

Original Article

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Trajectories of psychological distress among individuals exposed to the 9/11 World Trade Center disaster

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Abstract

Background. Individuals present in lower Manhattan during the 9/11 World Trade Center (WTC) disaster suffered from significant physical and psychological trauma. Studies of longitudinal psychological distress among those exposed to trauma have been limited to relatively short durations of follow-up among smaller samples.

Methods. The current study longitudinally assessed heterogeneity in trajectories of psychological distress among WTC Health Registry enrollees – a prospective cohort health study of responders, students, employees, passersby, and residents in the affected area ($N = 30\,839$) – throughout a 15-year period following the WTC disaster. Rescue/recovery status and exposure to traumatic events of 9/11, as well as sociodemographic factors and health status, were assessed as risk factors for trajectories of psychological distress.

Results. Five psychological distress trajectory groups were found: none-stable, low-stable, moderate-increasing, moderate-decreasing, and high-stable. Of the study sample, 78.2% were classified as belonging to the none-stable or low-stable groups. Female sex, being younger at the time of 9/11, lower education and income were associated with a higher probability of being in a greater distress trajectory group relative to the none-stable group. Greater exposure to traumatic events of 9/11 was associated with a higher probability of a greater distress trajectory, and community members (passerby, residents, and employees) were more likely to be in greater distress trajectory groups – especially in the moderate-increasing [odds ratios (OR) 2.31 (1.97–2.72)] and high-stable groups [OR 2.37 (1.81–3.09)] – compared to the none-stable group.

Conclusions. The current study illustrated the heterogeneity in psychological distress trajectories following the 9/11 WTC disaster, and identified potential avenues for intervention in future disasters.

Introduction

The tragic events of the 11 September 2001 (9/11) World Trade Center (WTC) disaster inflicted lasting psychological trauma on survivors, witnesses, and first responders throughout New York City and beyond. The events and aftermath of 9/11 resulted in significant losses of life and livelihood – nearly 2800 people died, and many more were injured. Substantial health outcomes have been documented in relation to the trauma experienced on 9/11 as well as exposure to the environmental contaminants. These health outcomes include depressive symptoms, posttraumatic stress disorder (PTSD), cardiovascular disease, respiratory disease, and a variety of other physical and mental health conditions. Farfel et al. (2008) found that 8.4% of 68444 9/11-exposees reported severe psychological distress post-9/11. In the 17 years that have elapsed since 9/11, these outcomes as well as other life events that have occurred in the interim – both related and unrelated to 9/11 – have likely contributed to the psychological distress reported by those who were affected.

Mental health outcomes following the 9/11 WTC disaster have been studied extensively, including longitudinal assessments of depression and PTSD (Adams & Boscarino, 2005; Brackbill, Stellman, Perlman, Walker, & Farfel, 2013; Jacobson, Norman, & Nguyen, 2018; Maslow et al., 2015; Perrin et al., 2007; Pietrzak et al., 2014; Welch et al., 2016). Although the majority of individuals exposed to the 9/11 WTC disaster had psychological symptoms below clinical thresholds over time, women, racial minorities, individuals with significant disaster exposure, and individuals with limited socioeconomic resources have been identified as higher risk for psychological conditions such as PTSD (Adams & Boscarino, 2006; Jacobson et al., 2018; Welch et al., 2016). Similar findings are reported in studies of mental health outcomes following other disasters (Benight et al., 2000; Farfel et al., 2008; Freedy, Saladin,

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Kilpatrick, Resnick, & Saunders, 1994; Hardin, Weinrich, Weinrich, Hardin, & Garrison, 1994; Norris, Perilla, Riad, Kaniasty, & Lavizzo, 1999; Shigemura et al., 2012). Much of the post-disaster mental health literature assesses PTSD as the primary outcome; few studies assess non-specific psychological distress as the primary outcome (Beaglehole et al., 2018). Non-specific psychological distress measures emphasize the dimensionality of mental health condition severity, and thus may capture 'sub-clinical' psychological symptoms that fall below the threshold for DSM diagnostic criteria (Kessler et al., 2003).

Assessing trajectories of psychological distress provides insight into variation among groups of individuals in their long-term psychological wellbeing following disaster exposure and the determinants of its course over time. Moreover, trajectory analyses, also referred to as latent growth curve modeling, typically have greater statistical power than similar traditional modeling approaches for a given dataset, and are highly flexible (Willett & Bub, 2014). For example, trajectory models can accommodate time-invariant and time-varying covariates, partially missing outcome data, unequal time intervals for observations, and non-normal distributions (Curran, Obeidat, & Losardo, 2010). Due to the chronic nature of many psychological conditions, identification of risk factors for and protective features against harmful mental health trajectories creates opportunities for intervention in the aftermath of a disaster.

Findings from studies of post-9/11 mental health implicate the extent of exposure, such as becoming injured due to or knowing someone who died during the 9/11 WTC disaster, as a strong predictor of mental health outcomes (Adams & Boscarino, 2006; Brackbill et al., 2013; Bromet et al., 2016; Galea et al., 2002). For example, Bromet et al. (2016) found that police officers with high exposure to traumatic events on 9/11 were nearly four times more likely to have PTSD 13 years after 9/11 than those with little to no exposure. Among lower Manhattan residents, DiGrande, Neria, Brackbill, Pulliam, and Galea (2011) found that those who were caught in the dust cloud, injured, and were witness to horrific events were respectively 1.57, 3.03, and 1.81 times more likely to have PTSD 2 years after 9/11 than those who were not. Similar findings can be found for natural disasters – high exposure survivors (life threat, physical proximity, and severe injury) of the 2004 Indian Ocean Tsunami were 3.5 times more likely to report elevated psychological distress than low exposure survivors (Wahlström, Michélsen, Schulman, & Backheden, 2008). PTSD is well documented among both civilians and rescue/recovery workers post-9/11 in studies specific to each population (Liu, Tarigan, Bromet, & Kim, 2014; Lowell et al., 2018). However, most studies do not include both civilians and rescue/recovery workers, and are unable to assess the relative mental wellbeing of civilians compared to rescue/recovery workers (Liu et al., 2014; Lowell et al., 2018). Moreover, to our knowledge, there are no studies of psychological distress and disaster exposure among a population including both rescue/recovery workers and civilians. Meta-analysis results suggest that the odds of PTSD following the WTC disaster was lower for rescue/recovery workers than exposed civilians, and a similar pattern may be present for psychological distress (Liu et al., 2014).

