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Cumulative Disaster Exposure and Mental and Physical Health Symptoms Among a Large Sample of Residents of the U.S. Gulf Coast Residents

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Abstract

A large body of research has linked disaster exposure to adverse mental and physical health outcomes. Few studies, however, have explored the cumulative impact of exposure to multiple disasters. Participants (N = 8,366) from the National Institute of Environmental Health Sciences Gulf Long-Term Follow-Up Study were classified as having been exposed to both, either, or neither Hurricane Katrina and the Deepwater Horizon oil spill (DHOS). Participants also reported on a range of mental and physical health symptoms. Logistic regression models found that participants who were exposed to both disasters had significantly higher odds of probable generalized anxiety disorder, odds ratio (OR) = 1.72, 95% CI [1.52, 1.96]; major depression, OR = 1.53, 95% CI [1.32, 1.77]; and posttraumatic stress disorder, OR = 2.51, 95% CI [2.03, 3.10], than participants who were exposed to only one disaster, ps < .001. Additionally, a linear regression model found that participants who were exposed to both disasters had significantly more physical health symptoms at the time of the spill than those who were exposed to only one disaster, B = 0.99, SE = .20, p < .001. The results indicate that cumulative disaster exposure confers enhanced risk for adverse mental and physical health outcomes. The findings demonstrate that screening for prior exposure among disaster-affected individuals might identify those at greatest risk for adverse health outcomes.

A large proportion of the global population will be exposed to one or more natural or human-made disasters in their lifetime (e.g., McLaughlin et al., 2013; Nickerson, Aderka, Bryant, & Hofmann, 2012). It is now well known that exposure to natural and human-made

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disasters is associated with a range of adverse mental health outcomes, including posttraumatic stress disorder (PTSD), major depression (MD), and generalized anxiety disorder (GAD) symptoms (e.g., Norris, Friedman, & Watson, 2002; North & Pfefferbaum, 2013). Although less studied, links between exposure and adverse physical health conditions have also been documented in the aftermath of a range of disasters, including hurricanes (e.g., Arcaya, Lowe, Rhodes, Waters, & Subramanian, 2014; Lee, Choi, Eun, & Kwon, 2006) and oil spills (e.g., Cope, Slack, Blanchard, & Lee, 2013; Kim et al., 2013).

Disasters are unevenly distributed geographically such that some geographic areas are vulnerable to multiple disaster exposures. One such area is the Gulf Coast region of the United States, which, as noted by Osofsky, Osofsky, Wells, and Weems (2014), faced 11 tropical storms and hurricanes, flooding of the Mississippi River, and several technological incidents between 1980 and 2012. Perhaps most impactful of these were Hurricane Katrina (henceforth referred to as Katrina), which struck the area in August 2005 and led to an estimated $81 billion (USD) in damages (Knabb, Rhome, & Brown, 2005), and the Deepwater Horizon oil spill (DHOS), in which approximately five million barrels of crude oil were released into the Gulf between the rig explosion on April 20, 2010, and the capping of the well on July 15, 2010 (Ramseur, 2010). Katrina and the DHOS have had profound effects on Gulf Coast communities, leading to substantial economic, ecological, and social impacts (Drescher, Schulenberg, & Smith, 2014; Shultz, Walsh, Garfin, Wilson, & Neria, 2014).

There is, of course, variability in the extent to which Gulf Coast residents were exposed. Some residents endured disaster-related experiences that increased the risk for adverse mental and physical health outcomes whereas others did not. In terms of Katrina, exposures that have been linked to adverse health outcomes include those involving displacement, injury or loss of a loved one, and financial hardship, among others (e.g., Fussell & Lowe, 2014; Galea et al., 2007; Galea, Tracy, Norris, & Coffey, 2008; Harville et al., 2011; Rhodes et al., 2010). For DHOS, highly impactful exposures have been found to include involvement in oil spill cleanup and response (OSCR) activities and other direct contact with oil as well as financial losses (e.g., Drescher et al., 2014; Fan, Prescott, Zhao, Gotway, & Galea, 2014; Harville, Shankar, Schetter, & Lichtveld, 2017; Kwok, McGrath et al., 2017).

