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Examining Associations Between Hurricane Sandy Exposure and Posttraumatic Stress Disorder by Community of Residence

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Exposure to 2012's Hurricane Sandy differed by community across New York City and nearby Long Island, and the differential impact of exposure on mental health concerns must be studied to enhance resilience in vulnerable communities. We assessed the association between self-reported Hurricane Sandy exposure and subsequent posttraumatic stress disorder (PTSD) symptoms, obtained through validated questionnaires completed by residents of lower Manhattan (n = 1,134), Queens/Long Island (LI)/Staten Island (SI; n = 622), and the Rockaways (n = 1,011); mean assessment times were 7, 14, and 32 months post-Sandy, respectively. The median number of hurricane exposures was similar for all communities; however, Rockaways residents had a higher proportion of likely PTSD symptoms (18.8%) compared to lower Manhattan (8.0%) and Queens/LI/SI residents (5.8%). Regarding likely PTSD, there was significant interaction between total hurricane exposure and community, $p = .002$, and flooding and community, $p = .040$. Number of hurricane exposures was associated with higher odds of likely PTSD in Queens/LI/SI, $AOR = 1.61$, 95% CI [1.34, 1.94]; lower Manhattan, $AOR = 1.43$, 95% CI [1.28, 1.59]; and the Rockaways, $AOR = 1.25$, 95% CI [1.16, 1.35]. Flooding was associated with increased odds of likely PTSD in the Rockaways, $AOR = 1.65$, 95% CI [1.01, 2.69]; and Queens/LI/SI, $AOR = 3.29$, 95% CI [1.08, 10.00]. This study emphasizes the differential impact of hurricane exposure on subsequent PTSD symptoms in three communities affected by Hurricane Sandy. Future preparedness and recovery efforts must understand community correlates of mental health concerns to promote resilience in vulnerable communities.

On October 29, 2012, Hurricane Sandy made landfall in the northeastern United States, causing billions of dollars of damage, extensive flooding, power outages, and shutdowns in transportation and health services (Federal Emergency Management Agency [FEMA], 2013). Previous studies have reported exposure to Hurricane Sandy to be associated with mental health difficulties, including posttraumatic stress disorder (PTSD; Boscarino, Hoffman, Adams, Figley, & Solhkhah, 2014; Caramanica, Brackbill, Stellman, & Farfel, 2015; Goldmann & Galea, 2014; Paxson, Fussell, Rhodes, & Waters, 2012; Schwartz et al., 2014; Schwartz, Rothenberg, Kerath, Liu, & Taioli, 2016). Studies conducted following Hurricane Sandy of both the general population (Schwartz et al., 2014) and of individuals who had also been exposed to the September 11, 2011, World Trade Center terrorist attacks (9/11; Caramanica et al., 2015) found that, similar to what has been reported in previous literature (Galea et al., 2007; Norris et al., 2002), an individual's level of trauma exposure influenced their mental health outcomes.

Research has focused on identifying factors that influence mental health outcomes in populations affected by Hurricane Sandy, including resilience and vulnerability to disaster-related stressors (Gruebner, Lowe, Sampson, & Galea, 2015; Lowe, Sampson, Gruebner, & Galea, 2015; Rodriguez-Llanes, Vos, & Guha-Sapir, 2013; Tompson, Benz, Agiesta, Cagney, & Meit, 2013). In general, lower socioeconomic status (SES) has been linked to increased vulnerability to mental health difficulties (Norris et al., 2002; Rodriguez-Llanes et al., 2013), whereas higher SES, networks of social support, and marital status can

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provide resilience following a disaster (Caramanica et al., 2015; Rodriguez-Llanes et al., 2013). Additionally, demographics including race, ethnic minority status, employment, and displacement after the disaster have also been shown to be risk factors for symptoms of mental health disorders (Galea et al., 2007; Tracy, Norris, & Galea, 2011). Following Hurricane Sandy, increased trauma exposure, older age, and non-Hispanic Black race have been shown to be associated with symptoms of posttraumatic stress (Lowe et al., 2015). Following 9/11, having less resilience was predicted by female gender, income decline, being directly affected by 9/11, prior traumatic events, and higher education level, whereas increased resilience was predicted by age older than 65 years and Asian race/ethnicity (Bonanno, Galea, Bucciarelli, & Vlahov, 2007).

Given the high level of sociodemographic and geographic diversity among populations exposed to Hurricane Sandy, geographic analysis has emerged as a tool to understand the spatial distribution of exposure, risk factors, and mental health outcomes following a natural disaster (Gruebner et al., 2015; Gruebner, Lowe, Tracy, Joshi, et al., 2016; Showalter & Lu, 2009). Geographic analyses have been utilized following 2005's Hurricane Katrina to identify vulnerable, impoverished, and racial or ethnic minority communities toward which interventions could be tailored and provided (Curtis, Mills, Kennedy, Fotheringham, & McCarthy, 2007). To our knowledge, geographic research following Hurricane Sandy has focused on the spatial distribution of mental health service and emergency department need and utilization (Hall et al., 2016; He et al., 2016; Lee et al., 2016; Lowe, Sampson, Gruebner, & Galea, 2016); only two studies have conducted a geographic analysis of risk factors for mental health symptoms after Hurricane Sandy while incorporating community and neighborhood level predictors (Gruebner et al., 2015; Lowe et al., 2015). Geographic analysis has also been implemented following 9/11, with the finding that proximity to Ground Zero (i.e., the World Trade Center site) in New York City was significantly related to the prevalence of probable PTSD after adjusting for age, sex, race/ethnicity, and education (Schlenger et al., 2002). A separate study of southern Manhattan residents found that residing south of Canal Street, Hispanic ethnicity, and two or more prior stressors were predictors of PTSD (Galea et al., 2002). These studies emphasize the role of geography in identifying risk factors for mental health symptoms as well as in identifying vulnerable communities.

