Exposure to multiple disasters: The long-term effect of Hurricane Sandy (October 29, 2012) on NYC survivors of the September 11, 2001 World Trade Center attack

Lisa M. Gargano*, Jiehui Li, Lucie Millien, Howard Alper, Robert M. Brackbill

World Trade Center Health Registry, Division of Epidemiology, New York City Department of Health and Mental Hygiene, New York, NY 10013, USA

ARTICLE INFO

ABSTRACT

This study evaluated the impact of pre-Hurricane Sandy (Sandy) post-traumatic stress disorder (PTSD) trajectories on the relationship between Sandy exposures and post-Sandy 9/11-related PTSD among World Trade Center Health Registry (Registry) enrollees. The study population included 3,199 adult Registry enrollees who completed three surveys prior to Sandy in 2003–4, 2006–7, and 2011–12; a post-Hurricane Sandy survey (2013); and a follow-up survey in 2015–16. PTSD was assessed using the PTSD Checklist (PCL). Latent class growth analysis was used to identify groups of enrollees who shared a similar trajectory of change in PCL score in the time period prior to Sandy. We compared enrollees in each trajectory group to assess the impact of Sandy-related PTSD, Sandy exposures, and optimism on 9/11-related PTSD status post-Sandy (2015–16) using bivariate analyses and multivariable log-binomial regression. Sandy-related PTSD was the strongest predictor of subsequent 9/11-related PTSD. Lower optimism and higher Sandy exposure significantly predicted 9/11-related PTSD only in some trajectory groups. Hurricane Sandy may have exacerbated previously resolved symptoms of 9/11-related PTSD. This indicates a need after a disaster to assess and address mental health sequelae from previous traumatic exposures.

1. Introduction

On October 29, 2012, Hurricane Sandy (Sandy) struck the New York metropolitan area, the same region devastated by the September 11, 2001 (9/11) terrorist attacks on the World Trade Center (WTC). Sandy was one of the most destructive and costliest storms in US history, resulting in numerous deaths, hundreds of thousands of home and businesses being damaged or destroyed, and long-lasting power and transportation outages (Abramson and Redlener, 2012). Sandy, therefore, provided a unique opportunity to examine the mental health impact of exposure to a second disaster in a high-risk cohort.

Post-traumatic stress disorder (PTSD) is one of the most commonly reported mental health sequela after 9/11 (Perlman et al., 2011). A number of cross-sectional studies show that the higher the 9/11-exposure, the greater the magnitude of increased risk of post-9/11 PTSD (DiGrande et al., 2011; Farfel et al., 2008; Galea et al., 2002; Galea and Resnick, 2005). More recent WTC-related studies that used group-based trajectory models have been conducted among those who participated in WTC rescue, recovery, and cleanup work (RRW) (Maslow et al., 2015; Pietrzak et al., 2014), a sample of NYC metropolitan area

residents post-9/11 (Norris et al., 2009), and Lower Manhattan residents, area workers, and passersby (Welch et al., 2016). Most of these studies identified between four and six PTSD trajectory groups that were categorized as chronic, delayed-onset, recovered, or resistant (Maslow et al., 2015; Pietrzak et al., 2014; Welch et al., 2016) and had the largest proportions (53%–85%) of individuals with consistently low PTSD symptomatology. Other trajectory studies that have evaluated PTSD among other trauma survivors including assault survivors (Steenkamp et al., 2012), persons experiencing traumatic injury (deRoon-Cassini et al., 2010; O'Donnell et al., 2007), political violence (Hobfoll et al., 2011), and ex-prisoners of war (ex-POWs) (Solomon et al., 2012) have also found similar number of trajectory groups. Retrospective and pre- and post-assessment studies have found three important predictors of post-disaster mental health: pre-disaster stressors, pre-disaster psychopathology, and the extent of the disaster-related exposures (Breslau et al., 2008; Bromet et al., 2017; Sayed et al., 2015).

The stress sensitization hypothesis suggests that prior trauma exposure could increase vulnerability to subsequent stressors or traumas. Several studies of disaster populations found evidence that subsequent

---

disaster stressors (Kessler et al., 2012; Yabe et al., 2014) and post-disaster life events and adversities (Maslow et al., 2015; Shrira et al., 2010; Smid et al., 2012; Welch et al., 2016; Zvolensky et al., 2015a,b) were associated with increased psychopathology. However, fewer studies have specifically examined the psychological effects of two community-wide disasters on the same population. A retrospective study of adults residing near the WTC conducted one month after Sandy found Sandy-related exposure was related to PTSD symptoms only among those participants with high-level of recollections of the 9/11 terrorist attacks and past hurricanes (Palgi et al., 2014; Shrira et al., 2014). A prospective study conducted by Caramanica et al. (2015) of Sandy exposure among individuals enrolled in the WTC Health Registry who resided within the New York, New Jersey, and Connecticut tristate area found that the number of Sandy exposures and pre-Sandy 9/11-related PTSD were strongly associated with Sandy-related PTSD (Caramanica et al., 2015). Another prospective study among WTC responders found that 9/11-exposure and pre-Sandy mental health status were associated with an increased likelihood of post-Sandy 9/11-related PTSD (Bromet et al., 2017).

