

Hurricane Sandy Exposure and the Mental Health of World Trade Center Responders

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The psychological consequences of a second disaster on populations exposed to an earlier disaster have rarely been studied prospectively. Using a pre- and postdesign, we examined the effects of Hurricane Sandy on possible World Trade Center (WTC) related posttraumatic stress disorder (PTSD Checklist score of ≥ 50) and overall depression (major depressive disorder [MDD]; Patient Health Questionnaire depression score of ≥ 10) among 870 WTC responders with a follow-up monitoring visit at the Long Island WTC Health Program during the 6 months post-Hurricane Sandy. The Hurricane Sandy exposures evaluated were damage to home (8.3%) and to possessions (7.8%), gasoline shortage (24.1%), prolonged power outage (42.7%), and filing a Federal Emergency Management Agency claim (11.3%). A composite exposure score also was constructed. In unadjusted analyses, Hurricane Sandy exposures were associated with 1.77 to 5.38 increased likelihood of PTSD and 1.58 to 4.13 likelihood of MDD; odds ratios for ≥ 3 exposures were 6.47 for PTSD and 6.45 for MDD. After adjusting for demographic characteristics, WTC exposure, pre-Hurricane Sandy mental health status, and time between assessments, reporting ≥ 3 Hurricane Sandy exposures was associated with a 3.29 and 3.71 increased likelihood of PTSD and MDD, respectively. These findings underscore the importance of assessing the impact of a subsequent disaster in ongoing responder health surveillance programs.

On October 29, 2012, Hurricane Sandy struck the New York (NY) metropolitan area, the same region devastated by the World Trade Center (WTC) attacks on September 11, 2001. Hurricane Sandy was one of the most destructive and costliest storms in United States history after Hurricane Katrina. More than 100 lives were lost, and more than 100,000 homes were destroyed. Long Island, NY, the location of the current study, sustained extensive property damage and prolonged power outages, along with widespread gasoline shortages that led to gasoline rationing. This study focuses on the short-term effects of

Hurricane Sandy on WTC responders from Long Island. Several studies of WTC responders have reported persistently high rates of posttraumatic stress and depressive symptoms, and chronic *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000) posttraumatic stress disorder (PTSD) since September 11, 2001 (e.g., Bromet et al., 2016; Cone et al., 2015; Liu, Tarigan, Bromet, & Kim, 2014; Luft et al., 2012; Maslow et al., 2015; Wisnivesky et al., 2011). Hurricane Sandy thus provided a unique opportunity to examine the mental health impact of a second disaster in a high-risk cohort.

A large number of studies have shown that natural and human-made disasters have adverse effects on mental health, especially PTSD and depression symptoms (e.g., Fergusson, Horwood, Boden, & Mulder, 2014; Neria, Nandi, & Galea, 2008; Norris et al., 2002; North, 2014; North & Pfefferbaum, 2013), with rates of PTSD ranging from 20% (North, 2014) to 40% (Neria et al., 2008) and rates of depression ranging from 5% to 10% (Goldmann & Galea, 2014), depending on the severity and location of the disaster and the timing and methodology of the study (Goldmann & Galea, 2014; Norris, Gaber, Friedman, & Watson, 2006). Although symptom levels typically decline after the first year (Norris et al., 2002), in some groups, including rescue workers (Berger et al., 2012; Morren, Dirkzwager, Kessels, & Yzermans, 2007), they have

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been found to persist for long periods (Bromet et al., 2016; Cone et al., 2015). Retrospective and pre- and postassessment studies have found three important predictors of postdisaster mental health: predisaster stressors, predisaster psychopathology, and the extent of disaster-related adversities (Breslau, Peterson, & Schultz, 2008; Brewin, Andrews, & Valentine, 2000; Brunet, Boyer, Weiss, & Marmar, 2001; Ginexi, Weihs, Simmens, & Hoyt, 2000; Sayed, Iacoviello, & Charney, 2015). Additional risk factors for disaster responders have included inadequate training (Alexander & Klein, 2009; Zhang et al., 2016) and types of prior exposure experiences (Dougall, Haberman, Delahanty, Inslicht, & Baum, 2000).

The stress sensitization hypothesis suggests that prior trauma exposure could increase vulnerability to subsequent stressors or traumas. Several studies of disaster populations indeed found evidence that secondary disaster stressors (Kessler et al., 2012; Yabe et al., 2014) and postdisaster life events and adversities (Maes, Mylle, Delmeire, & Janca, 2001; Maslow et al., 2015; Shrira, Palgi, Ben-Ezra, & Shmorkin, 2010; Smid et al., 2012; Zvolensky et al., 2015) were associated with increased psychopathology. However, only a few studies specifically examined the psychological effects of two community-wide disasters on the same population. To date, we found five such studies. Of these studies, three were retrospective studies that supported the stress sensitization hypothesis: a study of Holocaust survivors after the SCUD (tactical ballistic missiles) attacks on Israel (Robinson et al., 1994), a study of soldiers after recurrent combat exposure (Solomon, Mikulincer, & Jakob, 1987), and a web-based survey of adults near the WTC conducted 1 month after Hurricane Sandy (Palgi et al., 2014; Shrira, Palgi, Hamama-Raz, Goodwin, & Ben-Ezra, 2014). The remaining two studies were prospective. The first was a longitudinal assessment of a massive wildfire in 2007 followed by a deadly earthquake in 2008 (Papanikolaou, Adamis, Mellon, Prodromitis, & Kyriopoulos, 2011) that found a significant additive effect on distress. The second was a paper-pencil and Internet-based survey of Hurricane Sandy exposure among individuals enrolled in the WTC Health Registry surveillance program who resided within and outside of the Federal Emergency Management Agency (FEMA) defined inundation zones in the New York, New Jersey, and Connecticut tristate area (Caramanica, Brackbill, Stellman, & Farfel, 2015). The number of Sandy exposures, along with pre-Hurricane Sandy WTC-related PTSD (PTSD Checklist [PCL] ≥ 44) and low social integration, were strongly associated with post-Hurricane Sandy PTSD.