The primary objective of the present study was to examine the association between Hurricane Sandy exposure and likely PTSD symptoms among three communities from areas heavily exposed to Hurricane Sandy and areas with less exposure, including one region that was also exposed to 9/11 trauma. Secondarily, we evaluated the association between flooding and flooding severity with likely PTSD symptoms among the three communities, including factors such as SES that may impact this relation. We hypothesized that the association between hurricane exposure and likely PTSD symptoms would vary among the three groups, with the Rockaways community, which suffered a high level of exposure, demonstrating the strongest positive association between hurricane exposure and likely PTSD symptoms. We also hypothesized that demographic variables and previous mental health diagnoses would vary by region and modify the association between Hurricane Sandy exposure and likely PTSD symptoms.

Method

Participants and Procedure

Data from three existing studies, Leaders in Gathering Hope Together (LIGHT), Project Restoration (PR), and the World Trade Center Health Registry (WTCHR), were pooled for this study (Lieberman-Cribbin, Liu, Schneider, Schwartz, & Taioli, 2017; Caramanica et al., 2015). Project LIGHT was conducted from October 23, 2013, to February 25, 2015, and included participants from the New York regions of Long Island (LI), Queens, and Staten Island (SI). Residents of the Rockaways, which is an area of Queens, in the LIGHT sample were excluded from this analysis ($n = 36$). Project Restoration ran from June 5, 2014, to August 9, 2016, and included only residents of the Rockaways. The LIGHT and PR studies utilized convenience sampling, where interested potential participants approached the research booth at a variety of locations, including street fairs, libraries, and supermarkets. Eligible participants completed a self-report survey and were given $15 (USD) as compensation for their time. Exclusion criteria were not speaking English or Spanish, having cognitive impairments that prevented a participant from providing informed consent, being under 18 years of age, or not living in Long Island or New York City during Hurricane Sandy.

The WTCHR Hurricane Sandy survey was conducted from May 28, 2013, to November 7, 2013, and was distributed to enrollees who completed the Wave 3 survey (2011–2012) and lived in the tristate metropolitan area, which includes New York City, Long Island, and parts of Connecticut and New Jersey. Enrollees were sent lead letters via email and/or postal mail that described the study and invited them to participate. Internet surveys were then sent to individuals with valid e-mail addresses, followed by paper surveys mailed to study participants who did not have a valid e-mail address. E-mail reminders were sent to Internet survey nonresponders, and paper surveys were mailed to study participants who did not complete the Internet survey or did not have a valid email address. At the close of data collection, 4,558 surveys had been completed (51.4% response rate; Caramanica, Brackbill, Liao, & Stellman, 2014). The only WTCHR cohort participants included in the present analysis were those living in lower Manhattan at the time of Hurricane Sandy. The combined study sample included 2,767 participants (LIGHT, $n = 622$; PR, $n = 1{,}011$; WTCHR, $n = 1{,}134$). Approval for all described studies was given by the institutional review board of the Feinstein Institute for Medical Research at Northwell Health and the New York City Department of Health and Mental Hygiene.

Consented participants for Project LIGHT and PR completed the same 20-minute self-administered survey that queried participants' demographics (e.g., age, sex, race/ethnicity), education level, mental health history, and hurricane exposure (adapted from previous hurricane exposure tools; Bonanno et al., 2007; Paxson et al., 2012). The WTCHR enrollees completed a different Hurricane Sandy survey either by paper or online. The WTCHR Hurricane Sandy survey included questions on knowledge of evacuation zone status; home evacuation; storm and subsequent environmental exposures; loss of services; flood damage; costs of home repairs; activities related to storm response, such as rescue, clean-up, and repair; and physical and mental health assessments. As the WTCHR study used different questionnaires than LIGHT and PR, demographic variables and hurricane exposure items were harmonized, and equivalent elements from the LIGHT/PR questionnaire and the WTCHR questionnaire were organized and listed in a crosswalk (Supplemental Table S1).

Measures

Hurricane exposure. A full list of hurricane exposure items is given in Supplementary Table S1. Total number of exposures due to Hurricane Sandy was defined as the sum of all exposures indicated (range: 0–17). For LIGHT and PR, participants reported experiencing flooding in their home (*yes* or *no*), and, if so, how high the flood waters were (in feet). Flood severity was considered missing for participants who indicated flooding but did not provide a height ($n = 65$) or indicated flooding higher than 15 ft ($n = 9$). Flood severity was classified as less than 1 ft, 1 ft to less than 2 ft, 2 ft to less than 3 ft, 3 ft to less than 6 ft, and 6 ft to less than 15 ft.

For the WTCHR survey, participants were asked if any part of their home flooded because of Hurricane Sandy (*yes* or *no*). Participants were also asked how high the flood waters reached inside the living areas of the home: less than 1 ft, 1 ft to less than 2 ft, 2 ft to less than 3 ft, 3 ft to less than 6 ft, and 6 ft to less than 15 ft. Communities were defined as lower Manhattan, Queens/LI/SI (excluding Manhattan or the Rockaways), and the Rockaways. The Cronbach's alpha value for the total sample was .72 for the exposure items.

