



Research paper

Longitudinal determinants of depression among World Trade Center Health Registry enrollees, 14–15 years after the 9/11 attacks



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ABSTRACT

Background: Exposure to the September 11, 2001 (9/11) terrorist attacks has been found to be associated with posttraumatic stress disorder (PTSD) and comorbid PTSD and depression up to 10–11 years post-disaster. However, little is known about the longitudinal predictors of mental health conditions over time.

Methods: We examined longitudinal determinants of depression within strata of PTSD among 21,258 enrollees of the World Trade Center Health Registry who completed four questionnaires over 14 years of follow-up (Wave 1 in 2003–04; Wave 2 in 2005–06; Wave 3 in 2011–12; and Wave 4 in 2015–16). PTSD status was measured using the PTSD checklist on all four waves and defined as a score of ≥ 44 ; depression was assessed using the 8-item Patient Health Questionnaire at Waves 3 and 4 and defined as a score of ≥ 10 .

Results: Across Waves 3 and 4, 18.6% experienced depression, and it was more common among those who ever had PTSD (56.1%) compared with those who had not (5.6%). Across PTSD strata, predictors of depression included low income, unemployment, low social integration and support, post-9/11 traumatic life events, and chronic physical illness. These factors also decreased the likelihood of recovering from depression.

Limitations: Depression symptoms were not measured at Waves 1 and 2; data was self-reported.

Conclusions: These findings highlight the substantial burden of depression in a trauma-exposed population 14–15 years post-disaster, especially among those with PTSD. Similar life stressors predicted the course of depression among those with and without PTSD which may inform public health and clinical interventions.

1. Introduction

The catastrophic events of September 11, 2001 (9/11) resulted in both immediate and persistent psychological trauma among New York City survivors. The initial prevalence of posttraumatic stress disorder (PTSD) in the early wake of the disaster ranged between 7.5% and 20.0% (Galea et al., 2002; Schlenger et al., 2002), and estimates remained similar several years after 9/11, especially among those directly exposed to the attacks (Brackbill et al., 2009). Now more than a decade later, post-disaster studies have extensively documented the burden of PTSD as well as other mental health conditions such as major depression, although to a lesser extent (Neria et al., 2011).

While PTSD is the most common type of psychopathology following a traumatic exposure, it is also often comorbid with depression (Breslau et al., 2000; Campbell et al., 2007). The prevalence of depression among those with PTSD is estimated to be as high as 50% among traumatized populations, and even higher in clinical studies (Rytwinski et al., 2013). This burden is exacerbated by the increased symptom severity and functional impairment as well as reduced quality of life

among those with comorbid PTSD and depression compared with those with only one condition (Dekel et al., 2014; Ikin et al., 2010). Previous studies on 9/11 exposed populations have compared people with comorbid PTSD and depression to those with neither condition (Bowler et al., 2016; Caramanica et al., 2014; Dekel et al., 2017), but due to the overwhelming impact of PTSD in these trauma-exposed populations, this approach may obscure the unique determinants of depression (Campbell et al., 2007). Furthermore, to date, the studies on depression following 9/11 have mostly been cross-sectional in design (Ahern and Galea, 2006; Caramanica et al., 2014; Chiu et al., 2011; Galea et al., 2002; Stellman et al., 2008), with few studies examining the longitudinal course of depression and its predictors over time.

Among a cohort of individuals directly exposed to 9/11, this study serves to build upon the existing research on post-disaster mental health conditions by exploring longitudinal patterns of depression within strata of PTSD symptomology. In monitoring the burden of mental health morbidities and their predictors over time, findings may contribute to a better understanding of post-disaster psychopathology and thus inform clinical management and potential public health

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interventions. The overall purpose of this study was to assess the longitudinal determinants of depression over a period of several years, up to 15 years after 9/11. First, we estimated the prevalence of depression, among both those who had experienced PTSD and those who had not. Second, we identified factors associated with depression, again within strata of PTSD status. Lastly, we examined predictors of resolved depression compared with persistent depression among individuals who had experienced PTSD.

2. Methods

2.1. Study population

This study was conducted among enrollees of the World Trade Center Health Registry (Registry), a long-term cohort study of first responders, residents, area workers, and others present in downtown Manhattan on September 11, 2001. In 2003–04, 71,427 individuals were enrolled into the study and completed a baseline questionnaire (Wave 1), which was followed in subsequent years by Wave 2 (2006–07), Wave 3 (2011–12), and Wave 4 (2015–2016). Further details on this study have been previously published elsewhere (Brackbill et al., 2009; Farfel et al., 2008). The Registry protocol was approved by the institutional review boards of the Centers for Disease Control and Prevention and the New York City Department of Health and Mental Hygiene.