The current pre- and postassessment study extends reports about the psychological effects of Hurricane Sandy (e.g., Boscarino et al., 2013; Caramanica et al., 2015; Lowe, Sampson, Gruebner, & Galea, 2015; Palgi et al., 2014; Schwartz et al., 2015; Shrira et al., 2014) by systematically examining its acute effects on PTSD and depression among WTC responders in a health-monitoring program. Specifically, we tested the stress-sensitization hypothesis by evaluating the additive as well as the potential synergistic effects of Hurricane Sandy exposure on the mental health of WTC responders with high and

low levels of exposure to the September 11, 2001 attacks (Smid et al., 2012). World Trade Center-related PTSD and overall major depressive disorder (MDD) were the focus of this report. Consistent with prior disaster studies, we presented both unadjusted associations and models adjusted for demographic characteristics, WTC exposure severity, and prior psychopathology (Bromet et al., 2017).

Method

Participants and Procedures

The Hurricane Sandy cohort was derived from participants in a Centers for Disease Control- (CDC-) funded study of well-being, conducted through the Stony Brook University (SBU) WTC Health Program (Bromet et al., 2016; response rate = 76.8%). The health program, composed of two clinics on Long Island, provides ongoing monitoring and treatment of responders with documented WTC experience (Dasaro et al., 2015). The Hurricane Sandy cohort included 887 study participants with a follow-up monitoring visit during the 6 months after Sandy (November 2012 to April 2013). The analysis focused on participants ($n = 870$) who completed a brief Hurricane Sandy Questionnaire. Descriptive information about the sample is provided in Table 1.

The current study was approved by the Stony Brook University Committees on Research Involving Human Subjects. Written informed consent was obtained from the participants.

Measures

The key characteristics of Hurricane Sandy exposure were damage to home, damage to possessions, difficulty obtaining gasoline, loss of power, and filing a claim with FEMA. The first three items were rated on a 1 to 5 scale and dichotomized into absent (1 = *not at all*, 2 = *a little bit*, and 3 = *moderately*) versus present (4 = *quite a bit*, 5 = *extremely*) to capture an appropriate threshold for significant exposure (Kopala-Sibley et al., 2016). Loss of power for > 7 days and filing a claim with FEMA were binary variables. Total scores ranged from 0 to 5. Missing values were rare (0–1.3%). For ease of interpretation and analysis, we constructed a 3-level exposure composite (0, 1–2, 3–5) from all available binary data. The cutpoint of ≥ 3 marks the top decile (most exposed) of the distribution.

Possible WTC-related PTSD was assessed with the 17-item PTSD Checklist-Specific Version (PCL-S; Weathers, Litz, Herman, Huska, & Keane, 1993), which was administered at each monitoring visit. The PCL, rated 1 (*not at all*) to 5 (*extremely*), was modified to assess symptoms during the past month “in relation to 9/11.” The PCL had good convergent validity and internal consistency (Wilkins, Lang, & Norman, 2011), including in the Hurricane Sandy cohort ($\alpha = .95$). Scores were dichotomized at ≥ 50 to indicate possible PTSD (Terhakopian, Sinaii, Engel, Schnurr, & Hoge, 2008). The sensitivity and specificity

Table 1

Distribution of Risk Factors and Associations With Possible World Trade Center-Related Posttraumatic Stress Disorder and Major Depressive Disorder During the 6 Months After Hurricane Sandy

Risk factors	% of Sample	WTC-PTSD		MDD	
		OR	95% CI	OR	95% CI
Demographics					
Age, ≥ 50 years	47.6	1.18	[0.74, 1.86]	1.30	[0.89, 1.91]
Female	9.0	1.49	[0.73, 3.02]	0.89	[0.45, 1.79]
Non-Caucasian	16.4	0.77	[0.40, 1.48]	0.74	[0.42, 1.29]
≤ High school	21.7	1.66*	[1.01, 2.74]	1.55*	[1.01, 2.39]
Unmarried	11.3	2.51***	[1.41, 4.45]	1.95**	[1.16, 3.27]
Nontraditional responder	30.6	2.25***	[1.42, 3.57]	2.01***	[1.36, 2.97]
Hurricane Sandy ^a					
Damage to home	8.3	5.38***	[3.06, 9.48]	4.13***	[2.44, 6.99]
Damage to possessions	7.8	4.31***	[2.37, 7.84]	2.95***	[1.68, 5.17]
Gasoline problems	24.1	3.10***	[1.94, 4.94]	2.78***	[1.86, 4.14]
Lost power > 7 days	42.7	1.77*	[1.12, 2.81]	1.58*	[1.07, 2.33]
Filed FEMA application	11.3	2.08*	[1.15, 3.75]	2.38***	[1.44, 3.94]
Exposure composite:	42.6	1.00	—	1.00	—
0	48.9	2.32**	[1.32, 4.09]	1.81**	[1.15, 2.84]
1–2	8.5	6.74***	[3.33, 13.63]	6.45***	[3.56, 11.67]
3–5					
WTC Exposure					
Early WTC arrival ^b	77.8	4.82***	[1.92, 12.10]	1.77*	[1.04, 2.99]
Pre-Hurricane Sandy mental health					
Possible PTSD	9.2	40.17***	[22.31, 72.32]	16.36***	[9.70, 27.59]
Possible MDD	12.8	14.13***	[8.53, 23.41]	18.41***	[11.55, 29.36]

Note. $N = 870$. Possible WTC-PTSD was defined as ≥ 50 on the Posttraumatic Stress Disorder Checklist (PCL); possible MDD was defined as ≥ 10 on the Patient Health Questionnaire (PHQ9). Post-Hurricane Sandy PTSD and MDD rates among participants were 9.5% and 14.0%, respectively. PTSD = posttraumatic stress disorder; MDD = major depressive disorder; OR = odds ratio; CI = confidence interval; WTC = World Trade Center; FEMA = Federal Emergency Management Agency.