PTSD. Symptoms of PTSD were assessed in all three studies using the Posttraumatic Stress Disorder Checklist–Specific (PCL-S; Blanchard, Jones-Alexander, Buckley, & Forneris, 1996; Weathers, Litz, Herman, Huska, & Keane, 1993), a 17-item standardized self-report measure reflecting PTSD symptoms as given in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000) that was tailored to be specific to a traumatic event, in this case Hurricane Sandy. Likely PTSD was defined using the *DSM-IV* criteria such that for each item of the PCL questionnaire, a response of 3–5 (*moderately* or above) or 1–2 (below *moderately*) was deemed symptomatic and nonsymptomatic, respectively. Participants were considered to endorse (a) reexperiencing symptoms if they indicated a symptomatic response for at least one item related to Criterion B (Items 1–5), (b) hyperarousal symptoms if they indicated a symptomatic response to at least two items related to Criterion D (Items 13–17), and (c) avoidance or numbing symptoms if they indicated a symptomatic response to at least three items related to Criterion C (Items 6–12). If reexperiencing, hyperarousal, and avoidance/numbing were all present, the participant was considered to have likely PTSD symptoms (Weathers et al., 1993). In the present sample, the Cronbach's alpha value was .98 for the PCL.

Data Analysis

The frequency and percentages for categorical variables were computed by likely PTSD status for each community. For discrete variables, mean and standard deviations, or median and interquartile range (IQR), were calculated by likely PTSD status. Chi-square, one-way analysis of variance, and Kruskal–Wallis tests were performed to compare the sociodemographic composition and exposure among community samples. Cramer's V was used to measure the magnitude of the effect size.

A multivariable logistic regression model was performed to measure the effect of Hurricane Sandy exposure on likely PTSD symptoms by community, adjusting for all demographic variables and time between Hurricane Sandy exposure and questionnaire completion. An interaction between community and total number of hurricane exposures was tested and kept in the model if significant. To measure the effect of being flooded (*yes* or *no*) on likely PTSD symptoms by community, a multivariable logistic regression was performed, adjusting for the same demographics. Total number of hurricane exposures, not including flooding, was recalculated and used as an adjustment as well. The model to evaluate the effect of flooding severity was not stable and not pursued further. Adjusted odds ratios (*AOR*) and 95% confidence intervals (CI) are reported. Because of multiple testing of effects within three communities, confidence intervals for the effects of total number of Hurricane exposures and flooding (*yes*/*no*) were adjusted using Bonferroni corrections. For both models, more than 90.0% of the participants had complete data. All analyses were conducted using SAS (Version 9.4; SAS Institute, Cary, NC, USA).

Results

Descriptive Findings

Of the entire study sample, 36.5%, 22.5%, and 41.0%, respectively, were from the Rockaways, Queens/LI/SI, and lower Manhattan (Table 1). The average time to survey completion after Hurricane Sandy was shortest in the Manhattan sample (7 months) and longer in the Queens/LI/SI (14 months) and Rockaways (32 months) samples. Overall, 11.5% of participants demonstrated likely PTSD symptoms. Participants from

Table 1
Sociodemographic Characteristics and Hurricane Sandy-Related Posttraumatic Stress Disorder (PTSD) Status

	Queens/LI/SI ($n = 622$)			Rockaways ($n = 1{,}011$)			Lower Manhattan ($n = 1{,}134$)		
Variable	Total %	No PTSD %	PTSD %	Total %	No PTSD %	PTSD %	Total %	No PTSD %	PTSD %
Gender[a]									
Male	36.4	36.1	41.7	43.5	43.5	43.2	38.3	39.0	39.7
Female	63.6	63.9	58.3	56.5	56.5	56.8	61.7	61.0	70.3
Race[a]									
Non-Hispanic White	53.1	54.3	33.4	24.9	25.7	21.7	62.4	64.0	45.0
Non-Hispanic Black	16.9	17.4	8.3	52.4	52.7	51.1	6.4	6.5	4.4
Non-Hispanic Other	8.9	9.0	8.3	5.4	5.5	4.9	14.4	12.5	36.3
Hispanic	21.1	19.3	50.0	17.3	16.1	22.3	16.8	17.0	14.3
Education[a]									
≤ High School	6.6	6.3	11.8	21.8	20.0	29.3	11.6	14.3	11.4
> High School	93.4	93.7	88.2	78.2	80.0	70.7	88.4	85.7	88.6
Current mental health treatment[a]									
No	89.9	91.3	66.7	79.9	84.1	61.3	87.0	89.5	59.1
Yes	10.1	8.7	33.3	20.1	15.9	38.7	13.0	10.5	40.9
Mental health history[a]									
No	77.3	78.4	60.0	70.1	75.8	45.5	61.7	64.4	30.7
Yes	22.7	21.6	40.0	29.9	24.2	54.5	38.3	35.6	69.3
	M(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)	*M*(*SD*)
Age (years)[b]	47.8 (23.8)	47.9 (24.0)	47.4 (20.6)	45.2 (15.8)	44.8 (16.3)	47.0 (13.5)	58.2 (14.1)	58.2 (14.2)	58.4 (12.8)
	Mdn(IQR)	*Mdn*(IQR)	*Mdn*(IQR)	*Mdn*(IQR)	*Mdn*(IQR)	*Mdn*(IQR)	*Mdn*(IQR)	*Mdn*(IQR)	*Mdn*(IQR)
People in household[c]	3 (2–4)	3 (2–4)	3 (2–4)	3 (2–4)	3 (2–4)	3 (2–4)	2 (1–3)	2 (1–3)	2 (1–3)
Total number of hurricane exposures[c]	2 (1–4)	2 (1–4)	7 (4–9)	4 (2–6)	3 (2–6)	5 (3–8)	4 (3–6)	4 (3–6)	7 (5–9)
Time elapsed between Hurricane Sandy and Survey (months)[c]	14.0 (12.6–18.2)	14.4 (12.6–18.2)	13.0 (12.6–17.8)	31.8 (23.6–41.1)	32.8 (23.6–41.5)	30.5 (21.2–40.9)	7.0 (6.1–8.4)	7.0 (6.1–8.4)	6.9 (6.1–8.4)
Income level (USD)[d]	$83,631 ($64,696–$100,625)			$60,148 ($44,799–$80,237)			$99,537 ($71,865–$109,784)		

