



## Change in binge drinking behavior after Hurricane Sandy among persons exposed to the 9/11 World Trade Center disaster

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### ARTICLE INFO

#### Keywords:

Binge drinking  
Alcohol-related disorders  
9/11 terrorist attacks  
Cyclonic storms  
Disasters

### ABSTRACT

The objective of this study was to examine changes in drinking behavior after Hurricane Sandy among 3199 World Trade Center Health Registry (Registry) enrollees before (2011–12) and after Hurricane Sandy (2015–16). A composite Sandy exposure scale (none, low, medium and high) included Sandy traumatic experiences, financial and other factors. Probable Sandy-related posttraumatic stress disorder (PTSD) was defined as scoring  $\geq 44$  on PTSD Checklist, and binge drinking as consuming  $\geq 5$  alcoholic drinks for men or  $\geq 4$  for women on one occasion in the past 30 days. Some of the enrollees reported binge drinking post Sandy as new binge drinkers (4.7%) or consistent binge drinkers pre- and post-Sandy (19%). Compared with non-binge drinkers pre- and post-Sandy (66.9%), the adjusted odds ratios (aOR) for being new binge drinkers and consistent binge drinkers among high Sandy exposure enrollees were 2.1 (95%CI 1.1–4.1) and 2.5 (95%CI: 1.7–3.6), respectively. High Sandy traumatic experience alone was associated with consistent binge drinking (aOR: 1.9, 95%CI: 1.4–2.6). Among enrollees without 9/11 PTSD, those with Sandy PTSD were more likely to become new binge drinkers (aOR: 4.4, 95%CI: 1.4–13.9), while Sandy PTSD was not associated with any binge drinking behavior changes among those with 9/11 PTSD. Sandy exposure, Sandy traumatic experience, and Sandy PTSD were all associated with higher binge drinking intensity. Future natural disaster response should plan for treatment to address alcohol use and PTSD simultaneously.

### 1. Introduction

Hurricane Sandy (Sandy), with a diameter of 1000 miles, was the largest Atlantic hurricane and resulted in 71 billion dollars in damage (NOAA, 2018). On October 29, 2012, the storm surged onto beaches and shorelines and flooded large areas in the New York City metropolitan area (New York City, Long Island, New Jersey, and parts of Connecticut). The extent of the destruction resulted in multiple deaths and thousands of destroyed and damaged homes, as well as severe power and transportation disruption (Abramson and Redlener, 2012). In addition to the damage and economic costs, Sandy had adverse health effects on some who were exposed to this highly traumatic event.

Those who experience traumatic exposure during natural disasters are vulnerable to mental health conditions, such as posttraumatic stress disorder (PTSD) (Neria et al., 2008; Norris et al., 2002). Studies conducted after Sandy found that Sandy exposure was associated with Sandy-related PTSD among those with high level of recollections of the 9/11 terrorist attack (Palmi et al., 2014), and high Sandy exposure strongly predicted adverse mental health outcomes, such as PTSD and major depression (Boscarino et al., 2013). A previous study also

demonstrated that Sandy-related PTSD was associated with a prior history of PTSD, particularly among those who experienced a greater number of Sandy traumatic exposures (Caramanica et al., 2015).

The association between traumatic exposure and increased alcohol consumption has been examined among several disaster-exposed populations. A study in the wake of the 1995 bombing of the Alfred P. Murrah Federal Building in the Oklahoma City metropolitan area found higher rates of increased alcohol use among exposed adults (Smith et al., 1999). A study of individuals exposed to Hurricane Rita/Katrina concluded that hurricane-related traumatic events and post-disaster stressors may have resulted in increased post-disaster alcohol use (Cerdá et al., 2011). Additionally, frequent binge drinking was positively associated with increased 9/11-exposure and 9/11-related PTSD among individuals exposed to the 9/11 terrorist attacks in the New York City (Welch et al., 2014). However, there is no consensus about the duration of increased alcohol use after a traumatic event (Keyes, 2013). Some studies (Chou et al., 2007; Welch et al., 2017) concluded that the effect can last for years after a traumatic event, while other studies found that the association between disaster exposure and binge drinking observed soon after the disaster was short-term, in that the

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<https://doi.org/10.1016/j.pmedr.2020.101144>

Received 23 July 2019; Received in revised form 1 June 2020; Accepted 10 June 2020

Available online 14 June 2020

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effect of increased alcohol use was not detected beyond a year following the disaster (Boscarino et al., 2006; Nordlökken et al., 2016). Importantly, most of these studies were conducted retrospectively, thus the findings were likely subject to recall bias (Nordlökken et al., 2013).

