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Research Article

Probable Chronic Kidney Disease and Its Association with Extreme-Heat Exposure in Selected Local Government Areas of Yobe State, Northeastern Nigeria: A Community-Based Cross-Sectional Study with Hospital-Record Analysis

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Background: Chronic kidney disease (CKD) of unknown cause has been reported in northern Yobe State, Nigeria, where extreme heat is common, but its relationship with climate has not been tested. Repeated heat stress and dehydration have been proposed as contributing mechanisms, and community-based data from sub-Saharan Africa remain scarce.

Methods: We conducted a community-based cross-sectional study involving 1,200 adults recruited through cluster sampling from 24 communities across four local government areas (LGAs) in Yobe State: Bade, Nguru, Jakusko and Damaturu. Kidney abnormalities were assessed using estimated glomerular filtration rate (eGFR), calculated with the 2021 CKD-EPI equation, and urinary albumin-to-creatinine ratio (ACR). Participants were classified as having CKD-range abnormalities if eGFR was below 60 mL/min/1.73 m² and/or ACR was ≥30 mg/g on a single measurement. However, chronicity of at least three months was not established. Associations between individual outcomes and community-level extreme-heat exposure were assessed using generalized estimating equations (GEE), while annual LGA-level hospital presentations from 2014 to 2023 were examined using Poisson regression.

Results: Overall, 166 of the 1,200 participants (13.8%; 95% CI: 12.0–15.9) had kidney abnormalities meeting the study's CKD criteria based on a single measurement, without confirmation of chronicity. The prevalence was highest in Bade (18.3%) and lowest in Damaturu (8.3%). Each additional 10 extreme-heat days per year was associated with 33% higher odds of CKD-range abnormalities (adjusted OR: 1.33; 95% CI: 1.14–1.55).

Conclusion: Greater exposure to extreme-heat days was associated with higher odds of kidney abnormalities meeting the study's CKD criteria in the selected LGAs of Yobe State. However, the cross-sectional design and absence of repeat kidney-function measurements limit the interpretation of these findings. Longitudinal studies incorporating repeated kidney-function assessments and individual-level heat-exposure measurements are required to establish temporality and investigate potential causal relationships.

Keywords: *chronic kidney disease, climate change, extreme heat, Yobe State, Nigeria, heat stress nephropathy*

Introduction

Chronic kidney disease (CKD) affects roughly one in ten people worldwide and is a growing cause of premature death (GBD Chronic Kidney Disease Collaboration, 2020). Pooled estimates for sub-Saharan Africa and the world are both near 13–14% (Hill et al., 2016; Stanifer et al., 2014), but the burden is not evenly spread. A systematic review of African studies from 2000 to 2016 estimated a general-population prevalence of 15.8% for stages 1–5 and 4.6% for stages 3–5, with higher values in sub-Saharan Africa (17.7%) than in North Africa (6.1%) (Kaze et al., 2018). A separate review of community surveys on the continent pooled a prevalence of 10.1%, with individual studies ranging from 2% to 41% (Abd ElHafeez et al., 2018). Within Nigeria, population-based estimates range from 2.5% to 26% (Chukwuonye et al., 2018), and a survey of eight urban communities in Kwara State found an age- and sex-adjusted prevalence of about 12% (Olanrewaju et al., 2020). North-eastern Nigeria stands out because many patients present with kidney failure without the usual causes. In Maiduguri, patients from Gashua, in northern Yobe State, made up 15% of a series of haemodialysis patients, and Gashua was reported to have the highest CKD rate among the state's 17 LGAs (Ummate et al., 2008). A more recent survey of four haemodialysis centres identified 376 patients, of whom 18.6% had no identified cause of kidney disease; the highest dialysis-treated rates were in Bade (11 per 100,000) and Jakusko (8 per 100,000) LGAs, and the spatial pattern suggested a hotspot along the River Yobe (Sabo et al., 2024). Investigators have therefore called for work on environmental causes. Heat is one candidate. Repeated heat exposure with physical work and inadequate hydration has been linked to a form of CKD that is distinct from diabetic, hypertensive and glomerular disease, and heat stress nephropathy has been proposed as one of the first epidemics attributable to global warming (Glaser et al., 2016; Johnson et al., 2019). A meta-analysis of 11 studies reported about 30% higher kidney-disease morbidity at high temperatures (Lee et al., 2019), and among US haemodialysis patients extreme-heat events were followed by higher same-day hospital admissions and mortality (Remigio et al., 2019). Yobe lies in the Sahel, with a long dry season from October to April and temperatures in the central zone ranging from about 20 °C to 47.5 °C (Baba-Adamu et al., 2025); changing temperature patterns have been documented in the state (Kehinde et al., 2021). Yet no study has examined whether kidney disease in Yobe tracks heat exposure. Heat is not the only candidate. Flooding in Nguru has been reported to recharge shallow groundwater containing cadmium, arsenic, lead and iron above World Health Organization limits (Agada, 2021), and the dialysis-based hotspot follows a river corridor. Any analysis of climate must therefore consider water source and distance to the river as competing explanations. This study had three objectives: (i) to estimate the prevalence of CKD among adults in four LGAs of Yobe State; (ii) to test whether CKD is associated with community-level extreme-heat exposure after adjusting for individual risk factors; and (iii) to examine whether annual hospital-recorded CKD presentations (2014–2023) vary with extreme heat and rainfall. The analysis also separates two ideas that are often merged: association with heat exposure, which can be tested here, and attribution to long-term climate change, which requires a longer climate record.