Facing high levels of exposure to multiple disasters—for example, to both Katrina and the DHOS—is likely to be associated with an even greater risk for adverse outcomes than high levels of exposure to only one of these disasters. Several models of how high exposure to multiple disasters could influence health have been proposed (for a review, see Harville et al., 2017). The model that has received the most empirical support to date is a “cumulative” model wherein disasters influence health in a dose–response fashion. A series of studies by Harville and colleagues has illustrated the phenomenon of cumulative exposure for postdisaster mental health in the Gulf Coast (Harville et al., 2011, 2017; Jacobs & Harville, 2015). First, among a sample of 102 women from Southern Louisiana, individuals who had experienced severe exposure (defined as being forced to evacuate or experiencing the death of a relative) to both Katrina and Hurricane Gustav, which struck the area in September 2008, had elevated levels of both PTSD and depression symptoms relative to those who experienced severe exposure to only one or neither disaster (Harville et al., 2011). Second,

using a larger sample of 794 women, Jacobs and Harville (2015) examined the cumulative influence of four different domains of exposure to Katrina and Hurricane Gustav, as well as Hurricane Rita, which made landfall in the region less than a month after Katrina: damage (six exposures, such as damage to participant's house), danger (three exposures, such as perception that life was in danger), illness (four exposures, such as whether the participant experienced an illness or injury), and evacuation (single item that assessed whether the participant needed to evacuate during the disaster). Items for each exposure domain were summed across the three hurricanes, which led to a domain-specific cumulative exposure score. In adjusted models, the investigators found that higher levels of cumulative exposure to the danger and illness domains were associated with greater odds of depression, and higher cumulative exposure to the danger domain was related to higher odds of PTSD. In a more recent study that involved the same cohort (Harville et al., 2017), the research team incorporated a measure of exposure to DHOS, with items assessing five types of exposure: financial/income consequences, direct contact with oil (including cleanup work), oil spill–related damage, loss of use of the coast, and involvement in litigation. The results again supported a cumulative model of exposure such that an index of overall exposure to the hurricanes and DHOS was associated with increased odds of both depression and PTSD.

Whereas mounting evidence has therefore supported a cumulative model of exposure to multiple disasters in the study of mental health, only one published study, to our knowledge, has done so for physical health. In that study of emergency department patients in New York City, individuals who had experienced direct, indirect, or occupational exposure to both the September 11, 2001, World Trade Center (WTC) terrorist attacks and the American Airlines Flight 587 crash, which occurred in the New York City area in November 2001, were at risk for worse overall physical health relative to those exposed to only one or neither disaster (Fernandez et al., 2005). The imbalance in published studies of cumulative disaster exposure and adverse mental versus physical health outcomes raises the possibility that exposure to multiple disasters is more likely to yield the former than the latter. One way to test this possibility would be to examine the influence of cumulative exposure on both mental and physical health outcomes in the same sample. Such an examination could provide important insights into how the range of postdisaster consequences develops, and could identify, for example, which outcomes are likely to manifest in full after a single exposure and which tend to build with subsequent exposures. These insights could help inform efforts to screen for and monitor symptoms in geographic areas in which residents are likely to face multiple disaster exposures, such as in the U.S. Gulf Coast.

In the current study, we examined the influence of cumulative exposure to Katrina and DHOS on mental and physical health outcomes. Exposure to each disaster was defined by experiences that have been previously documented to increase risk for adverse mental and physical health outcomes. For Katrina, participants were classified as exposed if they experienced one of the following due to the hurricane and its aftermath: displacement; loss of a loved one or serious injury to oneself or a loved one, or financial hardship. For DHOS, participants were classified as exposed if they completed at least one day of oil spill response and cleanup (OSRC) work. The sample included participants who were classified as having experienced neither Katrina nor DHOS, either Katrina or DHOS, and both Katrina and DHOS.

Method

Participants and Procedure

The study sampled comprised participants from the National Institute of Environmental Health Sciences (NIEHS) Gulf Long-Term Follow-Up Study (GuLF STUDY). The GuLF STUDY is a prospective cohort study of individuals aged 21 years or older who either completed an OSRC safety training course or had previously received OSRC training as part of their ongoing employment (e.g., if they were part of the Coast Guard), and did one or more days of OSRC work. The safety training course consisted of a general module on the recognition, avoidance, reduction, and prevention of work-related safety and health hazards, as well as additional modules pertaining to the roles and responsibilities associated with specific positions. A detailed description of the GuLF STUDY has been published previously (Kwok, Engel et al., 2017). A total of 32,608 participants completed a telephone enrollment interview (Time 1 [T1]), between March 2011 and March 2013, which was an average of 87.30 weeks (i.e., 1.68 years) after the well was capped on July 15, 2010 (SD = 19.63; range: 36.57–141.14 weeks; Kwok, Engel et al., 2017). The survey assessed details of the participant's OSRC work, if any, as well as demographic characteristics, history of mental health conditions, financial worries, and physical health symptoms at the time of the spill. Participants were classified as workers if they participated in at least 1 full day of OSRC work and as nonworkers if they did not. Interviews at T1 took approximately 30–60 min.