We proposed to further investigate the long-term relationship between disaster exposure and alcohol consumption. To our knowledge, the current study provides the largest sample utilizing prospective longitudinal data on pre- and post-disaster alcohol consumption. We sought to (1) examine the changes in binge drinking behavior prior to and after Sandy, (2) assess the association between the change in binge drinking behavior, if any, and Sandy measures (such as Sandy traumatic experience, Sandy exposure, and Sandy-related PTSD), (3) determine whether the relationship between Sandy-related PTSD and the change in binge drinking behavior differed by the presence or absence of PTSD from prior trauma, and (4) assess the association between Sandy measures and the maximum number of drinks consumed among binge drinkers.

## 2. Methods

### 2.1. Study design and sample

Established in 2002, the World Trade Center Health Registry (Registry) is a longitudinal cohort study of over 70,000 individuals exposed to the 9/11 terrorist attacks on the World Trade Center in New York City. The Registry conducts periodic health surveys to monitor the long-term health impacts of 9/11 beginning with the baseline (Wave 1) survey conducted in 2003–2004 and three follow up surveys (Waves 2–4) (Brackbill et al., 2009; Farfel et al., 2008). Since Sandy occurred shortly after Wave 3 data collection (2011–12), 43,134 enrollees who both completed Wave 3 and lived in the tristate metropolitan area constituted the Sandy sub-study sample pool. Beginning in late March 2013, the selected 8870 enrollees, all available Registry enrollees residing in Federal Emergency Management Agency defined inundation zone ( $n = 4435$ ) and a sample of 4435 enrollees residing in non-inundation zones, were sent a paper or web survey starting 5 months after Sandy regarding Sandy-related exposures, and questions about their physical and mental health status. After several follow-up reminders, data collection ended in November 2013 with 4558 (51.4%) completed surveys (2443 from the inundation zone, and 2115 from the non-inundation zone) (Brackbill et al., 2014). The Registry protocol was approved by the US Center for Disease Control and Prevention and the New York City Department of Health and Mental Hygiene institutional review boards.

The study sample was limited to those who completed the enrollment (Wave 1), Sandy, Wave 3, and Wave 4 (2015–2016) surveys, and completed the drinking questions assessed at Wave 4 ( $n = 3536$ ). Enrollees who reported discordant binge drinking information between maximum number of drinks per drinking episode and number of binge drinking episodes in the last 30 days were excluded ( $n = 337$ ), resulting in a final analytic sample of 3199.

### 2.2. Dependent variables

The primary outcome for this study was any change in binge drinking behavior from before Sandy (measured at Wave 3) to after Sandy (measured at Wave 4). An episode of binge drinking was defined as having  $\geq 5$  (for men) or  $\geq 4$  (for women) drinks on a single occasion in the last 30 days. Enrollees who reported at least one binge drinking episode at Waves 3 and 4 were defined as ‘consistent binge drinkers’. Enrollees who reported having one or more episodes at Wave 3 but none at Wave 4 were defined as ‘former binge drinkers’. The enrollees who reported having more than one episode at Wave 4 but none at Wave 3 were defined as ‘new binge drinkers’. The enrollees who did not report any binge drinking episodes at both waves were defined as ‘non-binge drinkers’. In addition, we examined predictors of intense binge

drinking, measured by the maximum number of drinks consumed on a single occasion in the last 30 days at Wave 4.