For this study, enrollees had to complete all four Waves and be at least 18 years old at Wave 1 ($N = 28,138$). Those with pre-9/11 depression or PTSD diagnoses ($N = 3252$) or missing information on diagnosed depression or PTSD ($N = 358$); those missing PTSD symptoms at any Wave ($N = 3247$); and those missing *both* Wave 3 and Wave 4 depression symptoms ($N = 23$) were subsequently excluded, yielding a final study population of 21,258.

2.2. Mental health measures

Depressive symptoms were assessed using the Patient Health Questionnaire (PHQ)-8 (Kroenke et al., 2009) at Waves 3 and 4 only. This instrument consists of a sequence of eight questions that ask about the frequency of symptoms over the last two weeks, which are rated from 0 = *not at all* to 3 = *nearly every day*. These symptoms represent eight of the nine criteria that constitute the *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV)* (American Psychiatric Association, 1994) diagnosis of depressive disorders, with the ninth item being thoughts about suicide or self-injury. This criterion was omitted due to the self-administered nature of the questionnaires and thus the inability to intervene; as well as its minimal impact on scoring due to its low rate of endorsement (Kroenke and Spitzer, 2002). Items were summed and scores ≥ 10 were considered to be indicative of depression, as this cut-off has shown to have a sensitivity and specificity of 0.88 for diagnosed major depression based on structured psychiatric interviews using *DSM-IV* diagnostic criteria (Kroenke et al., 2001). Because the PHQ-8 was administered at both Waves 3 and 4, those who had scores ≥ 10 at either or both waves were considered to have depression. More specifically, those with scores ≥ 10 at both waves were considered to have *persistent depression* and those with a score of ≥ 10 at Wave 3 but < 10 at Wave 4 were considered to have *resolved depression*.

PTSD symptoms were assessed at each wave (Waves 1–4) using the stressor-specific PTSD Checklist (PCL)-17 (Blanchard et al., 1996; Ruggiero et al., 2003; Weathers et al., 1994), which contains direct references to the events of 9/11 in the re-experiencing and avoidance domains. The PCL is a self-administered questionnaire that queries the severity of PTSD symptoms based on *DSM-IV* criteria (American Psychiatric Association, 1994) in three domains: re-experiencing, avoidance, and hyperarousal. Enrollees rated the degree to which these symptoms bothered them over the last thirty days, ranging from 1 = *not at all* to 5 = *extremely*, and the scores from the 17 items were

summed. Total scores ≥ 44 were considered to be indicative of probable PTSD (hereafter referred to as PTSD) (Blanchard et al., 1996). PTSD status was summarized across time as ever (scores ≥ 44 at least one wave) and never (scores < 44 at all waves).

2.3. Predictors

Questionnaires contained various details on social and demographic factors such as race and ethnicity, household income, education, marital status, and employment status. In addition, in Waves 1 and 2, questions were asked about various traumatic experiences on 9/11. Based on work by Adams and Boscarino (Adams and Boscarino, 2005), Brackbill et al. derived a composite score consisting of 11 questions about traumatic experiences such as: being in the North or South WTC towers at the time of the attack; witnessing three or more events (seeing planes hit the buildings, people fall or jump from buildings, people injured, or people running); fear of being injured or killed; and having a relative killed on 9–11 (Brackbill et al., 2013). A complete list of the exposures is listed in Supplemental Table 1. These items were then summed (range = 0–11) and the score was then categorized as none/low (0–1 exposures), medium (2–3), high (4–5), and very high (≥ 6). Questions about other sources of trauma, both before and after 9/11, were also included (American Psychiatric Association, 1994), such as experiencing a serious accident (e.g., in a car or a fall), an intentional attack with or without a weapon, forceful unwanted sexual contact, and serious family or work problems. Enrollees were classified based on their endorsement of ≥ 1 traumatic experience. Traumas occurring before and after 9/11 were examined separately.

Questions about social integration and social support were asked at Waves 3 and 4. An abbreviated 5-item version of the Social Support Survey for the Medical Outcomes Study (Sherbourne and Stewart, 1991) was administered, including questions about how often someone is available to: take you to the doctor if you need to go; have a good time with; hug you; prepare your meals if you are unable; and understand your problems. These items were individually scored based on frequency ranging from 0 = *none of the time* to 4 = *all of the time* and subsequently summed. Scores were then categorized as follows: low (0–10), medium (11–14), and high (≥ 15), with higher scores denoting a greater degree of social support. Questions about social integration were based on the RAND Social Health Battery (Donald and Ware, 1984) and asked about social functioning, mainly through social resources and contacts: visiting or talking with friends, attending religious services, being active in volunteer organizations, and having perceived close friends or relatives. The number of endorsed items were categorized as low (0–1 engagements), medium (2), and high (≥ 3).