Note. Statistical differences were evaluated based on overall differences by community (Queens/LI/SI vs. Rockaways vs. Lower Manhattan) and not based on differences by PTSD; p values for all variables were $< .001$ except for gender ($p = .005$). IQR = interquartile range; LI = Long Island; SI = Staten Island. Statistical differences were evaluated based on overall differences by community (Queens/LI/SI vs. Rockaways vs. Lower Manhattan) and not based on differences by PTSD.

[a]Chi-square test performed to compare the sociodemographic composition and exposure among community samples. [b]One-way analysis of variance test performed to compare the sociodemographic composition and exposure among community samples. [c]Kruskal-Wallis test performed to compare the sociodemographic composition and exposure among community samples. [d]Differences in median income among communities could not be evaluated for significance due to their derivation from zip code–level data.

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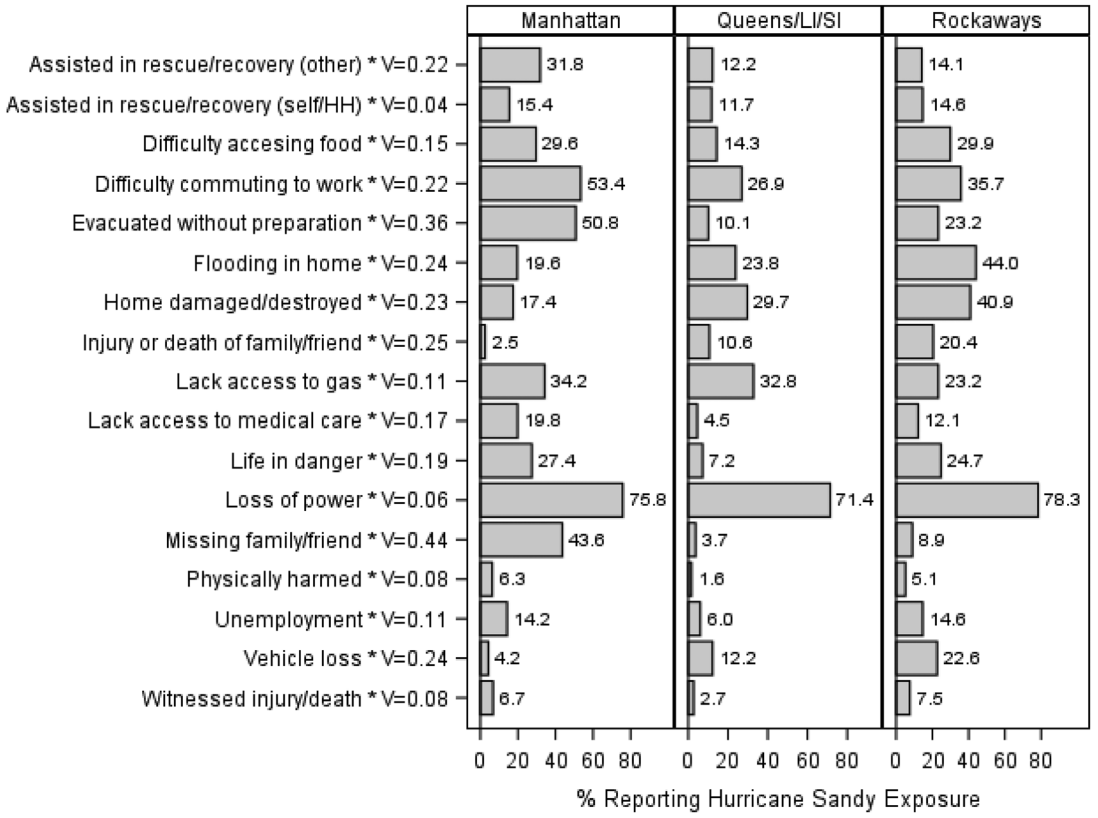

Figure 1. Hurricane exposure items compared by community. LI = Long Island; SI = Staten Island; HH = household; V = Cramer's *V*.

the Rockaways had a higher proportion of participants with likely PTSD symptoms than those from lower Manhattan and Queens/LI/SI (18.8% vs. 8.0% vs. 5.8%). Manhattan residents were, on average, older by about 10 years and had a slightly lower median number of people living in their household. The proportion of male participants with likely PTSD symptoms versus without likely PTSD symptoms was higher in the Queens/LI/SI sample, similar in the Rockaways, and lower in the lower Manhattan sample. The lower Manhattan cohort had more White participants than the other two cohorts. In all cohorts, most participants had at least above a high school education (78.2%–93.4%; Table 1).