### 2.3. Sandy variables

Several Sandy variables were used as the exposure measures in this study. We used a “Sandy traumatic experiences” measure which included nine individual trauma items derived from questions used after Hurricane Katrina (Galea et al., 2007). These questions assessed if participants were stranded during or after the storm, feared for their life or safety, were unsure about safety or whereabouts of others, family or friends were injured or killed; witnessed terrible events, were personally threatened/robbed/assaulted; family or friends were threatened/robbed/assaulted, home was broken into/robbed; were unable to communicate with others. The number of affirmative responses in the Sandy survey were used to create a three-level Sandy traumatic experience scale: none/low (0–1), medium (2–3), and high (4–9) (Caramanica et al., 2015).

A composite Sandy exposure scale was also used to measure Sandy exposure. This comprised of seven yes/no questions including being in the high Sandy traumatic experience category, evacuated home  $\geq 7$  days, had a flooded living area  $\geq 3$  feet of water, had a damaged home (uninhabitable or inhabitable), lost  $> 1$  possessions (e.g., important documents, items of sentimental or financial value, vehicle, other possessions), had a financial cost of damage  $\geq \$25,000$ , and sustained an injury in the first week after Sandy. Affirmative responses to these questions were summed to create a four level categorical variable for Sandy exposure including none (0), low (1–2), intermediate (3–4), and high (5–7) Sandy exposure (Caramanica et al., 2015).

Sandy-specific probable PTSD was assessed on the Sandy survey using a Sandy-specific version (Cronbach’s  $\alpha = 0.99$ ) of the PTSD Checklist Specific 17 (PCL-17), a 17-item self-reported symptom scale which referred specifically to the events of Sandy and corresponded to the DSM-IV criteria for PTSD (re-experiencing, avoiding, hyper-arousal) (Blanchard et al., 1996; Ruggiero et al., 2003). Respondents reported symptoms on a five-level Likert scale from ‘not at all’ (1) to ‘extremely’ (5), giving a possible score of 17 to 85. Probable Sandy-related PTSD was defined as a PCL score of  $\geq 44$  on the Sandy survey (Caramanica et al., 2015).

### 2.4. 9/11-related variables

Probable 9/11-related PTSD was assessed in Waves 1, 2, 3, and 4 using a 9/11-specific PCL-17, which was identical to Sandy-specific PTSD, except that the eight questions referred to 9/11 instead of Sandy. Probable 9/11-related PTSD was defined as a PCL score of  $\geq 44$  (Brackbill et al., 2009). Screening positive for probable 9/11-related PTSD at any wave was classified as ‘ever’ having 9/11-related PTSD compared to those who never had 9/11-related PTSD.

Exposure to 9/11 was defined using a 12-item composite measured in a previous Registry study, and categorized as low (0–1 exposure) or high ( $\geq 2$ ) (Brackbill et al., 2013).

### 2.5. Covariates

Covariates shown to be associated with binge drinking in the literature were included in the analyses (Naimi et al., 2003; Welch et al., 2017). Sex and race/ethnicity were collected at the Wave 1 survey, age at Sandy survey was derived from Sandy survey, and annual household income in 2015 was collected at the Wave 4 survey.

### 2.6. Statistical analysis

Chi-square tests were used to test the statistical significance of the association between changes in binge drinking and socio-demographic characteristics, 9/11-related PTSD, 9/11 exposure, Sandy traumatic

experience, composite Sandy exposure, and Sandy-related PTSD. Separate multinomial logistic regression models, adjusted for variables significant at the bivariate level, were used to assess associations between Sandy traumatic exposure, Sandy exposure, and Sandy-related PTSD and changes in binge drinking. A Registry study demonstrated that the odds of Sandy-related PTSD was significantly elevated among persons with 9/11-related PTSD (Caramanica et al., 2015). Since the Sandy-related PTSD is not independent from 9/11-related PTSD, the current study did not include 9/11-related PTSD in the regression model used to evaluate the relationship between Sandy-related PTSD and binge drinking behavior change. However, to examine whether factors associated with changes in binge drinking (consistent, former, new, and non-binge drinkers) were different among persons with or without a history of 9/11-related PTSD, we conducted a multinomial analysis stratified by 9/11-related PTSD status. Finally, a negative binomial regression analysis was performed to assess difference in the number of maximum number of drinks consumed during a binge drinking episode among binge drinkers at Wave 4 (2015–16) and Sandy traumatic exposure, composite Sandy exposure, and Sandy-related PTSD. All analyses were conducted using SAS software (version 9.4, SAS Institute Inc., Cary, NC).