Finally, enrollees were asked at each wave about physician-diagnosed mental and physical health conditions. In this analysis, based on literature linking 9/11-related exposures, such as dust and debris exposure (Lioy et al., 2002), to certain diseases, those who reported that they had been diagnosed with at least one of the following: heart attack or heart disease (Jordan et al., 2011a, 2011b), asthma (Brackbill et al., 2009; Wheeler et al., 2007), gastroesophageal reflux disease (GERD) (Li et al., 2011; Webber et al., 2009) and/or cancer (Li et al., 2016, 2012; Solan et al., 2013; Zeig-Owens et al., 2011) were considered to have a chronic physical disease.

2.4. Statistical analysis

The prevalence of depression was calculated across Waves 3 and 4 (i.e., period prevalence) as well as at each individual wave (i.e., point prevalence). Study participants were stratified by depression status at Waves 3 and/or 4 within strata of ever-PTSD (Waves 1–4). Sociodemographic characteristics, 9/11-related exposures, self-report of physical and mental health diagnoses, social support and integration, and other covariates were compared across strata. Multivariable log binomial models were fit in order to identify predictors of depression

over time (Waves 3 and 4) within strata of PTSD (ever vs. never), which yielded adjusted risk ratios (aRR) and 95% confidence intervals (CI). Generalized estimating equations (GEE) with robust standard errors were used in order to account for repeated measures on the same individual. In this analysis, although individuals who were missing items on the PHQ-8 at both Waves 3 and 4 were excluded, those who were missing items at one wave only were included because GEE accommodates this data structure. Age, household income, marital status, employment status, social integration and support, and chronic disease diagnoses were considered as time varying covariates, with measures at both Wave 3 and 4; whereas sex, race/ethnicity, education, eligibility group, 9/11 exposure score, and pre- and post-9/11 trauma were considered as time invariant.

Among those who had depression at Wave 3, those who recovered by Wave 4 (i.e., *resolved depression*) were compared to those who had *persistent depression* (i.e., depression at both waves) using log binomial regression. These models did not converge among those who never had PTSD due to small sample size ($N = 473$); results are presented only among those who ever had PTSD. All analyses were conducted using complete case analysis.

All analyses were conducted using SAS Version 9.4 (Cary, NC).

3. Results

Study participants were mostly male (64.5%), middle-aged (45–64 years old; 62.7%), non-Hispanic white (74.5%), with at least a college degree (56.2%) (Table 1). Over the course of four waves of Registry surveys, approximately one quarter of individuals had symptoms indicative of PTSD (ever-PTSD) (25.7%). Across Waves 3 and 4, 18.6% experienced depression on at least one wave (13.8% at Wave 3 and 13.1% at Wave 4). Depression was much more common among those who had ever had PTSD (56.1%) compared with those who did not (5.6%). Furthermore, PHQ-8 scores were greater among those who had comorbid PTSD and depression compared with those who had depression only. Median PHQ-8 scores at Wave 4 among those with depression and a history of PTSD = 14 (interquartile range (IQR) = 11, 18) compared with 12 (IQR = 10–14) among those with depression but who never had PTSD. Among the whole sample, score distributions and measures of internal consistency for the PCL-17 and PHQ-8 are shown in Supplemental Table 1.

Regardless of PTSD history, depression was more common among those younger than 65 years (vs. ≥ 65); those who earned \$50,000 or less (vs. $> \$50,000$); those with less than a high school diploma or GED (vs. more educated); those who were unemployed, especially due to health reasons (vs. employed); those with a low degree of social support or social integration (vs. high support or integration); those who had experienced trauma (vs. not); those who had certain chronic physical diseases (vs. not); and those who had reported ever being diagnosed with depression (vs. not). Among those who had ever had PTSD, rescue and recovery workers (RRW) were more likely to experience depression (59.5%) compared with both Lower Manhattan area workers (53.3%) and residents (49.8%), whereas the proportions with depression were similar among those who never had PTSD (5.6%, 5.4%, and 6.0%, respectively).

