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Research article

Rural heat health disparities: Evidence from the U.S. National Emergency Medical Services Information System (NEMSIS)

Minwoo Ahn[a], Ladd Keith[a], Heidi E. Brown[b,*]

[a] School of Landscape Architecture and Planning, University of Arizona, 1040 N Olive Road, Tucson, AZ 85719, United States
[b] Department of Epidemiology and Biostatistics, Mel and Enid Zuckerman College of Public Health, University of Arizona, 1295 N Martin Ave, Tucson, AZ 85724, United States

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ABSTRACT

Background: Increasing average temperatures and extreme heat events due to climate change have adverse effects on human health. Previous studies focus on the heat impacts in urban areas due to the focus on the greater population and urban heat island effect, but this tendency results in the effect of heat on rural health being overlooked.
Methods: Using the National Emergency Medical Services Information System (NEMSIS) data from 2021 to 2023, this study compares heat-related illness (HRI) in urban and rural areas of the U.S.
Results: We found the odds of EMS events in an urban area resulting with a positive outcome for the patient was 1.24 times that of EMS events in rural areas. This urban-rural disparity was not equal across regions with the odds of EMS events to rural areas of the Western U.S. resulting with a positive outcome for the patient was 54 % less than that for urban areas.
Conclusion: This critical evidence of a rural-urban heat health disparity calls attention to the impact of climate change-fueled heat impacts on health in communities of all sizes, and a need for more rural heat resilience research to inform practice.

1. Introduction

Extreme heat is being driven by climate change, with 2023 being the hottest year on record and the last decade being the hottest in recorded history [1]. A recent report found 76 extreme heat waves spanning 90 countries from 2023 to April 2024 [2]. It is estimated that for every 1°C increase in temperature, heat mortality risk increases by 35 % [3]. Extreme heat continues to be the story of concern for climate change and will intensify without clear reductions in greenhouse gas emissions in the near future [4]. Billions of people are at risk with the impact likely to increase given 37 % of heat-related deaths are attributable to human-induced climate change [5,6].

Increasing average temperatures and extreme heat events have detrimental effects on human health. Extreme heat events increase morbidity and mortality [7,8] with effects including cognitive decline [9], mortality among older adults [10] and adverse pregnancy and birth outcomes [11]. South Australia documented increased heat-related ambulance call-outs during 2008 and 2009 heat waves and an association between heat-related dehydration and acute renal failure [12]. A review of hospital admissions between 1989 and 2005 in Milwaukee Wisconsin, showed an association between high air temperature and five health outcomes (endocrine, genitourinary, renal, accidental, and self-harm) [13].

Human vulnerability to extreme heat has generally decreased due to better adaptation and infrastructure in developed nations [14]. These successes are largely attributed to air conditioning systems, improved work environments, better health generally, and implementation of heat warning systems [15]. Progress in reducing human vulnerability to heat is inequitable as adaptations have occurred unequally between different groups and communities [16]. In addition, people have different sensitivity to extreme heat depending on their baseline health status and poverty rates [14]. Thus, different dimensions of heat equity should be carefully examined to better understand the heat impact and to prescribe targeted policies to address the health impacts of extreme heat.

Previous heat research has tended to focus on the impact of heat on urban areas and explain results of temperature differentials through the urban heat island (UHI) effect [17,18]. Studies show that the UHI effect is proportional to the physical size of the city and that heat waves exacerbate heat island intensity [17]. The UHI effect is

* Corresponding author at: Department of Epidemiology and Biostatistics, Mel and Enid Zuckerman College of Public Health, University of Arizona, 1295 N Martin Ave, Tucson, AZ 85724, United States.
E-mail addresses: minwooahn@arizona.edu (M. Ahn), ladd@arizona.edu (L. Keith), heidibrown@arizona.edu (H.E. Brown).

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attributed to the artificial underlying surfaces compared to natural surfaces [18]. The effect of heat waves on dense urban areas tends to include higher thermal temperatures than surrounding rural or natural areas with less urbanization.

The UHI effect and its impact on urban populations has been the focus of heat research, while rural communities tend to be overlooked [19]. Extant studies on rural areas yield mixed findings. While several studies report rural residents have lower risk of heat-related health impacts [20,21], other studies show that rural communities are no less vulnerable, or even more severely affected, than urban areas [22–25]. Studies also suggest various factors that may intersect with urban-rural factors, including but not limited to social support, education, community safety, healthcare infrastructure, and remoteness [26–28]. These mixed results suggest research has not yet effectively assessed whether rural areas have inherent heat risk factors and how they compare to urban areas. We argue that this needs to be addressed by systematic comparative studies between urban and rural areas.

