High Heat Exposure and Medical Utilization among the CKD Population

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Key Points

- Exposure to days with higher heat indices was associated with increases in weekly utilization for a population with CKD.
- Higher heat indices were associated with a larger increase in kidney-related visits than all-cause utilization.
- Higher heat indices were associated with larger effects on kidney-related emergency department use for those least likely to have air conditioning.

Abstract

Background Extreme heat events have lengthened, become more frequent, and increased in intensity over the past few decades, and this trend is expected to continue. Extreme heat events have been shown to be associated with increased mortality and emergency department (ED) visits.

Methods We investigated the relationship between temperature and healthcare utilization among patients with CKD. We used panel regression models with individual and year fixed effects to evaluate how exposure to different levels of temperature (measured by heat index) was associated with changes in weekly healthcare utilization from October 1, 2015, to March 31, 2023. Data were derived from medical claims data, Parameter-Elevation Regressions on Independent Slopes Model climate data, and the Census block group of each individual. The study population was comprised of 916,886 individuals with commercial or Medicare insurance who had been diagnosed with CKD stage G3, G4, or G5. CKD was defined using diagnosis codes in medical claims and eGFR laboratory results. Exposure was the number of days in a week with a daily heat index in 5.6-degree Celsius bins.

Results We found that exposure to a higher heat index bin, 32.2°C–37.8°C compared with 15.6°C–21.1°C, was associated with an increase in weekly ED utilization (0.55%; 95% confidence interval [CI], 0.42% to 0.68%; $P < 0.001$), with larger percent increases for ED visits with a heat-related primary diagnosis code (2.07%; 95% CI, 1.63% to 2.51%; $P < 0.001$) or a kidney-related primary diagnosis code (1.37%; 95% CI, 0.56% to 2.17%; $P < 0.001$). ED visits with a primary diagnosis code related to kidney disease were associated with a larger effect among those least likely to have access to air conditioning (2.48%; 95% CI, 0.84% to 4.13%; $P < 0.01$). Smaller, statistically significant results were observed comparing heat indexes of 26.7°C–32.2°C to 15.6°C–21.1°C.

Conclusions Exposure to heat indexes above 32.2°C was associated with greater weekly ED utilization and ED utilization with heat-related or kidney-related primary diagnosis codes.

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Introduction

Extended periods of high heat are becoming more frequent and intense, and this trend is expected to continue.[1–3] Previous studies have demonstrated the relationship between extreme heat and an increased risk of hospital admission, emergency department (ED) use, and mortality among the general population in the United States.[4,5] Individuals with CKD, a population estimated to be approximately 35.5 million adults in the United States,[6] have been shown to be adversely affected by exposure to extreme heat. Extreme heat has been linked to both the development of CKD and the progression to ESKD—the final stage

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of CKD—as well as complications among individuals already experiencing those conditions.[7] Among individuals with ESKD, extreme heat has been shown to increase the risk of hospital admission and death.[8] Extreme heat exposure has also been associated with a higher risk of ED encounters related to kidney disease, including ED visits for AKI and kidney stones.[9–12]

Our objective was to evaluate the relationship between heat index and healthcare utilization among a population of patients with CKD with our hypothesis being that exposure to higher temperatures would increase utilization for CKD and heat-related diagnoses. Although many previous studies have focused on specific extreme heat events or heat waves in one geographic area,[8–12] we modeled the entire distribution of heat index exposure during an 8-year study period across the United States. Using a large, nationwide, individual-level dataset, we were also able to evaluate the heterogeneity of the relationship across different geographies and individual-level demographic and clinical characteristics. One specific characteristic of interest that we investigated was the probability of residential air conditioning (A/C), which has been shown to mitigate the temperature-mortality relationship in the United States.[13] In the United States, the lowest income quartile is twice as likely not to have A/C as the highest income quartile.[14]

Methods

Data Sources

This cohort study used healthcare claims linked with weather data from October 1, 2015, until March 31, 2023. The claims data were derived from the Healthcare Integrated Research Database, a repository of claims covering more than 40 million members of a large national payor with linked laboratory results from certain lab providers.[15]

Daily maximum temperature and vapor pressure deficit were derived from the Parameter-Elevation Regressions on Independent Slopes Model (version D1)[16] weather dataset by converting gridded 4 km data to Census block group level averages. Daily heat index was approximated using daily maximum temperature and vapor pressure deficit for temperatures above 26.7°C, and maximum temperature was used for temperatures under 26.7°C. The heat index calculation is a simplified approximation of true heat index which includes more factors (see Supplemental Appendix 1 for the equation).

We also used data measuring the probability of having A/C in the residence,[17] matched at the members' Census block group. The A/C data are only available in the largest metro areas in the United States, covering 66% of our study population.