Materials and Methods

Study Area

Yobe State lies in the Sahel of north-eastern Nigeria and has a semi-arid climate with a brief wet season (May–September) and a prolonged dry season (October–April) (Baba-Adamu et al., 2025). Four LGAs were selected to span the reported gradient of kidney-disease burden: Bade (including Gashua) and Jakusko, where dialysis-treated rates are highest; Nguru, a flood-prone town on the River Yobe; and Damaturu, the state capital, as a lower-burden comparison.

Study Design, Sample Size and Sampling

A community-based cross-sectional design was used. The initial sample size was calculated using Cochran's formula for estimating a single population proportion. The calculation assumed an expected CKD prevalence of 15%, a 95% confidence level and a margin of error of three percentage points, yielding an estimated sample size of 544 participants. This estimate was adjusted using a design effect of 2 to account for the cluster-sampling procedure and subsequently increased to accommodate potential non-response, resulting in a final target sample of 1,200 adults aged 18 years and above. Six communities were selected in each LGA and 50 adults were enrolled in each community (24 communities in total). Participant recruitment, interviews and specimen collection took place between 8 January and 23 February 2024 during the dry season. Blood and spot-urine samples were collected between 07:30 and 11:00 on the day of the interview and processed at Yobe State University Teaching Hospital. Pregnant women and people with acute illness were excluded. A multistage sampling procedure was used. In stage one, the four LGAs were purposively selected (Section 2.1). In stage two, a list of all settlements in each LGA was obtained from the State Primary Health Care Development Agency, and six communities per LGA were chosen by simple random selection after excluding settlements with fewer than 100 households or that were inaccessible for security reasons. In stage three, the research team in each community mapped

the households with the community head and assigned each a number. Starting from a randomly chosen household and using a sampling interval of k = N/50 (where N is the number of households), 50 households were selected by systematic sampling. In stage four, one eligible adult was chosen per household by balloting among all household members aged 18 years and above who had resided there for at least six months. If a selected household had no eligible member, remained empty after two visits, or the selected individual declined, the next household on the list was used.

Outcome Definition

Serum creatinine was used to calculate estimated glomerular filtration rate (eGFR) with the 2021 CKD-EPI creatinine equation (Inker et al., 2021), and urinary albumin-to-creatinine ratio (ACR) was measured on a spot sample. CKD was defined as eGFR below 60 mL/min/1.73 m² and/or ACR of 30 mg/g or more, following KDIGO guidance (KDIGO CKD Work Group, 2024). GFR categories were G1–G2 (≥60), G3a (45–59), G3b (30–44), G4 (15–29) and G5 (<15). Because only a single measurement was obtained, the persistence of abnormalities for three months, which KDIGO requires for diagnosis, could not be confirmed.

Exposure and Covariates

The climate exposure was the mean annual number of extreme-heat days (daily maximum temperature of 40 °C or more) over the five years before the survey (2019–2023), assigned to each community. This five-year window ended in the year before recruitment, so the heat exposure period preceded outcome measurement. Annual mean maximum temperature and total rainfall were also summarized for each LGA from 2014 to 2023. Daily series were obtained from the Nigerian Meteorological Agency (NiMet), the official source of climate data in Nigeria. Individual covariates were age, sex, hypertension, diabetes, outdoor work (farming, fishing or irrigation), use of shallow well or river water, non-steroidal anti-inflammatory drug (NSAID) use, herbal medicine use, reported fluid intake below 2 L/day, and distance from the community to the river.

