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Anxiety and depression after winter storm Uri: Cascading disasters and mental health inequities

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ABSTRACT

While cold weather disasters are likely to become more frequent under climate change, most health research is focused on heat waves, flooding or hurricanes. Oriented by a "cascading disaster health inequities" approach, we examine anxiety and depression after a cold-weather disaster using survey data (n = 790) collected in eight Texas metropolitan statistical areas following Winter Storm Uri (2021). 14.9% of respondents experienced anxiety (GAD-2) and 15.1% experienced depression (PHQ-2) six months after the event. In multivariable models, disability status and having more adverse event experiences during the storm increased odds of depression and anxiety. Minority racial/ethnic status was associated with greater odds of depression, but not anxiety. Those who were Black and disabled, Hispanic and disabled, disabled and Uri impacted, Black and Uri impacted or Hispanic and Uri impacted faced increased odds of depression compared to the applicable "doubly privileged" reference category. Those who were Hispanic and disabled or disabled and Uri impacted experienced elevated odds of anxiety compared to the applicable "doubly privileged" reference category. Results demonstrate the utility of a "cascading disasters mental health inequities" approach for illuminating how social factors intersect with disaster experiences to shape disparate risks.

1. Introduction

Winter Storm Uri hit the state of Texas on February 13, 2021, taking Texans by surprise and ravaging essential utilities statewide [1]. All 254 counties in Texas were impacted by this storm, with many locales reporting record or near-record low temperatures. In Austin, temperatures reached 6° Fahrenheit; in Dallas-Fort Worth, temperatures dropped to −2° Fahrenheit [2]. Icy conditions wreaked havoc across the state [3]. The storm claimed the lives of over 210 residents and caused over $80–130 billion in damages [4].

The storm led to various health-related challenges. During and after the storm, approximately one-fifth of residents in major metropolitan areas went without access to health care and the same proportion ran out of food [5]. Approximately 40% lacked access to a working toilet and were without adequate drinking water [5]. These difficult circumstances were stressful, even traumatic, for residents [6,7]. Six months after the storm, nearly one-fifth of residents of major metropolitan areas in Texas were suffering from the symptoms of post-traumatic stress caused by the storm [7]. About 15 months later, 16% of respondents to a different survey were still

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struggling from post-traumatic stress [6]. This paper extends previous research by examining post-Uri anxiety and depression, with a focus on intersecting health inequities associated with race/ethnicity, disability status, and adverse event experiences.

1.1. Winter storm Uri as a cascading disaster

The meteorological features of the storm cascaded to produce varied impacts. Cold temperatures caused power and water service outages and people became sick with gastrointestinal illnesses [5]. Widespread pipe bursts due to the cold weather overwhelmed the capacity of plumbers to respond, leading to long delays in restoring piped water [8]. The cold temperatures and utility outages led families to use unsafe heating methods, causing indoor fires and carbon monoxide poisoning [8]. The ways in which the impacts escalated led researchers to classify Uri and its sequalae as a cascading disaster [7,9]. Cascading disasters occur when progressive interactions between environmental hazards, social vulnerabilities, and infrastructure systems trigger secondary (tertiary, quaternary, etc.) events with strong subsequent impacts [10]. The concept of cascading disasters also applies when multiple causally unrelated disasters occur in the same place and time [11], as was the case with Uri and COVID-19 [7]. When Uri hit in February 2021, COVID-19 was still a major crisis in the US and in Texas. At that time, 90% of Americans had yet to receive even one dose of a COVID-19 vaccine [12].

While the storm and its cascading impacts affected much of Texas, recent studies have reported significant social disparities in severity of Uri impacts. There were dramatic race-based disparities in water and power outage durations for Black vs. White Texans [13]. People from racial/ethnic minority backgrounds had greater odds of Uri-specific post-traumatic stress as compared to White respondents, as did disabled vs. non-disabled respondents [7]. Households including someone with a disability were more severely impacted by Uri than households without disabled persons, in terms of service disruptions, colder temperatures, slower recovery, and adverse experiences [5]. As Uri occurred simultaneously with COVID-19, those who were more impacted by COVID-19 reported greater Uri-specific post-traumatic stress [7].

1.2. Weather-related disasters and mental health

Weather-related disasters, like flooding and heat waves, are associated with mental health problems [14–18]. The mental health effects of cold-weather extremes—the focus of this study—have received less attention [6,7,19]. While post-traumatic stress (e.g., flashbacks, avoidance of stimuli that serve as reminders of the event, hypervigilance, and/or disturbed sleep) is the most frequently studied mental health outcome after disasters [20], anxiety and depression affect substantial numbers of disaster survivors [21–23]. Interestingly, while there are growing concerns about anxiety and depression in the US, especially following the most acute period of the COVID-19 pandemic [24], these mental health outcomes are less often examined in response to weather-related disasters and very rarely in extreme cold-weather events like Uri.

Weather-related disasters are important to study in the context of a changing climate as increasingly frequent extremes are causally tied to anthropogenic climate change [25,26]. While emphasis is typically placed on the increased frequency of hot days and drought, climate change is also associated with increased atmospheric moisture, resulting in more frequent extreme precipitation events, including winter storms [27]. While more attention in the literature has been given to physical health impacts [28], climate change and mental health are increasingly being studied [20,29]. Mental health can be negatively affected by the loss of property, jobs, and resources, leading to stress, anxiety, and depression [30]. Climate change-related mental health research has tended to focus on heat waves, floods, droughts, tornados, vector-borne diseases, and wildfires, but not cold-weather disasters [20,29], the focus of our study.

1.3. Mental health inequities after cascading disasters

Research on the health consequences of cascading disasters is underdeveloped, as is research on health inequities stemming from cascading disasters. Health inequities are disparities in health that are unnecessary and avoidable in addition to being unjust [31]. Thomas et al. [11] assert that "incorporating, documenting, and assessing how marginalized groups suffer, cope, and adapt [after cascading disasters] is essential for achieving environmental justice" (p. 3). Addressing this call demands that scholars examine health inequities occurring after cascading disasters.