Study Population

The study population included adult (18 years or older) members of a large national insurer with commercial or Medicare insurance who were diagnosed with CKD stage G3, G4, or G5; individuals with early-stage CKD (G1 and G2) were excluded. CKD was defined using International Classification of Diseases Version 10 diagnosis codes in claims (see code list in Supplemental Appendix Table 1) and/or eGFR laboratory results (using the CKD Epidemiology Collaboration 2021 creatinine equation without a race variable[18,19]), requiring at least two diagnosis codes or laboratory results more than 90 days apart. Members were excluded from the sample in all weeks after a kidney transplant or the start of palliative care but were not excluded if they were undergoing dialysis. Individuals were included for all weeks that they had insurance enrollment with attrition being caused by change of insurer or death.

All members in our dataset had complete data with no missingness in their claims or their environmental exposure. The only variable with missing data was from the externally sourced indicator for A/C likelihood.

Exposure

The daily approximated heat index was categorized into nine 5.56C (10F) heat index (HI) bins with below −1.1°C and above 37.8°C as the extreme bins and 5.6°C bins for all values between −1.1°C and 37.8°C. Binning allows for estimation of nonlinear effects in heat index, *e.g.*, the estimated effect of moving 1 day from the 15.6°C–21.1°C bin to the 21.1°C–26.7°C does not have to be equal to the estimated effect of moving 1 day from the 21.1°C–26.7°C bin to the 26.7°C–32.2°C bin.[20] The exposure variables were defined as the number of days in a week (0–7) for each of the nine heat index bins. We also prefer this specification to a single binary indicator of extreme heat (such as a day above 32.2°C) which forces the comparison group to include hot but not extreme temperature such as days between 26.7°C and 32.2°C. Finally, we did not use relative temperatures as these can be difficult to interpret; *e.g.*, a day in January that is the 99th percentile for that Census block group compared with historical days in January is likely not extreme heat and may even be beneficial to health if it avoids extreme cold. One possible way to resolve this issue would be to limit our sample to only the summer months; however, this would change the estimation of the individual fixed effect (see below) and create gaps in our sample. Claims were combined with the weekly heat index measures using Census block group of residence using members' addresses on the first day of each week.

Outcomes

The outcomes of interest were weekly (*i.e.*, at least once a week) all-cause utilization in the ED, outpatient, and inpatient settings measured as a binary variable. We also looked at weekly utilization with a kidney-related or heat-related primary diagnosis code, such as dehydration (Supplemental Appendix Tables 2 and 3), with the expectation that utilization with heat-related primary diagnoses would increase the most.

Statistical Analysis

We estimated the relationship between heat and medical utilization with a linear probability model with individual and year fixed effects. We chose to use a linear probability model as it is less biased than a logistic regression for relatively rare events when using fixed effects.[21] As we observed individuals multiple times (weekly), we included individual fixed effects that controlled for unobservable individual characteristics and precluded the need for individual time-invariant controls.

The year fixed effects controlled for secular time trends common to all individuals like large-scale weather influences (El Niño / La Niña cycle), the coronavirus disease 2019 pandemic, and advances in technology. With these controls, we isolated how within-year temperatures affected an individual's healthcare utilization. Standard errors were clustered at the block group level.

The estimated heat index coefficients represent the average effect of moving 1 day in a week from the reference heat index bin (15.6°C–21.1°C) to that heat index bin. For example, the coefficient for the bin above 37.8°C represents the average difference in utilization associated with 1 additional day in a week with heat index over 37.8°C relative to the reference bin (15.6°C–21.1°C). If all days in a week are above 37.8°C, we would multiply the coefficient by 7 to evaluate the association of 7 days above 37.8°C compared with 7 days between 15.6°C and 21.1°C.

Heterogeneity analysis by A/C availability for utilization with a kidney-related primary diagnosis was conducted among the sample with available A/C data to determine if greater likelihood of having access to A/C could act to mitigate the effects of heat. Other heterogeneity analyses, including by CKD stage, sex, rurality, and region, were also conducted for the outcomes with a kidney-related primary diagnosis. These analyses were performed separately for each subgroup within a category using the same fixed-effect regression as our main model.

Cost Estimate

We used our regression results to estimate the increase in yearly costs due to greater heat compared with a historical baseline. We calculated the average allowed cost for each type of utilization with a kidney-related primary diagnosis in 2021 to use as a representative cost of each claim. We used Parameter-Elevation Regressions on Independent Slopes Model max temperature data from 1985 to 2014 to create a 30-year historical distribution of daily maximum temperatures and then determined the difference in the number of days in each temperature bin in 2022 compared with the historical distribution. Multiplying the estimated heat index coefficients by the number of additional days in each bin estimates the change in the number of visits associated with the increase in high heat days. We then multiplied this by the average cost of a visit to determine the total additional costs of utilization for all-cause visits and visits with a kidney primary diagnosis associated with the increase in high heat days.