The World Trade Center Health Registry (WTCHR), a prospective cohort health study of individuals exposed to 9/11, has monitored physical and mental health outcomes following the WTC disaster. Using this dataset, the current study aimed to (1) longitudinally assess trends in psychological distress among WTCHR enrollees over the 15-year period following the WTC

disaster, and (2) describe sociodemographic, health-related, and 9/11-related risk factors of psychological distress trajectories.

Methods

Participants and procedure

The WTCHR is a prospective cohort study of 71 426 individuals who were directly exposed to the WTC disaster. Enrollees consisted of rescue/recovery workers and volunteers, lower Manhattan residents, area workers, school students and staff, and passersby. They were either recruited from lists provided by governmental agencies, organizations, and employers (30%) or voluntarily enrolled in the WTCHR through outreach activities (70%). Further details on the recruitment process have been published elsewhere (Farfel et al., 2008; Murphy et al., 2007). Four waves of surveys have been completed to date – wave 1 (W1, 2003–2004), wave 2 (W2, 2006–2007), wave 3 (W3, 2011–2012), and wave 4 (W4, 2015–2016). A total of 71 426 individuals completed W1, 46 600 individuals completed W2, 43 133 individuals completed W3, and 36 862 individuals completed W4. The Registry protocol was approved by the institutional review boards of the Centers for Disease Control and the NYC Department of Health and Mental Hygiene.

The analytical sample was predominantly male (61.2%), age 25 and older at the time of the WTC disaster (94.5%), and non-Hispanic White (72.7%). Further descriptive statistics on the analytical sample are available in Table 1. The current study included enrollees who had completed W1, W2, and W4, and had at least two non-missing Kessler-6 Psychological Distress Scale (K6) scores among the three aforementioned waves ($N = 30\,839$ participants).

Measures

Psychological distress

Non-specific psychological distress was assessed using the K6, the truncated form of the Kessler-10 Psychological Distress Scale. The K6 has been shown to be equally sensitive at identifying serious mental illness as the K10 (Kessler et al., 2003). Similarly to the K10, the K6 asks respondents to report how often they experienced six emotional states related to psychological distress in the past 4 weeks. The responses range from 'All of the time', 'Most of the time', 'Some of the time', 'A little of the time', and 'None of the time'. Total scores ranged from 0 to 24, where 0 indicated the lowest degree of psychological distress, and 24 indicated the highest. The total score was obtained by the summation of the six emotional states related to psychological distress where 'All of the time' = 4, and 'None of the time' = 0. Individuals with a score greater than 12 were considered to have severe psychological distress, 8–12 as mild-moderate psychological distress, and 0–7 as little to no psychological distress (Dhingra, Strine, Holt, Berry, & Mokdad, 2009; Kessler et al., 2003, 2006; Wang et al., 2007). The K6 has high internal consistency and reliability (Cronbach's $\alpha = 0.89$), and has minimal bias with regard to demographic features such as sex and education (Kessler et al., 2002). The K6 was administered at waves 1, 2, and 4.

Time-invariant covariates

A series of time-invariant and time-varying covariates were included in the current analysis. Time-invariant variables refer to features that were assumed to stay constant across all waves.

Table 1. World Trade Center Health Registry enrollees' Kessler-6 (K6) scores at waves 1, 2, and 4

	Total population (N = 30 839)		Wave 1 K6		Wave 2 K6		Wave 4 K6	
	N	%	Mean	s.d.	Mean	s.d.	Mean	s.d.
<i>Time-invariant covariates</i>								
Sex								
Male	18 882	61.2	3.8	4.3	5	5	3.3	4.8
Female	11 957	38.8	5	4.8	5.8	5.1	3.7	4.9
Age at 9/11 (years)								
0–24	1703	5.5	4.1	3.9	5.5	4.6	3.8	4.7
25–44	15 820	51.3	4.3	4.5	5.4	5	3.7	5
≥45	13 314	43.2	4.3	4.7	5.1	5.1	3.1	4.6
Race								
Non-Hispanic White	22 424	72.7	3.8	4.2	5	4.8	3.3	4.6
Black	2731	8.9	5.5	5	5.4	5.3	3.3	4.7
Hispanic	3214	10.4	6.2	5.6	6.8	5.8	4.6	5.6
Asian	1516	4.9	4.8	4.6	5.8	5.2	4	5.1
Other	954	3.1	5.2	4.8	6.3	5.3	4.3	5.3
Education at wave 1								
≤High school or GED	6289	20.4	5.4	5.3	6.3	5.7	4.3	5.6
Some college	7619	24.7	4.4	4.6	5.6	5.2	3.6	4.9
College graduate	10 058	32.6	4	4.2	5.1	4.7	3.2	4.5
Graduate degree	6730	21.8	3.5	3.9	4.5	4.4	2.9	4.2
Income at wave 1								
<\$50 000	7199	25.7	5.9	5.4	6.7	5.7	4.6	5.5
\$50 000–100 000	12 031	43	4.1	4.3	5.2	5	3.4	4.8
>\$100 000	8776	31.3	3.3	3.8	4.4	4.4	2.8	4.1
Eligibility group								
Rescue/recovery worker	14 582	47.3	3.7	4.3	5	5	3.3	4.8
Community member	16 257	52.7	4.8	4.7	5.5	5	3.6	4.8
9/11 Summary exposure score ^a								
None/Low	11 002	35.7	3.1	3.7	4.1	4.4	2.6	4.1
Moderate	11 536	37.4	4.3	4.4	5.3	4.9	3.5	4.7
High	6635	20.6	5.4	4.9	6.5	5.3	4.3	5.3
Very high	1936	6.4	7.3	5.8	8.4	6	5.8	6.1
Pre-9/11 trauma ^b								
Yes	11 259	36.5	4.4	4.4	5.7	5	3.8	4.9
No	15 683	50.9	3.9	4.3	4.8	4.8	3	4.5
Post-9/11 trauma ^b								
Yes	11 645	37.8	5.3	4.9	6.7	5.4	5.1	5.6
No	19 194	62.2	3.7	4.2	4.4	4.6	2.4	3.9
Depression diagnosis ^c								
Yes	6400	20.8	7.1	5.5	9	5.8	7.5	6.2
No	24 439	79.1	3.5	3.9	4.3	4.3	2.4	3.7