As a first step, a prior study examined inequities in post-traumatic stress after Uri [7], focusing on the intersection of Uri-related utility disruptions and COVID-19. Having piped water outages and being highly impacted by COVID-19 were risk factors for post-traumatic stress after Uri. The same study then tested if specific combinations of disaster cascades influenced post-traumatic stress. Post-traumatic stress was more likely if respondents had a water and/or power outage and high COVID-19 impacts as compared to having no outages and low COVID-19 impacts [7]. While important to advancing research on cascading disasters and mental health inequities, the study did not consider how being doubly disadvantaged (e.g., being Black and disabled) influenced mental health, even though both race and disability were independently associated with odds of post-traumatic stress. It also did not clarify how sociodemographic characteristics combined with adverse experiences during Uri, a requisite to clarifying mechanisms through which health inequities are generated during cascading disasters. We address those limitations of prior work here in our study of anxiety and depression.

There is scientific consensus that anxiety and depression are associated with experiencing weather extremes and disasters, although all types of hazard events have not been comprehensively examined. Anxiety and depression research has primarily focused on high-profile disasters—like flooding [23], high wind conditions [32], forest fires [33], and hurricanes [34,35], among others [36]—rather than cold-weather events. To our knowledge, no published study has examined anxiety and depression after an extreme cold-weather event. In terms of why people might experience anxiety and depression after an extreme cold weather event like Uri, research on other types of disasters is instructive. This research has emphasized that being displaced from home [35], lacking social support to cope with the event, and losing access to basic services and utilities [21] can influence anxiety and depression.

There is emerging but limited evidence of mental health inequities related to race/ethnicity after weather disasters. For race/ethnicity, findings are mixed. Some have documented that racial/ethnic minority persons suffer disproportionately from mental health problems following disasters and extreme weather events [37], however, more have found White residents to be unequally affected [18,19,38]. Any post-event racial/ethnic disparities in mental health occur against a backdrop of underlying differences in mental health problems. Before COVID-19, the patterns showed increased risks of anxiety [39] and depression [40] for White Americans. More recent statistics, collected in 2021 during the COVID-19 pandemic, show no significant race/ethnicity-based disparities in anxiety. They also show that Americans of color are suffering disproportionately from depression relative to White Americans [41].

Persons with disabilities are rarely considered in studies of mental health after natural disasters [42]. Stough [42] reported, "researchers have virtually ignored the psychological effects of disaster on individuals with intellectual disabilities, physical disabilities, or sensory impairments" (p. 273). The limited evidence available suggests that people with disabilities experience depression, emotional stress [42] and emotional trauma [43] after disasters. In the general population (irrespective of disaster impacts), people with disabilities suffer from anxiety [44] and depression [45] at higher rates than the non-disabled. Since the COVID-19 pandemic, the directionality of these disparities has remained constant [46]. Of direct relevance here, after Uri, those with disabilities had increased odds of post-traumatic stress [7]. Very little research has focused on disability status and post-disaster risks of anxiety and depression.

In addition to race/ethnicity and disability, other factors also influence post-disaster anxiety and depression. These include SES [47,48], gender [47,49], age [47,50], prior disaster experience [51–53], social support [54,55], and COVID-19-related experiences [56].

1.4. Contributions

This paper makes four contributions to the study of disaster mental health. First, we examine anxiety and depression—adverse health outcomes that have not been examined in the context of a cold-weather disaster, but are of serious concern in the US today. Second, in addition to racial/ethnic inequities, we examine inequities by disability status. People with disabilities are widely known to be vulnerable after disasters, yet surprisingly few studies have quantified disparities for this group [42]. Third, while cold-weather disasters are likely to become more frequent under climate change, most attention is focused on heat waves, flooding, and hurricanes. Lastly, we advance a "cascading disaster health inequities" approach [7] using cross-classification to examine how social marginality (specifically racial/ethnic and disability status) cascades with adverse event-specific experiences to influence health risks.

In making these contributions, we answer the following research questions: How do race/ethnicity, disability, and adverse event experiences in Winter Storm Uri independently relate to the incidence of anxiety and depression? In comparison to the doubly privileged, how do different combinations of race/ethnicity, disability and adverse event impacts (representing mixed privilege/disadvantage and double disadvantage) relate to the incidence of anxiety and depression? We have three hypotheses for the first research question:

- H1: Racial/ethnic minority residents will have greater odds of depression, but not anxiety, compared to White residents
- H2: Disabled residents will have greater odds of anxiety and depression compared to non-disabled residents.
- H3: Having more adverse event experiences will result in greater odds of anxiety and depression compared to having fewer.

We also have three hypotheses for the second research question:

- H4: Being racial/ethnic minority and disabled (i.e., doubly disadvantaged) will result in greater odds of anxiety and depression relative to White and not disabled (i.e., doubly privileged).
- H5: Being disabled and Uri impacted (i.e., doubly disadvantaged) will result in greater odds of anxiety and depression relative to being not disabled and not Uri impacted (i.e., doubly privileged).
- H6: Being racial/ethnic minority and Uri impacted (i.e., doubly disadvantaged) will result in greater odds of anxiety and depression relative to being White and not Uri impacted (i.e., doubly privileged).

2. Materials and methods

2.1. Sampling and participants

The sampling frame comprised a random sample of adults aged ≥18 years with cellular telephones in eight Texas Metropolitan Statistical Areas (MSAs) ($n = 1964$). The included MSAs were Austin, Beaumont, Dallas, El Paso, Houston, Lubbock, McAllen and San Antonio. All eight MSAs were impacted by the storm and are in the top 11 for the most populous MSAs in the state. Six were served by the ERCOT grid, which was responsible for the major power supply disruptions. Participants in this study met five inclusion criteria: permanent residence in one of the MSAs at the time of Uri; ability to speak English or Spanish; ≥18 years of age; access to a cell phone; and at least partly responsible for making decisions for the household. They were randomly selected to take a telephone survey (conducted by professional bilingual interviewers in English or Spanish) in July 2021 about their experiences during Winter Storm Uri. In terms of language used, 89% of surveys were completed in English and the rest in Spanish.