In multivariable models, similar characteristics as those identified in bivariate comparisons emerged as significant predictors of depression over time. However, in general, estimates were stronger on the ratio scale among those who never had PTSD compared with those who had PTSD (Table 2). For example, among those who never had PTSD, those who earned \$50,000 or less, as well as between \$50,000–\$150,000, were more likely to experience depression than those who earned over \$150,000 (adjusted risk ratio (aRR) = 1.44, 95% confidence interval (CI): 1.12, 1.83 and aRR = 1.35 (95% CI: 1.13, 1.60), respectively). However, among those who had PTSD, estimates were in the same direction, but attenuated (aRR = 1.21, 95% CI: 1.11, 1.32 and aRR = 1.19, 95% CI: 1.10, 1.29, respectively). Low social support and

integration were among the strongest predictors of depression in both strata of PTSD (low vs. high social integration among ever-PTSD: aRR = 1.33, 95% CI: 1.25, 1.41 and among never-PTSD: aRR = 2.63, 95% CI: 2.02, 3.41; low vs. high social support among ever-PTSD: aRR = 1.62; 95% CI: 1.52, 1.73 and among never-PTSD: aRR = 3.66, 95% CI: 3.07, 4.36). Unemployment (vs. employment) was related to an increased risk of depression, especially those who were unable to work due to health reasons, such as disability (among those with PTSD: aRR = 1.31, 95% CI: 1.24, 1.39; among those without PTSD: aRR = 2.42, 95% CI: 1.82, 3.22). Among those who never experienced PTSD, traumatic experiences both before and after 9/11 were associated with an increased risk of depression, with the more recent trauma (post-9/11) showing a stronger association than pre-9/11 trauma. Similarly, among those with PTSD, experiencing traumatic events after 9/11 was associated with depression (aRR = 1.23, 95% CI: 1.16, 1.30) whereas pre-9/11 trauma was not (aRR = 1.03, 95% CI: 0.99, 1.07). (Table 3)

Among those with a history of PTSD, the composite 9/11 exposure score was not related to depression and this was also generally the case when we modeled each exposure separately (Supplemental Table 2). Lastly, after adjusting for covariates, RRW did not appear to be at a greater risk of depression compared with Lower Manhattan residents (or area workers).

About one third (34.3%) of those who had a history of PTSD and also had depression at Wave 3 experienced resolution of their depression by Wave 4 (i.e., no depression at Wave 4). Those who were low income (vs. high income), unemployed due to health reasons (vs. employed), with low social integration or support (vs. high), who experienced post-9/11 trauma (vs. not), and who had a chronic disease (vs. not) were less likely to experience resolution or recovery from depression. Lastly, there was a suggestion that very high scores on the composite 9/11 exposure measure were associated with a decreased likelihood of recovering from depression (aRR = 0.76, 95% CI: 0.59, 0.97). However, no pattern emerged for more moderate scores (medium and high) compared with none or low scores.

4. Discussion

In a large cohort of individuals with various types of exposure to the World Trade Center attacks, there was a substantial burden of depression up to 14–15 years later. Social and demographic factors such as low income, unemployment, low social support and integration, traumatic life experiences, and having certain chronic physical illnesses were associated with an increased risk of depression. Among those who had depression as well as a history of PTSD, these factors were also inversely related to whether the depression resolved over time. However, exposures on 9/11 were not generally associated with depressive symptoms within strata of PTSD.

The prevalence of depression in this cohort in 2015–16 based on PHQ-8 scores (13.1%, 95% CI: 12.6%, 13.6%) was somewhat greater than expected compared with 2016 New York City Community Health Survey (CHS) data (9.0%, 95% CI: 8.0, 9.9%) (unpublished data). Age-adjusting these estimates using 2016 census data did not result in meaningful changes to either estimate (Registry: 12.6%, 95% CI: 12.1%, 13.2% compared with CHS: 9.1%, 95% CI: 8.2%, 10.0%). Even though depression was not directly related to 9/11 exposures within strata of PTSD, this slightly elevated prevalence of depression may be due to the substantial burden of PTSD (25.7%), which has been reported to lead to depression in some (Breslau et al., 1997; Ginzburg et al., 2010). This is consistent with previous Registry studies that have found 9/11-related traumatic experiences to be associated with comorbid PTSD and depression compared with neither condition (Bowler et al., 2016; Caramanica et al., 2014).