(Continued)

Table 1. (Continued.)

	Total population (N = 30 839)		Wave 1 K6		Wave 2 K6		Wave 4 K6	
	N	%	Mean	S.D.	Mean	S.D.	Mean	S.D.
<i>Time-varying covariates^d</i>								
Marital status								
Married/cohabitating	20 454	66.3	3.9	4.3	4.9	4.8	3.1	4.5
Single/separated	10 199	33.1	5.1	4.9	6.2	5.4	4.3	5.4
Employment status								
Employed	26 479	85.9	4	4.3	5.1	4.7	3.2	4.4
Unemployed	4269	13.8	5.7	5.7	6.3	6	4	5.4
PTSD ^e								
Yes	4136	13.4	11.4	4.8	12.1	4.8	11.4	5.5
No	26 703	86.6	3.1	3.2	3.7	3.5	2.1	3.1
Diagnosed cardiovascular disease ^f								
Yes	9777	31.7	4.9	4.9	6	5.5	4	5.2
No	21 062	68.3	4	4.3	4.9	4.7	3	4.4
Diagnosed respiratory disease ^f								
Yes	7197	23.3	5.3	5.1	6.7	5.6	4.6	5.5
No	23 642	76.7	4	4.3	4.8	4.7	3	4.4
Diagnosed diabetes ^f								
Yes	2006	6.5	5.3	5.2	6.4	5.7	4.5	5.6
No	28 833	93.5	4.2	4.5	5.2	5	3.3	4.7
Diagnosed cancer ^f								
Yes	2512	8.2	4.2	4.7	5.2	5.1	3.5	4.9
No	28 327	91.8	4.3	4.5	5.3	5	3.5	4.8

Note: Numbers in table may not add up to 30 839 due to missing data.

^aCount of traumatic experiences on 9/11.

^bTraumatic events include events such as a serious accident at work, in a car, or somewhere else; an attack with a gun, knife, or some other weapon; or a situation where someone used physical force or the threat of physical force to make them have some type of unwanted sexual contact.

^cSelf-reported lifetime history of physician diagnosed depression.

^dTime-variant covariates are those that were collected at waves 1, 2, and 4.

^ePTSD as assessed by a score of ≥ 44 on the PCL-17.

^fSelf-report of physician diagnosis. Cardiovascular disease included hypertension, angina, heart attack, and stroke; respiratory disease included emphysema, COPD, and asthma; cancer included all cancer types.

Time-varying covariates refer to features that can fluctuate over time. Some covariates that may conceptually appear to be time-varying covariates were included as time-invariant covariates due to data limitations. Characteristics collected at W1 that were considered to be time-invariant can be found in Table 1. Participants were grouped into two eligibility groups for the purposes of enrollment – rescue/recovery workers and community members, which included students, employees, passersby, and residents in the affected area. Enrollees were also asked if they had experienced any pre-9/11 or post-9/11 traumatic life events, such as a serious accident at work, in a car, or somewhere else; an attack with a gun, knife, or some other weapon; or a situation where someone used physical force or the threat of physical force to make them have some type of unwanted sexual contact. Additional sociodemographic and relevant covariates can be found in Table 1. Sociodemographic characteristics and rescue/recovery status were assessed at wave 1, pre- and post-9/11 trauma, and 'ever' diagnosis with depression were retrospectively assessed at wave 4.

9/11 Exposure

To operationalize the extent of exposure to the WTC disaster, Brackbill et al. (2013) developed a 9/11 exposure summary variable based on study by Adams and Boscarino (2005). The summary score is the summation of 11 possible traumatic experiences related to 9/11 that were initially asked about at waves 1 and 2, such as seeing planes hit the buildings, people fall or jump from buildings, being in the North or South WTC towers at the time of the disaster, and losing a relative on 9/11. The summary score was grouped into four categories of exposure: none/low (0–1), moderate (2–3), high (4–5), and very high (≥ 6).

Time-varying covariates

All time-varying covariates were assessed at each wave; details can be found in Table 1. Physical health outcomes were assessed, including doctor-diagnosed lifetime history of cardiovascular

disease, respiratory disease, diabetes, and cancer. Cardiovascular diseases consisted of hypertension, angina, stroke, and heart attack; respiratory diseases consisted of emphysema, chronic obstructive pulmonary disease (COPD), and asthma. Cancer included all forms of cancer. PTSD status was determined by each enrollee's PTSD Checklist Civilian Version (PCL-17) score at a given wave (Ruggiero, Ben, Scotti, & Rabalais, 2003). Individuals with a PCL-17 score of ≥ 44 were considered to have PTSD at that time point (Blanchard, Jones-Alexander, Buckley, & Forneris, 1996).