We initially employed an address-based sampling (ABS) approach to create the sampling frame, which was enlarged with the addition of a cellular phone sample. We used an ABS to oversample persons living in subsidized rental housing provided by the U.S. Department of Housing and Urban Development (HUD). Details regarding our use of the ABS and cell phone sample are found elsewhere [7]. The cooperation rate for the survey was 50.8% as 896 of 1764 eligible participants took the survey. The University of Utah's and the University of Texas at El Paso's Institutional Review Boards reviewed the survey prior to its launch and declared it to be exempt. Those participating in our survey are reasonably representative of people and households in the sampled MSAs, in terms of median household income, housing tenure, and race/ethnicity [57].

Table 1
Descriptive statistics.

	N	Yes (Valid %)	No (Valid %)	Min-Max.	Mean	Stand. Dev.	N Missing	% Missing
Anxiety	779	116 (14.9)	663 (85.1)				11	1.4
Depression	779	118 (15.1)	661 (84.9)				11	1.4
EXPOSURE VARIABLES								
White, non-Hispanic	745	318 (42.7)	427 (64.6)				45	5.7
Black, non-Hispanic	745	81 (10.9)	664 (89.1)				45	5.7
Hispanic	749	265 (35.4)	484 (64.6)				41	5.2
Other non-Hispanic POC	745	82 (11.0)	663 (89.0)				45	5.7
Respondent has a disability	790	254 (32.2)	536 (67.0)				0	0
Sum of Uri adverse event experiences[a]	788			0–16	3.40	3.05	2	.03
Missed COVID test appointment	790	25 (3.2)	765 (96.8)				0	0
Missed COVID vaccine appointment	790	45 (5.7)	745 (94.3)				0	0
Gastrointestinal illness	790	49 (6.2)	741 (93.8)				0	0
Hypothermia	790	34 (4.3)	756 (95.7)				0	0
Lacked prescription meds	790	84 (10.6)	706 (89.4)				0	0
Time with no healthcare access	790	170 (21.5)	620 (78.5)				0	0
Ran out of food	790	153 (19.4)	637 (80.6)				0	0
Lacked money for living expenses	790	168 (21.3)	622 (78.7)				0	0
School cancelled	788	375 (47.6)	413 (52.4)				2	0.8
No comfortable place to sleep	790	268 (33.9)	522 (66.1)				0	0
No drinking water	790	291 (36.8)	499 (63.2)				0	0
No working toilet	790	327 (41.5)	463 (58.6)				0	3
Crowded living conditions	790	153 (19.4)	637 (80.6)				0	0
No adequate transportation	790	223 (28.2)	567 (71.8)				0	0
Feared for life	790	190 (24.1)	600 (75.9)				0	0
Split from household members	789	130 (16.5)	660 (83.5)				0	0
Uri Impacted (4+ adverse)	788	476 (60.4)	312 (39.6)				2	0.3
Race by Disability Cross-Classification								
White & Not Disabled (reference)	754	222 (29.4)	532 (70.6)				36	4.6
White & Disabled	777	96 (12.4)	681 (87.6)				13	1.6
Black & Not Disabled	755	48 (6.4)	707 (93.6)				35	4.4
Black & Disabled	777	33 (4.2)	744 (95.8)				13	1.6
Hispanic & Not Disabled	758	175 (23.1)	583 (76.9)				32	4.1
Hispanic & Disabled	779	90 (11.6)	689 (88.4)				11	1.3
Disability by Uri Impacts Cross-Classification								
Not Disabled & Not Uri Impacted (reference)	788	356 (45.2)	432 (54.8)				2	0.0
Disabled & Not Uri Impacted	788	120 (15.2)	668 (84.8)				2	0.0
Not Disabled & Uri Impacted	788	179 (22.7)	609 (77.3)				2	0.0
Disabled & Uri Impacted	788	133 (16.9)	655 (83.1)				2	0.0
Race by Uri Impacts Cross-Classification								
White & Not Uri Impacted (reference)	765	236 (30.8)	529 (69.2)				25	3.2
White & Uri Impacted	770	82 (10.6)	688 (89.4)				20	2.5
Hispanic & Not Uri Impacted	767	131 (17.1)	636 (82.9)				23	2.9
Hispanic & Uri Impacted	770	133 (17.3)	637 (82.7)				20	25
Black & Not Uri Impacted	765	37 (4.8)	728 (95.2)				25	3.2
Black & Uri Impacted	770	44 (5.7)	726 (94.3)				20	2.5
CONTROL VARIABLES								
Median income categories	734			1–10	5.26	2.87	55	7.1
Respondent is 65+	746	213 (28.6)	533 (71.4)				44	5.4
Woman	758	406 (53.6)	352 (46.4)				32	4.1
HH has one or more children (<18)	787	309 (39.3)	478 (60.7)				3	0.4
Own	790	521 (65.9)	269 (34.1)				0	0
Rent (not from HUD)	790	142 (18.0)	648 (82.0)				0	0
Rent (from HUD)	790	127 (16.1)	663 (83.9)				0	0
Social support scale (standardized)	774			−2.57–0.88	0	1	15	2.0
Prior disaster experience	774	461 (59.6)	313 (40.4)				16	1.9
Pre-existing medical conditions	765	312 (40.8)	453 (59.2)				25	3.2
Sum of COVID impacts	766			0–11	3.34	2.82	24	3.0
Physical health	767	175 (22.8)	592 (77.2)				23	2.9
Family/Friend physical health	766	298 (38.9)	468 (61.1)				24	3.0
Mental health	766	258 (33.7)	508 (66.3)				24	3.0
Family/Friend mental health	766	312 (40.7)	454 (59.3)				24	3.0
Finances	766	304 (39.7)	462 (60.3)				24	3.0
Living conditions	766	175 (22.8)	591 (77.2)				24	3.0
Employment status	766	198 (25.8)	568 (74.2)				24	3.0
Immigration status	766	24 (3.1)	742 (96.9)				24	3.0
Social life	766	500 (65.3)	266 (34.7)				24	3.0
Self and family/friend care	766	159 (20.1)	607 (79.2)				24	3.0
Access to healthcare	766	159 (20.8)	607 (79.2)				24	3.0

