Social Disparities in the Duration of Power and Piped Water Outages in Texas After Winter Storm Uri

Sara E. Grineski, PhD, Timothy W. Collins, PhD, Jayajit Chakraborty, PhD, Eric Goodwin, MS, Jacob Aun, MA, and Kevin D. Ramos

We assessed sociodemographic disparities in basic service disruptions caused by Winter Storm Uri in Texas. We collected data through a bilingual telephone survey conducted in July 2021 (n = 753). Being Black, having children, and renting one's residence were associated with longer power outage durations; being Black was also associated with longer water outages. Our findings highlight the need to plan for and ameliorate inequitable service outages and their attendant health risks in climate change–related extreme weather events such as Uri. (*Am J Public Health*. 2023;113(1):30–34. https://doi.org/10.2105/AJPH.2022.307110)

AJPH January 2023, Vol 113, No. 1

Winter Storm "Uri" included three arctic fronts that swept across the state of Texas from February 10 through 20, 2021. Treating Uri as a natural intervention, we examine sociodemographic disparities in power and water outage durations associated with the storm.

INTERVENTION AND IMPLEMENTATION

We treat Uri as a natural intervention because it triggered major societal disruptions. As numerous counties faced extreme low temperatures, 10 million people lost access to electricity[1] because electricity and gas systems were insufficiently winterized, the major electric grid operator (i.e., Electric Reliability Council of Texas) was isolated from the national grid and unable to import power, and some power plants were out of service for planned maintenance.[2] One study inferred that 69% of Texans went without power and 49% went without running water.[3] Power outage conditions directly caused 210 deaths (e.g., from carbon monoxide poisoning); when indirect causes are included, Uri led to an estimated 700 deaths.[2] Texas incurred $130 billion in economic losses as a result of the storm.[1] To understand the unequal effects of this event, we conducted a 35-minute telephone survey in English and Spanish across eight Texas metropolitan statistical areas in July 2021.

PLACE, TIME, AND PERSONS

The survey was administered to randomly selected residents 18 years or older in counties representing the following Texas metropolitan statistical areas: Dallas–Fort Worth, Houston, San Antonio, Austin, McAllen, El Paso, Beaumont–Port Arthur, and Lubbock (Figure A, available as a supplement to the online version of this article at http://www.ajph.org). The sampling frame was proportionally weighted according to the population (n = 1964). Of 1764 eligible respondents contacted, 896 (50.8%) completed the survey. We excluded 143 respondents who did not complete survey items used to construct three or more of our analysis variables, leaving a final sample size of 753.

We collected data on sociodemographic characteristics (independent variables) and the durations of power and water outages (in hours) associated with the storm, the latter two of which we analyzed as dependent variables. Descriptive statistics for all variables are shown in Table 1. To analyze the data, we used multiple imputation to address missing values and then employed our multiply imputed data in multivariable generalized estimating equation models.

PURPOSE

It is important to study events such as Uri because they cause power[4,5] and

TABLE 1— Descriptive Statistics Pertaining to a Household Survey Conducted in Eight Texas Metropolitan Statistical Areas: 2021

Variable	No. Households	Minimum	Maximum	Mean ±SD	Yes, No. (%)	No, No. (%)	Missing, (%)
Total hours home was without electricity	745	0.0	504.0	42.156 ±55.914			1.0
Total hours home was without piped water service	724	0.0	672.0	32.691 ±68.762			4.0
Household income[a]	734	1	10	5.260 ±2.868			0.3
Householder race/ethnicity							
Non-Hispanic White	748	0	1		329 (44.0)	419 (56.0)	0.7
Non-Hispanic Black	748	0	1		81 (10.8)	667 (89.2)	0.7
Hispanic	752	0	1		265 (35.2)	487 (64.8)	0.1
Non-Hispanic other	748	0	1		71 (9.5)	677 (90.5)	0.7
US-born householder	746	0	1		616 (82.6)	130 (17.4)	0.9
Household has a disabled member	753	0	1		341 (45.3)	412 (54.7)	0.0
Household has a member older than 65 y	743	0	1		271 (36.5)	472 (63.5)	1.3
Household has a child (or children)	750	0	1		289 (38.5)	461 (61.5)	0.4
Ownership status							
Owns	753	0	1		497 (66.0)	256 (34.0)	0.0
Rents, non-HUD	753	0	1		133 (17.7)	620 (82.3)	0.0
Rents from HUD	753	0	1		123 (16.3)	630 (83.7)	0.0
ERCOT power grid[b]	753	0	1		667 (88.6)	86 (11.4)	0.0
Freeze severity[c]	753	1.53	23.15	15.028 ±4.030			0.0

Note. ERCOT = Electric Reliability Council of Texas; HUD = Housing and Urban Development. The household sample size was 753.