A subsample of 24,275 English- or Spanish-speaking participants residing in one of the U.S. Gulf states (i.e., Alabama, Florida, Louisiana, Mississippi, or Texas) was invited to participate in a second assessment (Time 2 [T2]), which was conducted in the participant's home and included structured mental health indices and assessment of participants' exposure to Hurricane Katrina. Although 17,833 (73.5%) individuals initially agreed to participate, at total of 11,193 (62.8%), including 8,968 workers, completed T2 assessments an average of 14.38 weeks (SD = 16.72) after T1. Relative to the full T1 sample, T2 participants reported significantly lower socioeconomic status, more health problems, and were more likely to be racial and/or ethnic minorities. Of the 11,193 participants who completed the T2 assessment, 10,999 indicated whether or not they had been in the Gulf region at the time of Katrina, and of these, 8,366 participants (76.1%) provided complete data on all variables in the analysis; a total of 5,952 (71.2%) individuals in this group were in the Gulf region at the time of Katrina. The Institutional Review Board of the National Institute of Environmental Health Sciences approved the study procedures, and participants provided verbal consent at T1 and written consent at T2.

Measures

Cumulative disaster exposure.—Participants were classified as having been exposed to Katrina if they experienced any of the following: displacement from predisaster residence (*displacement*), loss of a loved one or serious injury to oneself or to a loved one (*loss or injury*), or job loss as a result of Katrina (*financial hardship*). Previous research has found each of these experiences to be associated with adverse health outcomes (e.g., Fussell & Lowe, 2014; Galea et al., 2007, 2008). Participants were classified as having been exposed

to DHOS if they participated in one or more days of OSRC work. Prior work with this data has found this dichotomous indicator of DHOS exposure to be associated with increased prevalence of both probable PTSD and probable MD (Kwok, McGrath et al., 2017). Katrina and DHOS exposures were summed, yielding a cumulative exposure index such that participants were classified as having been exposed to neither disaster (0), either Katrina or DHOS (1), or both Katrina and DHOS (2). This was included as a categorical variable in the analysis.

Mental health.—Three measures of mental health were included in the current study. First, GAD symptoms were assessed using the seven-item Generalized Anxiety Disorder–7 (GAD-7; Spitzer, Kroenke, Williams & Lowe, 2006). Participants were asked how many days during the past 2 weeks they were bothered by anxiety symptoms (e.g., "feeling nervous, anxious or on edge"). For each item, participants' responses were classified into four levels (0 = *0–1 days*, 1 = *2–6 days*, 2 = *7–11 days*, and 3 = *12–14 days*), and a sum of the responses was computed (range: 0–21). Cronbach's alpha of internal consistency in the current study was .93. Participants with scores of 10 or higher were classified as having probable GAD (Spitzer et al., 2006).

Second, MD symptoms were measured using the Patient Health Questionnaire–8 (PHQ-8; Kroenke, Spitzer, & Williams, 2001). Participants indicated how many days over the past 2 weeks they experienced each of eight symptoms of MD (e.g., "felt down, depressed, or hopeless"), and the same classification levels for items were used as with the GAD-7. The sum of items was computed (range: 0–24; Cronbach's $\alpha = .90$), and participants with PHQ-8 scores of 10 or higher were classified as having probable MD (Kroenke et al., 2001).

Third, PTSD symptoms were assessed using the four-item Primary Care PTSD Screen (PC-PTSD; Prins et al., 2003). Participants indicated whether they experienced symptoms from each *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*) PTSD symptom cluster over the prior month, and the sum of affirmative responses was computed (range: 0–4; Cronbach's $\alpha = .76$). Participants with scores of 3 or 4 were classified as having probable PTSD (Prins et al., 2003).

Physical health.—There were 24 items used to assess whether participants experienced various physical health symptoms at the time of the DHOS: cough; wheezing and/or whistling in chest; tightness in chest; shortness of breath; stuffy, itchy or runny nose; watery or itchy eyes; burning eyes; burning in nose, throat, or lungs; sort throat; severe headache or migraine; dizziness or lightheadedness; nausea; blurred or distorted vision; tingling or "pins and needles" in extremities; numbness in parts of the body; stumbling; heart palpitations and/or pounding; heavy sweating for no reason; strain and/or trouble urinating; lower back pain; fatigue and/or extreme tiredness; diarrhea or frequent bowel movements; constipation; and burning and/or redness on skin. These items were drawn from a larger inventory of physical health symptoms that was derived from standard inventories of respiratory symptoms (e.g., Ferris, 1978) as well as research on the physical health effects of oil spills (e.g., Aguilera, Méndez, Pásaro, & Laffon, 2010). A symptom was counted if it was reported as being experienced *all of the time* or *most of the time* (1) versus *sometimes, rarely*, or

never (0). The total count of physical health symptoms, ranging from 0 to 24, was included in the analysis.