In this study, we compare emergency medical service (EMS) events between urban and rural communities in the United States (U.S.), where extreme heat is ranked the deadliest weather-related hazard [29]. We use the publicly available National Emergency Medical Services Information System (NEMSIS) data from 2021 to 2023. We ask what the difference in heat-related illness (HRI) outcomes is between urban and rural communities across the U.S. and regionally (West, Midwest, South, and Northeast). We discuss the health implications of our findings and offer several future research directions.

2. Materials and methods

Data. NEMSIS is a national database designed for the storage of EMS data from U.S. states and territories that was recently made publicly available [30]. The data are readily available through their data portal which, from our experience, offers a fast response time per request. The database is split across 27 spreadsheets and includes hundreds of variables pertaining to patient status and care, EMS response and time, and demographics. Information submitted to NEMSIS is voluntary and completed by state and territory EMS officials. Each EMS call is an event, and it is not tracked (i.e., not identifiable to researchers) as to whether it is a repeat call.

We requested data for EMS calls for 2021, 2022, and 2023 from NEMSIS using their Research Request portal. From the nearly 159 million events across the U.S. that occurred in 2021 (n = 49,799,962), 2022 (n = 54,146,966) and 2023 (n = 55,568,658), we restricted the analysis to only those attributed to heat stroke/exhaustion and heat stroke/hyperthermia (~0.21 % of all events each year). Merging across multiple datasets, we generated a database with 31,938 entries, which included location information, minimal demographics, response times, and symptoms and outcomes for each heat related EMS event.

Location information for NEMSIS events is provided at Census Bureau designations (Regions and Divisions) and includes a NEMSIS generated urbanicity coding based on county of residence. Urbanicity categorization is defined by the 2013 USDA Urban Influence Codes (Urbanicity in the NEMSIS User Manual [31]). We reclassified the four categories into two: 1) urban: urban (83.7 %) and suburban (6.6 %) compared 2) rural: rural (8.0 %) and wilderness (1.8 %).

Patient disposition at the end of the EMS event is classified into four categories in the database: lower acuity, emergent, critical and dead without resuscitation efforts. Lower acuity includes "symptoms of an illness or injury that have a low probability of progression to more serious disease or development of complications [31]." Emergent refers to "symptoms of an illness or injury that may progress in severity or result in complications with a high probability for morbidity if treatment is not begun quickly [31]." Critical condition is defined as "symptoms of a life-threatening illness or injury with a high probability of mortality if immediate intervention is not begun to prevent further airway, respiratory, hemodynamic and/or neurologic instability [31]." To assess patient disposition at the end of the EMS event, we compared lower acuity to all other disposition categories combined.

Data analysis. Analyses were conducted in Stata v 17 (College Station, TX). General seasonal and between year trends were assessed visually. Because the data were not normally distributed, Wilcoxon rank-sum was used to compare median age between urban and rural. Pearson's Chi square was used to compare urban and rural for categorical data, correcting for small numbers using Fisher's Exact. Simple logistic regression (i.e., no covariates) was used to compare the odds of a positive outcome (disposition categorized as low acuity vs all other disposition categories) between the reclassified urban (urban and suburban) and rural (rural plus wilderness) events overall and by Census region. As a sensitivity analysis we also looked at urban and rural only (i.e., not including wilderness or suburban) and across all four urbanicity categories.

3. Results

Heat Related Illness. We used NEMSIS data to evaluate differences in EMS services between rural and urban settings for HRI. The 2020 US Census reports 80 % of the US population live in urban areas. However, because we combined urban and suburban, our estimated proportion of EMS calls that were urban is higher (89.2 %).

While the overall trend of HRI events in different months looks similar between urban and rural areas, 2021 peaked earlier in June, and 2022 lasted longer into later summer, including August and September (Fig. 1a). HRI events in 2023 peaked in July, which was higher than in previous years. Rural HRI events increased earlier (June) than urban HRI events. The regional variation in HRI events in 2021, 2022, and 2023 between Midwest, Northeast, South, and West are shown in Fig. 1b, Fig. 2. Regionally, Midwest tended to peak earlier, and other regions tended to peak later in summer and show a trend toward rural peaking before urban. Compared to other regions, the West tended to have a higher peak in July.