[a]Income variable categories were as follows: (1) < $10 000, (2) $10 000–$19 999, (3) $20 000–$29 999, (4) $30 000–$39 999, (5) $40 000–$49 999, (6) $50 000–$74 999, (7) $75 000–$99 999, (8) $100 000–$149 999, (9) $150 000–$249 999, and (10) ≥ $250 000.

[b]Data were not collected via our survey; we used Geographic Information System software to overlay geocoded locations of our respondents (based on household addresses) with a power grid polygon shapefile.

[c]Data were not collected via our survey; we used secondary data to create this measure. Freeze severity is a measure of the extent to which the minimum temperature during the storm deviated from the average minimum temperature. We calculated the minimum temperature that occurred between February 10 and 20, 2021, for each household on the basis of High-Resolution Rapid Refresh radar data. We then subtracted the average February minimum temperature in each metropolitan statistical area.

water[6,7] outages, which pose serious risks to public health. Disasters tend to disproportionately affect socially disadvantaged communities that lack resources to stay safe and recover quickly.[8] Because of the lack of outage data, few published studies have examined inequities in power and water outages. During Uri, an ecological analysis revealed that Texas counties with more severe power outages had greater concentrations of Hispanic residents.[2] A report on an Internet survey conducted after Uri showed minimal differences in reported outage durations between racial/ethnic groups[3] but lacked statistical testing and examination of other covariates. Another report showed that one tenth of the population in predominantly White areas suffered a nighttime blackout during Uri, as compared with one half in areas with large concentrations of racial/ethnic minority residents.[9]

Our survey data provide a unique basis for statistically examining household-level inequalities in the self-reported durations of both power and water outages during Uri. We addressed the following question: How were sociodemographic characteristics associated with the duration of basic service outages during Uri across the eight Texas metropolitan areas assessed?

EVALUATION AND ADVERSE EFFECTS

Observed means for power and water loss durations were 42 hours and 33 hours, respectively. In the multivariable generalized estimating equation models, being Black, having children, and renting one's residence were associated with longer power outages; being Black was associated with longer water outages (all *P*s < .05; Table 2). To determine how much longer, we used the

TABLE 2— Pooled Results of Multivariable Generalized Estimating Equations Including Data Collected Through a Household Survey Conducted in Eight Texas Metropolitan Statistical Areas: 2021

	Duration of Power Outage, b (95% CI)	Duration of Piped Water Outage, b (95% CI)
Intercept	2.76 (1.74, 3.79)	25.80 (4.80, 46.81)
2020 household income	−0.01 (−0.04, 0.03)	−1.62 (−3.49, 0.24)
Householder race/ethnicity		
Non-Hispanic White	0 (Ref)	0 (Ref)
Non-Hispanic Black	0.52 (0.30, 0.75)	25.34 (5.40, 45.33)
Hispanic	0.12 (−0.098, 0.34)	6.03 (−3.94, 16.01)
Non-Hispanic other	0.02 (−0.13, 0.30)	−0.57 (−15.08, 13.93)
Householder country of origin		
Foreign-born	0 (Ref)	0 (Ref)
US-born	0.14 (−0.14, 0.41)	−1.99 (−14.07, 10.09)
Household composition		
All household members are younger than 65 y	0 (Ref)	0 (Ref)
Household has an older member	0.05 (−0.17, 0.27)	0.56 (−10.49, 11.62)
Household has a disabled member	0.02 (−0.13, 0.16)	2.25 (−7.09, 11.59)
Household has a child (or children)	0.35 (0.19, 0.52)	5.20 (−5.64, 16.04)
Ownership status		
Owns	0 (Ref)	0 (Ref)
Rents, non-HUD	0.44 (0.12, 0.76)	12.85 (−2.20, 27.91)
Rents from HUD	0.14 (−0.08, 0.36)	13.72 (−3.60, 30.97)
ERCOT power grid	0.33 (−0.69, 1.34)	6.94 (−21.53, 35.41)
Freeze severity	0.03 (−0.01, 0.08)	1.07 (−1.03, 3.16)