Data analysis

We used the PROC TRAJ SAS (Version 9.4) macro developed by Jones et al. (2001) to conduct unadjusted and adjusted trajectory group analyses of psychological distress over time as measured by the K6. We first examined unadjusted models that determined K6 score trajectories, and subsequently fit adjusted models that incorporated all of the aforementioned time-varying and time-invariant covariates. Trajectory analysis enabled (1) estimation of membership in trajectory groups and (2) estimation of trajectory shapes. Estimation of membership in group trajectories allows for the description of individuals who are likely to have certain trajectories. The estimation of trajectory shapes helps assess salient characteristics that change over time and how they influence the shapes of trajectories within groups.

The PROC TRAJ user defines the hypothesized number of trajectories and the order (linear, quadratic, cubic, etc.) of the regression equation for each trajectory group (Jones & Nagin, 2007). The optimal number of groups and equation order are determined by incremental decreases in Bayesian information criteria (BIC) from the test model to the previous model (Jones et al., 2001). We assigned a censored normal distribution for the PROC TRAJ modeling, as previous analyses using PROC TRAJ with psychometric scales, including the K10 psychological distress scale, have used the censored normal distribution (Jones & Nagin, 2007; Pelayo-Terán et al., 2014; Thomas et al., 2016; Welch et al., 2016). For each enrollee, PROC TRAJ outputs the probability of assignment to each group; each enrollee is assigned to the group that they are most likely to be in (Jones et al., 2001). For adjusted models, PROC TRAJ assumes that time-invariant features influence the probability of group membership, and time-varying features influence the shapes of the trajectories (Jones et al., 2001). PROC TRAJ operates on complete-case analysis for covariates – enrollees who were missing for any of the time-varying or time-invariant covariates were not included in the analysis (Jones et al., 2001).

Model selection was conducted iteratively, starting with the number of groups set to one, and the order set to quadratic (Andruff, Carraro, Thompson, Gaudreau, & Louvet, 2009). The number of groups was increased in each iteration of the model; Δ BIC was monitored for substantial changes of >10 (Andruff et al., 2009). We did not consider model orders greater than quadratic for the current analysis as we only had three data points for the outcome. Once the optimal model was selected, posterior probabilities and group size estimates were obtained from the PROC TRAJ output. Next, the time-varying and time-invariant covariates were included in the aforementioned optimal model. Adjusted odds ratios (OR) and 95% confidence intervals (CI) were estimated for membership in each trajectory group relative to the reference trajectory group (i.e. none-stable). For time-varying covariates, PROC TRAJ outputs directly interpretable β coefficients estimating the effect of the time-varying covariate

on the shape of the trajectory within each specific trajectory group. Finally, using the group assignments from the unadjusted PROC TRAJ output, logistic regression models were fit for specific comparisons between the selected trajectories via PROC LOGISTIC; findings are available in the online Supplementary materials.

Results

Psychological distress trajectories

The optimal unadjusted model with the lowest relative BIC had five distinct trajectory groups with each trajectory modeled as a quadratic function. The groups were identified as: none-stable, low-stable, moderate-increasing, moderate-decreasing, and high-stable (Fig. 1). Three of the five trajectories were considered to be somewhat stable across the course of the WTCHR, whereas the remaining two were marked by a notable increase or decrease. The low-stable, moderate-increasing, moderate-decreasing, and high-stable groups will be collectively referred to as 'greater psychological distress trajectories' throughout the paper, as they will be compared to the reference group, none-stable. Table 2 describes the trajectories by average posterior probability, mean K6 score, and the proportion of individuals who were classified as having severe psychological distress at each time point. All parameter estimates obtained for each of the trajectory groups were significant at the $p < 0.05$ level. Approximately 80% of the study population was in either the none-stable or low-stable group. The high-stable group (3.9%) had the highest within-group proportion of participants with severe psychological distress at all time points (W1: 71.8%, W2: 88.8%, and W4: 77.0%). The mean posterior probability of assignment ranged from 0.77 to 0.88, which indicated a good model fit to the data.

Time-invariant covariates

Sociodemographic features

Women were more likely than men to be assigned to any trajectory group representing greater levels of psychological distress [adjusted ORs and 95% CIs at $\alpha = 0.05$ – low-stable: 1.68 (1.50–1.89), moderate-increasing: 1.75 (1.50–2.05), moderate-decreasing 1.37 (1.13–1.64), and high-stable: 1.34 (1.03–1.74)] *v.* the none-stable trajectory group (Table 3). Enrollees who were 25 years and older at the time of 9/11 were more likely than enrollees who were under 25 years to be assigned to any trajectory group representing greater levels of psychological distress, barring the high-stable group. Black enrollees were less likely than non-Hispanic White enrollees to be assigned to trajectory groups representing greater levels of psychological distress [ORs and 95% CIs – low-stable: 0.66 (0.55–0.79), moderate-decreasing: 0.42 (0.29–0.60), high-stable: 0.49 (0.30–0.80)] compared to the none-stable group, barring the moderate-increasing group. Other racial minority groups were more likely than non-Hispanic White enrollees to be assigned to trajectory groups representing greater levels of psychological distress. Lower income at W1 was associated with a higher probability of being in any of the greater distress trajectory groups compared to the none-stable group; education at W1 followed a similar pattern except in the low-stable *v.* none-stable comparison, where there was no association.