Covariates.—Demographic covariates in the analysis included: age (continuous), race (reference: non-Black), Hispanic ethnicity (reference: non-Hispanic), gender (reference: male), income (reference: high [greater than $50,000 USD] vs. low [$20,000 or less] and middle [$20,001–50,000]), marital status (reference: not separated, divorced, or widowed), and employment status (reference: employed). In addition, we included a dummy variable for whether participants reported being more worried about paying their bills since the spill. Lastly, we controlled for previous mental health problems. Participants indicated whether a doctor had ever diagnosed them with acute stress disorder, anxiety or an anxiety disorder, panic disorder, PTSD, or depression and, if so, the date when they were first diagnosed. Participants who answered affirmatively and provided either a date prior to the oil spill or who could not specify a date were coded as having a previous mental health problem.

Data Analysis

We first computed descriptive statistics for all variables included in the study. Additionally, we conducted chi-square analyses to compare the 8,366 participants included in the analysis versus the 2,633 who were dropped due to missing data. Multivariate analyses were conducted using SAS (Version 9.4) Proc Genmod. Binary logistic regression models were run for the three dichotomous mental health outcomes, and a linear regression model was run for the physical health symptom count. All models included cumulative exposure (i.e., neither exposure, exposure to either Katrina or DHOS, or exposure to both Katrina and DHOS) and adjusted for the aforementioned covariates. Pairwise comparisons of all three cumulative exposure classifications were computed.

Supplementary analyses were then conducted. To discern whether any of the three Katrina experiences was driving the pattern of results, the analyses were replicated with hurricane exposure defined by each experience alone. That is, we conducted three series of analyses, each using a defining exposure to Katrina: the first with hurricane-related displacement, the second with loss or injury, and the third with financial hardship.

Results

Preliminary Analyses

Of the 8,366 participants in the analysis, 2,048 (24.5%) were defined as exposed to Katrina and 6,728 (80.4%) were defined as exposed to DHOS. Descriptive statistics for cumulative disaster exposure and covariates are provided in Table 1. As shown, 14.8% of participants were exposed to neither Katrina nor DHOS, 65.4% to either Katrina or DHOS, and 19.8% to both Katrina and DHOS. The majority of participants were under 60 years of age (88.7%), male (77.6%), non-Black (64.6%), and non-Hispanic (94.5%). Table 2 lists descriptive statistics for mental and physical health outcomes. Nearly one-quarter of participants (23.2%; 95% confidence interval [CI] [22.3%, 24.1%]) were classified as having probable GAD, 15.8% (95% CI [15.1%, 16.7%]) as having probable MD, and 5.2% (95% CI, [4.7%,

5.7%]) as having probable PTSD. On average, participants reported 11.70 physical health symptoms (SD = 7.85) at the time of the spill.

Several significant differences were detected between the 8,366 participants included in the analysis versus the 2,633 who were dropped due to missing data. First, there were significant differences in exposure status, $\chi^2(2, N = 10{,}996) = 10.22$, $p = .006$, $\phi = .03$, with retained participants more likely to report either DHOS or Katrina exposure and less likely to report both exposures. Second, there were significant differences in covariates such that retained participants were significantly more likely to be: under 60 years of age, $\chi^2(1, N = 10{,}999) = 15.58$, $p < .001$, $\phi = -0.04$; Black, $\chi^2(1, N = 10{,}953) = 7.13$, $p = .008$, $\phi = .03$; female, $\chi^2(1, N = 10{,}999) = 3.89$, $p = .049$, $\phi = .02$; of a higher income level, $\chi^2(2, N = 10{,}219) = 27.14$, $p < .001$, $\phi = .05$; and employed, $\chi^2(1, N = 10{,}920) = 23.69$, $p < .001$, $\phi = -.05$. They were significantly less likely to be Hispanic, $\chi^2(1, N = 10{,}969) = 17.07$, $p < .001$, $\phi = -.04$; and report financial worries, $\chi^2(1, N = 10{,}915) = 17.10$, $p < .001$, $\phi = -.04$. Lastly, retained participants reported significantly lower GAD symptoms, Kruskal-Wallis $\chi^2(1, N = 10{,}467) = 10.50$, $p = .001$, $E^2_R < .01$; and PTSD symptoms, Kruskal-Wallis $\chi^2(1, N = 10{,}771) = 9.28$, $p = .002$, $E^2_R < .01$.