Note. CI = confidence interval; ERCOT = Electric Reliability Council of Texas; HUD = Housing and Urban Development. The household sample size was 753. The term pooled results refers to our use of multiple imputation to address missing values. We created 20 data sets with separate imputed values for missing observations and used these data in our pooled statistical analyses. Model specifications are normal with log link (for duration of power outage) and normal with identity link (for duration of piped water outage), with an exchangeable correlation matrix and clustering of metropolitan statistical areas (n = 8) by median age of housing stock categories (n = 8). Models also controlled for five winter climatic zone categories on the basis of average annual minimum winter temperature. Parameter estimate sizes are not comparable between the models owing to different model specifications (i.e., link functions). Collinearity diagnostics indicated an absence of multicollinearity in these models. SPSS version 28.0 (IBM, Somers, NY) was used in generating our models.

models in Table 2 to calculate estimated marginal means. In contrast to observed means (Table 1), estimated marginal means adjust for covariates (i.e., all other variables held at their observed means) and multivariable model specifications (Table 2). The model for power outage duration predicted 58.6 hours versus 34.8 hours for Black versus non-Hispanic White householders, 45.7 hours versus 34.3 hours for households with children versus those without, and 41.4 hours versus 32.1 hours for renters versus owners. For water outage duration, the model predicted 57.0 hours versus 31.6 hours for Black versus non-Hispanic White householders.

These significant findings were robust according to sensitivity analyses of multiply imputed data for all cases (n = 896; Table A, available as a supplement to the online version of this article at http://www.ajph.org), cases with complete data only (n = 699; Table B, available as a supplement to the online version of this article at http://www.ajph.org), and cases without outlier dependent variable values (n = 746 and n = 743; Table C, available as a supplement to the online version of this article at http://www.ajph.org). The only exceptions, when comparing the sensitivity analyses to the Table 2 findings, were the renter status–longer power outage finding becoming statistically nonsignificant (Tables B and C); Electric Reliability Council of Texas grid, public housing residence, and being US born becoming statistically significant for longer power outages (Table C); and renter status becoming statistically significant for longer water outages (Table C).

In terms of limitations, survey data were collected five months after the event, which could have led to recall bias. We do not know whether there was nonresponse bias in the sample. In addition, we did not model locations of critical facilities, the presence of which reduced the chance of blackouts by approximately 6% during Uri.[9]

SUSTAINABILITY

Research on social disparities associated with events such as Uri is important and should be prioritized. Because of climate change[10] and the public health effects of service outages,[4–7] Uri should serve as a bellwether nationwide. Black householders, householders with children, and renters experienced disproportionately longer outages and should be targeted with public health interventions, including provision of bottled water, small grants to purchase food, and blankets and warm jackets (especially when cold weather occurs in warm climates[11]). At a societal level, improving infrastructure systems to withstand extreme weather and equitably protect residents is of utmost public health importance.

PUBLIC HEALTH SIGNIFICANCE

Whereas previous research has highlighted disparities in power outages in minority areas[9] and Hispanic areas[2] in Texas during Uri, we found power outages of significantly longer durations for Black households. Households with children and renters also reported longer power outages. During a winter storm, power outages lead to relatively cold indoor temperatures, and cold is a leading cause of mortality; the attributable mortality rate in the United States for cold temperatures is an order of magnitude larger than it is for high temperatures.[12] Long-duration power and water outages are stressful for households as toilets cannot be flushed and lights cannot be turned on; furthermore, there are substantial economic costs associated with replacing food and buying bottled water. These stressors disproportionately affected Black householders, householders with children, and renters after Uri.

Gastrointestinal issues are a health risk associated with basic service outages. Black households likely faced increased risks of gastrointestinal issues after Uri because of their longer power and water outage durations relative to White households. One study showed that adolescents and adults with diarrhea after a daylong power outage in New York City were more than 2.5 times as likely as those without diarrhea to have consumed seafood and meats.[4] Although the Centers for Disease Control and Prevention recommends avoiding refrigerated food once power outages exceed four hours, that time window stretches to 24 to 48 hours for half-full and full freezers. Black households' outages exceeded the 48-hour window during which food would still edible, whereas White households' outages did not.

In addition, a systematic review revealed that gastrointestinal issues are associated with longer versus shorter water outages because pipes become increasingly vulnerable to backflow and intrusion.[6] This implies that Black households likely faced higher risks of gastrointestinal issues than White households after Uri because of the disproportionately longer outages they endured. AJPH

ABOUT THE AUTHORS

Sara E. Grineski is with the Department of Sociology, University of Utah, Salt Lake City. Timothy W. Collins, Eric Goodwin, and Kevin D. Ramos are with the Department of Geography, University of Utah. Jayajit Chakraborty and Jacob Aun are with the Department of Sociology and Anthropology, University of Texas at El Paso.