Positive and negative expectations regarding the future are important for understanding the vulnerability of people to mental health disorders (Chang and Sanna, 2001; Hart et al., 2008). Studies have found an inverse relationship between optimism and depressive symptoms (Chang and Sanna, 2001; Hart et al., 2008). A study of people exposed to a natural disaster found that compared to optimists, pessimists nurtured little hope for the future and were more at risk for depressive and anxiety disorders, and subsequent impairment of social functioning and quality of life (van der Velden et al., 2007).

The current pre- and post-assessment study extends reports about the psychological impact of Sandy (e.g., (Boscarino et al., 2013; Bromet et al., 2017; Caramanica et al., 2015; Lowe et al., 2015; Palgi et al., 2014; Schwartz et al., 2015; Shrira et al., 2014) by examining its effect on post-Sandy 9/11-related PTSD differentiated by pre-Sandy 9/11-related PTSD history using trajectory analysis. The goals of this study were to (1) describe the course of PTSD symptoms among Sandy-exposed people who were residents or workers exposed to 9/11 by identifying groups defined by similar PTSD trajectories over 10–11 years post-9/11 (pre-Sandy PTSD trajectories) and (2) determine if Sandy-related factors (PTSD, optimism, and exposure) were differentially associated with post-Sandy 9/11-related PTSD by pre-Sandy PTSD trajectory group. A previous study found that Sandy exposure was associated with re-experiencing 9/11 symptoms only among those who were non-symptomatic prior to Sandy, indicating that a history of PTSD was not necessary for re-experiencing 9/11 symptoms after Sandy (Li et al., 2018). We hypothesized that Sandy-related factors (PTSD, optimism, and exposure) would have the largest impact on post-Sandy 9/11-related PTSD among those trajectory groups that worsened or improved over time because (1) previous work indicates that Sandy exposure in the absence of PTSD may be sufficient to trigger PTSD symptoms and (2) those who already chronically screen positive for PTSD prior to Sandy will most likely continue to do so regardless of Sandy experiences ("ceiling effect"). The current study expands on this previous research with the utilization of longitudinal data on PTSD in the form of PTSD trajectories prior to Sandy, which will allow for examination on whether changes in PTSD status overtime impact risk of poor mental health outcomes from subsequent trauma exposures, rather than just looking at the previous time point. In addition, previous research investigated PTSD one month after (Palgi et al., 2014; Shrira et al., 2014), while the current study looks at 9/11-related PTSD 3–4 years after Sandy, extending the time period of investigation.

2. Methods

2.1. Study sample

The sampling pool for this study was the World Trade Center Health

Registry (Registry), a cohort study of 71,426 persons exposed to the events of 9/11 in New York City. To date, the Registry has conducted four waves of data collection, Wave 1 enrollment survey (2003–2004; $n = 68,806$ adults), Wave 2 (2006–2007; $n = 46,602$ (68%)), Wave 3 (2011–2012; $n = 42,934$ (63%)), and Wave 4 (2015–2016; $n = 36,864$ (52%)). Interviewing for the Hurricane Sandy survey was initiated approximately five months after Hurricane Sandy, which occurred approximately seven months after the completion of Registry Wave 3 data collection, as previously described (Caramanica et al., 2015). Briefly, a sample of Registry enrollees who completed the Wave 3 survey formed the sampling pool. Two study groups were selected based on residency within the NYC Tri-state area, including NYC, Long Island, and parts of Connecticut and New Jersey. The first group lived in the hurricane inundation zone ($n = 4,435$), as defined by the FEMA Modeling Task Force (Federal Emergency Management Agency Modeling Task Force, 2014) and the second group was a comparison group of randomly selected enrollees with an address outside the inundation zone ($n = 4,432$). At the close of data collection for the Sandy survey in November 2013, 4,558 surveys (51.4%) were completed.

For this analysis, the final sample consisted of those who completed the Sandy survey, as well as all four survey Waves including W4 which occurred 3 to 4 years after the Sandy survey, and had complete 9/11-related PTSD measures at each survey Wave ($n = 3,199$). Enrollees excluded for not having completed all three waves were more likely to have PTSD at Wave 1, male, non-white race, and under the age of 45 years. Also, those who did the Sandy survey, but did not complete the Wave 4 survey ($n = 532$), were more likely to be white race and 45–64 years of age at the Sandy survey. There was no difference in gender, Sandy-related PTSD, and Sandy exposures among those who did and did not complete Wave 4. The study protocol was approved by the NYC Department of Health and Mental Hygiene's Institutional Review Board.

2.2. Dependent variable

The outcome of interest was probable 9/11-related PTSD on the Wave 4 survey. PTSD was assessed using the PTSD Checklist-Civilian Version (PCL-17). The PCL-17 is a self-reported, 17-item scale corresponding to the criteria in the *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition (DSMIV) (American Psychiatric Association, 2000), which is commonly used in epidemiologic research, with excellent reliability (Cronbach's alpha = 0.95) and sensitivity ranging from 0.94 to 0.97, specificity from 0.86 to 0.99, and diagnostic efficiency from 0.83 to 0.96 (Blanchard et al., 1996). Selected symptoms were queried as specific to 9/11 and all were current (within the past 30 days). Enrollees with a PCL score of 44 or greater were considered to have probable PTSD, hereafter referred to as PTSD (Blanchard et al., 1996).