Multivariate Analyses

Mental health.—The results of binary logistic regression models predicting mental health outcomes are shown in Table 3. All comparisons among the three cumulative exposure classifications reached statistical significance. Relative to neither exposure, having both exposures was associated with 2.36 odds, 95% CI [1.96, 2.86], of probable GAD-7; 2.16 odds, 95% CI [1.73, 2.69] of probable MD; and 3.93 odds, 95% CI [2.68, 5.77] of probable PTSD. Having one exposure, relative to neither exposure, was associated with 1.37 odds, 95% CI [1.16, 1.62] of probable GAD; 1.41 odds, 95% CI [1.16, 1.72] of probable MD; and 1.57 odds, 95% CI [1.08, 2.27] of probable PTSD. Supporting a cumulative exposure model, having both exposures was also associated with a higher likelihood of each mental health outcome relative to having only one exposure. Specifically, relative to having one exposure, having both exposures was associated with 1.72 odds, 95% CI [1.52, 1.96] of probable GAD; 1.53 odds, 95% CI [1.32, 1.77] of probable MD; and 2.51 odds, 95% CI [2.03, 3.10] of probable PTSD.

Physical Health Symptoms

Table 4 shows the results of the linear regression model predicting physical health symptoms. Having both exposures and one exposure were associated with significantly more symptoms relative to having neither exposure. Specifically, relative to neither exposure, having both exposures was associated with 1.94 more physical health symptoms, 95% CI [1.41, 2.48], and one exposure was associated with 0.95 more physical health symptoms, 95% CI [0.51, 1.40]. Additionally, having both exposures was associated with significantly more physical health symptoms than having one exposure, such that participants who experienced both Katrina and DHOS reported 0.99 more physical health symptoms, 95% CI [0.59, 1.39], than those who reported only one exposure.

Supplementary Analyses

The patterns of significance for supplementary analyses that used hurricane-related displacement, loss or injury, and financial hardship to define Katrina exposure were consistent with those that used any of these experiences to define exposure, with one exception: having either exposure, relative to neither exposure, was not significantly associated with probable PTSD in the model that used financial hardship to define Katrina exposure. The full results of these models are available in Supplementary Tables 1–6.

Discussion

This study examined the cumulative influence of high levels of exposure to Katrina and DHOS on the mental and physical health of a large sample of U.S. Gulf Coast residents. Exposure to each disaster was defined by disaster-related experiences that prior research has shown to increase the risk of adverse health outcomes. For Katrina, participants were classified as exposed if they reported one or more of three different disaster-related stressors (displacement, injury or loss, and financial hardship), and for DHOS, participants were classified as exposed if they completed at least one day or more of OSRC work. We found that exposure to both disasters was associated with significantly higher odds of probable GAD, MD, and PTSD, as well as significantly more physical health symptoms at the time of the spill, relative to exposure to neither disaster. Moreover, relative to exposure to either disaster, exposure to both disasters was associated with significantly higher odds of each mental health outcome and significantly more physical health symptoms. The results thus suggest that disasters have a cumulative influence on mental and physical health.

The results for mental health are consistent with a growing body of research demonstrating the phenomenon of cumulative disaster exposure (e.g., Harville et al., 2011; Jacobs & Harville, 2015). Further research is needed to understand the mechanisms by which cumulative disaster exposure leads to mental health symptoms. One possibility is that the experience of additional disasters undermines feelings of safety, security, and hope for the future, thereby increasing the risk for mood and anxiety disorders. Other research suggests that the persistent social and economic stressors brought on by multiple exposures could account for heightened risk (Lowe, Tracy, Cerdá, Norris, & Galea, 2013). Potential biological mechanisms, such as epigenetic changes, allostatic load, and dysregulation of neurobiological stress-mediating systems (for reviews, see Juster, McEwen, & Lupien, 2010; Ryan, Chaudieu, Ancelin, & Saffrey, 2016; Sherin & Nemeroff, 2011), should also be explored in populations exposed to multiple disasters. Mental health symptoms stemming from a disaster could also increase vulnerability to traumatic and stressful events both generally and during a subsequent disaster, further contributing to risk (e.g., Liu, 2013; Lowe et al., 2013; Lowe, Walsh, Uddin, Galea, & Koenen, 2014). Given evidence of the interplay between mental health symptoms and both general and disaster-related traumatic and stressful events, we echo others' call for culturally sensitive mental health services that address the social and economic impacts of disasters along with patients' symptoms in communities facing multiple exposures (Osofsky et al., 2014; Osofsky, Palinkas, & Galloway, 2010). For example, recommendations for working with low-income populations, religious minorities, and communities of color (e.g., Hays, 2016; Sue & Sue, 2013) should

be integrated into postdisaster services. Future research that explores whether demographic characteristics modify the influence of cumulative exposure on outcomes would also be of value in identifying groups of survivors that might be most vulnerable to adverse outcomes.