9/11-Related characteristics

Community members were more likely to be assigned to greater psychological distress trajectories than rescue/recovery workers,

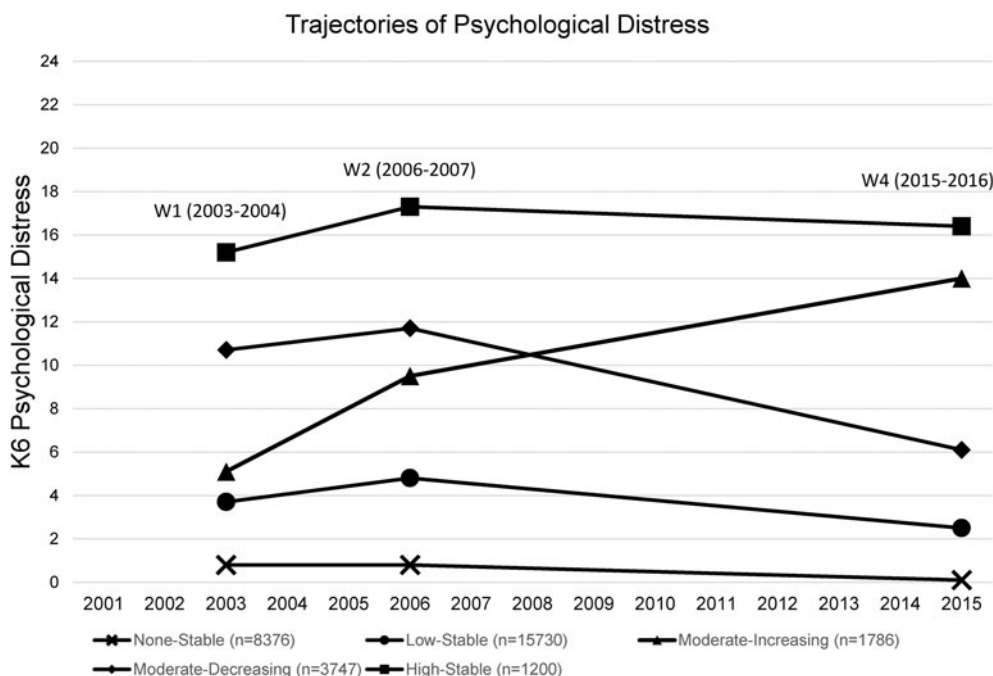


Fig. 1. Kessler-6 psychological distress trajectories, World Trade Center Health Registry, 2003–2016.

especially to the moderate-increasing (OR = 2.31, 95% CI 1.91–2.72) and high-stable groups (OR = 2.37, 95% CI 1.81–3.09) *v.* the none-stable group. A general trend of increasing ORs was observed from the low-stable group to the high-stable group. Enrollees with higher 9/11 summary exposure scale scores (high scores = high exposure) were more likely to be assigned to the greater psychological distress trajectories. This trend of increasing ORs was strongly consistent within each trajectory group for increasing exposure levels, and albeit less consistent, across the trajectory groups of increasing severity.

Psychosocial factors

Both pre- and post-9/11 trauma were associated with membership in the greater psychological distress trajectories; the magnitudes of ORs were larger for post-9/11 trauma. ORs of post-9/11 trauma for the moderate-increasing group and moderate-decreasing group were respectively, 3.35, 95% CI 2.84–3.95 and 6.42, 95% CI 5.38–7.67. A lifetime history of depression diagnosis was associated with greatly increased odds of membership in the greater psychological distress trajectories, especially for the high-stable *v.* none-stable comparison.

Time-varying covariates

Marital and occupational status

Table 4 contains adjusted β coefficients estimating the effect of time-varying covariates on the shape of each trajectory. Being married/cohabitating (*v.* single/separated) was associated with very small decreases in psychological distress, within all trajectory groups except for the high-stable where it was non-significant. In the moderate-increasing, moderate-decreasing, and high-stable groups, employment (*v.* unemployment) was associated with decreased levels of psychological distress ($\beta = -0.49$, $\beta = -1.18$, $\beta = -1.17$, and $p < 0.05$ within each group, respectively).

Health conditions

Cardiovascular disease and respiratory disease were respectively associated with a significant, small increase in psychological distress levels for the moderate-decreasing and moderate-increasing groups; both diseases were also associated with small increases in distress levels for the none-stable and low-stable groups. Diabetes was associated with a significant and small increase in psychological distress levels for all groups except for the high-stable group, where the β coefficient was non-significant. Cancer also did not have a significant effect, except for an association with slightly increased psychological distress in the low-stable group. PTSD was associated with significant, greatly increased levels of psychological distress for all trajectory groups (β range: 6.15–7.36, $p < 0.05$).

Discussion

Our analyses indicated that a five-trajectory group model best characterized psychological distress trajectories among this cohort of individuals exposed to the 9/11 WTC disaster. Three trajectories appeared relatively stable over time, whereas the other two demonstrated substantial increases or decreases. Overall, the majority of enrollees were in the none to low distress trajectories that remained stable through the study period. Stability in distress trajectories is not inherently an indication of psychological well-being. In the high-stable group, it indicates unremitting distress, whereas in the none-stable and low-stable groups, it is indicative of a relatively low, maintained level of distress. Previous studies monitoring trajectories of mental health outcomes such as PTSD and psychological distress following large-scale traumatic events generally show that stable, lower psychological distress trajectories are most prevalent (Lowe & Rhodes, 2013; Norris, Tracy, & Galea, 2009; Oe et al., 2016; Pietrzak et al., 2014). This is consistent with our findings that most enrollees were either in the none-stable or low-stable groups, corroborating other studies

Table 2. Trajectories of psychological distress: mean Kessler-6 (K6) score and severe psychological distress^a prevalence at waves 1, 2, and 4 with average posterior probabilities and intercept, linear, and quadratic parameter estimates