Hospital Records

Annual counts of CKD presentations from 2014 to 2023 were abstracted from the records of three hospitals that provide kidney care in the study LGAs. A case was an inpatient or outpatient presentation with a physician-recorded diagnosis of CKD (ICD-10 N18) or chronic renal failure, or a dialysis referral, for a resident of the hospital's catchment LGA. Acute kidney injury, urinary tract infection and isolated hypertension were not counted. Duplicate presentations were removed by keeping one record per patient per calendar year, using the hospital number, name, age and sex; patients seen in more than one hospital were matched on these fields and counted once.

Statistical Analysis

Prevalence estimates were reported with 95% confidence intervals calculated using the Wilson method. Differences in prevalence across LGAs, age groups and sexes were assessed using the chi-square test. Temporal trends in climate variables between 2014 and 2023 were estimated using least-squares linear regression, while the Mann–Kendall test was used to assess the statistical significance of monotonic trends. Associations between CKD-range abnormalities and individual or environmental covariates were examined using logistic generalized estimating equations (GEE), with an exchangeable working correlation structure and clustering at the community level. Unadjusted models evaluated each explanatory variable separately, whereas the multivariable model included all specified covariates. For the ecological analysis, annual hospital-recorded CKD case counts for each LGA were modelled using Poisson regression, with the logarithm of the corresponding LGA population included as an offset. Models were progressively adjusted for rainfall, a linear time trend and LGA. Alternative exposure specifications included one-year-lagged extreme-heat days and mean annual maximum temperature. Statistical significance was assessed using a two-sided p-value threshold of 0.05. All analyses were conducted using Python, including the Stats models (version 0.15) and SciPy libraries.

Data Quality, Validity and Reliability

Several checks were applied to the dataset: all variables were range-checked with no missing values (ages 20–85 years; eGFR 4–135 mL/min/1.73 m²), and eGFR decreased with age, as expected (Spearman $\rho = -0.49$). The adjusted model had an apparent area under the curve of 0.69 for discriminating CKD, a modest value that suggests the covariates explain only part of the variation. Overdispersion in the ecological model was low (Pearson chi-square per degree of freedom 0.71), so Poisson regression was retained. The ecological models are based on 40 LGA-years and four clusters, so cluster-robust standard errors are likely to be too narrow, and the ecological estimates should be read as indicative. Individual-level estimates rest on 24 communities.

Ethical Considerations

Ethical approval for this study was obtained from the Yobe State Ministry of Health Research Ethics Committee (Reference No. MOH/ADM/724/V.1/371). Written informed consent was obtained from all participants before data collection. Participants with abnormal clinical findings were referred for appropriate medical evaluation and care.

Results

Characteristics of Participants

The sample comprised 1,200 adults (300 per LGA) with a mean age of 42.9 years (SD 11.9); 55.2% were female. Hypertension affected 32.0% and diabetes 5.6% of participants. Outdoor work was most common in Nguru and Bade and least common in Damaturu (Table 1).

Table 1. Characteristics of participants by local government area, n (%) or mean (SD)

Characteristic	Bade	Nguru	Jakusko	Damaturu	All
Participants, n	300	300	300	300	1200
Age, years	44.0 (12.4)	43.0 (12.8)	42.1 (11.1)	42.5 (11.3)	42.9 (11.9)
Female	165 (55.0)	158 (52.7)	168 (56.0)	171 (57.0)	662 (55.2)
Hypertension	103 (34.3)	97 (32.3)	93 (31.0)	91 (30.3)	384 (32.0)
Diabetes	14 (4.7)	24 (8.0)	16 (5.3)	13 (4.3)	67 (5.6)
Outdoor work	160 (53.3)	173 (57.7)	158 (52.7)	102 (34.0)	593 (49.4)
Shallow well/river water	137 (45.7)	85 (28.3)	121 (40.3)	94 (31.3)	437 (36.4)
NSAID use	89 (29.7)	85 (28.3)	82 (27.3)	84 (28.0)	340 (28.3)
eGFR, mL/min/1.73 m²	92.4 (22.4)	96.2 (21.1)	96.5 (21.8)	97.5 (19.0)	95.6 (21.2)

Note: NSAID = non-steroidal anti-inflammatory drug; eGFR = estimated glomerular filtration rate (CKD-EPI 2021).