Hurricane Exposure

Median (IQR) total number of hurricane exposures was higher in lower Manhattan (*Mdn* = 4, IQR: 3–6) and the Rockaways (*Mdn* = 4; IQR: 2–6) than in Queens/LI/SI (*Mdn* = 2, IQR; 1–4), whereas the median (IQR) number of total hurricane exposures among participants with likely PTSD symptoms was highest in lower Manhattan (*Mdn* = 7, IQR: 5–9) and Queens/LI/SI (*Mdn* = 7, IQR: 4–9) compared to the Rockaways (*Mdn* = 5, IQR: 3–8), with the type of hurricane exposure items differing by community (Figure 1). The most frequently reported exposure for all three communities was loss of power or electricity (75.8% for lower Manhattan, 71.4% for Queens/LI/SI, and 78.3% for the Rockaways, whereas the lower Manhattan sample reported higher levels of having a family or friend missing (43.6%), having difficulty commuting (53.4%), and being evacuated quickly (50.8%). The Rockaways reported the highest percentage of family members or friends who were physically harmed or had died (20.4%) and flooding (44.0%); participants from Queens/LI/SI and lower Manhattan indicated flooding 23.8% and 19.6% of the time, respectively. Of individuals who experienced flooding, 74.4% (Rockaways), 72.9% (Queens/LI/SI), and 30.0% (lower Manhattan) stated that flood waters were at least 3 ft high.

Hurricane Exposure and PTSD

The percentage of likely PTSD symptoms among participants who experienced different hurricane exposures is presented by community in Figure 2. Among individuals who reported flooding, the percentage of those with likely PTSD symptoms was higher in the Rockaways compared to Queens/LI/SI and lower Manhattan (25.4% vs. 17.6% vs. 13.1%, respectively). Not being able to access medical care was associated with the highest proportion of participants with likely PTSD symptoms in Queens/LI/SI. Regarding witnessing death or injury and being physically harmed, the highest proportions of individuals with likely PTSD symptoms were in the Rockaways and lower Manhattan samples.

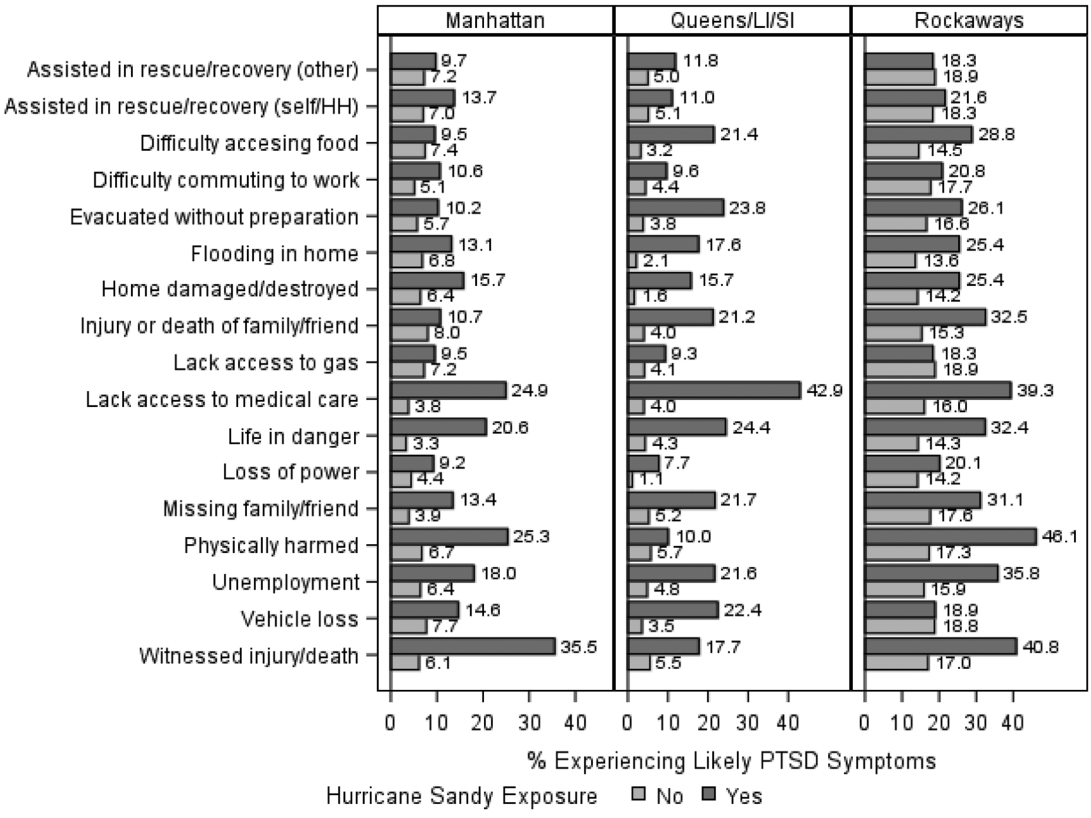

Figure 2. Likely posttraumatic stress disorder (PTSD) symptoms compared by hurricane exposure items and community. LI = Long Island; SI = Staten Island; HH = household; V = Cramer's *V*.