Ethics

This study used a limited dataset and was conducted in full compliance with the Health Insurance Portability and Accountability Act. The study analyzed health plan membership data for the purposes of the health plan's operations; therefore, institutional review board approval was not necessary.

Results

Study Population

Tables 1 and 2 present the population characteristics and unadjusted rates of outcomes per 1000 members for the full population and by likelihood of access to A/C, respectively. In the full sample, the majority (63%) of the population was at least 65 years. On the first date observed with CKD, 91% of individuals had stage G3, 6% had stage G4, and 3% had stage G5 CKD. Missing indicators for A/C likelihood were encountered for 34% of member-weeks with no other variables having any missingness.

Heat-related utilization comprised 2%–8% of total utilization (varying by setting), and kidney-related utilization comprised 3%–8%. The geographic distribution of the study population and the percentage of days with a heat index above 32.2°C, grouping the 32.2°C–37.8°C and above 37.8°C bins, are shown in Figure 1.

Effect of Heat Index

We found that exposure to an additional day with a heat index of 32.2°C–37.8°C, compared with 15.6°C–21.1°C, was associated with an increase in weekly ED utilization (0.55%; 95% confidence interval [CI], 0.42% to 0.6%; $P < 0.001$; 4.07 more members with a visit per week per 100,000 members) with larger percent increases in ED visits with a kidney-related primary diagnosis (1.37%; 95% CI, 0.56% to 2.17%; $P < 0.001$; 0.26 more members with a visit per week per 100,000 members; Figure 2). For 1 day of exposure to heat indexes of >37.8°C, compared with 15.6°C–21.1°C, we found a larger increase in ED visits with a kidney-related primary diagnosis (2.26%; 95% CI, 0.99% to 3.53%; $P < 0.001$; 0.43 more members with a visit per week per 100,000 members).

The results for outpatient utilization were similar but of smaller magnitude, with exposure to heat index 32.2°C–37.8°C associated with an increase in weekly outpatient utilization compared with 15.6°C–21.1°C (0.18%; 95% CI, 0.17% to 0.20%; $P < 0.001$; 56.80 more members with a visit per week per 100,000 members), with a larger percent increase for outpatient utilization with a kidney-related primary diagnosis (0.79%; 95% CI, 0.73% to 0.86%; $P < 0.001$; 19.09 more members with a visit per week per 100,000 members). For heat indexes 37.8°C, we found no significant relationship for all-cause outpatient utilization and an increase in weekly utilization for kidney-related primary diagnoses (0.53%; 95% CI, 0.43% to 0.63%; $P < 0.001$; 12.80 more members with a visit per week per 100,000 members).

Unlike ED and outpatient utilization, exposure to 32.2°C–37.8°C compared with 15.6°C–21.1°C was associated with a decrease in weekly all-cause inpatient utilization (−0.13%; 95% CI, −0.25% to −0.01%; $P = 0.03$; 1.56 fewer members with a visit per week per 100,000 members) and exposure to > 37.8°C was associated with a 0.30% decrease (95% CI, −0.49% to −0.11%; $P = 0.002$; 3.65 fewer members with a visit per week per 100,000 members). However, the association between 32.2°C and 37.8°C and >37.8°C compared with 15.6°C–21.1°C and inpatient visits with a kidney-related primary diagnosis were both positive (1.31%; 95% CI, 0.78% to 1.84%; $P < 0.001$; 0.61 more members with a visit per week per 100,000 members and 1.38%; 95% CI, 0.58% to 2.21%; $P = 0.001$; 0.64 more members with a visit per week per 100,000 members, respectively).

Exposure to 26.7°C–32.2°C compared with 15.6°C–21.1°C was associated with similar but smaller increases

Table 1. Population descriptive statistics, total, and by quartile of likelihood air conditioning access