2.3. Hurricane Sandy variables

Hurricane Sandy-related PTSD was assessed on the Sandy survey using a version of the PCL-17 that was specific to Sandy (Cronbach's alpha = 0.99), with a score of 44 or greater indicating probable Sandy-related PTSD. Optimism was assessed using a scale from the Hurricane Katrina Community Advisory Group survey (Hurricane Katrina Community Advisory Group, 2006). Enrollees were asked "How optimistic do you feel about the way things will turn out for you in the future?" and responses were, very optimistic, somewhat optimistic, not very optimistic, and not at all optimistic. Sandy exposure refers to the composite score of the seven items, used in a previous study (Caramanica et al., 2015). The scale comprised of seven exposures: high traumatic Sandy exposure, evacuated home ≥7 days, flooded living area with ≥3 feet of water, damaged home, loss of >1 possessions, financial cost of damage ≥$25,000, and any injury sustained in the first week after Sandy. The total number of exposures (range 0–7) was dichotomized by the mean into no exposures and 1 or more exposures.

2.4. WTC-related PTSD trajectories (Wave 1–3)

WTC-related PTSD used in the trajectory analysis came from the PCL-17 from Waves 1, 2, and 3. Questions were queried as specific to 9/11 and all were within the past 30 days. Similar to previous Registry publications (Maslow et al., 2015; Welch et al., 2016), the PROC TRAJ macro (Jones et al., 2001) in SAS (Version 9.4, SAS Institute Inc., Cary, NC), a group-based trajectory modeling with a censored normal distribution, was used to identify groups of enrollees with a similar pattern or trajectory of change in PCL score over time from Wave 1 to Wave 3 (Andruff et al., 2009; Nagin, 2005). We started with a single class model and added classes one at a time to examine improvements in model fit. The final model was selected based on parsimony, interpretability, and knowledge of our sample (Andruff et al., 2009; Nagin, 2005). We compared sample size-adjusted Bayesian information criterion (SSA-BIC) values between each model and the one preceding it. A lower SSA-BIC indicates a better model fit (Andruff et al., 2009; Nagin, 2005). A 5-group model was found to have the lowest SSA-BIC score while still accurately representing the distribution of the scores in this sample. The average posterior probability, which measures an individual's likelihood of membership in each of the model's trajectory groups, ranged from 81.7% to 95.0%. Groups were labeled according to their intercept (low, moderate, or high) and their slope (stable, increasing, or decreasing).

2.5. Demographic variables

We included the following demographic variables associated with PTSD in the literature. Demographic characteristics collected at Wave 1 were sex and race/ethnicity. Age at Wave 4 was categorized as 18–34 years, 35–44 years, 45–64 years, and 65 years or older.

2.6. Statistical analysis

Descriptive and bivariate statistics were used to describe the distribution of 9/11-related PTSD at Wave 4 in each trajectory group classified by their Sandy-related PTSD status. Risk ratios and 95% confidence intervals were calculated using multivariable log-binomial models to determine the impact of Sandy-related PTSD, optimism, and Sandy exposure on the risk of 9/11-related PTSD at Wave 4. Since there was almost no one with Wave 4 PTSD in the low, stable trajectory group, it was excluded from the multivariable analysis.

3. Results

3.1. Sample characteristics

Table 1 summarizes the characteristics of the 3199 enrollees. Over half were male (57.6%), three-quarters were white, non-Hispanic (75.4%), and almost two-thirds were 45–64 years of age (63.1%). Seven percent had Sandy-related PTSD, 1.9% said they were not at all optimistic about the future, and 38.8% had at least one Sandy exposure. For the trajectory groups, the largest proportion (50.4%) was assigned to a low-stable group, 29.7% to a moderate-stable group, 8.8% to a high-decreasing group, 7.1% to a moderate-increasing group, and 4.0% in a high-stable group. Overall, 13.1% of the sample had 9/11-related PTSD at Wave 4. At the bivariate level, 9/11-related PTSD at Wave 4 was associated with race/ethnicity, Sandy-related PTSD, optimism, Sandy exposure, and trajectory group (Table 1).

3.2. 9/11-related PTSD at Wave 4 by trajectory group and Sandy-related PTSD status

Each trajectory group was stratified by its Sandy-related PTSD status and the proportion with 9/11-related PTSD at Wave 4 was calculated (Fig. 1), in order to examine the impact of Sandy-related PTSD among

Table 1
Demographic, Sandy-related factors, and 9/11-related PTSD trajectory groups by 9/11-related PTSD and Wave 4 (2015–2016).