With regard to physical health, the results were also consistent with prior research that has shown associations between disaster exposure and symptoms (e.g., Arcaya et al., 2014; Lee et al., 2016), and the one prior study that linked cumulative exposure and overall physical health (Fernandez et al., 2005). Further research on this topic could provide more insight into the cumulative physical health impacts of disasters through more nuanced assessment of both exposures and symptoms. For example, it is possible that a stronger cumulative influence of disasters would be observed for disaster-related experiences that are most likely to directly affect physical health, such as contact with mold, oil spill chemicals, cleaning agents, and other toxins and irritants. Another possibility is that disasters have a stronger cumulative impact on physical health if they involve the same type of physical health risks. One might expect, for example, to see a stronger cumulative effect of two oil spills than a single oil spill combined with a different type of disaster, as in the case for participants with multiple exposures in the current study. It is also likely that disaster-related experiences within and across disasters vary in their effects on different classes of physical health symptoms as well as on ratings of overall physical health. As such, further research on this topic should separately examine different classes of physical health symptoms, such as respiratory, digestive, and neurological symptoms, along with general ratings of physical health. In this vein, the social and economic stressors that typically follow disasters, particularly in communities that endure multiple exposures, might be more likely to influence general ratings of physical health, versus specific classes of physical health symptoms, to the extent to which such ratings are reflective of survivors' mental health. Future research should address this possibility and more generally explore the complex interplay of physical and mental health symptoms over time in the context of cumulative disaster exposure.

The results of the study should be interpreted in light of its limitations, the most critical of which pertain to our measurement of disaster exposure. Because all participants completed OSRC safety training, it is likely that they each experienced some DHOS exposure, irrespective of whether they went on to participate in OSRC work. Similarly, it is possible that many of the participants were at least somewhat affected by Katrina, even if they did not endorse one of the Katrina-related experiences that would classify them as being exposed. As such, there were no truly unexposed participants in the study, and it would be useful for future research to include individuals who lived outside of the disaster-affected area when each disaster struck to serve as the unexposed subsample. Classifying participants with some exposure as "unexposed" might have led to an underestimation of the influence of cumulative exposure on mental and physical health outcomes. The advantage of our approach, however, was that we focused on experiences that prior research has shown to increase the risk for adverse mental and physical health outcomes. On the other hand, it is also worth noting that we did not include in our classification other disaster-related experiences, such as property damage and loss in the case of Katrina and financial losses and other means of direct contact with oil in the case of DHOS, that have been linked with adverse health outcomes (e.g., Fan et al., 2014; Rhodes et al., 2010). Therefore, future

research should take a more comprehensive accounting of all experiences most critical to postdisaster health when classifying exposure.

Specific to Katrina, using displacement as an indicator of exposure was perhaps problematic in that a diverse array of circumstances could lead a survivor not to return to his or her predisaster residence (Fussell, 2015). For some Katrina survivors, for example, displacement could reflect sufficient social and economic resources to evacuate and to resettle in a different neighborhood whereas for others, displacement could reflect an inability to return due to insufficient resources. Future research should therefore more thoroughly assess displacement and identify the displacement experiences most critical to postdisaster health when considering how to classify participants' exposure.

Regarding of measurement of DHOS exposure, classifying participants as exposed if they completed one day of OSRC work versus using a longer duration might have affected the results. On one hand, the cumulative influence of disaster might only be apparent after a certain threshold of work; on the other hand, exposure to the spill might have had the strongest impact on the mental and physical health of those who left work after a short period of time. We note here that prior work with this dataset has found no variation in patterns of results when workers who completed 2 weeks or less of work (4.6% of workers in the current study) were excluded. In contrast, a previous analysis of workers in the GuLF STUDY sample (Kwok, McGrath et al., 2017) found that specific aspects of OSRC work, including having smelled oil, dispersants, or cleaning chemicals; a higher level of estimated total hydrocarbon exposure; and exposure to burning or flaring oil, were linked to a higher prevalence of PTSD and depression. It is thus likely that a stronger association between cumulative exposure and mental health outcomes, and perhaps physical health outcomes as well, would have been observed had we used one of these alternative indicators of DHOS exposure. Future research that includes OSRC work as a dichotomous indicator of oil spill exposure should explore this possibility. It is further possible that some participants—both those classified as exposed and unexposed to DHOS—were from areas outside of the Gulf Coast. Being from other areas certainly could have influenced participants' experience of the oil spill—for example, the likelihood that they experienced financial hardship due to the spill's effects. Although it is unclear how this would affect the pattern of results in the current study, further research should take this into account when developing more nuanced assessments of cumulative exposure.