Variable	Full Sample		A/C Quartile 1		A/C Quartile 2		A/C Quartile 3		A/C Quartile 4	
	N	Percent	*N*	Percent	*N*	Percent	*N*	Percent	*N*	Percent
Age ranges, yr										
18–64	343,489	37%	62,192	39%	54,021	36%	50,715	34%	52,981	36%
64–74	249,066	27%	44,957	28%	40,344	27%	38,711	26%	39,351	27%
75–84	220,914	24%	35,488	22%	37,173	24%	37,727	26%	36,006	25%
85+	110,740	12%	18,645	12%	20,388	13%	20,437	14%	17,322	12%
Female	478,051	52%	86,966	54%	79,465	52%	74,575	51%	69,757	48%
Obesity	202,746	22%	37,663	23%	32,707	22%	29,914	20%	27,815	19%
Heart failure	144,889	16%	27,266	17%	23,605	16%	22,326	15%	20,052	14%
Smoking	52,724	6%	10,785	7%	7603	5%	6743	5%	5331	4%
Diabetes	386,800	42%	74,583	46%	63,135	42%	58,010	39%	53,628	37%
Hypertension	747,014	81%	131,308	81%	121,629	80%	117,480	80%	113,031	78%
CKD stage on index										
G3	845,140	91%	144,297	89%	138,405	91%	135,805	92%	134,934	93%
G4	55,141	6%	10,788	7%	9178	6%	8227	6%	7504	5%
G5	23,924	3%	6196	4%	4343	3%	3557	2%	3221	2%
Region										
Midwest	233,331	26%	34,967	22%	34,292	23%	33,100	23%	32,328	22%
Northeast	121,142	13%	27,982	17%	23,623	16%	23,549	16%	19,536	14%
South	302,595	33%	45,800	28%	44,473	29%	40,435	28%	41,131	29%
West	255,484	28%	52,240	32%	49,184	32%	49,104	34%	50,960	35%
Rural	142,684	15%	562	0%	809	1%	305	0%	96	0%
Health insurance										
Commercial	536,209	58%	86,754	54%	86,503	57%	86,558	59%	89,673	62%
Medicare Advantage	238,986	26%	57,610	36%	41,402	27%	33,542	23%	27,737	19%
Medicare Supplement	149,014	16%	16,918	10%	24,021	16%	27,490	19%	28,250	19%

A/C, air conditioning.

in healthcare utilization than exposure to 32.2°C–37.8°C across outcomes. The increase in utilization with a heat-related primary diagnosis was similar in magnitude (although slightly smaller) to the increase in utilization with kidney-related primary diagnoses across settings.

Heterogeneity

We observed heterogeneity by likelihood to have access to A/C in the relationship between exposure to higher heat indexes and utilization with a kidney-related primary diagnosis code (Figure 3). Exposure to high heat index, 32.2°C–37.8°C, for individuals residing in Census block groups with the lowest likelihood of having A/C, was associated with a 2.48% (95% CI, 0.84% to 4.13%; $P < 0.01$) higher likelihood of having an ED visit with a kidney-related primary diagnosis. Those residing in census block groups with the highest likelihood of having A/C were only 1.49% ($P = 0.21$) more likely to have a kidney-related

Table 2. Average number of visits per week per 1000 members (October 1, 2015–March 31, 2023), total, and by quartile of likelihood air conditioning access

Utilization Rates	Full Sample	AC Quartile 1	AC Quartile 2	AC Quartile 3	AC Quartile 4
	Visits per Week per 1000 Members[a]	Visits per Week per 1000 Members[a]	Visits per Week per 1000 Members[a]	Visits per Week per 1000 Members[a]	Visits per Week per 1000 Members[a]
ED	7.34	7.97	6.85	6.44	6.05
Heat primary ED	0.64	0.69	0.61	0.58	0.54
Kidney primary ED	0.19	0.27	0.18	0.16	0.14
Outpatient	308.30	297.75	308.22	316.15	314.82
Heat primary outpatient	8.45	8.51	8.55	8.60	8.30
Kidney primary outpatient	24.02	32.88	25.16	22.24	20.59
Inpatient	12.09	13.42	12.46	12.22	11.26
Heat primary inpatient	0.26	0.31	0.27	0.25	0.22
Kidney primary inpatient	0.46	0.59	0.47	0.43	0.39

ED, emergency department.
[a]Indicates average number of visits shown.