	Total	9/11-related PTSD at Wave 4		*p*-value*
		Yes	No	
	N (%)	*N* (%)	*N* (%)	
Total	3199 (100)	418 (13.1)	2781 (86.9)	
Sex				
Male	1843 (57.6)	223 (12.1)	1620 (87.9)	0.06
Female	1356 (42.4)	195 (14.4)	1161 (85.6)	
Race/Ethnicity				
White, non-Hispanic	2413 (75.4)	283 (11.7)	2130 (88.3)	<**0.0001**
Black, non-Hispanic	273 (8.5)	39 (14.3)	234 (85.7)	
Hispanic	307 (9.6)	61 (19.9)	246 (80.1)	
Asian	140 (4.4)	19 (13.6)	121 (86.4)	
Other/Multiracial	66 (2.1)	16 (24.2)	50 (75.8)	
Age (at W4) (years)				
18–34	50 (1.6)	5 (10.0)	45 (90.0)	0.13
35–44	315 (9.8)	38 (12.1)	277 (87.9)	
45–64	2019 (63.1)	285 (14.1)	1734 (85.9)	
65 +	815 (25.5)	90 (11.0)	725 (89.0)	
Sandy-related PTSD				
Yes	221 (7.4)	132 (59.7)	89 (40.3)	<**0.0001**
No	2767 (92.6)	233 (8.4)	2534 (91.6)	
Sandy exposure				
High (1–7)	1241 (38.8)	234 (18.9)	1007 (81.1)	<**0.0001**
Low (0)	1958 (61.2)	184 (9.4)	1774 (90.6)	
Optimism after Sandy				
Not at all optimistic	59 (1.9)	33 (55.9)	26 (44.1)	<**0.0001**
Not very optimistic	384 (12.4)	128 (33.3)	256 (66.7)	
Somewhat optimistic	1723 (55.7)	201 (11.7)	1522 (88.3)	
Very optimistic	926 (30.0)	35 (3.8)	891 (96.2)	
Trajectory groups				
Low, Stable	1612 (50.4)	8 (0.5)	1604 (99.5)	<**0.0001**
Moderate, Stable	950 (29.7)	81 (8.5)	869 (91.5)	
High, Decreasing	281 (8.8)	86 (30.6)	195 (69.4)	
Moderate, Increasing	227 (7.1)	126 (55.5)	101 (44.5)	
High, Stable	129 (4.0)	117 (90.7)	12 (9.3)	

PTSD, Post-traumatic stress disorder.
Boldface indicates statistical significance ($p < 0.05$).
* Chi-square test.

trajectory groups on 9/11-related PTSD at Wave 4. Regardless of Sandy-related PTSD status, almost no one in the low-stable group had 9/11-related PTSD at Wave 4. The opposite was seen with the high-stable group; regardless of Sandy-related PTSD status almost all went on to have 9/11-related PTSD at Wave 4. However, Sandy-related PTSD increased the relative proportion of those who reported symptoms for 9/11-related PTSD at W4 in the moderate-stable, high decreasing, and moderate-increasing groups. Specifically, for the moderate-stable group, of those who had Sandy-related PTSD, 26% went on to have 9/11-related PTSD at Wave 4 compared to only 7% in the group with no Sandy-related PTSD. Similarly, a larger proportion of those in the high-decreasing and moderate-increasing groups who had Sandy-related PTSD went on to have 9/11-related PTSD at Wave 4, compared to those who did not have Sandy-related PTSD.

3.3. Association between Sandy experiences and 9/11-related PTSD at Wave 4

In multivariable models, Sandy-related PTSD emerged as a significant predictor of 9/11-related PTSD at Wave 4 in the moderate-stable (adjusted risk ratio (aRR) = 1.7, 95% confidence interval (CI) = 1.2, 2.0), high-decreasing group (aRR = 1.4, 95% CI = 1.2,
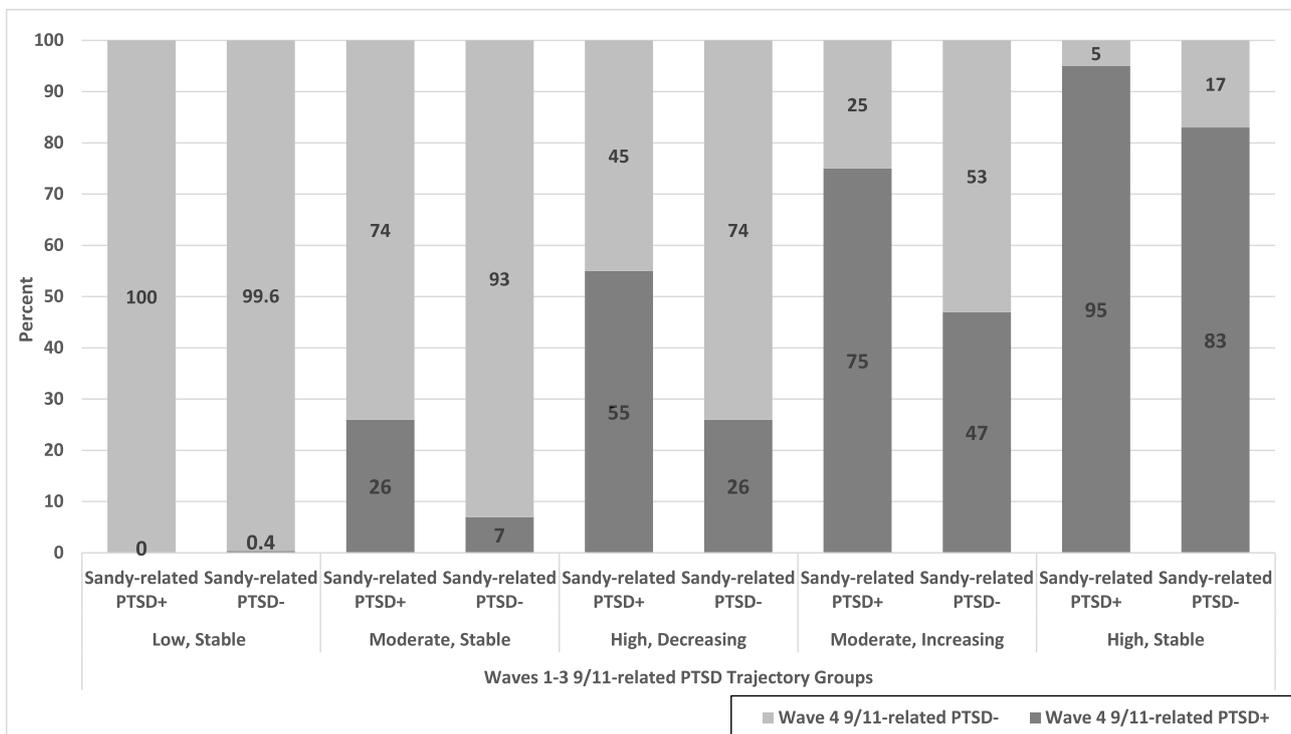
Fig. 1. Wave 4 9/11-related PTSD status by W1-3 9/11-related PTSD trajectory group and Sandy-related PTSD status.