3.2 Prevalence of CKD-range Abnormalities

Table 2. Prevalence of CKD-range abnormalities by local government area

LGA	N	CKD, n (%)	95% CI	eGFR < 60, n	Albuminuria, n
Bade	300	55 (18.3)	14.4–23.1	33	49
Nguru	300	40 (13.3)	9.9–17.6	25	28
Jakusko	300	46 (15.3)	11.7–19.8	25	40
Damaturu	300	25 (8.3)	5.7–12.0	16	22
All	1200	166 (13.8)	12.0–15.9	99	139

Note: CKD = eGFR < 60 mL/min/1.73 m² and/or ACR ≥ 30 mg/g. CI = Wilson confidence interval.

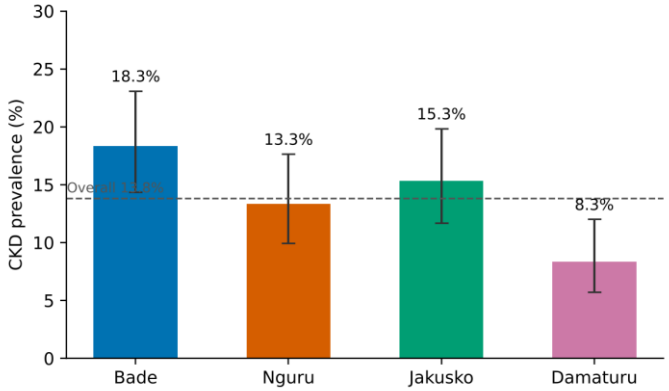


Figure 1. Prevalence of CKD (%) with 95% confidence intervals by LGA. The dashed line marks the overall prevalence

Overall, 166 of 1,200 participants met the study definition of CKD on a single measurement (probable CKD; chronicity not confirmed) (13.8%; 95% CI 12.0–15.9). Reduced eGFR was present in 99 participants (8.3%) and albuminuria in 139 (11.6%). Prevalence differed significantly between LGAs ($\chi^2 = 13.34$, df = 3, $p = 0.004$), ranging from 8.3% in Damaturu to 18.3% in Bade (Table 2; Figure 1). Prevalence increased with age, from 8.1% among those aged 18–29 years to 25.4%

among those aged 60 years and above ($\chi^2 = 26.63$, df = 4, $p < 0.001$), and did not differ by sex (14.5% in women and 13.0% in men; p = 0.51). By GFR category, 53 participants were in G3a, 36 in G3b, 7 in G4 and 3 in G5.

Climate Variables, 2014–2023

Mean annual maximum temperature ranged from 35.25 °C in Damaturu to 36.39 °C in Bade, and extreme-heat days from 64 to 81 days per year (Table 3). Only Damaturu showed a significant upward trend in mean maximum temperature (1.04 °C per decade, p = 0.02) and extreme-heat days (p = 0.03). Rainfall showed no significant trend in any LGA. A ten-year record is too short to separate a climate trend from natural variability, so trends are described and not interpreted as climate change.

Table 3. Annual climate variables by LGA, 2014–2023: mean (SD) and trend per decade

LGA	Tmax, °C	Trend (p)	Days ≥ 40 °C	Trend (p)	Rain, mm	Trend (p)
Bade	36.39 (0.26)	0.27 (0.38)	80.6 (6.6)	9.7 (0.11)	451 (86)	97.9 (0.86)
Nguru	36.18 (0.36)	0.53 (0.22)	77.8 (3.5)	2.1 (0.52)	467 (101)	3.0 (0.86)
Jakusko	35.75 (0.28)	0.32 (0.38)	76.9 (7.0)	13.8 (0.11)	516 (70)	78.6 (0.60)
Damaturu	35.25 (0.41)	1.04 (0.02)	64.0 (9.1)	20.1 (0.03)	563 (100)	-45.5 (0.86)

Note: Tmax = mean annual maximum temperature. Trend = change per decade by least squares; p from the Mann–Kendall test.