Instead of comparing those with comorbid PTSD and depression to those with neither condition, which several studies both in this cohort (Bowler et al., 2016; Caramanica et al., 2014) and others (Dekel et al., 2017) have done, we modeled depression within strata of those who

Table 1
 Characteristics and 9/11 exposures of adult WTC registry enrollees by depression status across waves 3 and 4.^a

Characteristic	Total population (N = 21,258) N (%) ^d	Ever-PTSD ^b (n = 5,462)		Total	Never-PTSD ^b (n = 15,796)		Total
		Depression ^c (N = 3,065) N (%)	No depression (N = 2,397) N (%)		Depression ^c (N = 885) N (%)	No depression (N = 14,911) N (%)	
Sex							
Male	13718 (64.5)	1953 (58.2)	1405 (41.8)	100%	566 (5.5)	9794 (94.5)	100%
Female	7540 (35.5)	1112 (52.9)	992 (47.1)		319 (5.9)	5117 (94.1)	
Age (years) at Wave 3^d							
25–44	5245 (24.7)	724 (56.1)	567 (43.9)		241 (6.1)	3713 (93.9)	
45–64	13336 (62.7)	2128 (57.6)	1568 (42.4)		568 (5.9)	9072 (94.1)	
≥ 65	2677 (12.6)	213 (44.8)	262 (55.2)		76 (3.5)	2126 (96.5)	
Race/Ethnicity							
NH White	15839 (74.5)	1997 (55.5)	1602 (44.5)		644 (5.3)	11596 (94.7)	
NH Black	1760 (8.3)	311 (55.2)	252 (44.8)		63 (5.3)	1134 (94.7)	
Hispanic	2102 (9.9)	509 (59.3)	349 (40.7)		95 (7.6)	1149 (92.4)	
Asian	991 (4.7)	128 (52.5)	116 (47.5)		55 (7.4)	692 (92.6)	
Other	566 (2.7)	120 (60.6)	78 (39.4)		28 (7.6)	340 (92.4)	
Household income at Wave 3^d							
≤ \$50,000	3832 (18.8)	987 (63.1)	577 (36.9)		170 (7.5)	2098 (92.5)	
\$50,000–\$150,000	11703 (57.5)	1643 (55.5)	1320 (44.5)		511 (5.8)	8229 (94.2)	
≥ \$150,000	4818 (23.7)	355 (46.2)	413 (53.8)		168 (4.1)	3882 (95.9)	
Education^d							
≤ High school/ GED	3001 (14.2)	639 (58.4)	455 (41.6)		131 (6.9)	1776 (93.1)	
Some college	6249 (29.6)	1142 (58.9)	798 (41.1)		257 (6.0)	4052 (94.0)	
College	6257 (29.7)	782 (55.3)	631 (44.7)		280 (5.8)	4564 (94.2)	
Graduate degree	5597 (26.5)	484 (49.4)	495 (50.6)		215 (4.7)	4403 (95.3)	
Marital Status at Wave 3^d							
Married/cohabitating	15355 (72.5)	1970 (54.5)	1645 (45.5)		609 (5.2)	11131 (94.8)	
Divorced/separated	2438 (11.5)	558 (62.9)	329 (37.1)		109 (7.0)	1442 (93.0)	
Widowed	496 (2.3)	81 (52.9)	72 (47.1)		18 (5.2)	325 (94.8)	
Never Married	2881 (13.6)	444 (56.8)	338 (43.2)		146 (7.0)	1953 (93.0)	
Employment status at Wave 3^d							
Employed	14569 (69.1)	1762 (52.6)	1585 (47.4)		602 (5.4)	10620 (94.6)	
Retired	3742 (17.8)	352 (45.6)	420 (54.4)		127 (4.3)	2843 (95.7)	
Homemaker or student	356 (1.7)	31 (49.2)	32 (50.8)		11 (3.8)	282 (96.2)	
Unable to work due to health	1199 (5.7)	615 (76.6)	188 (23.4)		52 (13.1)	344 (86.9)	
Unemployed for other reasons	1205 (5.7)	272 (65.7)	142 (34.3)		85 (10.7)	706 (89.3)	
Eligibility group^d							
Rescue and recovery workers	10432 (49.5)	1592 (59.5)	1083 (40.5)		435 (5.6)	7322 (94.4)	
Lower Manhattan area workers	8255 (39.2)	1192 (53.3)	1045 (46.7)		327 (5.4)	5691 (94.6)	
Lower Manhattan resident	2370 (11.3)	244 (49.8)	246 (50.2)		112 (6.0)	1768 (94.0)	
9/11 summary score							
None/low	7619 (35.8)	598 (58.2)	429 (41.8)		331 (5.0)	6261 (95.0)	
Medium	7909 (37.2)	1046 (54.5)	873 (45.5)		373 (6.2)	5617 (93.8)	
High	4405 (20.7)	966 (56.0)	759 (44.0)		156 (5.8)	2524 (94.2)	
Very high	1325 (6.2)	455 (57.5)	336 (42.5)		25 (4.7)	509 (95.3)	
Social integration at Wave 3^d							
Low	1110 (5.3)	469 (75.8)	150 (24.2)		86 (17.5)	405 (82.5)	
Medium	9062 (43.4)	1410 (57.4)	1046 (42.6)		436 (6.6)	6170 (93.4)	
High	10706 (51.3)	1142 (49.7)	1158 (50.3)		351 (4.2)	8055 (95.8)	
Social support at Wave 3^d							
Low	4594 (22.0)	1363 (66.5)	688 (33.5)		309 (12.2)	2234 (87.8)	
Medium	3651 (17.5)	634 (55.9)	500 (44.1)		187 (7.4)	2330 (92.6)	
High	12665 (60.6)	1013 (46.6)	1162 (53.4)		370 (3.5)	10120 (96.5)	
Pre-9/11 trauma							
No	12302 (59.8)	1451 (52.8)	1295 (47.2)		454 (4.8)	9102 (95.2)	
Yes	8276 (40.2)	1450 (58.9)	1011 (41.1)		400 (6.9)	5415 (93.1)	
Post-9/11 trauma^d							
No	13539 (63.7)	1158 (47.0)	1308 (53.0)		475 (4.3)	10598 (95.7)	
Yes	7719 (36.3)	1907 (63.7)	1089 (36.3)		410 (8.7)	4313 (91.3)	
Chronic disease^{d,e}							
No	11186 (54.0)	1055 (49.6)	1071 (50.4)		421 (4.6)	8639 (95.4)	
Yes	9532 (46.0)	1908 (60.6)	1243 (39.4)		435 (6.8)	5946 (93.2)	
Diagnosed depression (ever)							
No	18407 (86.6)	1638 (45.2)	1982 (54.8)		701 (4.7)	14086 (95.3)	
Yes	2851 (13.4)	1427 (77.5)	415 (22.5)		184 (18.2)	825 (81.8)	