Of the EMS events for HRI, two-thirds were male patients (65.7 %), with rural EMS events being more common among males than among females (Table 1). The median patient age was 50 years old, with rural median age slightly higher than urban, 52 years old vs 50 years old, respectively (p = 0.03).

Response Time. As expected, the total response time, which is the time between the unit being notified by dispatch and the unit going back into service after the event, was longer for rural events (median difference = 2.1 min; Mann-Whitney $p < 0.001$). The median time for rural HRI EMS calls to travel from the call scene to arrive at the patient's destination took three minutes longer than for urban events (Mann-Whitney $p < 0.001$). The median time between the unit being notified by dispatch and the unit arriving on the call scene was 1.7 min longer for rural events (Mann-Whitney $p < 0.001$).

Event Outcome. Among the 20,587 HRI events where the outcome at the end of the EMS event was recorded, there were 56 fatal outcomes (cardiac arrest that did not recover), with 8,678 HRI events missing the outcome (29.7 %). We find no difference by urban/rural for deaths (though the numbers are small when stratified: n = 7 deaths in rural; X^2 = 0.493, p = 0.49). We find no differences in AED use (n = 10) or CPR (n = 19) between urban and rural, but whether or not AED or CPR was implemented was only reported for 205 and 69 events, respectively. Patients from urban areas fared better (lower acuity) at the end of the EMS events than those from rural areas (OR: 1.24, 95 % CI 1.13, 1.36).

Regional variation. Patient disposition for heat health outcomes differed by geographic location (Table 2). When stratifying by region, the frequency of an urban EMS event in the West ending with the

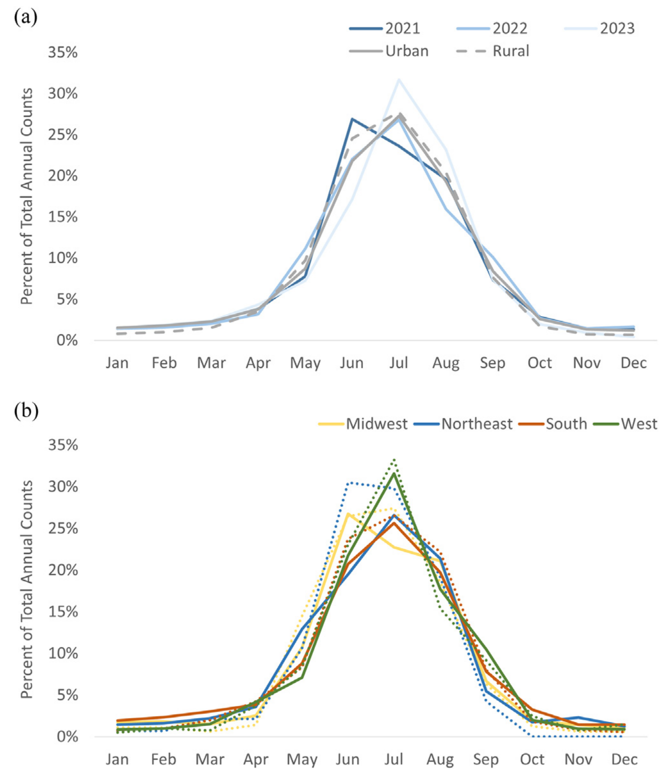

Fig. 1. (a). Percent of total annual HRI events by month comparing totals by year and urban versus rural area in the U.S. Grey lines indicate urban (solid) and rural (dashed), while blue color gradient indicates year. (b). Percent of total annual HRI events by month comparing different US Census regions. Solid lines indicate urban, and dashed lines indicate rural.

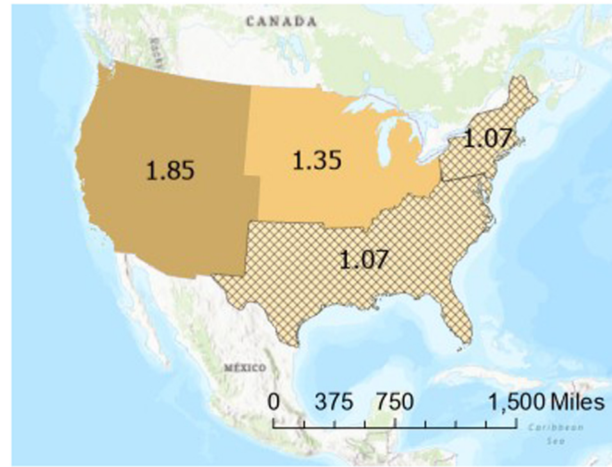

Fig. 2. Odds of Urban EMS Event ending with Lower Acuity compared with Rural by Census Region. Hash marks indicate non-significant differences. * Note West includes Alaska and Hawaii.

patient at lower acuity is almost twice that of a rural event ending in lower acuity (OR: 1.85, 95 % CI 1.48, 2.32).