^aMissing values = 4 (gasoline), 6 (power), and 11 (possessions). ^bArrival at the WTC site on September 11 or September 12, 2001.

* $p < .05$. ** $p < .01$. *** $p < .001$.

of the cutpoint with a research diagnosis based on the Structured Clinical Interview for DSM-IV (SCID; Spitzer, Williams, Gibbon, & First, 1992) were 73.0% and 96.5%, respectively.

Possible MDD was determined from the Patient Health Questionnaire (PHQ9; Kroenke, Spitzer, & Williams, 2001). The PHQ9 assessed the criterion symptoms of *DSM-IV* MDD over the previous 2 weeks on a scale from 0 (*not at all*) to 3 (*nearly every day*). Cronbach's α was used to calculate the internal consistency for the Hurricane Sandy sample ($\alpha = .91$). The recommended cutpoint for possible MDD is ≥ 10 (Kroenke & Spitzer, 2002). The sensitivity and specificity of the cutpoint with current SCID MDD were 90.2% and 91.7%, respectively.

We analyzed three sets of covariates. The demographic variables were age, sex, educational attainment, marital status, and responder type (police vs. nontraditional responders, such as construction, maintenance, and transportation workers). WTC exposure was operationalized as arrival on September 11 or 12, 2001, when environmental and psychological conditions

were most pernicious; arrival on September 11 or 12, 2001 was significantly associated with exposure to the dust cloud and human remains, and losing colleagues or friends in the tower collapse. Possible pre-Hurricane Sandy WTC-PTSD and MDD were assessed using the measures described above for the nearest pre-Hurricane Sandy visit.

Data Analysis

Unadjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to examine the associations of Hurricane Sandy exposure and the risk factors with post-Hurricane Sandy WTC-PTSD and MDD. Multivariable logistic regression adjustment was also calculated with variables entered in four increasingly comprehensive blocks to test if the effect of Sandy exposure was explained by demographic, WTC, or pre-Hurricane Sandy mental health. Model 1 included the 3-level Sandy exposure variable. Model 1 also adjusted for time from pre-Hurricane Sandy assessment to Hurricane

Sandy and from Hurricane Sandy to the post-Hurricane Sandy visit, with time operationalized as above or below the median of 12 months for pre-Hurricane Sandy and 3 months for post-Hurricane Sandy. Model 2 added demographic characteristics that were significant in the bivariate analysis (Table 1; $p \leq .05$). Model 3 added WTC exposure and was repeated to include the interaction term of WTC $\times$ Hurricane Sandy Exposure. Finally, Model 4 added pre-Sandy mental health on the same outcome variable. Cox and Snell R^2 was reported for each block, along with block and final model p values. Missing values on the PCL and PHQ9 were rare ($< 1\%$), and missingness was handled by calculating the total score of the questionnaire using ipsative mean imputation, given the high internal consistency of the scales (Schafer & Graham, 2002). Data were analyzed using SPSS, version 23.

Results

The mean age of the sample was 49.9 ($SD = 8.3$) years. The sample was primarily male, employed full- or parttime, married, Caucasian, and police (vs. nontraditional) responders (Table 1). The majority of participants were at the WTC on September 11 or September 12, 2001. A minority of responders had pre-Hurricane Sandy WTC-PTSD (9.2%) and MDD (12.8%). The most common Hurricane Sandy exposures were loss of power for ≥ 7 days, followed by extreme concern about finding gasoline, filing a FEMA claim, extensive damage to their home, and extensive damage to their possessions (Table 1). In all, 42.6% of responders had no Hurricane Sandy exposure, 48.9% had one to two exposures, and 8.5% had three to five exposures. Of note, experiencing three to five exposures was not associated with WTC arrival time, $OR = 1.5$, 95% CI [0.8, 2.9].

The post-Hurricane Sandy rates of WTC-PTSD and MDD were 9.5% and 14.0%, respectively. The two domains were comorbid, with 65 (46.8%) of the 139 responders with PTSD or MDD having both conditions. The individual Hurricane Sandy exposures were associated with a 1.77- to 5.38-fold elevated likelihood of PTSD and 1.58- to 4.13-fold likelihood of MDD (Table 1). The strongest associations were found for damage to a participant's home and possessions and concerns about finding gasoline, whereas the weakest associations were found for prolonged loss of power and for filing a FEMA claim. Experiencing three to five exposures was associated with a 6.74- and 6.45-fold increased odds of PTSD and MDD, respectively.

Among the covariates, less education, being unmarried, and nontraditional responder type were each associated with WTC-PTSD and MDD. Early arrival at the WTC site was more strongly associated with possible PTSD ($OR = 4.82$) than MDD ($OR = 1.77$). As expected, pre-Hurricane Sandy PTSD and MDD were the strongest predictors of post-Hurricane Sandy mental health.