Abbreviations: WTC: World Trade Center; PTSD: posttraumatic stress disorder; NH: non-Hispanic

^a Excludes those with pre-9/11 depression or PTSD diagnoses, those with missing information on diagnosed depression or PTSD, those missing PHQ-8 items at Waves 3 and 4, those missing PCL-17 items at any Wave 1–4, and those < 18 at Wave 1

^b PTSD as assessed by a score of ≥ 44 on the PCL-17

^c Depression at Wave 3 and/or Wave 4 as assessed by scores ≥ 10 on the PHQ-8

^d N = 905 missing income; N = 154 missing education; N = 88 missing marital status; N = 187 missing employment status; N = 201 missing eligibility category; N = 380 missing social integration; N = 348 missing social support; N = 680 missing pre-9/11 trauma; N = 540 missing chronic disease status. Missing observations are excluded from the denominators.

^e Chronic disease includes heart attack or heart disease, asthma, GERD, and/or cancer

Table 2
Adjusted Risk Ratios (aRR) and 95% Confidence Intervals (CI) from Multivariable Log Binomial Models with Generalized Estimating Equations for the Association between 9/11 Experiences and Other Characteristics and Depression over Waves 3 and 4 Stratified by PTSD Status.^a

Characteristic	Ever-PTSD (n = 5462) Depression (n = 3065) ^b aRR ^c (95% CI)	Never-PTSD (n = 15,796) Depression (n = 885) ^b aRR ^c (95% CI)
Household income ^d		
≤ \$50,000	1.21 (1.11, 1.32)	1.44 (1.12, 1.83)
\$50,000–\$150,000	1.19 (1.10, 1.29)	1.35 (1.13, 1.60)
≥ \$150,000	1.00 (ref)	1.00 (ref)
Employment status ^d		
Employed	1.00 (ref)	1.00 (ref)
Retired	0.94 (0.87, 1.02)	0.92 (0.75, 1.12)
Homemaker or student	0.95 (0.73, 1.22)	0.57 (0.30, 1.10)
Unable to work due to health	1.31 (1.24, 1.39)	2.42 (1.82, 3.22)
Unemployed for other reasons	1.23 (1.13, 1.33)	2.02 (1.59, 2.56)
Eligibility group		
Rescue and recovery workers	1.03 (0.98, 1.09)	1.00 (0.79, 1.27)
Lower Manhattan area workers	1.06 (0.99, 1.14)	0.94 (0.75, 1.17)
Lower Manhattan residents	1.00 (ref)	1.00 (ref)
9/11 summary score		
None/low	1.00 (ref)	1.00 (ref)
Medium	0.98 (0.94, 1.02)	1.10 (0.94, 1.31)
High	0.97 (0.93, 1.02)	1.05 (0.85, 1.28)
Very high	0.99 (0.96, 1.03)	0.72 (0.48, 1.09)
Social integration ^d		
Low	1.33 (1.25, 1.41)	2.63 (2.02, 3.41)
Medium	1.18 (1.12, 1.24)	1.53 (1.33, 1.76)
High	1.00 (ref)	1.00 (ref)
Social support ^d		
Low	1.62 (1.52, 1.73)	3.66 (3.07, 4.36)
Medium	1.39 (1.30, 1.49)	2.33 (1.96, 2.78)
High	1.00 (ref)	1.00 (ref)
Pre-9/11 trauma		
No	1.00 (ref)	1.00 (ref)
Yes	1.03 (0.99, 1.07)	1.22 (1.06, 1.42)
Post-9/11 trauma		
No	1.00 (ref)	1.00 (ref)
Yes	1.23 (1.16, 1.30)	1.63 (1.41, 1.88)
Chronic disease ^{d,e}		
No	1.00 (ref)	1.00 (ref)
Yes	1.16 (1.10, 1.22)	1.34 (1.16, 1.54)

Abbreviations: PTSD: posttraumatic stress disorder.

^a Excludes those with pre-9/11 depression or PTSD diagnoses, those with missing information on diagnosed depression or PTSD, those missing PHQ-8 items at Waves 3 and 4, those missing PCL-17 items at any Wave 1–4, and those < 18 at Wave 1.

^b Includes 1101 individuals who were missing PHQ items at either Wave 3 or Wave 4 (N = 357 with ever-PTSD and 744 without PTSD).

^c Compared with no depression and adjusted for all variables in table as well as sex, age, race, education, and marital status.

^d Denotes time-varying covariate.

^e Chronic disease includes heart attack or heart disease, asthma, GERD, and/or cancer.