CORRESPONDENCE

Correspondence should be sent to Sara E. Grineski, University of Utah Department of Sociology, 380 S 1530 E Room 301, Salt Lake City, UT 84112 (e-mail: sara.grineski@soc.utah.edu). Reprints can be ordered at http://www.ajph.org by clicking the "Reprints" link.

PUBLICATION INFORMATION

Full Citation: Grineski SE, Collins TW, Chakraborty J, Goodwin E, Aun J, Ramos KD. Social disparities in the duration of power and piped water outages in Texas after Winter Storm Uri. *Am J Public Health*. 2023;113(1):30–34.

Acceptance Date: August 29, 2022.

DOI: https://doi.org/10.2105/AJPH.2022.307110

CONTRIBUTORS

S. E. Grineski conceptualized and conducted the statistical analysis and wrote the first draft of the article. T. W. Collins and J. Chakraborty advised on the study design and statistical analysis and contributed to the writing of the article. E. Goodwin, J. Aun, and K. D. Ramos prepared the non-survey-based data for the project and contributed to the writing of the article. S. E. Grineski, T. W. Collins, and J. Chakraborty obtained the funding for the project.

ACKNOWLEDGMENTS

This article is based on work supported by the National Science Foundation under grants CMMI-2127941 and CMMI-2127932, and the National Institute of Environmental Health Sciences under award R25 ES031497.

We gratefully acknowledge the survey participants for taking the time to be part of our study.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

HUMAN PARTICIPANT PROTECTION

This project was declared exempt by the institutional review boards of the University of Utah and the University of Texas at El Paso as per exemption category 2.

REFERENCES

1. Busby JW, Baker K, Bazilian MD, et al. Cascading risks: understanding the 2021 winter blackout in Texas. *Energy Res Soc Sci*. 2021;77:102106. https://doi.org/10.1016/j.erss.2021.102106
2. Flores NM, McBrien H, Do V, Kiang MV, Schlegelmilch J, Casey JA. The 2021 Texas power crisis: distribution, duration, and disparities. *J Expo Sci Environ Epidemiol*. 2022 [Epub ahead of print]. https://doi.org/10.1038/s41370-022-00462-5

3. Watson K, Crock R, Jones M. The winter storm of 2021. Available at: https://uh.edu/hobby/winter2021/storm.pdf. Accessed April 14, 2022.
4. Marx MA, Rodriguez CV, Greenko J, et al. Diarrheal illness detected through syndromic surveillance after a massive power outage: New York City, August 2003. *Am J Public Health.* 2006;96(3):547–553. https://doi.org/10.2105/AJPH.2004.061358
5. Casey JA, Fukurai M, Hernández D, Balsari S, Kiang MV. Power outages and community health: a narrative review. *Curr Environ Health Rep.* 2020;7(4):371–383. https://doi.org/10.1007/s40572-020-00295-0
6. Ercumen A, Gruber JS, Colford JMJ. Water distribution system deficiencies and gastrointestinal illness: a systematic review and meta-analysis. *Environ Health Perspect.* 2014;122(7):651–660. https://doi.org/10.1289/ehp.1306912
7. Säve-Söderbergh M, Bylund J, Malm A, Simonsson M, Toljander J. Gastrointestinal illness linked to incidents in drinking water distribution networks in Sweden. *Water Res.* 2017;122:503–511. https://doi.org/10.1016/j.watres.2017.06.013
8. Wisner B, Blaikie P, Cannon T, Davis I. *At Risk: Natural Hazards, People's Vulnerability and Disasters.* 2nd ed. London, England: Routledge; 2004.
9. Carvallo J, Chi Hsu F, Shah Z, Jay T. Frozen out in Texas: blackouts and inequity. Available at: https://www.rockefellerfoundation.org/case-study/frozen-out-in-texas-blackouts-and-inequity. Accessed June 29, 2022.
10. National Academies of Sciences, Engineering, and Medicine. Attribution of extreme weather events in the context of climate change. Available at: https://nap.nationalacademies.org/catalog/21852/attribution-of-extreme-weather-events-in-the-context-of-climate-change. Accessed July 1, 2022.
11. Li D, Zhang Y, Li X, Meyer M, Bazan M, Brown R. "I didn't know what to expect or what to do": impacts of a severe winter storm on residents of subsidized housing in Texas. Available at: https://ssrn.com/abstract=4047541. Accessed June 29, 2022.
12. Burkart KG, Brauer M, Aravkin AY, et al. Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study. *Lancet.* 2021;398(10301):685–697. https://doi.org/10.1016/S0140-6736(21)01700-1