### 3. Results

Table 1 presents the sociodemographic and other select characteristics of the entire study sample and by binge drinking status. Overall, participants were predominately male (58.9%), 55 years of age or older at the time the Sandy survey was conducted (53.0%), non-Hispanic white (78.3%), and with a household income  $\geq$ \$75,000 in 2015 (68.5%). About one-third (31.9%) of the study participants ever had 9/11-related PTSD and more than half of them had high 9/11 exposures (58.1%). One-seventh (14%) of study participants had a high Sandy

**Table 1**  
Characteristics of Hurricane Sandy survey participants by drinking behavior category.

	ALL		Non-Binge drinker		New Binge drinker		Former Binge Drinker		Consistent Binge Drinker		p-value
	No.	%	No.	%	No.	%	No.	%	No.	%	
Total	3089		2068	66.9	144	4.7	290	9.4	587	19.0	
Gender (in 2003)											< 0.0001
Male	1819	58.9	1101	60.5	96	5.3	199	10.9	423	23.3	
Female	1270	41.1	967	76.1	48	3.8	91	7.2	164	12.9	
Age, years (at Sandy survey)											< 0.0001
18–44	528	17.1	256	48.5	47	8.9	74	14.0	151	28.6	
45–54	924	29.9	574	62.1	39	4.2	88	9.5	223	24.1	
55+	1637	53.0	1238	75.6	58	3.5	128	7.8	213	13.0	
Race/Ethnicity (in 2003)											< 0.0001
White	2420	78.3	1554	64.2	121	5.0	230	9.5	515	21.3	
Non-White	669	21.7	514	76.8	23	3.4	60	9.0	72	10.8	
Household gross income in 2015)											< 0.0001
$\geq$ \$75,000	2012	68.5	1256	62.4	103	5.1	201	10.0	452	22.5	
< \$75,000	924	31.5	693	75.0	36	3.9	73	7.9	122	13.2	
9/11-related PTSD											0.0065
Ever	876	31.9	552	63.0	52	5.9	91	10.4	181	20.7	
Never	1866	68.1	1287	69.0	71	3.8	171	9.2	337	18.1	
9/11 Exposure (at 2003)											< 0.0001
High	1664	58.1	1041	62.6	80	4.8	175	10.5	368	22.1	
Low	1200	41.9	892	74.3	46	3.8	95	7.9	167	13.9	
Composite Sandy Exposure											< 0.0001
None	1889	61.2	1340	70.9	77	4.1	173	9.2	299	15.8	
Low	692	22.4	447	64.6	37	5.3	64	9.2	144	20.8	
Intermediate	304	9.8	177	58.2	16	5.3	37	12.2	74	24.3	
High	204	6.6	104	51.0	14	6.9	16	7.8	70	34.3	
Sandy Traumatic Experiences											< 0.0001
None/Low	1473	47.7	1040	70.6	62	4.2	136	9.2	235	16.0	
Med	1182	38.3	776	65.7	57	4.8	120	10.2	229	19.4	
High	434	14.0	252	58.1	25	5.8	34	7.8	123	28.3	
Sandy-related PTSD											0.0142
Yes	203	7.0	123	60.6	18	8.9	16	7.9	46	22.7	
No	2680	93.0	1795	67.0	119	4.4	252	9.4	514	19.2	

**Table 2**  
Multinomial logistic regression analysis of new binge/former binge/consistent binge drinkers with non-binge drinkers as the reference category.