Sensitivity analysis. To test the effect of reclassification of the four categories into just urban and rural, we looked at only the entries listed as urban and rural, excluding the smaller categories of suburban and wilderness. Across all comparisons, the odds of an EMS event from just urban areas ending with low acuity was still greater than the odds of EMS events from just rural areas ending in low acuity, with stronger associations and narrower confidence intervals (see supplementary tables). We also checked the association between patient disposition after EMS care across all the four USDA urbanicity categories. Again, the odds of an EMS call ending with the patient in low acuity was greater for urban areas compared to rural (OR:1.2, 95 % CI 1.1,1.3) and compared to wilderness (OR: 1.6, 95 % CI 1.3,1.9), though only marginally when comparing urban and suburban (OR: 1.1, 95 % CI 0.97,1.2). For the four categories, the number of events were too small to be stratified by Census Region.

4. Limitations

While this represents a first use of these public data comparing heat-related outcomes between urban and rural counties in the U.S., it is a limited dataset and has some data concerns. Heat-related illnesses and deaths are underreported by as much as 50-fold in some studies [32]. We expect that issue also exists in these EMS data and likely, by restricting the analysis to cases identified as HRI, we are missing additional heat-related cases. Related, the generalizability to HRI burden in urban and rural communities is limited as these data are likely more severe cases, i.e., requiring EMS services. Extreme heat can also impact populations in less acute ways (e.g., heat stress) which could be a particular risk for vulnerable groups such as older adults or those with co-morbidities not captured in this analysis.

The data were incomplete for some variables – as might be expected for EMS data where patient care is foremost. We found evidence that the age data may not be reliable: specifically, the maximum age reported was 120 years of age and, in some instances, events attributed to a pediatric patient would be listed with an age greater than 18 years of age and vice versa. This issue for incomplete or inaccurate data prohibited more robust analyses, including stratifying by age and comparing race.

Finally, the urbanicity classification was provided within the dataset and calculated as the county within which the event occurred. This may bias the association with urbanicity as counties in the US West are larger but still have population centers (i.e., a person living in a city of a rural county). However, our finding that transport times were longer for rural events, suggests that even at the county level, the urbanization classification is still detecting differences.

5. Discussion and conclusion

The literature focuses overwhelmingly on urban heat and its effects, while rural heat impacts tend to be overlooked. We begin to address this gap by analyzing a national dataset to compare rural and urban heat related illness in the U.S. Three years (2021–2023) of EMS event data comparing HRI outcomes between urban and rural events in the U.S. showed patients from rural regions tended to have less desirable HRI outcomes compared to urban patients. This serves as a reminder that, not only do rural areas experience adverse heat events, but the effects are also disproportionally negative.

Others have also shown differences in survival for urban patients with out-of-hospital cardiac arrest, though what drives these differences is less known [33]. Mell et al. [34], found significantly longer (almost twice as long) response times for rural EMS events using ZIP code level data [34]. In a survey of EMS directors, medical direction and integration into EMS was seen as a critical need for rural EMS [35]. Remoteness and healthcare infrastructure may explain the inequitable outcomes we observed [24], or the real drivers may be broader.

Divergent findings in the literature regarding urban and rural health also suggest that we should look beyond just geography to uncover the drivers of observed differences in HRI. While population density and built environment matter, age also shapes HRI outcomes [36]. Regardless of geographic location, older populations are most affected by heatwaves and extreme heat events in Germany and Spain. Within the U.S., rural areas have increasingly older populations [37]. Evidence from Poland suggests that small towns tend to have

Table 1
Description of NEMSIS heat related illness.