A more general limitation of our assessment of exposure was that each disaster was coded dichotomously. Similar approaches have been used in prior research. For example, Harville et al. (2011) coded participants' "severe exposure" to Katrina and Hurricane Gustav dichotomously based on whether participants had been forced to evacuate or had experienced the death of a relative. Fernandez et al. (2005) also defined exposure to the September 11, 2001, terrorist attacks on the World Trade Center and the American Airlines Flight 587 crash dichotomously, such that participants who experienced direct, indirect, or occupational disaster-related experiences to each disaster were considered "exposed." The advantage of this rough approach to classification is the facility it provides in demonstrating the health impact of each additional disaster—for example, comparing the influence of one versus two disasters on outcomes, as we did in the current study. On the other hand, this

approach does not capture the variability in exposure within each disaster, with some survivors experiencing few and others experiencing many disaster-related stressors among those who, in our study, would be classified as merely “exposed.” The dichotomous approach also gave each disaster equal weight in its influence on outcomes, and it is certainly possible that the disasters did not have equivalent effects. For example, it is possible that some disasters have the potential of yielding a greater number of stressful experiences than others. Given these limitations of dichotomous indicators, it would be useful for future researchers to incorporate means of assessing cumulative exposure that allow for varying counts of stressful experiences across different disasters, such as that taken in studies by Harville and colleagues (Harville et al., 2017; Jacobs & Harville, 2015). Within each disaster, it might also be useful to allow for different stressors to carry more or less weight based on their association with mental health outcomes.

At least six additional limitations of the study are worth noting. First, we did not assess participants’ exposure to other disasters, particularly those that had affected the area prior to or during the course of the study; such disasters include Hurricanes Gustav and Ike and the flooding of the Mississippi River in 2012. Thus, our study does not fully explore the cumulative health impact of disasters in the Gulf Coast. Had we collected data on these other disasters, for example, it is possible that some participants who had been classified as “unexposed” in the currents tudy would have been more accurately coded as having been exposed to one or more disasters. On the other hand, individuals who were exposed to either or both Katrina and DHOS might have been more likely than unexposed participants to have endured these other disasters. The impact of the limited number of disasters assessed in the current study on the pattern of results (i.e., whether this led us to over- or underestimate the influence of cumulative exposure on health outcomes) is therefore unclear. Second, we utilized self-report measures of mental and physical health symptoms, which are not substitutable for clinical diagnoses. This approach, however, is notably consistent with other epidemiological research on disasters (e.g., Galea et al., 2007; Tracy, Norris, & Galea, 2011). Third, the timeframes of assessment differed across the outcomes such that GAD and MD symptoms were in reference to the past 2 weeks, PTSD symptoms to the past month, and physical health symptoms to the time during the spill (i.e., in most cases, more than a year in the past). This variation limits the extent to which the mental and physical health results in particular can be compared because it is possible that the pattern of results across outcomes would be different had the timeframes been more comparable. Future research on this topic should therefore be careful to measure outcomes within the same timeframe, perhaps including assessments of both acute and chronic symptoms, to more precisely make comparisons across different classes of health outcomes. Fourth, we cannot rule out the possibility of reverse causality, meaning that participants who were suffering from mental or physical health symptoms may have been more likely to report exposure, leading to inflated associations between exposure and health outcomes. This issue is perhaps more concerning for our assessment of Katrina versus DHOS given the longer amount of time that had passed, the nature of the disaster-related experiences defining exposure, and that exposures and outcomes were assessed at the same time point. Concerns about reverse causality are lessened, however, because we controlled for pre-DHOS mental health diagnoses. Fifth, although the sample of participants who had completed OSRC worker safety training is of

special interest given their potentially enhanced risk of adverse outcomes, it nonetheless might limit the extent to which the results are generalizable to other populations in the Gulf Coast region. Sixth, there were several systematic differences between participants who completed the baseline and follow-up surveys as well as between those who were included in the analysis versus those who were dropped due to missing data; this thus limits the generalizability of the findings to the population of individuals who completed OSRC work training.