[a] The complete question stems for the adverse event items are: You or someone in your household missed a COVID test appointment; You or someone in your household missed a COVID vaccine appointment; You suffered from gastrointestinal illness; You or someone in your household suffered from hypothermia; You had to go without needed prescription medications; You went without access to health care or medical services for some time; You ran out of food; You lacked money for living expenses for some time; Your children's school was cancelled; You went without a comfortable place to sleep for some time; You went without adequate drinking water for some time; You went without access to a working toilet for some time; You experienced crowded living conditions; You went without adequate transportation for some time; You feared for your life during the Winter Storm; and You had to split up and stay in different location from some members of your household for any period of time.

2.2. Variables

To conduct the analyses reported here, we excluded participants who were missing responses for 24% or more of the analysis variables, making the final sample size equal 790.

2.2.1. Dependent variables

To assess anxiety, we used the ultra-brief Generalized Anxiety Disorder (GAD-2) 2-item scale [58], which pertains to the prior two weeks. The GAD-2 is based on the first two items on the GAD-7 [59] (i.e., "feeling nervous, anxious, or on edge" and "not being able to stop of control worrying"), which represent core anxiety symptoms. GAD-2 scores range from 0 to 6 after the two items are summed, with $\geq$3 being the recommended cut-off for anxiety; when $\geq$2 is used, the rate of false positive is unacceptably high [58]. Kroenke and colleagues [58] found that the GAD-7 and the GAD-2 are equally effective for screening purposes. For depression, we used the parallel ultra-brief Patient Health Questionnaire (PHQ-2), which is derived from the PHQ-9 [60]. We scored this similarly using a $\geq$3 as the cut point on a scale of 0–6. The PHQ-2 captures depressed mood (through the stem: "little interest or pleasure in doing things") and anhedonia (through the stem: "feeling down, depressed or hopeless"), the two core symptoms for depression [58]. PHQ-2 is a valid measure for screening major depression and it matches other instruments [61–63]. These two measures have been used together in other research focused on mental health in the COVID-19 era [41].

2.2.2. Exposure variables

The exposure variables in this analysis are race/ethnicity, disability, and adverse event experiences due to Winter Storm Uri. We measured race/ethnicity in four mutually exclusive categories: non-Hispanic White (reference group); Hispanic/Latinx; non-Hispanic Black; and non-Hispanic, non-Black person of color (POC). We assessed disability status with a dichotomous variable. A respondent was coded as "disabled" if they responded with a "yes" to any of the following disabilities: hearing difficulties; vision difficulties; difficulties concentrating, remembering or making decisions; difficulties walking or climbing stairs; difficulties dressing or bathing; and difficulties doing errands alone. We borrowed this disability survey question directly from the American Community Survey (ACS) [64].

To capture the householder's adverse event-specific experiences during Uri, we asked a series of 16 items following the question stem, "Which of the following happened to you during or soon after the Texas Winter Storm?" to which the respondent was instructed to respond with yes [1] or no (0). The complete list of the 16 items is included in the note to Table 1 and we summed these items to create a score (that equally weights each item). The score had adequate internal consistency with a Cronbach's alpha of 0.792 [65]. Similar checklists of adverse event experiences have been used in research on other disasters [66,67] and this same checklist was used as a dependent variable in an analysis of disability and public housing residence after Uri [5].

Then, to operationalize intersectional identities such that combinations of social positions are considered [68], we used a cross-classification approach. This approach is conventional in intersectional health research [69,70] and frequently used [71–73]. Specifically, we cross-classified three sets of variables to create mutually exclusive intersectional strata. Each strata contains mutually exclusive intersectional positions representing social positions of double privilege, mixed privilege and disadvantage, and double disadvantage [74]. Before beginning, we re-coded adverse event experiences into "Uri Impacts" using a dichotomous variable with $\geq$4 experiences coded as 1 and $\leq$ 3 as 0. First, we cross-classified race/ethnicity by disability, with the categories of White & Not Disabled (reference), White & Disabled, Hispanic & Not Disabled, Hispanic & Disabled, Black & Not Disabled, and Black & Disabled. Second, we cross-classified disability by adverse event experiences, with the categories of Not Disabled & Not Uri Impacted (reference), Disabled & Not Uri Impacted, Not Disabled & Uri Impacted, and Disabled & Uri Impacted. Third, we cross-classified race/ethnicity by adverse event experiences, with the categories, White & Not Uri Impacted (reference), White & Uri Impacted, Hispanic & Not Uri Impacted, Hispanic & Uri Impacted, Black & Not Uri Impacted, and Black & Uri Impacted. We initially cross-classified disability by combining race/ethnicity with adverse event impacts, but the cell sizes became too small and the statistical models would not converge.

2.2.3. Control variables

To adjust for socioeconomic status (SES), we used median household income categories (ranging from 1 (<$10,000) to 10 ($\geq$$250,000)) and housing tenure (i.e., owner-occupancy (reference), rent a HUD-assisted multifamily property, or rent from a private landlord).

While we asked a gender question that included non-binary options, all respondents selected "woman" (coded 1) or "man" (coded 0). We also included older age, with respondents being coded 1 if they were $\geq$65 years old, and if the household contained any members under 18 (1 = yes, 0 = no). To gauge prior disaster experience, we asked, "Have you lived through a disaster before the Texas Winter Storm?" with yes being coded 1 and no being coded 0.

To operationalize social support, we employed the 6-item F-SouzU, which is a reliable and valid scale [75] that has been recently used in a study of disaster mental health [7]. To create the score, we summed the items such that higher scores pertain to more support. The Cronbach's alpha for the sum scores was 0.889.