Table 2 shows the multivariable findings for WTC-PTSD (top half) and overall MDD (bottom half). Regarding PTSD, having three to five Hurricane Sandy exposures remained significant

in each model, although the adjusted odds ratios (AORs) decreased from 6.61 (Model 1) to 3.29 (Model 4). Reporting one to two Sandy exposures also retained significance, although the AORs were smaller. Responder type was the only covariate that remained significant in Models 2 through 4. Early arrival at the WTC site was associated with a 5.08-fold increased likelihood of PTSD in Model 3. We note that the association of Early Arrival $\times$ High Hurricane Sandy Exposure was nonsignificant ($p = .867$). In Model 4, although the AOR for pre-Hurricane Sandy PTSD was 32.77, both Hurricane Sandy and WTC exposures remained significant.

We next examined the associations of each Hurricane Sandy exposure with WTC-PTSD in separate multivariable analyses. There were three stressors that retained their significance after adjusting for all of the covariates: damage to home, $AOR = 2.76$, 95% CI [1.26, 6.08], $p = .012$; damage to possessions, $AOR = 3.04$, 95% CI [1.34, 6.86], $p = .008$; and concern about obtaining gasoline, $AOR = 2.05$, 95% CI [1.11, 3.79], $p = .022$.

Turning to possible MDD, experiencing three to five Hurricane Sandy exposures was significant ($p \leq .001$) in all four models, though the AOR decreased from 6.34 (Model 1) to 3.71 (Model 4). Reporting one to two exposures was significant only in Models 1 through 3. Nontraditional responder type was the only significant demographic covariate. Arrival at the WTC site on September 11 or September 12, 2001 was significant in Model 3, but there was no synergistic effect with Hurricane Sandy exposure ($p = .961$) and the AOR became nonsignificant in Model 4. In Model 4, the AOR for pre-Hurricane Sandy MDD was 16.08. As noted for PTSD, experiencing three to five Hurricane Sandy exposures and responder type remained significant in the fully adjusted model.

We next examined the associations of the individual Hurricane Sandy exposures with possible MDD in separate multivariable analyses. The same three stressors as found for WTC-PTSD were significant in the fully adjusted models for MDD, namely, damage to home, $AOR = 2.27$, 95% CI [1.18, 4.38], $p = .014$; damage to possessions, $AOR = 2.38$, 95% CI [1.19, 4.76], $p = .014$; and concern about finding gasoline, $AOR = 1.87$, 95% CI [1.15, 3.01], $p = .011$.

Discussion

The current study found that Hurricane Sandy exposures were significantly associated with possible WTC-PTSD and MDD, even after adjusting for demographic characteristics (including traditional/nontraditional responder type), prior exposure (early WTC arrival), and prior psychopathology. There were three Hurricane Sandy characteristics (extensive damage to home, extensive damage to possessions, and extreme concern about finding gasoline) that were particularly significant. The study is valuable in providing a pre- and postanalysis of the impact of Hurricane Sandy on WTC responders, many of whom have had persistently elevated PTSD and MDD symptoms since September 11, 2001.

Table 2

Multivariable Associations of Hurricane Sandy Exposure With Possible World Trade Center-Related Posttraumatic Stress Disorder and Major Depressive Disorder

	Possible PTSD							
	Model 1 ^a		Model 2		Model 3		Model 4	
	AOR	95% CI	AOR	95% CI	AOR	95% CI	AOR	95% CI
Number of Hurricane Sandy exposures								
0	1.00	—	1.00	—	1.00	—	1.00	—
1–2	2.33**	[1.32, 4.10]	2.17**	[1.22, 3.84]	2.12**	[1.19, 3.78]	2.28*	[1.13, 4.59]
3–5	6.61***	[3.25, 13.42]	5.61***	[2.72, 11.53]	5.11***	[2.46, 10.64]	3.29*	[1.29, 8.42]
≤ High school			1.40	[0.82, 2.38]	1.32	[0.78, 2.26]	0.85	[0.43, 1.69]
Unmarried			2.18*	[1.20, 3.96]	2.19*	[1.19, 4.01]	1.91	[0.88, 4.17]
Nontraditional responder			2.01**	[1.24, 3.26]	2.26***	[1.38, 3.70]	2.42**	[1.30, 4.49]
Early WTC arrival ^a					5.08***	[2.00, 12.94]	3.99*	[1.33, 11.91]
Pre-Hurricane Sandy PTSD							32.77***	[17.34, 61.94]
	Possible MDD							
Hurricane Sandy exposures								
0	1.00	—	1.00	—	1.00	—	1.00	—
1–2	1.81**	[1.15, 2.85]	1.72*	[1.09, 2.72]	1.71*	[1.08, 2.70]	1.47	[0.89, 2.45]
3–5	6.34***	[3.49, 11.51]	5.65***	[3.08, 10.36]	5.41***	[2.94, 9.96]	3.71***	[1.81, 7.61]
≤ High school			1.34	[0.85, 2.12]	1.31	[0.83, 2.06]	0.91	[0.53, 1.56]
Unmarried			1.67	[0.97, 2.87]	1.66	[0.96, 2.87]	1.53	[0.81, 2.88]
Nontraditional responder			1.80**	[1.19, 2.72]	1.89**	[1.25, 2.87]	1.87*	[1.16, 3.02]
Early WTC arrival ^b					1.78*	[1.03, 3.07]	1.78	[0.96, 3.28]
Pre-Hurricane Sandy MDD							16.08***	[9.82, 26.32]

Note. Includes demographic characteristics with $p \leq .05$ in Table 1. For PTSD, the Cox and Snell R^2 values were for Model 1 (.034, $p = .000$), Model 2 (.053, $p = .001$), Model 3 (.071, $p = .000$), and Model 4 (.205, $p = .000$). Values for MDD were Model 1 (.042, $p = .000$), Model 2 (.057, $p = .003$), Model 3 (.062, $p = .030$), and Model 4 (.190, $p = .000$). PTSD = posttraumatic stress disorder; MDD = major depressive disorder; AOR = adjusted odds ratio; CI = confidence interval; WTC = World Trade Center.

