Gong *et al.*, “High-Salt Diet Accelerated the Decline of Residual Renal Function in Patients With Peritoneal Dialysis,” *Front. Med. (Lausanne).*, vol. 8, Sep. 2021, doi: 10.3389/fmed.2021.728009.

[85] J. E. Hall, “Renal Dysfunction, Rather Than Nonrenal Vascular Dysfunction, Mediates Salt-Induced Hypertension,” *Circulation*, vol. 133, no. 9, pp. 894–906, Mar. 2016, doi: 10.1161/CIRCULATIONAHA.115.018526.

[86] C. Johnson *et al.*, “Mean Dietary Salt Intake in Urban and Rural Areas in India: A Population Survey of 1395 Persons,” *J. Am. Heart Assoc.*, vol. 6, no. 1, Jan. 2017, doi: 10.1161/JAHA.116.004547.

[87] G. Kimura, Y. Dohi, and M. Fukuda, “Salt sensitivity and circadian rhythm of blood pressure: the keys to connect CKD with cardiovasucular events,” *Hypertension Research*, vol. 33, no. 6, pp. 515–520, Jun. 2010, doi: 10.1038/hr.2010.47.

[88] R. Lesmana *et al.*, “Effect of Dietary Sodium on α, β, and γ Epithelial Sodium Channel (ENaC) Gene Expression in Kidney Tubules of Wistar Rats,” *Majalah Kedokteran Bandung*, vol. 51, no. 4, pp. 240–245, Dec. 2019, doi: 10.15395/mkb.v51n4.1764.

[89] Y. Ohta, T. Tsuchihashi, K. Kiyohara, and H. Oniki, “High salt intake promotes a decline in renal function in hypertensive patients: a 10-year observational study,” *Hypertension Research*, vol. 36, no. 2, pp. 172–176, Feb. 2013, doi: 10.1038/hr.2012.155.

[90] N. Spahia, M. Rroji, A. Idrizi, G. Spasovski, and M. Barbullushi, “Sodium and water dynamics in the progression of chronic kidney disease: mechanisms and clinical significance,” *Int. Urol. Nephrol.*, vol. 56, no. 6, pp. 1953–1963, Jan. 2024, doi: 10.1007/s11255-023-03903-8.

[91] I. Tudorancea, T. E. Lohmeier, B. T. Alexander, D. Pieptu, D. N. Serban, and R. Iliescu, “Reduced Renal Mass, Salt-Sensitive Hypertension Is Resistant to Renal Denervation,” *Front. Physiol.*, vol. 9, Apr. 2018, doi: 10.3389/fphys.2018.00455.

[92] A. Verma and C. Popa, “The Interplay Between Dietary Sodium Intake and Proteinuria in CKD,” *Kidney Int. Rep.*, vol. 8, no. 6, pp. 1133–1136, Jun. 2023, doi: 10.1016/j.ekir.2023.04.030.

[93] J. A. Wright and K. L. Cavanaugh, “Dietary Sodium in Chronic Kidney Disease: A Comprehensive Approach,” *Semin. Dial.*, vol. 23, no. 4, pp. 415–421, Jun. 2010, doi: 10.1111/j.1525-139X.2010.00752.x.

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