Model	New Binge vs. Non-binge Drinker AOR (95%CI)	Former Binge vs. Non-binge Drinkers AOR (95%CI)	Consistent Binge vs. Non-binge Drinkers AOR (95%CI)	
Sandy Exposure <sup>a</sup>				
1	None	ref.	ref.	
	Low	1.3 (0.8, 2.0)	1.0 (0.7, 1.4)	1.4 (1.1, 1.8)
	Intermediate	1.6 (0.9, 3.0)	1.4 (0.9, 2.2)	1.6 (1.1, 2.2)
	High	2.1 (1.1, 4.1)	1.2 (0.7, 2.1)	2.5 (1.7, 3.6)
Sandy Traumatic Experiences <sup>a</sup>				
2	None/low	ref.	ref.	
	Med	1.2 (0.8, 1.8)	1.1 (0.8, 1.4)	1.2 (1.0, 1.6)
	High	1.5 (0.8, 2.6)	1.0 (0.7, 1.6)	1.9 (1.4, 2.6)
Sandy-related PTSD <sup>b</sup>				
3	No	ref.	ref.	
	Yes	2.4 (1.3, 4.3)	1.0 (0.6, 1.8)	1.5 (1.0, 2.2)

<sup>a</sup> The model was adjusted for gender, age, race, household income, any previous probable 9/11-related PTSD, and 9/11 exposure.

<sup>b</sup> The model was adjusted for gender, age, race, household income, and 9/11 exposure.

traumatic experience, 6.6% of them reported high composite Sandy exposure, and 7% of them reported probable Sandy-related PTSD.

Two-thirds of participants were classified as non-binge drinkers (66.9%) and 19% were continued binge drinkers (Table 1). Less than 10% of participants were identified as new binge drinkers (9.4%) and nearly five percent were former binge drinkers (4.7%). Compared to non-binge drinkers, “ever” binge drinkers (including new, former, and consistent) were more likely to be males; those who were 18–44 years

old at the Sandy survey; those who identified as non-Hispanic white; those with higher income; those with prior history of PTSD; those who experienced high 9/11 exposures; those who reported high composite Sandy experience; and those who screened positive for Sandy-related PTSD.

Table 2 shows the association between Sandy measures and binge drinking behavior in three separate multinomial models with non-binge drinkers as the reference. Participants with high composite Sandy exposure were more than two times more likely to become new binge drinkers than participants with no Sandy exposures [Adjusted Odds Ratio (AOR): 2.1, 95% Confidence Interval (CI): 1.1–4.1]. There was no statistically significant association between former binge drinking and any of the Sandy measures. Additionally, participants who experienced a high Sandy-related traumatic experience had nearly twice the odds of continued binge drinking compared to those exposed to low Sandy-related trauma (AOR:1.9, 95% CI: 1.4–2.6). Compared with those with no Sandy exposure, participants across all levels of the composite Sandy exposure were more likely to continue binge drinking. In addition, the more severe Sandy exposure persons reported, the more likely they would be consistent binge drinkers. Those who reported Sandy-related PTSD were more than twice as likely to become new binge drinkers (AOR: 2.4, 95% CI: 1.3–4.3) and 1.5 times likely to continue binge drinking (95% CI: 1.0–2.2) compared to those without Sandy PTSD.

Table 3 examines the relationship between Sandy-related PTSD and changes in binge drinking behavior stratified by 9/11-related PTSD status. Among those who ever had 9/11-related PTSD, the associations between Sandy-related PTSD and binge drinking were not significant for any of the three drinking categories compared to those without Sandy-related PTSD. However, among participants who never had 9/11-related PTSD, the association between Sandy-related PTSD and new binge drinking was statistically significant. Those with Sandy-related PTSD, who never had 9/11-related PTSD, were more than four times as likely to become 'new' binge drinkers compared to those without Sandy-related PTSD (AOR: 4.4, 95% CI: 1.4–13.9). We did not observe a significant association among former or consistent binge drinkers.

The association between Sandy measures and the maximum number of drinks consumed during a binge drinking episode among binge drinkers at Wave 4 was assessed in separate negative binomial regression models presented in Table 4. Participants with low Sandy traumatic experience drank 10% more per drinking episode than participants who experienced no Sandy-related trauma [incidence rate ratios (IRR): 1.10, 95% CI: 1.0–1.2]. Persons with high Sandy traumatic experience also drank 10% more than those with no Sandy trauma, but this relationship did not reach statistical significance (IRR: 1.1, 95% CI: 0.99–1.2). Those with high Sandy exposure drank 10% more than the participants with no Sandy exposure (95% CI: 1.0–1.2). Participants with Sandy-related PTSD drank 20% more per episode than those without Sandy-related PTSD (95% CI: 1.1–1.3).