Group	Posterior probability			Wave 1			Wave 2			Wave 4			Parameter estimates						
	N	%	Mean	s.d.	Severe psychological distress		K6 score	Mean	s.d.	Severe psychological distress		K6 score	Mean	s.d.	N	%	Intercept	Linear	Quadratic
					N	%				N	%								
1	8376	27.2	0.82	0.1	0.8	0.2	0	0	0.8	1.2	0	0	0.1	0.5	0	0	-0.76*	0.23*	-0.04*
2	15730	51.0	0.83	0.1	3.7	2.8	89	0.6	4.8	3	205	1.3	2.5	2.5	9	0.1	3.39*	0.52*	-0.06*
3	1786	5.8	0.77	0.2	5.1	3.3	25	1.4	9.5	4.2	398	22.3	14	3.4	1049	59	5.38*	1.64*	-0.08*
4	3747	12.2	0.77	0.2	10.7	3.8	1048	28	11.7	3.7	1436	38.3	6.1	3.3	51	1.4	10.11*	0.61*	-0.09*
5	1200	3.9	0.88	0.2	15.2	4.2	862	71.8	17.3	3.7	1066	88.8	16.4	4.1	924	77.0	14.98*	0.94*	-0.07*

Note: * $p < 0.05$.
^aA K6 score of ≥ 13 was considered severe psychological distress.

highlighting the resilience of trauma-exposed survivors (Bonanno, 2004). The US average K6 score has been relatively stable over the past two decades, with a mean K6 score of 2.6 through the time period of our study (Tomitaka et al., 2019). Barring the none-stable group, all distress trajectories exceeded this national average – an expected finding given the uniquely trauma exposed population. Despite exceeding the national average, the majority of the study population remained well within the K6 score threshold for little to no psychological distress ($K6 \leq 7$) (Dhingra et al., 2009; Kessler et al., 2002; Wang et al., 2007).

Results pertaining to sex, age, education, income, and their respective relationships with psychological distress align with previous findings (Adeola & Picou, 2012; Canino, Bravo, Rubio-Stipec, & Woodbury, 1990; Galea, Nandi, & Vlahov, 2005a; Jorm et al., 2005). Women, older enrollees, enrollees with less education and income were more likely to be in greater distress trajectory groups (Galea et al., 2005; Lowe & Rhodes, 2013). Previous studies on psychological distress among the trauma-exposed were limited in sample size and follow-up duration; however, our findings in the WTCR, with a considerably larger sample size and over a decade of follow-up, suggest the generalizability of the previous literature on socioeconomic disparities in psychological distress among the trauma-exposed.

Our analyses indicated that Black enrollees were significantly more likely to be in the none-stable group than nearly all greater distress trajectory groups compared to non-Hispanic White enrollees. Black individuals report higher non-specific psychological distress than non-Hispanic White individuals in nationally representative cross-sectional epidemiologic surveys, and in our data Black enrollees had a higher unadjusted mean and median K6 scores at baseline than non-Hispanic White enrollees (Barnes & Bates, 2017; Bratter & Eschbach, 2005; Williams, Yan, Jackson, & Anderson, 1997). However, importantly, this pattern is observed in unadjusted analyses in both previous studies and our data. Our adjusted findings indicating that Black enrollees were significantly more likely to be in the none-stable trajectory are aligned with previous research assessing racial disparities in psychological distress, adjusted for socioeconomic factors (Bratter & Eschbach, 2005). There is evidence suggesting that the processes underlying psychological distress are vastly different between Black and White individuals, and it is possible that unmeasured social factors such as social support and coping are contributing to this finding (Lincoln, Chatters, & Taylor, 2003). For all other racial minority groups, our findings were generally consistent with previous findings (Adeola & Picou, 2012; Canino et al., 1990; Galea et al., 2005a; Jorm et al., 2005).

Our results indicated that enrollees who experienced higher levels of exposure to the traumatic events of 9/11 were more likely to be members of greater psychological distress trajectories. Previous studies assessing 9/11 disaster exposure, as well as exposure to other disasters, have found that greater levels of disaster exposure are associated with greater psychological sequelae (Adams & Boscarino, 2006; Brackbill et al., 2013; Bromet et al., 2016; Galea et al., 2002; Paz García-Vera, Sanz, & Gutiérrez, 2016). Many of these studies do not assess a sample containing both rescue/recovery workers and Manhattan residents, area workers, school students and staff, and passersby (Liu et al., 2014; Lowell et al., 2018). Previous studies of unmet mental health needs among individuals exposed to the WTC disaster have found unmet mental health needs to be higher among community members compared to rescue/recovery workers (Brackbill et al., 2013). A meta-analysis by Liu et al. (2014) suggested that probable PTSD

Table 3. Adjusted ORs and 95% CIs for associations between time-invariant characteristics and Kessler-6 (K6) trajectory group membership