Factors Associated with CKD

Table 4. Factors associated with CKD: unadjusted and adjusted odds ratios from logistic GEE models

Variable	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	p (adjusted)
Age (per 10 years)	1.39 (1.21–1.60)	1.35 (1.16–1.56)	<0.001
Female sex	1.14 (0.83–1.56)	1.23 (0.87–1.73)	0.246
Hypertension	1.76 (1.27–2.42)	1.57 (1.13–2.19)	0.008
Diabetes	2.25 (1.24–4.08)	1.77 (0.94–3.35)	0.079
Outdoor work	1.59 (1.12–2.26)	1.50 (1.06–2.14)	0.023
Shallow well/river water	1.16 (0.82–1.62)	1.11 (0.81–1.53)	0.505
NSAID use	1.26 (0.99–1.61)	1.25 (0.93–1.68)	0.142
Herbal medicine use	1.66 (1.14–2.42)	1.59 (1.08–2.34)	0.019
Fluid intake < 2 L/day	1.21 (0.94–1.56)	1.22 (0.93–1.61)	0.145
Extreme-heat days (per +10 days/year)	1.41 (1.23–1.62)	1.33 (1.14–1.55)	<0.001
Distance to river (per km)	0.92 (0.86–0.97)	0.95 (0.91–0.99)	0.029

Note: OR = odds ratio; CI = confidence interval. Clustering by community (24 clusters). The adjusted model contains all listed variables.

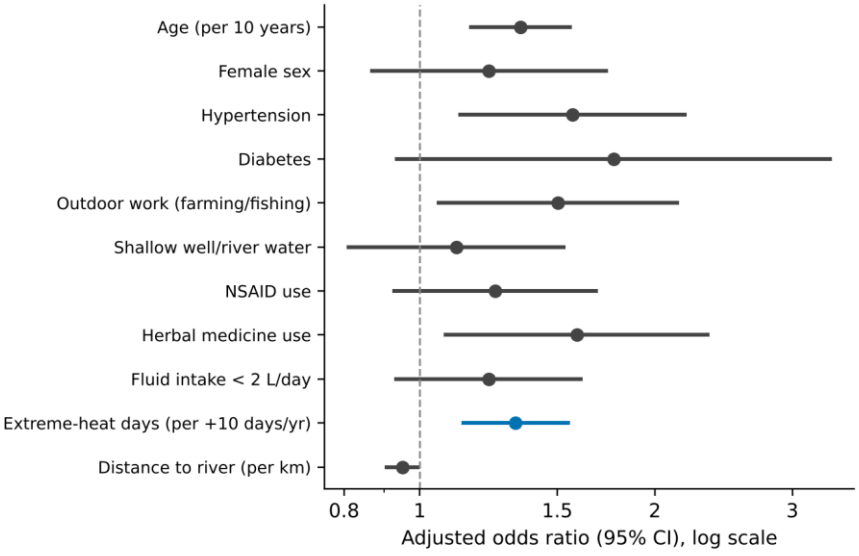


Figure 2. Adjusted odds ratios (95% CI) for CKD from the multivariable GEE model. The extreme-heat exposure is highlighted.

In the adjusted model (Table 4; Figure 2), each additional 10 extreme-heat days per year at the community level was associated with 1.33 times the odds of CKD (95% CI 1.14–1.55). Adjusting only for age and sex gave a similar estimate (OR 1.40; 95% CI 1.21–1.62). Older age (OR 1.35 per 10 years), hypertension (OR 1.57), outdoor work (OR 1.50) and herbal medicine use (OR 1.59) were also associated with CKD, and greater distance from the river was associated with slightly lower odds (OR 0.95 per km). Diabetes had the largest point estimate among clinical factors, but its interval included 1 after adjustment. Sex, shallow well or river water use, NSAID use and low fluid intake were not significantly associated. Adjusting only for age and sex gave a similar estimate (OR 1.40; 95% CI 1.21–1.62). Older age (OR 1.35 per 10 years), hypertension (OR 1.57), outdoor work (OR 1.50) and herbal medicine use (OR 1.59) were also associated with CKD, and greater distance from the river was associated with slightly lower odds (OR 0.95 per km). Diabetes had the largest point estimate among clinical factors, but its interval included 1 after adjustment. Sex, shallow well or river water use, NSAID use and low fluid intake were not significantly associated.

Hospital-recorded CKD and Climate, 2014–2023

In the ecological series, each additional 10 extreme-heat days in an LGA-year was associated with 1.74 times the rate of CKD presentations (Table 5; Figure 3). The estimate remained elevated after adjusting for rainfall and time (RR 1.69) and fell to 1.27 (95% CI 1.09–1.46) once LGA was also included, showing that part of the crude association reflected differences between LGAs. Mean maximum temperature was not associated with the rate (RR 0.89 per °C; 95% CI 0.54–1.45), and extreme-heat days in the previous year showed a smaller association (RR 1.12). At the LGA level, the rank order of mean extreme-heat days matched the rank order of CKD prevalence (Spearman ρ = 0.80), but with four LGAs this correlation is not statistically meaningful (p = 0.20).