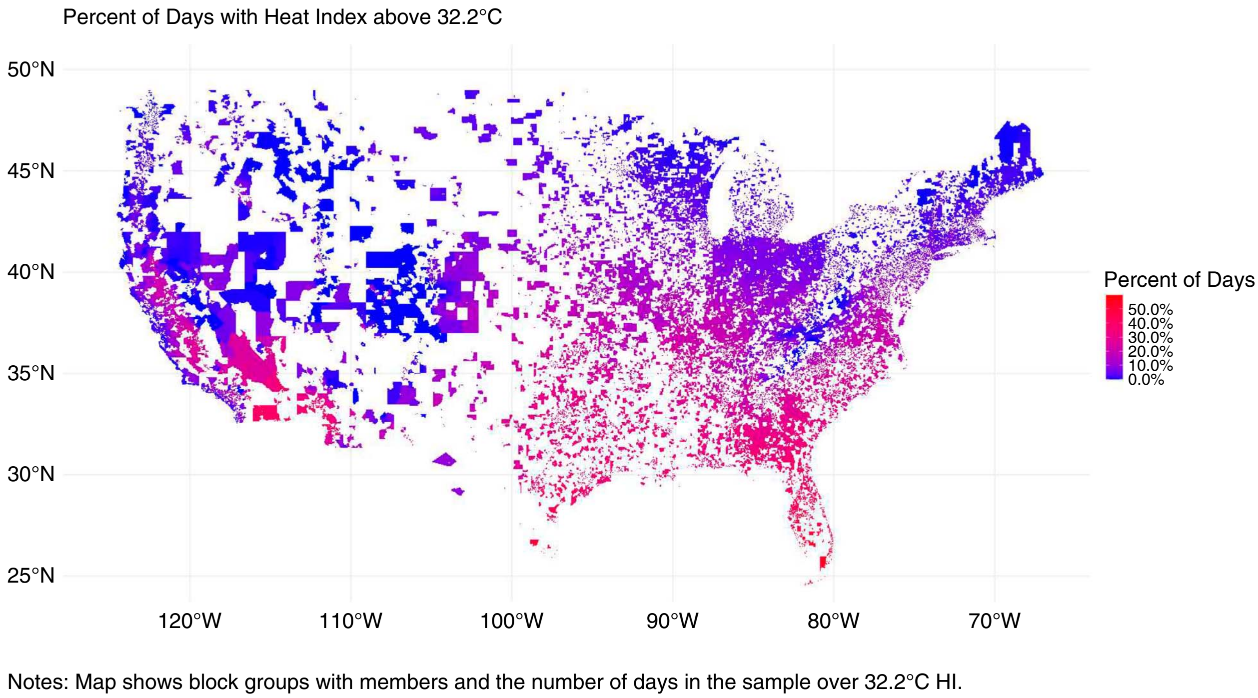

Figure 1. Map of population distribution and high heat index exposure. Map shows block groups with members and the number of days in the sample over 32.2°C HI. No members in our sample reside in the white block groups.

ED visit. We did not observe statistically significant heterogeneity by A/C quartile in the inpatient and outpatient settings.

We did not detect statistically significant differences in effect by sex (Supplemental Appendix Table 4), region (Supplemental Appendix Table 5), or rurality (Supplemental Appendix Table 6). We additionally did not observe a difference in the effect of heat on the likelihood of a kidney-related ED visit by CKD stage as we are limited by the number of members who have stages G4 and G5 (Supplemental Appendix Table 7). Finally, we did not observe a difference in the effect of heat on the likelihood of an ED visit when excluding members undergoing dialysis treatment (data not shown).

Cost Estimate

One additional day with a maximum heat index of 32.2°C–37.8°C compared with 15.6°C–21.1°C was associated with a $6743/$4491/$93 greater cost per 100,000 members with stages G3–5 CKD for outpatient/inpatient/ED visits, respectively, with kidney-related primary diagnoses (see Table 3). This translated to $67,563 greater spending per 100,000 individuals in 2021 across all settings for kidney-related utilization compared with a 30-year historical temperature average across all temperature bins.

Discussion

Global increases in the frequency and intensity of high heat could lead to negative health effects and greater cost among individuals with chronic medical conditions such as CKD. We find that exposure to high heat indexes is associated with greater utilization for all-cause and kidney-related utilization across ED, inpatient, and outpatient settings for a population with CKD. The results in the ED setting are similar in magnitude to previous findings.[9] Furthermore, the association between greater heat exposure and ED visits with a kidney-related primary diagnosis was larger for those least likely to have access to A/C. Since access to A/C was measured at the census block group level, we expect that the effect of A/C access on the relationship between heat index and healthcare utilization is underestimated. As expected, we saw higher utilization with a primary heat-related diagnosis associated with higher temperatures. Interestingly, the results for primary kidney diagnosis were similarly large.

Extreme heat can increase the need for medical attention but could also dissuade individuals from getting less emergent and less critical care. Extreme heat can make receiving preventative care dangerous if an individual does not have access to transportation. This can be seen with all-cause outpatient visits for the above 37.8°C bin having the same visit rate as the reference 15.6°C–21.1°C bin. As heat-related and kidney-related outpatient visits increase, we would expect to see other types of outpatient visits decrease. For an extended extreme heat event, this avoidance of care could be harmful to long-term health.[22,23] Sequelae of heat stress detected by the diagnosis codes including volume depletion, syncope and disorders of fluid and electrolyte balance (Supplemental Appendix Table 2) are associated with decreased kidney perfusion that could contribute to AKI as well as have the potential to result in progressive loss of kidney function. Heat exposure-related kidney disease is well described in other countries as well.[24,25] Although not the focus of the paper, the