Table 2
Adjusted Risk Ratios (aRRs) of having 9/11-related PTSD at Wave 4 (2015–2016).

Model		Moderate, Stable aRR* (95% CI)	High, Decreasing aRR* (95% CI)	Moderate, Increasing aRR* (95% CI)	High, Stable aRR* (95% CI)
1	Sandy-related PTSD				
	Yes	**1.7 (1.2, 2.0)**	**1.4 (1.2, 1.7)**	**1.2 (1.1, 1.4)**	1.0 (0.9, 1.1)
	No	Reference	Reference	Reference	Reference
	Optimism after Sandy				
	Not at all optimistic	**7.8 (2.9, 20.7)**	**2.4 (1.1, 5.3)**	1.6 (0.5, 4.8)	1.0 (0.8, 1.3)
	Not very optimistic	**3.7 (1.6, 8.6)**	**2.0 (1.1, 3.8)**	1.5 (0.9, 2.5)	1.0 (0.8, 1.2)
	Somewhat optimistic	2.0 (0.9, 4.4)	1.2 (0.6, 2.2)	1.2 (0.7, 2.1)	0.9 (0.7, 1.1)
	Very optimistic	Reference	Reference	Reference	Reference
2	Sandy exposure				
	High	1.4 (0.9, 2.2)	1.3 (0.9, 1.9)	**1.3 (1.1, 1.6)**	1.1 (0.9, 1.2)
	Low	Reference	Reference	Reference	Reference

Bolded values have $p < 0.05$.
PTSD, post-traumatic stress disorder; aRR, adjusted risk ratio; CI, confidence intervals.
* Adjusted for gender, race/ethnicity, age at Wave 4.

1.7), and moderate-increasing group (aRR = 1.2, 95% CI = 1.1, 1.4) (Table 2). Optimism was independently associated with 9/11-related PTSD at Wave 4. In each trajectory group there was a dose-response relationship between optimism and 9/11-related PTSD at Wave 4, the lower the optimism the higher the risk of 9/11-related PTSD at Wave 4, although this was only statistically significant in the moderate-stable and high-decreasing groups. Sandy-exposure statistically significantly predicted 9/11-related PTSD at Wave 4 only in the moderate-increasing group (aRR = 1.4, 95% CI = 1.1, 1.8). While not significant in the other three groups, the estimates were similar in magnitude and direction, with the increased risk ranging from 10–40%.

4. Discussion

The current study found that Sandy-related PTSD and post-Sandy optimism were significantly associated with probable 9/11-related PTSD several years after Sandy. This study is valuable in providing a pre- and post-analysis of the impact of Sandy on persons exposed to the 9/11 disaster, some of who have had persistently elevated PTSD symptoms since Wave 1 in 2003–2004. In addition, this study demonstrated a longer term effect of 9/11-related PTSD following Sandy than a previous study (Bromet et al., 2017).

Our findings replicated those of previous prospective studies showing that the emotional impact of a prior trauma is a critical risk factor after a subsequent disaster (Breslau et al., 1999; Bromet et al., 2017; Caramanica et al., 2015). Confirming our hypothesis, having Sandy-related PTSD in those trajectory groups in transition (high-decreasing and moderate-increasing) resulted in an increased odds of subsequent 9/11-related PTSD at Wave 4. An unexpected result was the impact Sandy-related PTSD had on subsequent 9/11-related PTSD among the moderate-stable group. This findings is counter to a study by Breslau et al. (2008), which showed that only those with PTSD from exposure to prior trauma were at an increased risk of PTSD from a subsequent trauma (Breslau et al., 2008). The moderate-stable group may represent "subclinical" PTSD, demonstrating that the use of cut-off score may not be the best approach to identifying potentially vulnerable

populations. Subsequent trauma can serve as a trigger for re-experiencing of prior trauma, as has been seen with Sandy and 9/11 (Li et al., 2018), even in the absence of existing 9/11-related PTSD symptoms, as was the case in this study's high-decreasing group.