^aModel 1 adjusts for time from pre-Hurricane Sandy visit to hurricane and from Hurricane Sandy to posthurricane visit. ^bArrival at the WTC on September 11 or September 12, 2001.

* $p < .05$. ** $p < .01$. *** $p < .001$.

The findings were in line with those of prior prospective studies that showed that the emotional impact of an initial trauma is a critical risk factor after a subsequent disaster (Breslau, Chilcoat, Kessler, & Davis, 1999; Caramanica et al., 2015; Ursano et al., 1999; Wolfe, Erickson, Sharkansky, King, & King, 1999). Although prior psychiatric status of a participant did not overshadow the effect of Hurricane Sandy exposure on that participant's mental health, it was the strongest predictor, having double-digit ORs though quite wide CIs.

Overall, the proportion of responders with possible WTC-PTSD and MDD increased only slightly from the pre- to the post-Hurricane Sandy monitoring visit. However, it is noteworthy that the ORs for ≥ 3 (vs. 0) Hurricane Sandy exposures and WTC-PTSD ($OR = 6.74$) and MDD ($OR = 6.45$) translate to post-Hurricane Sandy rates of 25.7% (WTC-PTSD) and 31.1% (MDD) in the highly Hurricane Sandy-exposed group. These rates were similar to those reported in a web-based survey 1 month after the hurricane (Palgi et al., 2014; 23.6% screened positive for PTSD), but higher than those found for New Jersey

shore residents assessed with a phone screen 6 months post-Hurricane Sandy (Boscarino et al., 2013; 14.5%) and WTC Health Registry participants in a web-based survey 6 to 12 months after the hurricane (Caramanica et al., 2015; 11.3% living in an inundation zone screened positive for PTSD on a Hurricane Sandy-related PCL). In this regard, it is important to emphasize that the WTC responders as a group, especially the nontraditional responders, have demonstrated poorer mental health all along than other populations affected by the September 11, 2001 attacks, such as the residents of the inundation zone included in the WTC Health Registry study.

The most important predictors in our study were consistent with those found in previous disaster research, namely, prior psychopathology, prior trauma exposure, and disaster severity. North and Pfefferbaum (2013) recommended that these three classes of risk factors should form the core of needs assessment surveys of disaster survivors. Under the usual circumstances, early identification of these high-risk populations after a large-scale disaster is challenging (Neria & Schultz, 2012).

In populations enrolled in health surveillance programs, however, high-risk individuals are more readily identifiable and an assessment of a second disaster's aftermath can be integrated into the monitoring protocol. In addition to established risk factors for PTSD, such as prior trauma exposure and preexisting psychopathology, nontraditional responders are a high-risk group; thus their situation after a second disaster should be routinely assessed. Employers of disaster responders might also screen for mental health symptoms and exposures after new disasters to identify and refer those people in need of care. Another approach is to train disaster responders to build up psychological resources to cope with disaster exposures before engaging in disaster response work (Schreiber et al., 2004).

The strengths of the study include the pre- and postdesign, the focus on traditional and nontraditional responders, the inclusion of a WTC-specific and a general mental health outcome, and the ability to examine WTC and Hurricane Sandy exposure in the same models. The limitations include the voluntary nature of the responder cohort, the focus on responders attending the Stony Brook WTC Health Program who are primarily male and Caucasian (although in most respects, the sample is similar to the entire WTC Health Program cohort; Bromet et al., 2016), the absence of a reliable pre-Hurricane Sandy social support measure, the lack of a non-WTC exposed comparison group, diagnoses determined from cutpoints on symptom questionnaires (although the cutpoints were selected to indicate latent clinical disorders), and the focus only on the acute phase after Hurricane Sandy. Thus, for example, in the short term, filing claims with FEMA was less strongly associated with mental health compared with other Hurricane Sandy exposures. Conceivably, the long-term impact may be considerably stronger given the class-action lawsuits that were subsequently filed alleging altered engineering reports that led to systematic underpayment of insurance claims. Another limitation of the current study is that nondisaster life events and adversities were not included in the analysis. Thus, future studies should take a broader and longer-term approach to understanding the stress process (Turner & Lloyd, 1995).

Overall, the present findings add to a small body of research on double disasters, and an even smaller number of pre-and poststudies of double disasters. Consistent with these studies, prior mental health had the strongest association with post-Hurricane Sandy well-being, but Hurricane Sandy exposure had an independent effect on mental health. Although retrospective studies suggest that recollections of past traumas contribute importantly to the impact of a current trauma on mental health (Palmi et al., 2014), a pre- and postdesign is key to understanding the effects of the initial disaster after a second disaster occurs.

In conclusion, Hurricane Sandy exposures, like those of Hurricane Katrina (Galea et al., 2007), were related to poor mental health, independent of demographic characteristics, including marital status (Fullerton, Ursano, & Wang, 2004), responder type, severity of initial trauma, and prehurricane mental health. These results suggest that the problems that

arose in the wake of Hurricane Sandy contributed to the burden already carried by WTC responders as a result of the pernicious exposures they experienced on and after September 11, 2001, and underscore the importance of assessing the impact of a subsequent disaster in ongoing health surveillance programs.