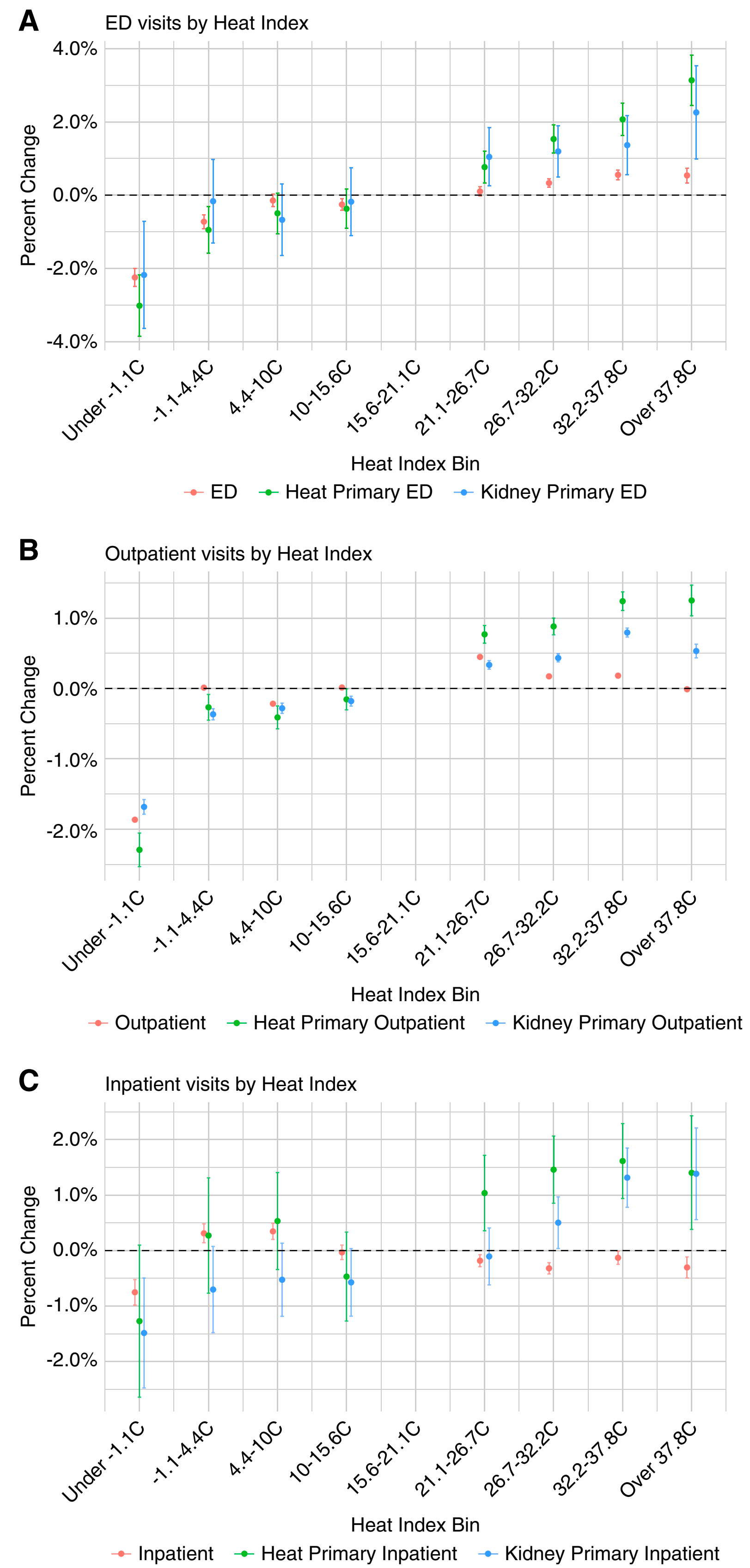

Figure 2. Relationship between temperature and utilization by setting. Bars represent 95% CIs. CI, confidence interval; ED, emergency department.