The role of protective or resilience factors against PTSD are just as important as risk factors. Findings showed that those who reported lower optimism had an increased risk for developing 9/11-related PTSD at Wave 4. This association between optimism and poor mental health outcomes has been seen in the general population, with an association between depressive symptoms and lower optimism (Chang and Sanna, 2001; Hart et al., 2008) as well as in disaster-exposed populations (van der Velden et al., 2007). Similar findings have been found with constructs closely related to optimism, such as coping self-efficacy, hope, and hardiness (van der Velden et al., 2007). Optimism has also been shown to have a significant positive relation with coping strategies, such as looking for social support, and emphasis of the positive aspects of a stressful situation (Scheier et al., 1986). Many of these coping strategies have been found to be protective factors against 9/11-related PTSD, including social support (Adams et al., 2018; Schwarzer et al., 2016) and benefit finding and sense making (Richardson, 2015). People with high optimism may be more likely to seek out social support after a trauma and/or impose meaning on their traumatic experiences, thereby fostering recovery from them. Conversely, low optimism might render life more unpredictable or uncontrollable from the perspective of the trauma survivor, thereby increasing the risk for long-term mental health distress. In combination with the aforementioned studies, these findings suggest that information about optimistic views among disaster-exposed populations may help identify those who are at risk for post-disaster mental health disorders. In addition, promoting an optimistic disposition through psychotherapy may be an effective strategy against mental health disorders. It has been observed that even one single session of cognitive-behavioral therapy after a traumatic event, targeted at enhancing coping, may improve the person's well-being (Basoglu et al., 2005). Future research should explore protective psychological and personality factors further in the development of trauma-related mental health symptoms.

While not statistically significant for all trajectory groups, there was indication that high levels of Sandy exposure were associated with 9/11-related PTSD at Wave 4. This would be consistent with findings from Bromet et al. (2017) that demonstrated that Sandy exposure was associated with 9/11-related PTSD and depression among both traditional and nontraditional 9/11 rescue and recovery workers (Bromet et al., 2017). In addition, our findings demonstrate a longer term effect of Sandy on 9/11-related PTSD beyond 6 months post-Hurricane Sandy. Therefore, people exposed to a second disaster are a high-risk group. Their situation after the second disaster should be routinely assessed and mental health services should be provided.

Early identification of high-risk populations after a disaster is challenging (Neria and Shultz, 2012). However, the most important predictors in our study were consistent with those found in previous disaster research, namely, prior psychopathology and disaster severity. North and Pfefferbaum (2013) recommended that these risk factors, as well as prior trauma exposure, form the core of needs assessment surveys of disaster survivors (North and Pfefferbaum, 2013). In a population such as the Registry's or other health surveillance programs, where pre-disaster health data have been collected, high-risk individuals are more readily identifiable and an assessment of a second disaster's aftermath can be integrated into the monitoring protocol and research plans. In recognition of the fact that disasters can create or exacerbate mental health issues, FEMA allocated $50 million toward mental health services after Sandy, although a subsequent study found that only 7.8% of exposed individuals reported needing mental health services, 4.4% reported using mental health services, and 5.9% still had unmet mental health needs (Lowe et al., 2016). Project Hope was subsequently funded as a more targeted approach that connected individuals with mental health needs with additional resources

(Manuel, 2013). Research has suggested that those with lower perceived well-being or elevated PTSD symptoms have lower trust in hospital and medical services (Ben-Ezra et al., 2014; Oswald and Wu, 2010), precisely those individuals prone to be in need of such services in the aftermath of a disaster, one study showed that after Sandy those with PTSD symptoms were more likely to report a need for mental health services and that increases numbers of disaster-related stressors increased the odds of reporting unmet mental health care need (Lowe et al., 2016). More research is required to predict and understand areas of future mental health needs after a disaster and to design interventions that encourage people to seek care and/or decrease barriers to care post-disaster.

The strengths of this study include the pre- and post-design and the use of trajectory analysis, which allowed for the utilization of historical data. We also have a longer post-Sandy observation period than previous publications, detailed data on Sandy exposure, and a sizable sample which allowed us to investigate the effect of Sandy among each of the trajectory groups. Limitations include a Sandy survey response rate of 51.4%, which may bias the findings. Our trajectory analysis was limited to enrollees who completed Waves 1–3, therefore, selection bias is a concern. However, previous investigation of this issue has shown that non-response did not bias measures of association between 9/11 and several health conditions (Yu et al., 2015). Other limitations include the self-reported nature of Sandy exposure, which may have resulted in possible recall bias. The use of a self-administered checklist rather than clinical interview, to determine PTSD symptoms, however the PCL is widely used in epidemiologic studies and is considered to have good diagnostic efficiency (Blanchard et al., 1996), In addition, there is limited information available on the psychometric properties of the optimism question (Hurricane Katrina Community Advisory Group, 2006). Finally, because of the volunteer nature of the Registry, findings may not be generalizable.

Overall, the present findings add to a small body of literature on populations exposed to multiple disasters, and an even smaller number of pre- and post-disaster studies. These findings also underscore the need to assess a history of PTSD and not just focus on the most recent measure, as those with a decreasing PCL score were at an increased risk of post-Sandy 9/11-related PTSD, with a higher effect size than those in the moderate-increasing group with PCL scores above the cut-off for probable PTSD. These results suggest that the mental health problems that arose after Sandy contributed to the burden already carried by persons exposed to the 9/11 disaster and highlight the importance of assessing the impact of subsequent disasters in ongoing health surveillance programs.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2019.01.090.

References

Abramson, D.M., Redlener, I., 2012. Hurricane sandy: lessons learned, again. Disaster

Med. Public Health Prep. 6 (4), 328–329.