References

- Alexander, D. A., & Klein, S. (2009). First responders after disasters: A review of stress reactions, at-risk, vulnerability, and resilience factors. *Prehospital and Disaster Medicine*, 24, 87–94. doi:10.1017/s1049023x00006610
- American Psychiatric Association. (2000). Diagnostic and statistical manual of mental disorders (4th ed., text rev.). Washington, DC: Author.
- Berger, W., Coutinho, E. S. R., Figueira, I., Marques-Portella, C., Luz, M. P., Neylan, T. C., . . . Mendlowicz, M. V. (2012). Rescuers at risk: A systematic review and meta-regression analysis of the worldwide current prevalence and correlates of PTSD in rescue workers. *Social Psychiatry & Psychiatric Epidemiology*, 47, 1001–1011. doi:10.1007/s00127-011-0408-2
- Boscarino, J. A., Hoffman, S. N., Kirchner, H. L., Erlich, P. M., Adams, R. E., Figley, C. R., & Solhkhah, R. (2013). Mental health outcomes at the Jersey Shore after Hurricane Sandy. *International Journal of Emergency Mental Health*, 15, 147–158.
- Breslau, N., Chilcoat, H. D., Kessler, R. C., & Davis, G. C. (1999). Previous exposure to trauma and PTSD effects of subsequent trauma: Results from the Detroit area survey of trauma. *American Journal of Psychiatry*, 156, 902–907. doi:10.1176/ajp.156.6.902
- Breslau, N., Peterson, E. L., & Schultz, L. R. (2008). A second look at prior trauma and the posttraumatic stress disorder effects of subsequent trauma. *Archives of General Psychiatry*, 65, 431–437. doi:10.1001/archpsyc.65.4.431
- Brewin, C. R., Andrews B., & Valentine, J. D. (2000). Meta-analysis of risk factors for posttraumatic stress disorder in trauma-exposed adults. *Journal of Consulting and Clinical Psychology*, 68, 748–766. doi:10.1037/0022-006X.68.5.748
- Bromet, E. J., Atwoli, L., Kawakami, N., Navarro-Mateu, F., Piotrowski, P., King, A. J., . . . Kessler, R. C. (2017). Post-traumatic stress disorder associated with natural and human-made disasters in the World Mental Health Surveys. *Psychological Medicine*, 47, 227–241. doi:10.1017/S0033291716002026
- Bromet, E. J., Hobbs, M. J., Clouston, S. A., Gonzalez, A., Kotov, R., & Luft, B. J. (2016). *DSM-IV* post-traumatic stress disorder among World Trade Center responders 11–13 years after the disaster of 11 September 2001 (9/11). *Psychological Medicine*, 46, 771–783. doi:10.1017/S0033291715002184
- Brunet, A., Boyer, R., Weiss, D. S., & Marmar, C. R. (2001). The effects of initial trauma exposure on the symptomatic response to a subsequent trauma. *Canadian Journal of Behavioural Science*, 33, 97–102. doi:10.1037/h0087132
- Caramanica, K., Brackbill, R. M., Stellman, S. D., & Farfel, M. R. (2015). Posttraumatic stress disorder after Hurricane Sandy among persons exposed to the 9/11 disaster. *International Journal of Emergency Mental Health*, 17, 356–362. doi:10.4172/1522-4821.1000173
- Cone, J. E., Li, J., Kornblith, E., Gocheva, V., Stellman, S. D., Shaikh, A., . . . Bowler, R. M. (2015). Chronic probable PTSD in police responders in the World Trade Center Health Registry ten to eleven years after 9/11. *American Journal of Industrial Medicine*, 58, 483–493. doi:10.1002/ajim.22446
- Dasaro, C. R., Holden, W. L., Berman, K. D., Crane, M. A., Kaplan, J. R., Lucchini, R. G., . . . Todd, A. C. (2015). Cohort profile: World Trade