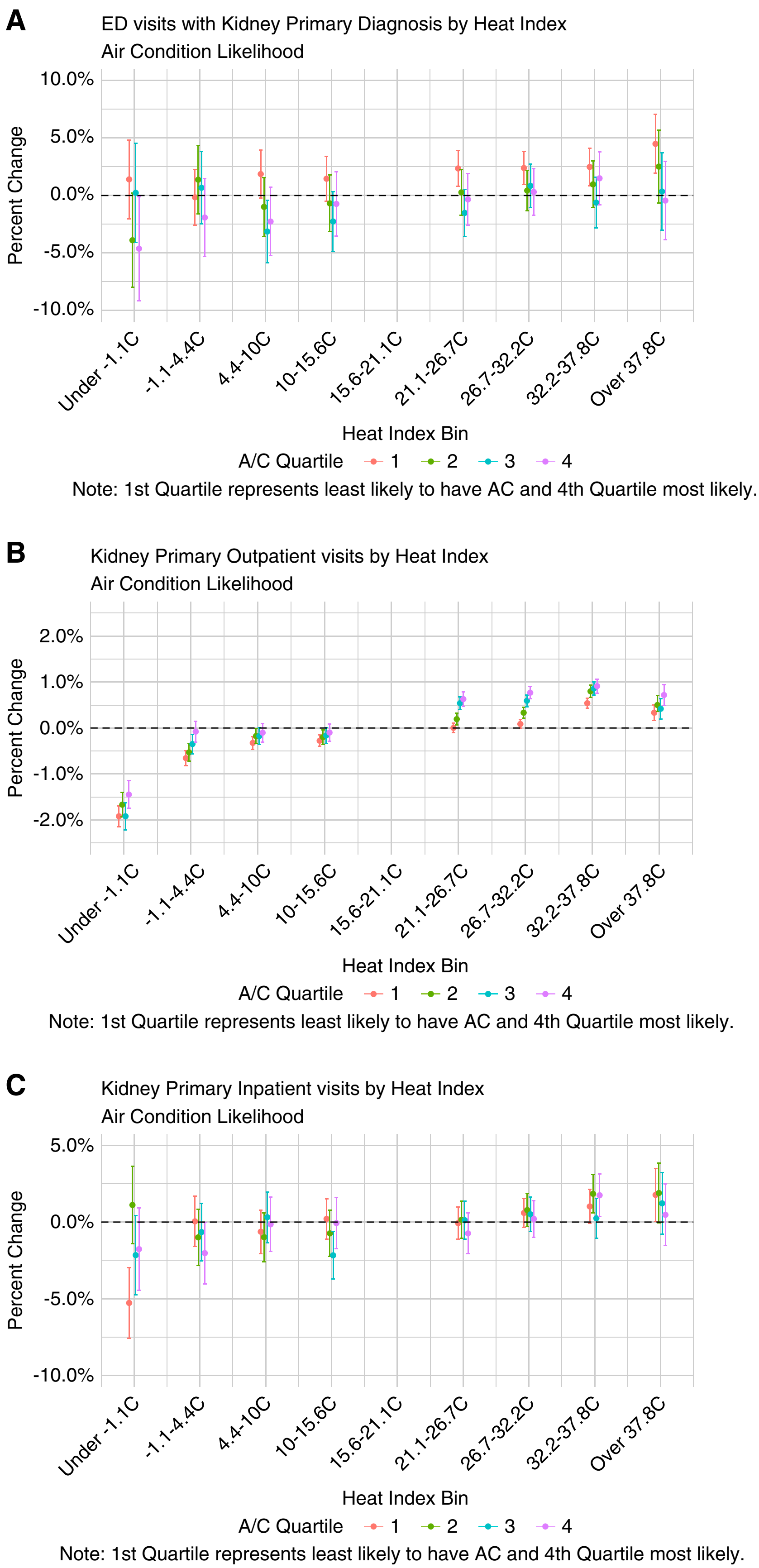

Figure 3. Relationship between temperature and utilization by AC probability quartiles. Bars represent 95% CIs.

Table 3. Regression coefficients and estimated cost calculations

ED Costs for Visits with Primary Kidney Diagnoses

Heat Index	Estimated Change in Probability of Visit in a Week for 1 Additional Day in Bin	Change in Days per Year in Bin Relative to 30-yr Historical Mean	Average Cost of Visit	Estimated Cost of Additional Visits per Day in Bin per 100k	Cost Per 100k Per Year
21.1°C–26.7°C[a]	0.000002	3.29	$353	$71	$233
26.7°C–32.2°C[a]	0.000002	1.92	$353	$81	$156
32.2°C–37.8°C[a]	0.000003	3.07	$353	$93	$285
37.8°C+[a]	0.000004	1.34	$353	$153	$206

Outpatient Kidney Costs for Visits with Primary Kidney Diagnoses

Heat Index	Estimated Change in Probability of Visit in a Week for 1 Additional Day in Bin	Change in Days per Year in Bin Relative to 30-yr Historical Mean	Average Cost of Visit	Estimated Cost of Additional Visits per Day in Bin per 100k	Cost Per 100k Per Year
21.1°C–26.7°C[a]	0.000081	3.29	$353	$2848	$9369
26.7°C–32.2°C[a]	0.000105	1.92	$353	$3709	$7138
32.2°C–37.8°C[a]	0.000191	3.07	$353	$6743	$20,687
37.8°C+[a]	0.000128	1.34	$353	$4521	$6059

Inpatient Kidney Costs for Visits with Primary Kidney Diagnoses

Heat Index	Estimated Change in Probability of Visit in a Week for 1 Additional Day in Bin	Change in Days per Year in Bin Relative to 30-yr Historical Mean	Average Cost of Visit	Estimated Cost of Additional Visits per Day in Bin per 100k	Cost Per 100k Per Year
21.1°C–26.7°C	−0.000001	3.29	$7397	−$372	−$1223
26.7°C–32.2°C[a]	0.000002	1.92	$7397	$1717	$3305
32.2°C–37.8°C[a]	0.000006	3.07	$7397	$4491	$13,779
37.8°C+[a]	0.000006	1.34	$7397	$4737	$6348

Costs use average cost for a visit in 2022. Thirty-year historical mean derived using 1985–2014 and the change compared with historic mean is the difference in number of days in each bin in 2022 compared with the 30-year means. ED, emergency department.
[a]Coefficient is significant.

avoidance for temperatures below −1.1°C is noteworthy and could show that extreme cold could decrease access to care, leading to worse outcomes.