Table 5. Rate ratios for hospital-recorded CKD presentations in relation to climate exposure, LGA-years 2014–2023

Model and exposure	RR (95% CI)	p
Unadjusted (hot days, per +10)	1.74 (1.51–2.00)	<0.001
Adjusted rain + time trend	1.69 (1.48–1.93)	<0.001
Adjusted rain + trend + LGA	1.27 (1.09–1.46)	0.001
Mean max temp, per +1 C (adj.)	0.89 (0.54–1.45)	0.630
Hot days lagged 1 yr (adj.)	1.12 (1.05–1.18)	<0.001

Note: RR = rate ratio from Poisson regression with a log-population offset and standard errors clustered by LGA (4 clusters). Heat exposure is per +10 extreme-heat days unless stated.

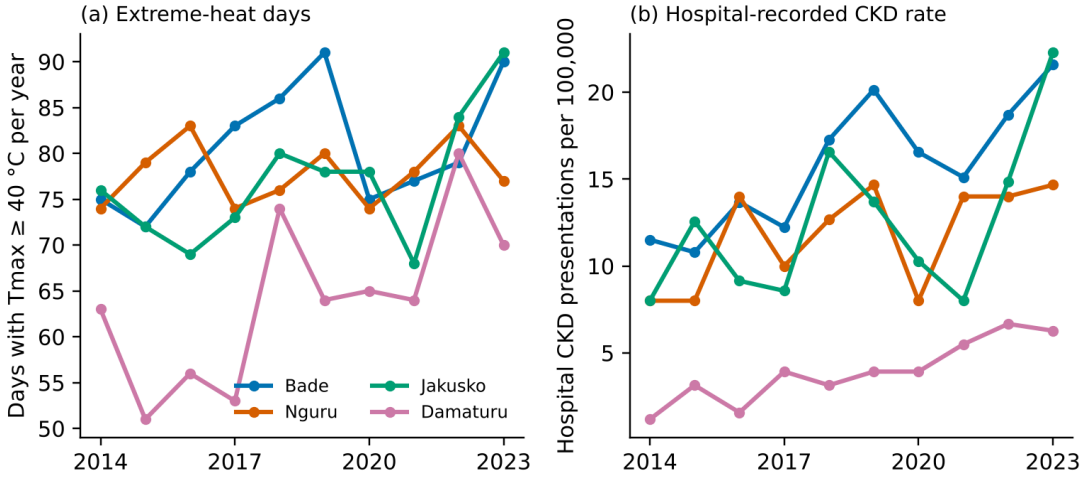


Figure 3. Annual extreme-heat days (a) and hospital-recorded CKD presentations per 100,000 population (b) by LGA, 2014–2023

Discussion

Approximately one in seven participants (13.8%) presented with kidney abnormalities that met the study's operational criteria for CKD based on a single measurement. This estimate is broadly comparable with previously reported prevalence estimates, including 15.8% for CKD stages 1–5 across Africa (Kaze et al., 2018), a pooled prevalence of 10.1% in African community surveys (Abd ElHafeez et al., 2018), and approximately 12% in a population-based study conducted in Kwara