Multivariable Analyses

Total hurricane exposure. From the multivariable model, using 90.1% of the sample with complete data ($n = 2{,}492$), the interaction between total number of hurricane exposures and community on likely PTSD was significant, $p = .002$, indicating that the association between total number of hurricane exposures and PTSD was different based on community (Table 2 and Figure 3). Specifically, for participants in Queens/LI/SI, an increase in one hurricane exposure was associated with 61% greater odds of likely PTSD *AOR* = 1.61, 95% CI [1.34, 1.94], whereas among lower Manhattan and Rockaways participants, the same increase in exposure was associated with 43%, *AOR* = 1.43, 95% CI [1.28, 1.59]; and 25%, *AOR* = 1.25, 95% CI [1.16, 1.35], greater odds of likely PTSD, respectively. Having a history of mental health difficulties, *AOR* = 2.53, 95% CI [1.83, 3.49], and being currently treated for mental health difficulties, *AOR* = 2.32, 95% CI [1.65, 3.27], were also significantly associated with likely PTSD. Education, gender, and time between Hurricane Sandy exposure and questionnaire completion were not significantly associated with likely PTSD when adjusting for other variables. However, non-Hispanic Black race, *AOR* = 1.73, 95% CI [1.15, 2.60], and Hispanic ethnicity, *AOR* = 2.59, 95% CI [1.74, 3.85], were associated with increased odds of likely PTSD symptoms as compared to non-Hispanic White race.

Flooding. In the multivariable model that evaluated whether flooding had a differential impact on likely PTSD depending on community ($n = 2{,}433$), the interaction between flooding and community was significant, $p = .037$. Although there was no significant association between flooding and likely PTSD among the lower Manhattan group, *AOR* = 0.89, 95% CI [0.45, 1.78], flooding was associated with increased odds of likely PTSD in the Rockaways, *AOR* = 1.65, 95% CI [1.01, 2.69]; and Queens/LI/SI, *AOR* = 3.29, 95% CI [1.08, 10.00]. These analyses adjusted for the same covariates as were adjusted for as in the overall exposure model, with similar odds ratios and confidence intervals.

Discussion

This work adds to the literature on Hurricane Sandy exposure and PTSD symptoms at the community level and incorporates an additional population with potential past 9/11 trauma to elucidate the geographic factors associated with PTSD symptoms. Although the associations were not in the hypothesized direction, the results indicated the impact of

Table 2
Association Between Total Number of Hurricane Exposures and Likely Posttraumatic Stress Disorder (PTSD) Symptoms

Factor	*AOR*	95% CI
Total Number of Hurricane Exposures		
Manhattan[a]	1.43	[1.28, 1.59]
Queens/LI/SI[a]	1.61	[1.34, 1.94]
Rockaways[a]	1.25	[1.16, 1.35]
Age (years)	1.01	[1.00, 1.02]
Gender: Female vs. Male	1.10	[0.82, 1.47]
Race		
Non-Hispanic Black vs. White	1.73	[1.15, 2.60]
Non-Hispanic Other vs. White	1.30	[0.74, 2.26]
Hispanic vs. White	2.59	[1.74, 3.85]
Education: ≤ High School vs. > High School	0.84	[0.58, 1.23]
MH Treatment: Yes vs. No	2.32	[1.65, 3.27]
History of MH issues: Yes vs. No	2.53	[1.83, 3.49]
Time elapsed between Hurricane Sandy and survey (months)	0.98	[0.96, 1.00]

Note. MH = mental health; LI = Long Island; SI = Staten Island; AOR = adjusted odds ratio.
[a]Confidence intervals were adjusted using a Bonferroni correction for testing three hypotheses from the interaction between total number of hurricane exposures and community ($\alpha = .0167$) in each model.

hurricane exposure on PTSD symptoms differed by community, with flooding significantly associated with PTSD in the Rockaways and Queens/LI/SI but not lower Manhattan in the current study. These findings have relevant public health implications as they emphasize flooding, the characteristics of a community, and resilience in determining PTSD symptoms.

Although the importance of individual- and community-level factors on mental health symptoms has been previously discussed (Lowe et al., 2015), this analysis utilized a reported value for flooding and determined the impact of flooding on PTSD symptoms. Past estimates of Hurricane Sandy exposure on mental health have characterized flooding based on the area of a census tract that was flooded (Gruebner et al., 2015; Lowe et al., 2015) according to the FEMA Modeling Task Force (FEMA Modeling Task Force, 2015). However, not only is using individual estimates more accurate for determining individual mental health symptoms, but past research has indicated self-perception of exposure to be a stronger predictor of mental health outcomes than FEMA measurements (Lieberman-Cribbin et al., 2017). Regardless of whether participants were overreporting flood heights, individuals' perceptions of flood height were more important as perceptions of exposure may influence mental health symptoms resulting from these exposures (Heir, Piatigorsky, & Weisæth, 2009; Heir & Weisæth, 2008; Mason, Andrews, & Upton, 2010; Paranjothy et al., 2011); however, there is no literature examining these relations longitudinally, thus creating the possibility that the association also goes in the other direction. It is possible that individuals with mental health difficulties may perceive a higher level of exposure, for example. Additionally, this work emphasizes the complex associations among hurricane exposure, socioeconomic characteristics, and unmeasured elements that can together amplify the perception of exposure (Abramson & Garfield, 2006; Bourque, Siegel, Kano, & Wood, 2006; Carroll, Morbey, Balogh, & Araoz, 2009; Fernandez et al., 2015; Lowe, Tracy, Cerdá, Norris, & Galea, 2013; Paranjothy et al., 2011).