- Center Health Program General Responder Cohort. *International Journal of Epidemiology*, 1–8. doi:10.1093/ije/dyv099
- Dougall, A. L., Herberman, H. B., Delahanty, D. L., Inslicht, S. S., & Baum, A. (2000). Similarity of prior trauma exposure as a determinant of chronic stress responding to an airline disaster. *Journal of Consulting and Clinical Psychology*, 68, 290–295. doi:10.1037/0022-006X.68.2.290
- Fergusson, D. M., Horwood, J., Boden, J. M., & Mulder, R. T. (2014). Impact of a major disaster on the mental health of a well-studied cohort. *JAMA Psychiatry*, 71, 1025–1031. doi:10.1001/jamapsychiatry.2014.652
- Fullerton, C. S., Ursano, R. J., & Wang, L. (2004). Acute stress disorder, posttraumatic stress disorder, and depression in disaster or rescue workers. *American Journal of Psychiatry*, 161, 1370–1376. doi:10.1176/appi.ajp.161.8.1370
- Galea, S., Brewin, C. R., Gruber, M., Jones, R. T., King, D. W., King, L. A., . . . Kessler, R. C. (2007). Exposure to hurricane-related stressors and mental illness after Hurricane Katrina. *Archives of General Psychiatry*, 64, 1427–1434. doi:10.1001/archpsyc.64.12.1427
- Ginexi, E. M., Weihs, K., Simmens, S. J., & Hoyt, D. R. (2000). Natural disaster and depression: A prospective investigation of reactions to the 1993 Midwest floods. *American Journal of Community Psychology*, 38, 495–518. doi:10.1023/A:1005188515149
- Goldmann, E., & Galea, S. (2014). Mental health consequences of disasters. *Annual Review of Public Health*, 35, 169–183. doi:10.1146/annurev-publhealth-032013-182435
- Kessler, R. C., McLaughlin, K. A., Koenen, K. C., Petukhova, M., & Hill, E. D.; WHO World Mental Health Survey Consortium. (2012). The importance of secondary trauma exposure for post-disaster mental disorder. *Epidemiology and Psychiatric Sciences*, 21, 35–45. doi:10.1017/S2045796011000758
- Kopala-Sibley, D. C., Kotov, R., Bromet, E. J., Carlson, G. A., Danzig, A. P., Black, S. R., & Klein, D. N. (2016). Personality diatheses and Hurricane Sandy: Effects on post-disaster depression. *Psychological Medicine*, 46, 865–875. doi:10.1017/S0033291715002378
- Kroenke, K., & Spitzer, R. L. (2002). The PHQ-9: A new depression diagnostic and severity measure. *Psychiatric Annals*, 32, 1–7. doi:10.3928/0048-5713-20020901-06
- Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, 16, 606–613. doi:10.1046/j.1525-1497.2001.016009606.x
- Liu, B., Tarigan, L. H., Bromet, E. J., & Kim, H. (2014). World Trade Center disaster exposure-related probable posttraumatic stress disorder among responders and civilians: A meta-analysis. *PLoS One*, 9, e101491. doi:10.1371/journal.pone.0101491
- Lowe, S. R., Sampson, L., Gruebner, O., & Galea, S. (2015). Psychological resilience after Hurricane Sandy: The influence of individual- and community-level factors on mental health after a large-scale natural disaster. *PLoS One*, 10, e0125761. doi:10.1007/s10597-015-9947-4
- Luft, B. J., Schechter, C. B., Brohier, J., Reissman, D. B., Guerrero, K., Udasin, I., . . . Bromet, E. J. (2012). Exposure, probable PTSD and lower respiratory illness among World Trade Center rescue, recovery and clean-up workers. *Psychological Medicine*, 42, 1069–1079. doi:10.1017/S003329171100256X
- Maes, M., Mylle, J., Delmeire, L., & Janca, A. (2001). Pre- and post-disaster negative life events in relation to the incidence and severity of post-traumatic stress disorder. *Psychiatry Research*, 105, 1–12. doi:10.1016/S0165-1781(01)00325-0
- Maslow, C. B., Caramanica, K., Welch, A. E., Stellman, S. D., Brackbill, R. M., & Farfel, M. R. (2015). Trajectories of scores on a screening instrument for PTSD among World Trade Center rescue, recovery, and clean-up workers. *Journal of Traumatic Stress*, 28, 198–205. doi:10.1002/jts.22011
- Morren, M., Dirkzwager, A. J. E., Kessels, F. J. M., & Yzermans, C. J. (2007). The influence of a disaster on the health of rescue workers: A longitudinal study. *Canadian Medical Association Journal*, 176, 1279–1283. doi:10.1503/cmaj.060626
- Neria, Y., Nandi, A., & Galea, S. (2008). Post-traumatic stress disorder following disasters: A systematic review. *Psychological Medicine*, 38, 467–480. doi:10.1017/S0033291707001353
- Neria, Y., & Schultz, J. M. (2012). Mental health effects of Hurricane Sandy: Characteristics, potential aftermath, and response. *Journal of the American Medical Association*, 308, 2571–2572. doi:10.1001/jama.2012.110700
- Norris, F. H., Friedman, M. J., Watson, P. J., Byrne, C. M., Diaz, E., & Kaniasty, K. (2002). 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981–2001. *Psychiatry*, 65, 207–239. doi:10.1521/psyc.65.3.207.20173
- Norris, F. H., Galea, S., Friedman, M. J., & Watson, P. J. (2006). *Methods for disaster mental health research*. New York, NY: Guilford Press.
- North, C. S. (2014). Current research and recent breakthroughs on the mental health effects of disasters. *Current Psychiatry Reports*, 16, 481. doi:10.1007/s11920-014-0481-9
- North, C. S., & Pfefferbaum, B. (2013). Mental health response to community disasters: A systematic review. *Journal of the American Medical Association*, 310, 507–518. doi:10.1001/jama.2013.107799
- Palgi, Y., Shrira, A., Hamama-Raz, Y., Palgi, S., Goodwin, R., & Ben-Ezra, M. (2014). Not so close but still extremely loud: Recollection of the World Trade Center terror attack and previous hurricanes moderates the association between exposure to Hurricane Sandy and post-traumatic stress symptoms. *Comprehensive Psychiatry*, 55, 807–812. doi:10.1016/j.comppsy.2014.01.013
- Papanikolaou, V., Adamis, D., Mellon, R. C., Prodromitis, G., & Kyriopoulos, J. (2011). Double disaster: Mental health of survivors of wildfires and earthquake in a part of Greece. *Psychology*, 2, 132–137. doi:10.4236/psych.2011.22021
- Robinson, S., Hemmendinger, J., Netanel, R., Rapaport, M., Zilberman, L., & Gal, A. (1994). Retraumatization of Holocaust survivors during the Gulf War and SCID missile attacks on Israel. *British Journal of Medical Psychology*, 67, 353–362. doi:10.1111/j.2044-8341.1994.tb01803.x
- Sayed, S., Iacoviello, B. M., & Charney, D. S. (2015). Risk factors for the development of psychopathology following trauma. *Current Psychiatry Reports*, 17, 612. doi:10.1007/s11920-015-0612-y
- Schafer, J. L., & Graham, J. W. (2002). Missing data: Our view of the state of the art. *Psychological Methods*, 7, 147–177. doi:10.1037/1082-989X.7.2.147
- Schreiber, S., Yoeli, N., Paz, G., Barbash, G. I., Varssano, D., Fertel, N., . . . Halpern, P. (2004). Hospital preparedness for possible nonconventional casualties: An Israeli experience. *General Hospital Psychiatry*, 26, 359–366. doi:10.1016/j.genhosppsych.2004.05.003
- Schwartz, R. M., Sison, C., Kerath, S. M., Murphy, L., Breil, T., Sikavi, D., & Taioli, E. (2015). The impact of Hurricane Sandy on the mental health of New York area residents. *American Journal of Disaster Medicine*, 10, 339–346. doi:10.5055/ajdm.2015.0216
- Shrira, A., Palgi, Y., Ben-Ezra, M., & Shmorkin, D. (2010). Do Holocaust survivors show increased vulnerability or resilience to post-Holocaust cumulative adversity? *Journal of Traumatic Stress*, 23, 367–375. doi:10.1002/jts.20524
- Shrira, A., Palgi, Y., Hamama-Raz, Y., Goodwin, R., & Ben-Ezra, M. (2014). Previous exposure to the World Trade Center terrorist attack and