	Urban	Rural	Total	
Sex				
Female	9,888 (34.8 %)	1,002 (32.3 %)	10,890 (34.3 %)	$X^2(1) = 6.1$, $p = 0.01$
Male	19,764 (65.5 %)	2,100 (67.7 %)	20,864 (65.7 %)	
Median Age (IQR)	50 (31,67)	52 (31,68)	50 (31,67)	$Z = 2.2$, $p = 0.03$
Median Response Times (IQR) in minutes				
Total response time	59.0 (41.5, 78.0)	61.1 (42.1, 87.0)	59.0 (41.6, 78.8)	$Z = 7.1$, $p < 0.001$
Transport Time	13.0 (8.3,19.4)	16.0 (7.1,29)	13.0 (8.2, 20)	$Z = 10.6$, $p < 0.001$
Dispatch to Arrival	7.4 (5.0,11.4)	9 (5,16)	7.5 (5,12)	$Z = 8.2$, $0 < 0.001$
Death at End of Event*	49	7	56	$X^2(1)$=0.49, $p = 0.49$
Use of AED*	6	4	10	$X^2(1)$=0.29, $p = 0.73$
CPR given*	14	5	19	$X^2(1)$=2.96, $p = 0.12$

* These variables are incomplete/include missing data.

higher HRI associated mortality rates than larger cities [38]. In the U.S. context, studies show that migrant and seasonal farmworkers are especially vulnerable to heat exposure in rural regions [39–41]. Other studies also suggest factors including demographic and socioeconomic characteristics, accessibility to cooling facilities, and medical infrastructure influence the disparity between urban and rural regions [24,42]. With our sample, we were not able to robustly examine age differences but we did find a greater proportion of males among rural events. We argue that these demographic, social, regional, and infrastructure accessibility factors should also be considered to better predict and explain heat-health outcomes [8]. These factors could be considered as heat-health interventions are planned and implemented in rural communities.

Policy implications. While heat governance should be advanced in an integrated way to organize and coordinate key decisionmakers vertically and horizontally [43,44], we emphasize that rural regions should not be overlooked and that there is evidence these communities experience equal or worse heat-health outcomes compared to urban areas in the U.S. Heat equity and vulnerability should be assessed and evaluated in a holistic manner using systematic heat equity metrics. More empirical data is needed to evaluate the effectiveness of heat governance arrangements in rural areas on heat health outcomes. While our findings were limited to urban and rural differences in the U.S., researchers could replicate our analysis in other national contexts with available EMS data to see if the findings are generalizable elsewhere. Finally, regions are diverse and there might be inherent limitations of benchmarking or adopting policies from one nation to another. National and institutional contexts should be considered for effective policy making [45].

With climate change increasing average temperatures and extreme heat events adversely impacting health outcomes, we systematically compared various outcome measures (EMS response time, conditions after EMS service) between urban and rural areas. Heat-health research must move beyond its current urban focus to better document rural heat-health outcomes and needs. While our study reveals additional dimensions of equity by drawing different types of HRI outcome data, future studies can further dissect fine-grained analyses at the U.S. county and/or state level. County and state-level policy analysis will allow us to examine how different state and county policies affect public health outcomes while controlling for various socio-economic and climate factors. With fine-grained individual-level data, future studies can also address whether and how additional equity dimensions such as age, occupation, and socioeconomic status affect heat-health outcomes.

Table 2
Condition after EMS care, by US census region.

	Urban	Rural	Total	OR (95 % CI)
Midwest				
Lower Acuity	1,560	195	1,755	1.35 (1.08, 1.68)
Emergent, Critical or Dead	1,028	173	1,201	
Northeast				
Lower Acuity	527	52	579	1.07 (0.65, 1.76)
Emergent, Critical or Dead	246	26	272	
South				
Lower Acuity	4,750	913	5,663	1.07 (0.95, 1.21)
Emergent, Critical or Dead	2,257	465	2,722	
West				
Lower Acuity	4,904	172	5,076	1.85 (1.48, 2.32)
Emergent, Critical or Dead	2,234	145	2,379	
Total				
Lower Acuity	11,741	1,332	13,073	1.24 (1.13, 1.38)
Emergent, Critical or Dead	5,765	809	6,574	
Total	17,506	2,141	19,647	

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Heidi Brown & Ladd Keith reports financial support was provided by National Oceanic and Atmospheric Administration. Heidi Brown reports financial support was provided by Centers for Disease Control and Prevention Climate Ready States and Cities. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Minwoo Ahn: Writing – review & editing, Writing – original draft, Visualization. **Ladd Keith:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Heidi E. Brown:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.joclim.2025.100432.

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