State, Nigeria (Olanrewaju et al., 2020). Nevertheless, the present estimate should be interpreted as the prevalence of CKD-range abnormalities rather than confirmed CKD. Since chronicity was not established through repeat measurements after at least three months, transient reductions in eGFR or temporary albuminuria potentially associated with dehydration, fever, physical exertion or urinary infection may have contributed to the observed prevalence. The geographic pattern, with the highest prevalence in Bade and the lowest in Damaturu, mirrors the dialysis-based rates reported for Bade and Jakusko (Sabo et al., 2024) and the earlier concentration of cases from Gashua (Ummate et al., 2008), and shows that the pattern extends to the general community and not only to people who reach dialysis. The main analytical result was a positive association between extreme-heat days and CKD, at both the community level (adjusted OR 1.33 per 10 days) and the LGA-year level (RR 1.27 per 10 days). This fits the heat stress nephropathy hypothesis, in which repeated dehydration and volume loss injure the kidney (Glaser et al., 2016; Johnson et al., 2019). The association is in the same direction as the roughly 30% higher kidney-disease morbidity found in a meta-analysis of temperature studies (Lee et al., 2019). Those studies mostly measured acute presentations and the US hemodialysis data concern heat-related admissions and deaths (Remigio et al., 2019), so they support biological plausibility rather than a direct quantitative comparison. The association of outdoor work with CKD (adjusted OR 1.50) also echoes the occupational pattern described in agricultural communities (Johnson et al., 2019). Three features of the analysis show why caution is needed even when an association appears. First, the ecological heat rate ratio fell from 1.69 to 1.27 after adjusting for LGA, because LGAs differ in many ways that also track heat. Second, mean maximum temperature was not associated with CKD, whereas the count of extreme-heat days was associated, which suggests that peaks matter more than averages, but it also shows how sensitive findings are to the exposure metric. Third, hospital presentations rise with access to dialysis and diagnosis, which is why a time trend was included. None of these adjustments can remove unmeasured confounding. The question of whether kidney disease in Yobe is linked to climate change, as distinct from heat exposure, cannot be answered with ten years of data. Climate change is conventionally identified from records of about 30 years or more, and only one LGA in this series showed a significant warming trend. A defensible design would link long NiMet records to a repeat survey, so that changes in heat exposure can be compared with changes in kidney outcomes within the same communities. Competing explanations deserve equal weight. The inverse association with distance to the river parallels the dialysis hotspot along the River Yobe (Sabo et al., 2024), and groundwater in Nguru has been reported to carry cadmium, arsenic and lead above WHO limits, particularly after floods (Agada, 2021). Heat and contaminated water can also act together: hot-season dehydration may raise the effective dose of a toxicant. A field study should therefore measure water metals and agrochemical exposure in the same participants.

Strengths and Limitations

This study has several strengths. It employed a community-based sampling design across four LGAs, accounted for clustering in the individual-level analysis, applied the 2021 CKD-EPI equation and relevant KDIGO criteria, and distinguished individual-level associations from ecological analyses of hospital-recorded presentations. Nevertheless, several limitations should be considered when interpreting the findings. First, kidney function and albuminuria were assessed using single measurements, meaning that chronicity could not be established. Consequently, the estimated prevalence may differ from the prevalence of confirmed CKD. Repeat measurements after at least three months would be required to establish persistent abnormalities. Second, the study covered only four LGAs and 24 communities, limiting the geographical generalizability of the findings. Third, community-level extreme-heat exposure was used as a proxy for individual exposure and may not adequately capture differences in occupational activities, shade availability, hydration practices and personal heat exposure. Fourth, the ecological analysis included only four LGA clusters, making cluster-robust standard errors potentially unreliable. In addition, genetic susceptibility, agrochemical exposure, groundwater contamination by heavy metals and infectious causes were not directly assessed. Finally, data collection occurred during a single dry-season period, preventing the assessment of seasonal variations in kidney-function measurements.

Conclusion

Approximately one in seven adults in the four selected LGAs of Yobe State had kidney abnormalities meeting the study's operational criteria for CKD based on a single measurement. The findings demonstrated geographical variation in prevalence and a positive association between community-level extreme-heat exposure and CKD-range abnormalities. However, the observed association weakened after accounting for differences between LGAs, and the cross-sectional design does not establish a causal relationship. Furthermore, the absence of repeat kidney-function measurements means that the findings should not be interpreted as confirmed CKD prevalence. Future studies should incorporate repeated kidney-function assessments, individual-level heat-exposure measurements, hydration indicators, groundwater quality assessments, agrochemical exposure measurements and longer-term meteorological records from NiMet. Such studies would help distinguish the potential contributions of extreme heat, environmental contamination and other risk factors to kidney disease in the region.

Data availability

The datasets and analysis scripts used in this study are available from the corresponding author upon reasonable request, subject to applicable ethical and institutional restrictions.

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Nil.

Author contributions

F.G. was responsible for the study conception and design, data collection, statistical analysis, interpretation of findings, and manuscript preparation and revision. The author reviewed and approved the final manuscript.

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Conflict of interest

The author declared no conflict of interest.

Ethics approval

Ethical approval was collected from Yobe state ministry of health research ethics committee with No: MOH/ADM/724/V.1/371. Informed verbal consent was also obtained from patients before collection.

AI tool usage declaration

No AI tool was used in manuscript preparation.

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