- posttraumatic symptoms among older adults following Hurricane Sandy. *Psychiatry*, 77, 374–385. doi:10.1521/psyc.2014.77.4.374
- Smid, G. E., van der Velden, P. G., Lensvelt-Mulders, G. J., Knipscheer, J. W., Gersons, B. P., & Kleber, R. J. (2012). Stress sensitization following a disaster: A prospective study. *Psychological Medicine*, 42, 1675–1686. doi:10.1017/S0033291711002765
- Solomon, Z., Mikulincer, M., & Jakob, B. R. (1987). Exposure to recurrent combat stress: Combat stress reactions among Israeli soldiers in the Lebanon war. *Psychological Medicine*, 17, 443–440. doi:10.1017/S0033291700024995
- Spitzer, R. L., Williams, J. B., Gibbon, M., & First, M. B. (1992). The Structured Clinical Interview for DSM-III-R (SCID). I. History, rationale, and description. *Archives of General Psychiatry*, 49, 624–629. doi:10.1001/archpsyc.1992.01820080032005
- Terhakopian, A., Sinaii, N., Engel, C. C., Schnurr, P. P., & Hoge, C. W. (2008). Estimating population prevalence of posttraumatic stress disorder: An example using the PTSD Checklist. *Journal of Traumatic Stress*, 21, 290–300. doi:10.1002/jts.20341
- Turner, R. J., & Lloyd, D. A. (1995). Lifetime traumas and mental health: The significance of cumulative adversity. *Journal of Health and Social Behavior*, 36, 360–376. doi:10.2307/2137325
- Ursano, R. J., Fullerton, C. S., Epstein, R. S., Crowley, B., Vance, K., Kao, T. C., & Baum, A. (1999). Peritraumatic dissociation and posttraumatic stress disorder following motor vehicle accidents. *American Journal of Psychiatry*, 156, 1808–1810. doi:10.1176/ajp.156.11.1808
- Weathers, F. W., Litz, B. T., Herman, D. S., Huska, J. A., & Keane, T. M. (1993, October). *The PTSD Checklist (PCL): Reliability, validity, and diagnostic utility*. Paper presented at the Annual Convention of the International Society for Traumatic Stress Studies, San Antonio, TX.
- Wilkins, K. C., Lang, A., & Norman, S. B. (2011). Synthesis of the psychometric properties of the PTSD Checklist (PCL) military, civilian and specific versions. *Depression and Anxiety*, 28, 569–606. doi:10.1002/da.20837
- Wisnivesky, J. P., Teitelbaum, S. L., Todd, A. C., Boffetta, P., Crane, M., Crowley, L., . . . Landrigan, P. J. (2011). Persistence of multiple illnesses in World Trade Center rescue and recovery workers: A cohort study. *Lancet*, 378, 888–897. doi:10.1016/S0140-6736(11)61180-X
- Wolfe, J., Erickson, D. J., Sharkansky, E. J., King, D. W., & King, L. A. (1999). Course and predictors of posttraumatic stress disorder among Gulf War veterans: A prospective analysis. *Journal of Consulting and Clinical Psychology*, 67, 520–528. doi:10.1037/0022-006X.67.4.520
- Yabe, H., Suzuki, Y., Mashiko, H., Nakayama, Y., Hisata, M., Niwa, S., . . . Abe, M.; Mental Health Group of the Fukushima Health Management Survey. (2014). Psychological distress after the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident: Results of a mental health and lifestyle survey through the Fukushima Health Management Survey in FY2011 and FY2012. *Fukushima Journal of Medical Science*, 60, 57–67. doi:10.5387/fms.2014-1
- Zhang, G., Pfefferbaum, B., Narayanan, P., Lee, S., Thielman, S., & North, C. S. (2016). Psychiatric disorders after terrorist bombings among rescue workers and bombing survivors in Nairobi and rescue workers in Oklahoma City. *Annals of Clinical Psychiatry*, 28, 22–30.
- Zvolensky, M. J., Farris, S. G., Kotov, R., Schechter, C. B., Bromet, E., Gonzalez, A., . . . Luft, B. J. (2015). World Trade Center disaster and sensitization to subsequent life stress: A longitudinal study of disaster responders. *Preventive Medicine*, 75, 70–74. doi:10.1016/j.ypmed.2015.03.017