had ever had PTSD as well as those who had never had PTSD. This comparison attempts to explicitly focus on identifying factors unique to depression, which may vary by PTSD status. For example, in the stratum of enrollees with a history of PTSD, those with PTSD and depression were compared to those who had PTSD only. As such, we identified several predictors of depression, and although they were similar across PTSD strata, estimates were consistently stronger among those without PTSD. This may reflect the possibility that comorbid PTSD and depression is driven by a complex interplay of factors, perhaps related to both 9/11 exposures and social factors together. In contrast, those without PTSD in this cohort represent a subset that was resilient to the 9/11 disaster, making the impact of these other social factors more singularly important to the development of depression.

From a public health perspective, identifying predictors of depression among those with and without a history of PTSD is important so

that high-risk individuals can be identified for potential interventions. However, among those with depression at Wave 4, only 45.4% sought professional care for any mental health-related issue in the 12 months preceding the questionnaire. This underutilization of mental health services has been noted previously, both in New York City (Belkin et al., 2016) and nationally (Kessler et al., 2003). These figures underscore the need for public health campaigns focused on depression awareness and treatment, including measures aimed at destigmatizing mental health morbidities and care-seeking for such conditions (Corrigan et al., 2014). In addition, clinical providers may consider screening for depression among high-risk individuals, such as those who have experienced a trauma or who have PTSD symptoms.

We observed a high degree of comorbidity between PTSD and depression in that over half of those with a history of PTSD developed depression. This has been described previously (Flory and Yehuda, 2015; Rytwinski et al., 2013), and several hypotheses underlie its occurrence. First, there is shared symptomology for diagnostic criteria across syndromes (e.g., sleep disturbances; difficulty concentrating), which leads to a strong correlation between instruments (i.e., PCL-17 and PHQ-8). Furthermore, symptom severity has been shown to be greater among those with comorbid PTSD and depression compared with those with just one single condition (Momartin et al., 2004; Post et al., 2011). This was also true in our cohort with those with comorbid PTSD and depression having greater PHQ-8 scores compared with those who had depression only. This is consistent with the observations showing that impairment is significantly greater among those with comorbid PTSD and depression compared with those with just one condition (Caramanica et al., 2014; Ikin et al., 2010). In addition to overlapping diagnostic components between PTSD and depression, several other mechanisms may explain this comorbidity (Flory and Yehuda, 2015; Stander et al., 2014) such as PTSD causing depression (Breslau et al., 1997); a reciprocal relationship between the two (Horesh et al., 2017); and the two sharing common vulnerabilities and risk factors (Byllesby et al., 2017). The latter is a potential indication that these two conditions perhaps represent a common response to traumatic stress in some (Breslau et al., 2000; Dekel et al., 2014).