Adams, S.W., Bowler, R.M., Russell, K., Brackbill, R.M., Li, J., Cone, J.E., 2018. PTSD and comorbid depression: social support and self-efficacy in World Trade Center tower survivors 14–15 years after 9/11. Psychol. Trauma.

American Psychiatric Association, 2000. Diagnostic and Statistical Manual of Mental Disorders, forth ed. text rev.), Washington, DC.

Andruff, H., Carraro, N., Thompson, A., Gaudreau, P., B., L., 2009. Latent class growth-modelling: a tutorial. Tutorials Quant. Methods Psychol. 5, 11–24.

Basoglu, M., Salcioglu, E., Livanou, M., Kalender, D., Acar, G., 2005. Single-session behavioral treatment of earthquake-related posttraumatic stress disorder: a randomized waiting list controlled trial. J. Trauma Stress 18 (1), 1–11.

Ben-Ezra, M., Goodwin, R., Palgi, Y., Kaniasty, K., Crawford, M.Z., Weinberger, A., et al., 2014. Concomitants of perceived trust in hospital and medical services following Hurricane Sandy. Psychiatry Res. 220 (3), 1160–1162.

Blanchard, E.B., Jones-Alexander, J., Buckley, T.C., Forneris, C.A., 1996. Psychometric properties of the PTSD Checklist (PCL). Behav. Res. Ther. 34 (8), 669–673.

Boscarino, J.A., Hoffman, S.N., Kirchner, H.L., Erlich, P.M., Adams, R.E., Figley, C.R., et al., 2013. Mental health outcomes at the Jersey Shore after Hurricane Sandy. Int. J. Emerg. Ment. Health 15 (3), 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. Am. J. Psychiatry 156 (6), 902–907.

Breslau, N., Peterson, E.L., Schultz, L.R., 2008. A second look at prior trauma and the posttraumatic stress disorder effects of subsequent trauma: a prospective epidemiological study. Arch. Gen. Psychiatry 65 (4), 431–437.

Bromet, E.J., Clouston, S., Gonzalez, A., Kotov, R., Guerrera, K.M., Luft, B.J., 2017. Hurricane Sandy exposure and the mental health of World Trade Center responders. J. Trauma Stress 30 (2), 107–114.

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. Int. J. Emerg. Ment. Health 17 (1), 356–362.

Chang, E.C., Sanna, L.J., 2001. Optimism, pessimism, and positive and negative affectivity in middle-aged adults: a test of a cognitive-affective model of psychological adjustment. Psychol. Aging 16 (3), 524–531.

deRoon-Cassini, T.A., Mancini, A.D., Rusch, M.D., Bonanno, G.A., 2010. Psychopathology and resilience following traumatic injury: a latent growth mixture model analysis. Rehabil. Psychol. 55 (1), 1–11.

DiGrande, L., Neria, Y., Brackbill, R.M., Pulliam, P., Galea, S., 2011. Long-term posttraumatic stress symptoms among 3,271 civilian survivors of the September 11, 2001, terrorist attacks on the World Trade Center. Am. J. Epidemiol. 173 (3), 271–281.

Farfel, M., DiGrande, L., Brackbill, R., Prann, A., Cone, J., Friedman, S., et al., 2008. An overview of 9/11 experiences and respiratory and mental health conditions among World Trade Center Health Registry enrollees. J. Urban Health 85 (6), 880–909.

Federal Emergency Management Agency Modeling Task Force, 2014. FEMA MOTF-Hurricane Sandy impact Analysis. US Department of Homeland Security, Federal Emergency Management, Washington, DC.

Galea, S., Ahern, J., Resnick, H., Kilpatrick, D., Bucuvalas, M., Gold, J., et al., 2002. Psychological sequelae of the September 11 terrorist attacks in New York City. N. Engl. J. Med. 346 (13), 982–987.

Galea, S., Resnick, H., 2005. Posttraumatic stress disorder in the general population after mass terrorist incidents: considerations about the nature of exposure. CNS Spectr. 10 (2), 107–115.

Hart, S.L., Vella, L., Mohr, D.C., 2008. Relationships among depressive symptoms, benefit-finding, optimism, and positive affect in multiple sclerosis patients after psychotherapy for depression. Health Psychol. 27 (2), 230–238.

Hobfoll, S.E., Mancini, A.D., Hall, B.J., Canetti, D., Bonanno, G.A., 2011. The limits of resilience: distress following chronic political violence among Palestinians. Soc. Sci. Med. 72 (8), 1400–1408.

Hurricane Katrina Community Advisory Group, 2006. Overview of Baseline Survey Results.

Jones, B.L., Nagen, D.S., Roeder, K., 2001. A SAS procedure based on mixture models for estimating developmental trajectories. Sociol. Methods Res. 29, 374–393.

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. Epidemiol. Psychiatr. Sci. 21 (1), 35–45.

Li, J., Alper, H.E., Gargano, L.M., Maslow, C.B., Brackbill, R.M., 2018. Re-experiencing 9/11-Related PTSD symptoms following exposure to Hurricane Sandy. Int. J. Emerg. Ment. Health 20 (3).

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 (5), e0125761.

Lowe, S.R., Sampson, L., Gruebner, O., Galea, S., 2016. Mental health service need and use in the aftermath of Hurricane Sandy: findings in a population-based sample of New York City residents. Community Ment. Health J. 52 (1), 25–31.