In the health area, we asked two items, both of which were used in a recent study of disaster mental health [7]. The first asked if the respondent had any medical conditions that might put them at a higher risk for COVID. They indicated "yes" or "no" in response to cardiovascular conditions, chronic lung disease or moderate to severe asthma, obesity, diabetes, hypertension, a weakened immune system, kidney or liver disease, and developmental or intellectual disability. If a respondent answered yes to any of the items, they were coded 1, and they were given a 0 if not. The second assessed if the COVID-19 pandemic had impacted the following areas of their life (yes = 1/no = 0): physical health, family and close friends' physical health, mental health, family and close friends' mental health, finances, living conditions, employment status, immigration status, social life, ability to care for oneself or other family members, and access to health care. We summed the 11 items and the mean was 3.3 with a range from 0 to 11; the Cronbach's alpha was 0.812.

2.3. Statistical analysis

2.3.1. Multiple imputation

We used a regression-based multiple imputation approach to address missing data. This involved burning in 20 complete data sets (after 200 iterations per data set), with imputed values for each missing data point [76]. We input 82 variables in the multiple imputation procedure, including each individual item in our composite and scaled variables. We used multiple imputation because dropping cases with missing values from analyses can introduce bias [77].

2.3.2. Statistical approach

We chose to use a generalized estimating equation (GEE) statistical modelling approach [78–80] because our data are clustered

Table 2
Generalized Estimating Equation[a] (GEE) results for Anxiety ($n = 790$): 1) examines race/ethnicity, disability and adverse event experiences (sum score) separately; 2) examines race/ethnicity by disability; 3) examines disability by adverse event experiences (i.e., Uri impacted) and 4) race/ethnicity by adverse event experiences (i.e., Uri impacted).

Model #:	1			2			3			4		
	OR	CI	p	OR	CI	p	OR	CI	p	OR	CI	p
White, non-Hispanic	1.000						1.000					
Black, non-Hispanic	1.305	0.483, 3.530	0.599				1.379	0.517, 3.675	0.520			
Hispanic	1.103	0.567, 2.148	0.772				1.157	0.605, 2.213	0.658			
Respondent is disabled	3.426	2.106, 5.575	<0.001							3.701	2.306, 5.939	<0.001
Sum of Uri adverse event experiences	1.143	1.062, 1.231	<0.001	1.154	1.067, 1.248	<0.001						
White & Not Disabled												
Black & Not Disabled				1.328	0.439, 4.016	0.614						
Black & Disabled				3.920	0.990, 15.517	0.052						
Hispanic & Not Disabled				0.949	0.342, 2.636	0.920						
Hispanic & Disabled				3.881	1.718, 8.767	0.001						
White & Disabled				3.226	1.309, 7.946	0.011						
Not Disabled & Not Uri Impacted							1.000					
Disabled & Not Uri Impacted							3.521	1.574, 7.877	0.002			
Not Disabled & Uri Impacted							1.897	0.946, 3.803	0.071			
Disabled & Uri Impacted							6.914	3.258, 14.672	<0.001			
White & Not Uri Impacted										1.000		
White & Uri Impacted										1.670	0.632, 4.417	0.301
Hispanic & Not Uri Impacted										1.087	0.348, 3.396	0.885
Hispanic & Uri Impacted										2.028	0.725, 5.670	0.178
Black & Not Uri Impacted										0.949	0.219, 4.110	0.944
Black & Uri Impacted										2.823	0.784, 10.171	0.113

[a] GEEs are binary logistic models, with an exchangeable correlation matrix, and they adjust for clustering in terms of median age of housing stock category ($n = 8$) and MSA ($n = 8$). Models adjust for other non-Hispanic person of color, median household income, gender, presence of children, older age, housing tenure, social support, prior disaster experience, pre-existing medical conditions, COVID-19 impacts.

within MSAs as per our sampling design. GEEs are appropriate when the analyst seeks to account for clustering as a nuisance parameter, as we do here. GEEs are also appropriate for non-normally distributed data [81], which also makes them an ideal modelling strategy for this analysis. Our anxiety and depression variables are dichotomous and demand binary logistic models. We used an exchangeable correlation matrix and adjusted for clustering in terms of median decade of housing construction category ($n = 8$) and MSA ($n = 8$). The eight median decade of housing construction categories correspond with the response options for the American Community Survey instrument housing item ("About when was this building first built?"): 2000 or later, 1990 to 1999, 1980 to 1989, 1970 to 1979, 1960 to 1969, 1950 to 1959, 1940 to 1949, and 1939 or earlier). These same specifications were used in a similar study on post-traumatic stress [7]. Prior studies have used median year of home construction as a clustering variable since it closely corresponds with the urban developmental context within which participating households are nested [82]. Our models do not suffer from multicollinearity as per the variance inflation factors, condition indices and variance proportions [83].

2.3.3. Modelling plan

For each dependent variable, we ran four statistical models. The first model addresses the first research question and includes the exposure variables and all control variables (Models 1 and 5). The next three models address the second research question. The second model examines the cross-classification of race/ethnicity and disability (Models 2 and 6), and with the removal of three variables from Model 1: disability, Black, and Hispanic. The third adds the cross-classification of disability and Uri Impacts (Models 3-7); as compared to the first model, this model removes adverse event experiences sum and disability. The fourth model adds the cross-classification of race/ethnicity with Uri Impacts, which requires removing Black, Hispanic, and the adverse event experience sum from the first model

Table 3
Generalized Estimating Equation[a] (GEE) Results for Depression ($n = 790$): 1) examines race/ethnicity, disability and adverse event experiences (sum score) separately; 2) examines race/ethnicity by disability; 3) examines disability by adverse event experiences (i.e., Uri impacted) and 4) race/ethnicity by adverse event experiences (i.e., Uri impacted).