A novel aspect of these findings is the association of greater utilization with lower access to A/C as a potentially actionable contributor to kidney health disparities. Heat exposure has not traditionally been considered a contributor to modifiable social determinants of kidney health that traditionally focus on income, employment, educational attainment, health literacy, access to healthcare, housing, air pollution, cigarette smoking, alcohol use, and aerobic exercise.[26,27] Kidney health disparities have been described since the 1980s that include greater prevalence of risk factors (type 2 diabetes and hypertension), more rapid progression or loss of kidney function over time, and reduced access to patient-centric kidney failure replacement therapies or kidney transplant and home dialysis.

Trends in extreme heat and the current literature may be used to support education of patients on the importance of hydration, avoidance of prolonged heat exposure, and the interaction between heat exposure and certain medications. This research supports educating people with kidney disease to limit heat stress by maintaining hydration while preserving urine output as well as ensuring access to A/C at home and workplace accommodations. Clinicians may need to engage with employers to advocate for these strategies. In addition, sick day medication guidance that is implemented for acute illness can also be applied for heat exposure among patients with CKD to suspend hemodynamic medications (such as diuretics) that sensitize patients to the adverse effects of dehydration.[28]

These findings can also be used by health plans and public health officials for designing interventions and climate resilience plans. Health plans can help design interventions by identifying heat-vulnerable populations, using predictive analytics to identify heat-related risk patterns, and crafting personalized plans and protective services for patients who are high-risk. In addition, health plans can offer supportive services such as transportation to cooling centers, provision of evaporative air coolers and other air conditioners through Medicare Advantage supplemental benefits, and enhanced case management check-ins for high-risk patients during extreme heat events. Public health systems can further inform climate resiliency plans for high-heat areas, such as implementing cooling centers and collaborating with local health systems and authorities for heat wave alerts. As we observed heterogeneity in the effect of heat on different populations, interventions should target the most vulnerable populations. Further investigation into the true economic effect of climate-relevant health issues will allow health systems to identify, prepare for, and alleviate avoidable expenses and health problems, while promoting climate research, policy, and action. Our findings suggest that greater access to A/C may reduce the risk of heat stress and improve health in the CKD population, although it should be noted that overuse of A/C may contribute to future extreme heat events. Furthermore, continued research addressing the effect of interventions such as A/C on the long-term relationship between heat exposure and health as well as disparities in access to mitigation and differential effects of heat on health for vulnerable populations is needed to fully understand this relationship.[29–31]

The strengths of our study compared with previous research are the use of individual level claims data for a large nationwide population and the modeling of the relationship between heat index and health outcomes across the full temperature distribution. However, our study has several limitations regarding how heat exposure is measured. We use Census block group of residence at the beginning of each week to assign heat for the week, but we cannot observe the actual location of the individual. We do not account for exposure time of the maximum temperature within a day and do not account for overnight low temperatures which could affect an individual's ability to cool themselves and their homes. The approximated heat indexes we used are also not as accurate as using measured maximum heat indexes. The findings may underestimate utilization or not be fully generalizable to the Medicaid, dual eligible, and uninsured populations that likely have higher social needs and lower A/C access.

Exposure to heat indexes above 26.7°C, but especially above 32.2°C, was associated with increased weekly ED utilization, both overall and with heat-related or kidney-related primary diagnosis codes in a population with CKD. Our results add to the literature by quantifying the healthcare utilization effects of exposure to high heat indexes and changes in weather patterns. Novel aspects of the findings are the associations of utilization with low A/C access that suggest the need for individual, clinician, and health system-level interventions. Further research is needed to determine the efficacy and cost-effectiveness of possible interventions.

Disclosures

Disclosure forms, as provided by each author, are available with the online version of the article at http://links.lww.com/CJN/C236.

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Data Sharing Statement

Data cannot be shared. The data used for this study included proprietary health claims and clinical data and cannot be shared for privacy reasons.

Supplemental Material

This article contains the following supplemental material online at http://links.lww.com/CJN/C235.

Supplemental Appendix 1. Heat index calculation.
Supplemental Appendix Table 1. CKD ICD-10 codes.
Supplemental Appendix Table 2. Heat-related visits.
Supplemental Appendix Table 3. Kidney-related visits.
Supplemental Appendix Table 4. ED kidney-related primary diagnosis by sex.
Supplemental Appendix Table 5. ED kidney-related primary diagnosis by region.
Supplemental Appendix Table 6. ED kidney-related primary diagnosis by rurality.
Supplemental Appendix Table 7. ED kidney-related primary diagnosis by current CKD stage.

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