#### 4. Discussion

Our study was able to address one common limitation of most

**Table 3**

Multinomial logistic regression analysis of new binge/former binge/consistent binge drinkers with non-binge drinkers as the reference category, stratified by 9/11-related PTSD status.

Ever 9/11-related PTSD (n = 705)			Never 9/11-related PTSD (n = 1691)		
New Binge vs. Non-binge Drinker AOR (95%CI)	Former Binge vs. Non-binge Drinkers AOR (95%CI)	Consistent Binge vs. Non-binge Drinkers AOR (95%CI)	New Binge vs. Non-binge Drinkers AOR (95%CI)	Former Binge vs. Non-binge Drinkers AOR (95%CI)	Consistent Binge vs. Non-binge Drinkers AOR (95%CI)
<i>Sandy-related PTSD</i>					
No	ref.	ref.	ref.	ref.	ref.
Yes	1.4 (0.7, 3.0)	0.8 (0.4, 1.6)	1.1 (0.7, 1.8)	<b>4.4 (1.4, 13.9)</b>	1.3 (0.4, 4.6)

The model was adjusted for gender, age, race, household income, and 9/11 exposure.

**Table 4**

Incidence rate ratios (IRR) for the association between Sandy experiences and binge drinking intensity among binge drinkers at Wave 4.

	Max Drinks in an episode, reported at W4 IRR (95%CI)
<i>Sandy Exposure<sup>a</sup></i>	
None	ref.
Low	1.0 (1.0, 1.1)
Intermediate	1.0 (0.9, 1.2)
High	<b>1.1 (1.0, 1.2)</b>
<i>Sandy Traumatic Experiences<sup>a</sup></i>	
None	ref.
Low	<b>1.1 (1.0, 1.2)</b>
High	1.1 (1.0, 1.2) <sup>c</sup>
<i>Sandy-related PTSD<sup>b</sup></i>	
No	ref.
Yes	<b>1.2 (1.1, 1.3)</b>

<sup>a</sup> The model was adjusted for gender, age, race, household income, any previous probable PTSD, and 9/11 exposure.

<sup>b</sup> The model was adjusted for gender, age, race, household income, and 9/11 exposure.

<sup>c</sup> The estimate is not statistically significant.

previous drinking studies, in that we utilized a large sample of people with prospective pre- and post-disaster data. We found that high Sandy traumatic experience, high composite Sandy exposure, and Sandy-related PTSD were positively associated with consistent binge drinking behavior among people exposed to 9/11 as well as drinking intensity among binge drinkers at Wave 4. Also, Sandy-related PTSD was associated with new binge drinking behavior. In addition, when we consider the impact of PTSD related to a previous traumatic event on those with Sandy-related PTSD, persons who never had 9/11-related PTSD were four times more likely to be new binge drinkers compared to non-binge drinkers. Meanwhile, Sandy-related PTSD was not associated with new, former, nor consistent binge drinking among those who ever had 9/11-related PTSD.

The current study found an association between new and consistent binge drinking two to three years after the event, while a previous study only found an association at one year post event between disaster exposure and binge drinking, with no associations found at later time points (Boscarino et al., 2006). This finding is more aligned with findings from a previous Registry study (Welch et al., 2017) which found that disaster exposure was associated with binge drinking 10 years after the event. In addition, an early study conducted after the Beverly Hills supper club shooting in 1977 found an increase in alcohol abuse more than 2 years after the event (Green et al., 1985). Our current study added new evidence that exposure to a traumatic event such as Sandy is associated with new and consistent binge drinking years after the event.

Our findings added new evidence on the causal relationship between hurricane exposure and binge drinking. A previous study showed that Sandy traumatic experience was one of the most significant predictors for developing Sandy-related PTSD (Caramanica et al., 2015)

and our current study found that Sandy traumatic experience was associated with consistent binge drinking. Sandy traumatic experience, however, was not associated with new binge drinking. More importantly, the composite Sandy exposure that incorporated not only individual Sandy traumatic experience, but also financial and other Sandy impact assessments was associated with new binge drinking, as well as consistent binge drinking. Those with low and intermediate composite Sandy exposures showed increased AOR of the new binge drinking but the association was not significant.