Model #:	5			6			7			8		
	OR	CI	p	OR	CI	p	OR	CI	p	OR	CI	p
White, non-Hispanic	1.000						1.000					
Black, non-Hispanic	2.441	1.081, 5.516	0.032				2.639	1.163, 5.988	0.020			
Hispanic	2.554	1.228, 5.308	0.012				2.688	1.337, 5.404	0.006			
Respondent is disabled	3.240	1.668, 6.296	0.001							3.608	1.850, 7.036	<0.001
Sum of Uri adverse event experiences	1.154	1.075, 1.238	<0.001	1.159	1.080, 1.242	<0.001						
White & Not Disabled												
Black & Not Disabled				2.916	0.867, 9.914	0.084						
Black & Disabled				6.904	1.674, 28.484	0.008						
Hispanic & Not Disabled				2.344	0.640, 8.583	0.198						
Hispanic & Disabled				9.072	2.730, 30.144	<0.001						
White & Disabled				3.388	0.728, 15.765	0.120						
Not Disabled & Not Uri Impacted							1.000					
Disabled & Not Uri Impacted							2.447	0.879, 6.808	0.087			
Not Disabled & Uri Impacted							1.373	0.692, 2.722	0.365			
Disabled & Uri Impacted							6.009	2.617, 13.798	<0.001			
White & Not Uri Impacted										1.000		
White & Uri Impacted										1.358	0.417, 4.425	0.612
Hispanic & Not Uri Impacted										2.531	0.847, 7.561	0.096
Hispanic & Uri Impacted										3.985	1.323, 12.001	0.014
Black & Not Uri Impacted										0.868	0.147, 5.112	0.876
Black & Uri Impacted										6.120	2.068, 18.109	0.001

[a] GEEs are binary logistic models, with an exchangeable correlation matrix, and they adjust for clustering in terms of median age of housing stock category ($n = 8$) and MSA ($n = 8$). Models adjust for respondent being other non-Hispanic person of color, median household income, gender, presence of children, older age, housing tenure, social support, prior disaster experience, pre-existing medical conditions, COVID-19 impacts.

(Models 4 and 8). In the second and fourth models, we did not remove "other POC", as it is not an included category in the cross-classified "race/ethnicity by …" variables. In these models incorporating cross-classified terms, we use the double privilege position as the reference category. To explore if the results are sensitive to our use of multiple imputation, we present findings of a complete case analysis (for Models 1–8) as a sensitivity analysis.

Following [7], we applied proportional weights—constructed using total HUD population in each MSA, total population of each MSA, HUD resident population in the sample per MSA, and total sample per MSA—to all models to correct for the oversample of HUD-residents.

3. Results

Table 1 reports descriptive statistics for dependent, exposure and control variables. Among our participants, 14.9% screened positive for anxiety and 15.1% for depression. The percentages of respondents who were non-Hispanic White, Hispanic/Latinx; non-Hispanic Black; and non-Hispanic, non-Black person of color (POC) were 42.7%, 35.4%, 10.9%, and 11%, respectively. 32% of the sample was disabled. In terms of adverse event experiences, scores ranged from 0 (none) to 16 (all), with a mean of 3.4. Results for the anxiety and depression models are presented in Table 2 and Table 3, respectively.

3.1. Anxiety

As per Table 2 and in **Model 1**, we found that there were no significant differences in odds of anxiety based on race/ethnicity. Having a disability increased the odds of anxiety substantially (odds ratio: 3.43, 95% confidence interval: 2.11–5.58, $p < 0.001$). Having an additional Uri-associated adverse event experience was associated with greater odds of anxiety (1.14, 1.06–1.23, $p < 0.001$).

Model 2. (Table 2) examines the cross-classification of race/ethnicity and disability with anxiety. There were no significant differences in odds of anxiety for respondents without disabilities based on their race/ethnicity. When compared to the doubly privileged, i.e., White respondents without disabilities, Hispanic and White respondents with disabilities had elevated odds (3.88, 1.72–8.77, $p = 0.001$; 3.23, 1.31–7.95, $p = 0.011$, respectively). While not significant ($p = 0.052$), Black respondents with disabilities also had elevated odds (3.92, 0.99–15.52) relative to White respondents without disabilities.

Model 3. (Table 2) examines anxiety based on the cross-classification of disability and the dichotomous Uri impacts. Disabled respondents with (6.91, 3.26–14.67 $p < 0.001$) and without (3.52, 1.57–7.88, $p = 0.002$) Uri impacts had greater odds of anxiety relative to the doubly privileged reference group (i.e., non-disabled respondents without Uri impacts). Among those without a disability, those impacted by Uri had greater odds of anxiety (1.90, 0.95–3.80) than those not impacted, but not significantly ($p = 0.07$).

Model 4. (Table 2) examines the cross-classification of race/ethnicity and Uri impacts with anxiety. There were no significant differences between double disadvantage or mixed privilege/disadvantage categories and the doubly privileged.

3.2. Depression

As per **Model 5** in Table 3, racial/ethnic minority respondents had greater odds of depression than non-Hispanic White respondents. Compared to White respondents, the odds for Black respondents were 2.44 (1.08–5.52, $p = 0.032$); they were 2.55 for Hispanic respondents (1.23–5.31, $p = 0.012$). Having a disability increased the odds of depression (OR: 3.24, 1.67–6.30, $p = 0.001$). Having an additional Uri-associated adverse event experience was associated with greater odds of depression (1.15, 1.08–1.24, $p < 0.001$).

Model 6. in Table 3 examines the cross-classification of race/ethnicity and disability with depression. There were no significant differences in odds of depression between respondents of different race/ethnicity relative to Whites among those without disabilities. When compared to White respondents without disabilities (i.e., the doubly privileged), the doubly disadvantaged groups (i.e., Black and Hispanic respondents with disabilities) had elevated odds (6.90, 1.67–28.48, $p = 0.008$; 9.07, 2.73–30.14, $p < 0.001$, respectively). In contrast, White respondents with disabilities, a mixed status group, did not have significantly different odds of depression (3.38, 0.73–15.77, $p = 0.120$) relative to White respondents without disabilities.