Despite these limitations, the results of the study demonstrate the influence of cumulative disaster exposure on the mental and physical health of Gulf Coast residents. The results suggest the need for practitioners to screen for prior exposure when disasters strike and for the monitoring of both mental and physical health symptoms, especially among residents with multiple exposures. In the U.S. Gulf Coast and other regions that are susceptible to enduring multiple disasters, accessible and affordable mental health services are needed to offset the cumulative effects of exposure.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Descriptive Statistics for Cumulative Disaster Exposure and Covariates

Variable	*n*	%
Cumulative disaster exposure		
Both DHOS and Katrina	1,651	19.7
Either DHOS or Katrina	5,474	65.4
Neither	1,241	14.8
Age (years)		
< 60	7,432	88.8
≥ 60	934	11.3
Gender		
Male	6,501	77.7
Female	1,865	22.4
Race		
Non-Black	5,394	64.5
Black	2,972	35.4
Hispanic ethnicity		
Yes	459	5.5
No	7,907	94.5
Income		
Low (≤ $20,000)	3,331	39.8
Medium ($20,001–50,000)	2,720	32.7
High (≥ $50,001)	2,315	27.5
Marital status		
Separated, divorced, or widowed	1,944	23.3
Not separated, divorced, or widowed	6,422	76.7
Employment status		
Employed	4,810	57.3
Unemployed	3,556	42.7
More worried about paying bills since DHOS		
Yes	4,425	53.1
No	3,941	46.9
Previous mental health problem		
Yes	1,549	18.6
No	6,817	81.4

Note. *N* = 8,366. DHOS = Deepwater Horizon oil spill; Katrina = Hurricane Katrina.

Table 2

Descriptive Statistics for Mental and Physical Health Outcomes

Outcome	*n*	%	*M*	*SE*
Mental health outcomes				
Probable GAD (GAD-7 ≥ 10)				
Yes	1,940	23.2	--	--
No	6,426	76.8	--	--
Probable MD (PHQ-8 ≥ 10)				
Yes	1,326	15.8	--	--
No	7,040	84.2	--	--
Probable PTSD (PC-PTSD ≥ 3)				
Yes	433	5.2	--	--
No	7,933	94.8	--	--
Physical health symptoms	--	--	11.70	7.85

Note. $N = 8{,}366$. GAD = generalized anxiety disorder; GAD-7 = Generalized Anxiety Disorder-7; MD = major depression; PHQ-8 = Patient Health Questionnaire-8; PTSD = posttraumatic stress disorder; PC-PTSD = Primary Care Posttraumatic Stress Disorder Screen.

Table 3

Results of Binary Logistic Regression Analyses Predicting Mental Health Outcomes[a]

Outcome and Exposure Classification	*B*	*SE*	*OR*	95% CI
Probable GAD (GAD-7 ≥ 10)				
Both Katrina and DHOS vs. Neither	0.86***	0.10	2.36	[1.96, 2.86]
Either Katrina or DHOS vs. Neither	0.32**	0.09	1.37	[1.16, 1.62]
Both Katrina and DHOS vs. Either Katrina or DHOS	0.55***	0.07	1.72	[1.52, 1.96]
Probable MD (PHQ-8 ≥ 10)				
Both Katrina and DHOS vs. Neither	0.77***	0.11	2.16	[1.73, 2.69]
Either Katrina or DHOS vs. Neither	0.34**	0.10	1.41	[1.16, 1.72]
Both Katrina and DHOS vs. Either Katrina or DHOS	0.43***	0.08	1.53	[1.32, 1.77]
Probable PTSD (PC-PTSD ≥ 3)				
Both Katrina and DHOS vs. Neither	1.37***	0.20	3.93	[2.68, 5.77]
Either Katrina or DHOS vs. Neither	0.45*	0.19	1.57	[1.08, 2.27]
Both Katrina and DHOS vs. Either Katrina or DHOS	0.92***	0.11	2.51	[2.03, 3.10]

Note. $N = 8{,}366$. DHOS = Deepwater Horizon oil spill. GAD = generalized anxiety disorder; GAD-7 = Generalized Anxiety Disorder-7; MD = major depression; PHQ-8 = Patient Health Questionnaire-8; PTSD = posttraumatic stress disorder; PC-PTSD = Primary Care Posttraumatic Stress Disorder Screen.

[a]Models controlled for age, race, Hispanic ethnicity, gender, income, marital status, employment, financial worries, and previous mental health problems.

*$p < .05$.

**$p < .01$.

***$p < .001$.

Table 4

Results of Linear Regression Analysis Predicting Physical Health Symptoms[a]

Exposure Classification	*B*	*SE*	95% CI
Both Katrina and DHOS vs. Neither	1.94***	0.27	[1.41, 2.48]
Either Katrina or DHOS vs. Neither	0.95***	0.23	[0.51, 1.40]
Both Katrina and DHOS vs. Either Katrina or DHOS	0.99***	0.20	[0.59, 1.39]

Note. $N = 8{,}366$. DHOS = Deepwater Horizon oil spill; Katrina = Hurricane Katrina.

[a]Model controlled for age, race, Hispanic ethnicity, gender, income, marital status, employment, financial worries, and previous mental health problems.

*$p < .05$.

**$p < .01$.

***$p < .001$.