We found the odds of new binge drinking and consistent binge drinking were elevated among enrollees with Sandy-related PTSD compared to those without. When stratified by 9/11-related PTSD status, Sandy-related PTSD was not associated with any binge drinking behavior pattern (e.g., being new, former, and consistent binge drinkers compared with non-binge drinkers) among those who ever reported 9/11-related PTSD. Whereas, among those who never had 9/11-related PTSD, those with Sandy-related PTSD were four times more likely to become new binge drinkers. This is contrary to a study of changes in alcohol use after Hurricane Katrina which found that high levels of prior lifetime trauma (such as hurricane-related trauma) was associated with increased alcohol use over time while low or medium prior lifetime trauma exhibited no significant association (Cerdá et al., 2011). Our findings are more aligned to the protective-stabilizing model of resilience (Fergus and Zimmerman, 2005) which suggested that prior lifetime trauma exposures as a protective factor helped neutralize the effect of additional trauma exposure. Another study (Li et al., 2018) found additional trauma was not associated with increased risk of re-experiencing the prior traumatic event. Our current study thus adds new evidence that PTSD is associated with binge drinking change among those without prior trauma-related PTSD.

On the other hand, some studies have found decreased alcohol consumption associated with disaster-related exposure (Cepeda et al., 2010; Nordlökken et al., 2013). However, our current study did not find that former binge drinking was associated with either of our Sandy exposure measures or Sandy-related PTSD. One explanation could be that the previous studies reported decreasing alcohol consumption and while the current study investigated binge drinking behavior pattern, the decreased alcohol consumption observed from previous studies could occur mainly among non-binge drinkers or consistent binge drinkers.

Binge drinking is a serious and preventable public health problem (CDC, 2018), ultimately costing the United States \$ 191 billion in 2010 (Sacks et al., 2015). Our findings raise several important considerations for future research. Binge drinking is one of potentially several negative health behaviors that could stem from repeated disaster exposures and future research should focus on other behaviors, like opioid misuse (Hassan et al., 2017). Additionally, further research is needed on alcohol use disorder, which is diagnosable disabling condition related to binge drinking (Esser et al., 2014). This research can provide additional information for future emergency preparedness planning and targeting interventions post-disaster to exposed persons most at risk for negative health behaviors.

## 5. Strengths and limitations

The major strength of this study is the large and diverse prospective cohort of persons exposed to the NYC 9/11 terrorist attacks with a substantial group who were also directly affected by Hurricane Sandy. The availability of pre-Sandy information on this cohort, including data collected on drinking behavior, 9/11-related PTSD, and other comorbidities, enabled us to address the prior traumatic experience history while evaluating the relationship between the Sandy experiences on binge drinking behavior change. More importantly, the prospective drinking data prior to Sandy likely decreased recall bias for pre-disaster alcohol consumption. Nevertheless, this study also has several limitations including loss to follow-up between Sandy and Wave 4. Those who

completed Wave 4 were more likely to be White non-Hispanic compared to those who did not complete Wave 4. There was no difference in Sandy exposure, traumatic Sandy experience, or Sandy PTSD between those who did and did not complete Wave 4. Self-reported alcohol consumption may underestimate the severity of binge drinking. In addition, survey respondents may have chosen to participate in the Sandy survey because they perceived that they had a greater exposure to Sandy and/or experienced more severe impacts which could potentially result in selection bias.

## 6. Conclusion

Severe natural disasters are becoming more common, increasing the need for public health preparedness and emergency response. Planning for future natural disasters should include tailored outreach, assessment and treatment for alcohol and substance abuse regardless of survivors' prior traumatic experiences. The current study's findings also highlight the need for therapies to address alcohol and PTSD symptoms simultaneously among those who were affected.

## CRedit authorship contribution statement

**Sean Locke:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Angela-Maithy Nguyen:** Investigation, Writing - review & editing. **Liza Friedman:** Writing - review & editing. **Lisa M. Gargano:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision.

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