Model 7. in Table 3 cross-classifies disability with Uri impacts in relation to depression. Disabled respondents with Uri impacts had significantly greater odds of depression than non-disabled respondents without Uri impacts (6.01, 2.62–13.80, $p < 0.001$). Those mixed status groups, i.e., those who were disabled and not Uri impacted (2.45, 0.88–6.81) and not disabled but Uri impacted (1.37, 0.69–2.72), had higher odds than the doubly privileged reference group, but not significantly ($p = 0.09$ and $p = 0.37$, respectively).

Model 8. (Table 3), which focuses on depression, includes the cross-classification of race/ethnicity with Uri impacts. There were no significant differences in odds of depression between respondents of different race/ethnicity relative to Whites among those that were not Uri impacted, although one finding approached significance. Hispanic respondents who were not impacted had higher odds of depression than White respondents who were not impacted (2.53, 0.847–7.56, $p = 0.096$). Black respondents and Hispanic respondents who were impacted by Uri had higher odds of depression than White non-impacted respondents (6.12, 2.07–18.11 $p = 0.001$, 3.99, 1.32–12.00, $p = 0.014$). In contrast, White respondents who were Uri impacted did not have significantly different odds of depression (1.358, 0.42–4.43, $p = 0.612$) relative to White respondents who were not Uri impacted.

3.3. Sensitivity analysis: complete case analysis

The majority of the complete case findings for Models 1–8 agree with the MI findings in terms of direction and significance (p <

0.05), with a few minor exceptions (only in terms of differences in significance). In Model 1 (depression): Black and Hispanic are positive but at $p < 0.10$ instead of $p < 0.05$ in the complete case analysis. In the complete case analysis Model 2 (depression), "White and disabled" is positive, but at $p = 0.118$ instead of $p < 0.05$, and "Black and disabled" is positive at $p < 0.05$ instead of $p < 0.10$. For Model 6 (anxiety), "Black and disabled" is positive at $p = 0.186$ instead of $p < 0.05$, and "White and disabled" is positive at $p = 0.013$ instead of $p = 0.12$. Finally, in Model 4 (Depression), "Hispanic and Uri Impacted" is positive at $p = 0.121$ instead of $p < 0.05$. This suggests that results are not particularly sensitive to our use of MI, although the loss of several findings in the complete case analysis likely reflects how statistical power improved through the use of MI [84].

4. Discussion

While anxiety and depression have not been examined in the aftermath of cold-weather disasters, the proportions of people in our study suffering from both conditions approximate the statistics reported after other types of disasters. In terms of why cold-weather extremes may worsen mental health, it is partly due to how such events entrap people in housing units. This leads to increased social isolation and missed work, which can worsen financial stress and mental health [85]. Mental health challenges can also impair people's abilities to cope with weather disasters. Specifically, we found here that 14.9% met the screening criteria for anxiety and 15.1% did so for depression, six months after the storm. Comparable figures (for adolescents only) reported one year after a super-cyclone in India were 12.0% and 17.6%, respectively [34]. A meta-analysis of four United Kingdom-based studies found that the anxiety rate was 19.8% and the depression rate was 21.35% twelve months after the participants had their homes flooded [23]. Another meta-analysis of 31 papers reported a range of depression rates for adults between 5.8% and 54.0% depending on the study specifics [36]. Among residents of a Canadian community affected by a wildfire, anxiety rates were 19.8% six months later [33]. Our depression and anxiety rates are based on a population-based sample of persons who lived in metropolitan areas affected by the storm. They do not apply to a sample of those most affected (e.g., aid workers, those who experienced home damage, those who stayed in warming shelters). Previous research has shown that rates of mental health problems are higher in more directly affected persons [86]; for example, post-disaster post-traumatic stress disorder prevalence has been estimated at 30–40% among direct disaster victims, 10–20% among rescue workers, and 5–10% in the general population [86].

In terms of racial/ethnic disparities, we found increased risk of depression (but not anxiety) among racial/ethnic minority respondents, as we had hypothesized (H1). Black and Hispanic persons had a more than twofold increase in risk of depression relative to White persons. Some disaster studies have found increased risk for White persons, but it is essential to note that these studies took place pre-COVID-19 [18,19,38]. This is an important detail because the US has seen a major shift in racial/ethnic disparities in population-level anxiety and depression since 2020. Instead of White people having higher rates of depression [39], in 2021, it was people of color [41]. And, in terms of anxiety, there were no differences between racial/ethnic groups in 2021 [41]. Our findings reflect the US national post-COVID-19 trends whereby there were no racial/ethnic disparities for anxiety and non-White persons had higher rates of depression. Being more severely impacted by Uri substantially raised the odds of depression for Black and Hispanic respondents, suggesting storm impacts may have intensified the underlying trend for these groups.

As hypothesized (H2), we found that disability status was an important risk factor for elevated odds of anxiety and depression after Uri. Having a disability was associated with a threefold increase in risk in both conditions. These findings underscore the need to continue to focus on persons with disabilities after disasters, as they are underexamined [42], yet vulnerable to adverse effects. Persons with disabilities are at risk after a disaster due to a lack of social support, poverty, and structural exclusion [87]. Those with independent living and/or self-care difficulties may suffer due to disruptions in the services they depend on daily, which can cause mental health concerns [88]. For example, persons with disabilities who need full-time assistance may become separated from their caregivers [89]; some individuals with vision difficulties, for example, have been separated from their assistance dogs or durable medical equipment (e.g., canes) [42]. Additionally, many people rely on medical equipment that requires electricity and power outages caused by natural disasters, including Uri, make persons with disabilities more vulnerable [90]. This could directly impact physical health but also mental health due to the stress of coping with these disruptions. Persons with developmental disabilities have been distressed by emergency-related stimuli, like sirens, bells, flashing lights, strangers, and emergency personnel [42]. When going to shelters, individuals with physical disabilities may also face barriers to accessing basic facilities such as bathrooms [91], which may affect their mental health. While people with disabilities have higher rates of anxiety and depression in the US [44,45], we found that persons with disabilities who were also more severely impacted by Uri had elevated risks for both conditions.