Participants in the lower Manhattan sample reported the lowest proportion of flood exposure as well as the lowest proportion of flooding that was less than 3 ft high, whereas the percentage of participants with likely PTSD among those who reported home flooding was smaller in the lower Manhattan sample than in the Queens/LI/SI and Rockaways samples. Additionally, the effect of one additional hurricane exposure on PTSD was larger among Queens/LI/SI residents than the Rockaways and lower Manhattan groups, with flooding a statistically significant driver of likely PTSD in Queens/LI/SI and the Rockaways but not in lower Manhattan. This elucidates that the likelihood of PTSD symptoms cannot be attributed to the number of hurricane exposures alone but rather that the type of exposures plays a part, as the median number of hurricane exposures was four in both lower Manhattan and the Rockaways and two in Queens/LI/SI. Although the Rockaways sample had the largest proportion of participants who reported flooding, loss of power, witnessed injury or death, home damaged or destroyed, and injury or death of family or friend, the lower Manhattan cohort had the largest proportion of individuals who reported family or friend missing, evacuated without preparation, life in danger, lack of access to gasoline, and difficulty commuting to work. Notably, the proportion of PTSD symptoms was higher for each of these exposures in the Rockaways sample compared to lower Manhattan, even including the variables with higher prevalence in the lower Manhattan sample. Similarly, the highest proportion of likely PTSD in the Rockaways group was found in individuals who reported flooding in the home, witnessing injury or death, being physically harmed, lacking access to medical care, feeling of life in danger, unemployment, home damaged or destroyed, family or friend missing, injury or death of family or friend, and difficulty accessing food. This may underscore the greater resilience of the lower Manhattan sample potentially due to differences in socioeconomic factors (including income, as demonstrated in the current results) as well as exposure to community violence and other trauma that has been reported as more prevalent in the Rockaways community (Hernández et al., 2018; Schumacher, 2013). This was also supported by the lower median number of hurricane exposures among individuals with likely PTSD in the Rockaways group ($Mdn = 5$, IQR: 3–8) compared to the Queens/LI/SI ($Mdn = 7$, IQR: 4–9) and lower Manhattan groups ($Mdn = 7$, IQR: 5–9) as well as the highest initial probability of likely PTSD among the Rockaways group (0.25) compared to lower Manhattan (0.03) and Queens/LI/SI (0.03), even among individuals who reported no hurricane exposures (Figure 3).

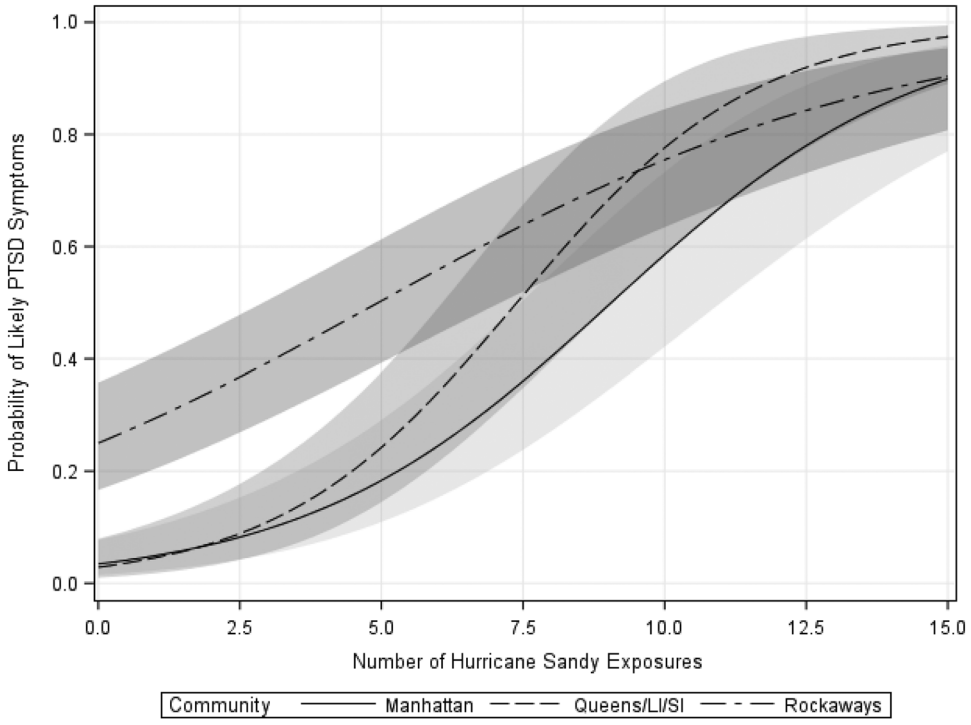

Figure 3. Association between the number of hurricane exposures and the predicted probability of likely posttraumatic stress disorder (PTSD) symptoms, stratified by community. Figure based on predicted probabilities computed at mean values for age, gender, race, education, previous mental health history, and currently being in mental health treatment. LI = Long Island; SI = Staten Island.