Characteristic	Group 2: Low-stable		Group 3: Moderate-increasing		Group 4: Moderate-decreasing		Group 5: High-stable	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sex								
Male (ref)	–	–	–	–	–	–	–	–
Female	1.68*	1.50–1.89	1.75*	1.50–2.05	1.37*	1.13–1.64	1.34*	1.03–1.74
Age at 9/11 (years)								
0–24 (ref)	–	–	–	–	–	–	–	–
25–44	0.52*	0.39–0.71	0.74	0.50–1.08	0.39*	0.27–0.56	0.96	0.51–1.81
≥45	0.35*	0.26–0.47	0.56*	0.38–0.84	0.17*	0.11–0.25	0.56	0.29–1.06
Race								
Non-Hispanic White (ref)	–	–	–	–	–	–	–	–
Black	0.66*	0.55–0.79	0.96	0.76–1.21	0.42*	0.29–0.60	0.49*	0.30–0.80
Hispanic	1.00	0.84–1.21	1.85*	1.50–2.28	1.21	0.93–1.59	1.99*	1.44–2.75
Asian	1.08	0.60–1.03	2.49*	1.86–3.33	2.02*	1.40–2.91	2.09*	1.18–3.72
Other	1.52*	1.01–2.29	2.96*	1.17–7.45	4.15*	1.64–10.47	3.32*	0.98–11.25
Education at wave 1								
≤High school or GED (ref)	–	–	–	–	–	–	–	–
Some college	0.90	0.77–1.05	0.58*	0.48–0.7	0.63*	0.50–0.80	0.34*	0.25–0.48
College graduate	0.95	0.82–1.11	0.56*	0.46–0.68	0.63*	0.50–0.80	0.41*	0.3–0.56
Graduate degree	0.98	0.83–1.16	0.39*	0.31–0.49	0.54*	0.42–0.70	0.33*	0.23–0.47
Income at wave 1								
<\$50 000 (ref)	–	–	–	–	–	–	–	–
\$50 000–100 000	0.82*	0.71–0.96	0.52*	0.44–0.62	0.59*	0.48–0.72	0.36*	0.27–0.47
>\$100 000	0.69*	0.58–0.81	0.30*	0.24–0.37	0.34*	0.27–0.43	0.15*	0.11–0.22
Eligibility group								
Rescue/recovery worker (ref)	–	–	–	–	–	–	–	–
Community member	1.54*	1.37–1.73	2.31*	1.97–2.72	2.20*	1.83–2.65	2.37*	1.81–3.09
9/11 Summary exposure score^a								
None/Low (ref)	–	–	–	–	–	–	–	–
Moderate	1.55*	1.38–1.74	2.29*	1.93–2.72	1.93*	1.59–2.34	2.12*	1.56–2.89
High	2.36*	2.01–2.76	4.38*	3.56–5.37	3.11*	2.47–3.93	3.44*	2.42–4.90
Very high	4.23*	3.06–5.83	9.15*	6.51–12.86	3.93*	2.60–5.93	11.70*	7.4–18.48
Pre-9/11 trauma^b								
No (ref)	–	–	–	–	–	–	–	–
Yes	1.39*	1.25–1.55	1.56	1.35–1.80	1.60*	1.36–1.89	1.51*	1.19–1.92
Post-9/11 trauma^b								
No (ref)	–	–	–	–	–	–	–	–
Yes	2.69*	2.38–3.04	3.35*	2.84–3.95	6.42*	5.38–7.67	5.62*	4.36–7.24
Depression diagnosis^c								
No (ref)	–	–	–	–	–	–	–	–
Yes	6.91*	5.10–9.36	31.09*	22.83–42.34	69.13*	50.16–95.29	128.05*	86.38–189.82

Note: * $p < 0.05$. All analyses were relative to none-stable group (1) and mutually adjusted for all covariates.

^aCount of traumatic experiences on 9/11.

^bTraumatic events include events such as a serious accident at work, in a car, or somewhere else; an attack with a gun, knife, or some other weapon; or a situation where someone used physical force or the threat of physical force to make them have some type of unwanted sexual contact.

^cSelf-reported lifetime history of physician diagnosed depression.

Table 4. β -coefficients and standard errors (s.e.) for associations between time-varying^a characteristics and Kessler-6 (K6) score by K6 trajectory group

Characteristic	Group 1: None-stable		Group 2: Low-stable		Group 3: Moderate-increasing		Group 4: Moderate-decreasing		Group 5: High-stable	
	β (s.e.)	<i>p</i> value	β (s.e.)	<i>p</i> value	β (s.e.)	<i>p</i> value	β (s.e.)	<i>p</i> value	β (s.e.)	<i>p</i> value
Marital status										
single/separated (ref)	-	-	-	-	-	-	-	-	-	-
Married/cohabitating	-0.36* (0.1)	<0.01	-0.31* (0.05)	<0.01	-0.35* (0.12)	<0.01	-0.34* (0.13)	0.01	-0.23 (0.22)	0.31
Employment status										
Unemployed (ref)	-	-	-	-	-	-	-	-	-	-
Employed	0.1 (0.12)	0.4	0.07 (0.06)	0.26	-0.49* (0.13)	<0.01	-1.18* (0.16)	<0.01	-1.17* (0.25)	<0.01
PTSD ^b										
No (ref)	-	-	-	-	-	-	-	-	-	-
Yes	7.36* (0.27)	<0.01	6.15* (0.08)	<0.01	6.51* (0.13)	<0.01	6.67* (0.14)	<0.01	6.52* (0.24)	<0.01
Cardiovascular disease ^c										
No (ref)	-	-	-	-	-	-	-	-	-	-
Yes	0.34* (0.1)	<0.01	0.38* (0.05)	<0.01	0.09* (0.12)	0.43	0.6* (0.14)	<0.01	0.46 (0.23)	0.05
Respiratory disease ^c										
No (ref)	-	-	-	-	-	-	-	-	-	-
Yes	0.25 (0.16)	0.11	0.19* (0.09)	0.04	0.37* (0.18)	0.04	0.29 (0.23)	0.2	0.34 (0.31)	0.28
Diabetes ^c										
No (ref)	-	-	-	-	-	-	-	-	-	-
Yes	0.52* (0.11)	<0.01	0.44* (0.06)	<0.01	0.44* (0.12)	<0.01	0.45* (0.14)	<0.01	0.34 (0.23)	0.14
Cancer ^c										
No (ref)	-	-	-	-	-	-	-	-	-	-
Yes	-0.21 (0.14)	0.15	-0.26* (0.07)	<0.01	-0.16 (0.18)	0.38	0.05 (0.21)	0.83	-0.23 (0.34)	0.49

Note: * $p < 0.05$.