Manuel, J., 2013. The long road to recovery: environmental health impacts of Hurricane Sandy. Environ. Health Perspect. 121 (5), a152–a159.

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. J. Trauma Stress 28 (3), 198–205.

Nagin, D.S., 2005. Group-based Modeling of Development. Harvard University Press, Cambridge, MA.

Neria, Y., Shultz, J.M., 2012. Mental health effects of Hurricane Sandy: characteristics, potential aftermath, and response. JAMA 308 (24), 2571–2572.

Norris, F.H., Tracy, M., Galea, S., 2009. Looking for resilience: understanding the longitudinal trajectories of responses to stress. Soc. Sci. Med. 68 (12), 2190–2198.

North, C.S., Pfefferbaum, B., 2013. Mental health response to community disasters: a systematic review. JAMA 310 (5), 507–518.

O'Donnell, M.L., Elliott, P., Lau, W., Creamer, M., 2007. PTSD symptom trajectories: from early to chronic response. Behav. Res. Ther. 45 (3), 601–606.

Oswald, A.J., Wu, S., 2010. Objective confirmation of subjective measures of human well-being: evidence from the U.S.A. Science 327 (5965), 576–579.

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 posttraumatic stress symptoms. Compr. Psychiatry 55 (4), 807–812.

Perlman, S.E., Friedman, S., Galea, S., Nair, H.P., Eros-Sarnyai, M., Stellman, S.D., et al., 2011. Short-term and medium-term health effects of 9/11. Lancet 378 (9794), 925–934.

Pietrzak, R.H., Feder, A., Singh, R., Schechter, C.B., Bromet, E.J., Katz, C.L., et al., 2014. Trajectories of PTSD risk and resilience in World Trade Center responders: an 8-year prospective cohort study. Psychol. Med. 44 (1), 205–219.

Richardson, K.M., 2015. Meaning reconstruction in the face of terror: an examination of recovery and posttraumatic growth among victims of the 9/11 World Trade Center attacks. J. Emerg. Manag. 13 (3), 239–246.

Sayed, S., Iacoviello, B.M., Charney, D.S., 2015. Risk factors for the development of psychopathology following trauma. Curr. Psychiatry Rep. 17 (8), 612.

Scheier, M.F., Weintraub, J.K., Carver, C.S., 1986. Coping with stress: divergent strategies of optimists and pessimists. J. Pers. Soc. Psychol. 51 (6), 1257–1264.

Schwartz, R.M., Sison, C., Kerath, S.M., Murphy, L., Breil, T., Sikavi, D., et al., 2015. The impact of Hurricane Sandy on the mental health of New York area residents. Am. J. Disaster Med. 10 (4), 339–346.

Schwarzer, R., Cone, J.E., Li, J., Bowler, R.M., 2016. A PTSD symptoms trajectory mediates between exposure levels and emotional support in police responders to 9/11: a growth curve analysis. BMC Psychiatry 16, 201.

Shrira, A., Palgi, Y., Ben-Ezra, M., Shmotkin, D., 2010. Do Holocaust survivors show increased vulnerability or resilience to post-Holocaust cumulative adversity? J. Trauma Stress 23 (3), 367–375.

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 (4), 374–385.

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. Psychol. Med. 42 (8), 1675–1686.

Solomon, Z., Horesh, D., Ein-Dor, T., Ohry, A., 2012. Predictors of PTSD trajectories following captivity: a 35-year longitudinal study. Psychiatry Res. 199 (3), 188–194.

Steenkamp, M.M., Dickstein, B.D., Salters-Pedneault, K., Hofmann, S.G., Litz, B.T., 2012. Trajectories of PTSD symptoms following sexual assault: is resilience the modal outcome? J. Trauma Stress 25 (4), 469–474.

van der Velden, P.G., Kleber, R.J., Fournier, M., Grievink, L., Drogendijk, A., Gersons, B.P., 2007. The association between dispositional optimism and mental health problems among disaster victims and a comparison group: a prospective study. J. Affect. Disord. 102 (1–3), 35–45.

Welch, A.E., Caramanica, K., Maslow, C.B., Brackbill, R.M., Stellman, S.D., Farfel, M.R., 2016. Trajectories of PTSD among lower Manhattan residents and area workers following the 2001 World Trade Center disaster, 2003–2012. J. Trauma Stress 29 (2), 158–166.

Yabe, H., Suzuki, Y., Mashiko, H., Nakayama, Y., Hisata, M., Niwa, S., et al., 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 J. Med. Sci. 60 (1), 57–67.

Yu, S., Brackbill, R.M., Stellman, S.D., Ghuman, S., Farfel, M.R., 2015. Evaluation of non-response bias in a cohort study of World Trade Center terrorist attack survivors. BMC Res. Notes 8, 42.

Zvolensky, M.J., Farris, S.G., Kotov, R., Schechter, C.B., Bromet, E., Gonzalez, A., et al., 2015a. World Trade Center disaster and sensitization to subsequent life stress: a longitudinal study of disaster responders. Prev. Med. 75, 70–74.

Zvolensky, M.J., Kotov, R., Schechter, C.B., Gonzalez, A., Vujanovic, A., Pietrzak, R.H., et al., 2015b. Post-disaster stressful life events and WTC-related posttraumatic stress, depressive symptoms, and overall functioning among responders to the World Trade Center disaster. J. Psychiatr. Res. 61, 97–105.