Research focusing on vulnerable populations in public housing affected by Hurricane Sandy, including individuals living in Far Rockaway, has proposed that marginalized populations face a delayed period in recovery stemming from a depleted "resilience–reserve" (Carbone & Wright, 2016; Hernández et al., 2018; Petkova et al., 2018). Essentially, chronic hardships, such as poverty, can decrease these groups' capacity to have resilience in the face of an acute exposure (e.g., Hurricane Sandy). This could explain the higher proportion of PTSD symptoms in the Rockaways sample and the elevated probability of PTSD in the Rockaways, even among individuals with no hurricane exposures. It also integrates with previous literature linking lower SES with increased vulnerability to mental health difficulties, particularly after disasters (Bonanno et al., 2007; Norris et al., 2002; Paxson et al., 2012; Rhodes et al., 2010; Rodriguez-Llanes et al., 2013) and literature linking the loss of income with less resilience (Bonanno et al., 2007). Conversely, higher SES and networks of social support can provide resilience following a disaster (Bonanno et al., 2007; Gallo, de los Monteros, & Shivpuri, 2009; Heid, Pruchno, Cartwright, & Wilson-Genderson, 2017), which may have been more present in the lower Manhattan sample compared to the other samples (Bonanno et al., 2007; Rodriguez-Llanes et al., 2013). It is possible that the presence of more social and economic resources in the lower Manhattan sample modified the impact of both Hurricane Sandy and potential past 9/11 exposure in this cohort (Bonanno et al., 2007; Palgi et al., 2014). In the Queens/LI/SI sample, there was a larger increase (i.e., steeper slope) in the probability of PTSD symptoms that began at around four hurricane exposures and, compared to the Rockaways sample, resulted in a higher likelihood of PTSD with nine or more exposures. It is possible that among the Queens/LI/SI sample, which had the most varied demographics as well as exposures, there was more of a threshold effect in that once people had exceeded approximately four exposures, they crossed a threshold by which protective factors and resilience no longer attenuated negative mental health impacts, thereby sharply increasing the probability of PTSD symptoms.

Additionally, we report that non-Hispanic Black and Hispanic participants had higher odds of likely PTSD symptoms compared to non-Hispanic White participants, which supports previous disaster literature following Hurricane Sandy and Hurricane Katrina (Galea, Tracy, Norris, & Coffey, 2008; Lowe, Manove, & Rhodes, 2013; Lowe et al., 2015; Norris et al., 2002; Rhodes et al., 2010) and supports the assertion that racial and ethnic minorities are disproportionately negatively affected by natural disasters (Galea et al., 2007; Lowe et al., 2015; Tracy et al., 2011).

The present study was not without limitations. As convenience sampling was used in LIGHT and PR, there was a potential for sampling bias and, consequentially, higher recorded estimates of mental health symptoms. Potentially, participants who were greatly affected by Hurricane Sandy and those seeking help to recover could be more likely to participate, which

has the potential to increase the rates of those with PTSD symptoms in the data. Also, there are limitations to the study measures that were used. For example, it is possible that our measure of Hurricane Sandy exposure did not account for all possible exposures related to the hurricane, such as increased crime or community violence following the hurricane. Also, our measure of likely PTSD symptoms is not indicative of a clinical diagnosis as it is a brief, self-report instrument. Only true clinician-administered diagnostic instruments can determine diagnoses, but due to training and time constraints, those were not feasible for use with the participants in the various studies included in this analysis. Additionally, there could be recall bias, as surveys were completed at least one year after Hurricane Sandy. Further, there were temporal differences in PTSD assessment between the three studies analyzed, in that the time since the hurricane varied across the three studies. In the multivariable analysis, however, there was no association between time since hurricane and PTSD symptoms. The presence of financial incentives could have influenced participation in lower SES communities. However, to reduce potential bias from convenience sampling, recruitment was conducted to reflect the demographic distribution of the recruitment area and provide variability in hurricane exposure (Lieberman-Cribbin et al., 2017). Additionally, although past exposure to 9/11 has been reported to be associated with PTSD symptoms, 9/11 exposure and resultant 9/11-related PTSD was not determined in PR or LIGHT and thus could not be adjusted for in this analysis (Caramanica et al., 2015). Data were also pooled from existing data sources with different study protocols; however, efforts were made to harmonize the data. A mixed model was used to account for variation due to community.

This study emphasizes the differential impact of hurricane exposure on PTSD symptoms in three communities affected by Hurricane Sandy, with flooding significantly associated with PTSD symptoms in the Rockaways and Queens/LI/SI but not in lower Manhattan. The importance of community was highlighted by the fact that not only did these communities experience different frequencies and types of exposures but that the same exposure was differentially associated with PTSD symptoms in the lower Manhattan and Rockaways samples. In the face of future natural disasters, it is vital to understand community predictors of mental health concerns to address vulnerable communities in addition to marginalized groups and to target resilience, flood preparedness, and recovery efforts. For example, future disaster preparedness efforts could ensure that mental health first responders target areas of increased exposure, such as those with extensive flooding, and also provide mental health first aid in temporary shelters and other locations where displaced people may go. Further, the findings of the study highlight the longer-term impacts of hurricane exposure and support the need for funding and policies that ensure additional mental health support is available for an extended period after a natural disaster and not just in the immediate aftermath.

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