^aTime-varying covariates are those that were collected at waves 1, 2, and 4.

^bPTSD as assessed by a score of ≥ 44 on the PCL-17.

^cSelf-report of physician diagnosis. Cardiovascular disease included hypertension, angina, heart attack, and stroke; respiratory disease included emphysema, COPD, and asthma; cancer included all cancer types.

risk was higher among community members compared to rescue/recovery workers. The current study produced similar results; we observed a consistent trend wherein rescue/recovery workers were less likely to be in the greater distress trajectory groups. Rescue/recovery worker status is likely an important factor in the relationship between disaster exposure and psychological distress.

Despite adjusting for disaster exposure, as well as a large number of other time-varying and time-invariant confounders such as PTSD diagnosis, pre- and post-9/11 trauma, community members were more likely to be in the greater distress trajectory groups, with a general trend of increasing effect sizes across greater distress trajectory groups. It is possible that rescue/recovery workers were better equipped to cope with the trauma of 9/11 than community members due to occupational training. Feder et al. (2016) found that perceived preparedness was negatively associated with severe PTSD trajectories in a study of first-responders to the WTC disaster. Among UK Armed Forces Personnel deployed in Iraq, perceived preparedness was negatively associated with PTSD symptoms (Iversen et al., 2008). Although there is gradation in perceived preparedness within first-responders, it is likely that first responders generally felt more prepared for exposure to the traumatic events of the WTC disaster, than community members. Lower income, younger age, single marital status, distrust of government, and limited exposure to public service announcements are all associated with limited personal disaster preparedness (Kohn et al., 2012). Concerted efforts to increase disaster preparedness among civilians may yield mental health benefits following exposure to a disaster.

First-responders often engage in collective coping via formal and informal peer-support (Adams, Anderson, Turner, & Armstrong, 2011; Clompus & Albarran, 2016; Moran & Roth, 2013; Prati, Pietrantonio, & Cicognani, 2011). The limited sociodemographic and cultural heterogeneity of WTC first-responders, close collectivist culture of first-responder organizations, and shared traumatic experiences may have afforded a more available and reliable peer support system to the WTC first-responders (Crupi & Brondolo, 2017; Freedman, 2004). Long-form interviews of WTC first-responders also revealed occupational rituals that developed among first responders, such as routine communal prayers throughout the weeks following the disaster – even referred to as ‘ground zero religion’ (Freedman, 2004). Such a level of communal support may not have been broadly available to community members exposed to the WTC disaster.

This study has several strengths. Although the K6 is a widely used scale, longitudinal analyses involving the K6 are fairly limited in number. This is important because the K6 is significantly associated with a variety of mental health conditions; a longitudinal analysis of the K6 can yield insight on the long-term response to a disaster (Kessler et al., 2002). Although our work is descriptive, exploring the sociodemographic, disaster exposure-related, and health-related risk factors is important in an area of study where sample sizes have been small, and duration of follow-up is relatively short. The WTCHR has a large sample size; to our knowledge, this study is the largest trajectory analysis of psychological distress over time. The prospective cohort study design of the WTCHR facilitated an extensive follow-up period of 15 years post-disaster. Additionally, due to the breadth of topics covered by the WTCHR, we were able to adjust models for covariates hypothesized to be important in the relationship between exposure to 9/11 and psychological distress. Finally, the SAS macro PROC TRAJ is robust to the data limitations we encountered such as inconsistent gaps of time between wave surveys,

non-normally distributed outcomes, and only having three K6 scores for each individual.

However, this study also had some limitations. The current analysis is not causal, as the WTCHR data collection began 2 years after 9/11; pre-9/11 K6 scores were not available. Although we were able to adjust for a substantial number of confounders, the psychological distress reported by participants cannot necessarily be solely attributed to the events of 9/11. The inability to incorporate wave 3 K6 data due to an error in the wave 3 survey may have affected our trajectory analysis results. Additionally, some factors that conceptually are likely time-varying were represented as time-invariant variables due to the structure of the queries in the WTCHR. For example, income was not asked about at wave 2. Additionally, the analytical sample was predominantly White, of high education and income, and employed, which may affect the generalizability of our results. In addition, because this cohort has been followed up to 15 years post-disaster, substantial attrition from the cohort occurred. Previous investigations of this attrition have found that although 9/11 variables were not associated with non-response, those with PTSD at baseline were more likely to drop out of future surveys. Thus, attrition and loss to follow-up may have biased the analytical sample toward individuals who were healthier (Yu, Brackbill, Stellman, Ghuman, & Farfel, 2015). Although this likely led to issues with external validity, we cannot exclude the possibility of selection bias. The analytical strategy included a large number of covariates; thus, it is possible that multiple testing could have led to some false-positive results. However, we focused on patterns of associations rather than pure statistical significance. Finally, although responses were checked for consistency, all survey items were based on self-report and liable to recall error.

Conclusions

The longitudinal psychological response to traumatic events is heterogeneous; clear patterns of stable, worsening, and improving psychological well-being became apparent in a large population of individuals exposed to the WTC disaster. By adjusting for a variety of demographic, socioeconomic, physical and mental health features, we were able to further explore the relationship between disaster exposure, rescue/recovery worker status, and psychological distress. To our knowledge, our study is the largest analysis with the longest duration of follow-up of psychological distress trajectories among the trauma-exposed, and indicated areas for further study and potential targets for psychological intervention among trauma-exposed individuals. Therapy services emphasizing collective coping following a disaster, as well as increasing public awareness of disaster preparedness may be potential avenues for improving long-term psychological well-being following a disaster.

Supplementary material. The supplementary material for this article can be found at <https://doi.org/10.1017/S0033291720004912>

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Conflict of interest. The authors have no conflicts of interest to declare.

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