More storm related adverse event experiences were associated with greater odds of anxiety and depression, which supports H3. Each additional experience increased risk by about 15%. The adverse event experiences in our checklist related to infrastructural losses at home, safety concerns, physical health challenges, inability access to health care, and economic problems. This suggests that, among survivors of an extreme cold-weather event, experiencing more adverse circumstances was associated with worse anxiety and depression after the event. A similar pattern emerged for post-traumatic stress after Uri as per the two studies on the topic. In one, loss of utility service, loss of communication access, other storm experiences, serious injuries, and social disruption were associated with greater avoidance behaviors 15 months later [6]. In the other, loss of piped water was associated with greater odds of post-traumatic stress; loss of piped water was more intensely associated with post-traumatic stress when the household was also highly impacted by COVID-19 [7]. After Hurricane Katrina, those that had been displaced (vs. not displaced) had higher rates of depression (but not anxiety) three months after the storm [35]. Taken together, these findings suggest that very difficult experiences during a weather event negatively impact mental health in the aftermath.

In examining race/ethnicity, disability, and adverse event experiences separately, we found that disability status and adverse event experiences were associated with both outcomes and that race/ethnicity was associated with depression (but not anxiety). However, when we apply a cascading disaster health inequities approach and consider their synergies, a more nuanced picture of cascading risk emerged that diverged between anxiety and depression.

For anxiety, across the analyses and among the exposure variables, disability status emerged as the primary risk factor, although Uri impacts (i.e., having four or more adverse event experiences) also mattered. When cross-classifying disability with race/ethnicity, those who were disabled had greater odds of anxiety, while those who were not disabled did not (regardless of race/ethnicity, although the finding for Black/Disabled approached significance at $p = 0.052$). This supports H4. Those who were doubly disadvantaged in terms of being disabled and Uri impacted were at nearly seven times greater risk than those who were doubly privileged in terms of being not disabled and not Uri impacted (which aligned with H5), but those who were disabled and not Uri impacted (mixed privilege/disadvantage group) also had greater risk (i.e., odds ratio was three and a half times greater). While Uri impacts were significant alone, when we cross-classified them with race/ethnicity, there were no differences in anxiety risk relative to the doubly privileged (which does not align H6). In sum, the cross-classification analyses revealed that Uri impacts were a risk factor for anxiety, but disability was the overriding risk factor.

For depression, the cross-classification results reveal a manifestation of White privilege in terms of disability and Uri impacts posing attenuated depression risks for White respondents relative to Black and Hispanic/Latinx respondents. When looking at the cross-classification of race/ethnicity and disability, having a disability increased the odds of depression quite dramatically (e.g., by six and nine times, respectively) for Black and Hispanic respondents (relative to White non-disabled respondents), but not for White respondents. This supports H4. Put more simply, being disabled did not increase risk of depression for White respondents. In the same regard, being Uri-impacted increased risk of depression for Black and Hispanic/Latinx respondents (by six and nearly four times, respectively) relative to White non-Uri-impacted respondents, but not for White respondents (which aligns with H6). In addition, results support H5, as those who were double disadvantaged in terms of disability and Uri impacts faced the greatest risk of depression. Taken together, we found that racial/ethnic minority status, disability status, and Uri impacts were risk factors for depression, and that disability and Uri impacts did not amplify risks for White respondents as they did for Black and Hispanic/Latinx respondents.

4.1. Limitations

Since we conducted the survey five to six months after Uri, recall may have been difficult for some respondents, although longer gaps between events and data collection are common in disaster mental health research. There are limitations with the measures used to screen for anxiety and depression. We used the GAD-2 [58] and the PHQ-2 [60], which do not substitute for medical diagnoses. With these measures, we captured a snapshot of anxiety and depression in July 2021, as we do not have a measure of pre-existing anxiety and depression. This is a limitation as pre-existing mental health psychopathology can increase risk for post-disaster mental health problems [33,92]. Additionally, those metrics are not Uri-specific. All persons in our survey lived in a Uri-impacted county, but they were not impacted equally. Accounting for adverse event experiences in the models and adjusting for county effects as a nuisance parameter through the GEEs helped to address this. We did not include all possible covariates that could be associated with our outcomes. For example, religious beliefs and marital status [36], which may correlate with depression after disaster, were not included; neither was social capital (although social support was). While multiple imputation helps to address potential biases associated with missing data and avoids the loss of precision and power that accompanies excluding cases due to missing data, there are limitations with this approach applicable to this study. Specifically, the MI procedure assumes normality in the variables and assumes that the data are missing at random [77]. Finally, a limitation of the cross-classification approach is small cell sizes in some categories. Indeed, a full application of our approach would have entailed three-way cross-classified variables combining disability status, race/ethnicity and Uri impacts (e.g., Black/non-disabled/Uri-impacted). Small counts made that analysis impossible. Future research with a larger sample size would enable more robust comparisons between risk groups and more complete application of the cascading disaster health inequities approach.

5. Conclusion

Findings from this study, along with [7], illustrate the utility of a cascading disaster health inequities approach. Together, these two analyses show how inequities in mental health after cascading disasters are complex in both expected and unexpected ways. A cascading disaster health inequities approach illuminates how social factors crosscut features of the disaster (e.g., adverse experiences) and how the disaster crosscuts other stressors within the underlying social context (e.g., COVID-19) [7]. We encourage scholars to apply this perspective to other cascading disasters to generate new knowledge and important insights about how these factors operate. Practically, this approach allows for the identification of specific groups in need of support. While pre-2020 models of disaster recovery would have emphasized the risks for White persons' mental health, COVID-19 marked a major transition that is likely reflected here in terms of post-disaster mental health risks for persons of color. These results suggest that persons of color who are also disabled and/or more severely impacted by the disaster may need additional support to address depression; those who are disabled and also more severely impacted by the storm may need similar supports to address anxiety.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2023.103933.

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