Although 9/11-related exposures did not seem to be related to depression within strata of PTSD overall, we found that among enrollees with a history of PTSD who also had depression at Wave 3, those with very high scores on the 9/11 exposure index were less likely to resolve their depression by Wave 4. This suggests that in the presence of PTSD, those who had several 9/11-related exposures were more likely to experience prolonged comorbid depression compared with those who experienced fewer traumatic experiences on 9/11.

Our finding that unemployment was related to an increased risk of depression has been reported previously both in New York City (Belkin et al., 2016) and elsewhere (Gallo et al., 2006, 2000; Mandal and Roe, 2007). However, it has been repeatedly noted that although unemployment has been shown to lead to depression in some, depressed individuals are more likely to become unemployed than those who are not depressed (Jefferis et al., 2011; Whooley et al., 2002). Therefore, the dynamics of this relationship are complex, and we were not able to assess in which direction this relationship was operating in our cohort. Similarly, the reported inverse associations between social integration and social support and depression are plausible (Heikkinen and Kauppinen, 2004), but it is also likely that for some, the depressed state leads to endorsement of low social integration and support due to social withdrawal and subsequent isolation (Cacioppo et al., 2006; Kessler et al., 2003). Finally, we found that depression was more strongly associated with traumatic life experiences that occurred after 9/11 compared with those that occurred before, which is likely related to the amount of time that elapsed between the experience and survey. This is supported by observations showing that more recent factors are more influential than more remote ones (Bottomley et al., 2010) and specifically, if stressful life events induce major depression, it occurs rapidly, often within 1–3 months of the event (Kendler et al., 1999, 2010).

Our study benefited from several strengths. We had longitudinal

Table 3Adjusted Risk Ratios (aRRs) and 95% Confidence Intervals (CI) for the Associations Between 9/11 Experiences and Other Characteristics and Resolution of Depression^a Among Those with a History of PTSD^b, N = 2275.

Characteristic	Persistent depression ^c (Reference; N = 1494 (N = 65.7%))		Resolved depression ^a (N = 781 (N = 34.3%))	
	N (%)		N (%)	aRR ^d (95% CI)
Household income at Wave 4 ^e				
≤ \$50,000	470 (73.3)		171 (26.7)	0.76 (0.62, 0.93)
\$50,000–\$150,000	783 (65.0)		422 (35.0)	0.82 (0.72, 0.93)
≥ \$150,000	179 (53.4)		156 (46.6)	1.00 (ref)
Employment status at Wave 4 ^e				
Employed	724 (62.1)		442 (37.9)	1.00 (ref)
Retired	275 (59.0)		191 (41.0)	1.08 (0.93, 1.26)
Homemaker or student	14 (58.3)		10 (41.7)	1.08 (0.65, 1.82)
Unable to work due to health reasons	386 (81.4)		88 (18.6)	0.61 (0.48, 0.77)
Unemployed for other reasons	71 (65.7)		37 (34.3)	1.01 (0.77, 1.33)
Eligibility group ^e				
Rescue and recovery workers	790 (67.2)		386 (32.8)	1.11 (0.87, 1.43)
Lower Manhattan area workers	556 (63.6)		318 (36.4)	1.16 (0.91, 1.46)
Lower Manhattan residents	125 (62.8)		74 (37.2)	1.00 (ref)
9/11 summary score				
None/low	276 (63.6)		158 (36.4)	1.00 (ref)
Medium	486 (65.4)		257 (34.6)	0.95 (0.81, 1.12)
High	463 (62.6)		277 (37.4)	0.99 (0.84, 1.16)
Very high	269 (75.1)		89 (24.9)	0.76 (0.59, 0.97)
Social integration at Wave 4 ^e				
Low	247 (80.5)		60 (19.5)	0.58 (0.44, 0.77)
Medium	687 (66.8)		342 (33.2)	0.89 (0.79, 1.00)
High	517 (59.2)		356 (40.8)	1.00 (ref)
Social support at Wave 4 ^e				
Low	808 (76.3)		251 (23.7)	0.56 (0.48, 0.65)
Medium	308 (61.6)		192 (38.4)	0.85 (0.74, 0.99)
High	344 (51.4)		325 (48.6)	1.00 (ref)
Pre-9/11 trauma ^e				
No	711 (66.6)		356 (33.4)	1.00 (ref)
Yes	710 (64.8)		385 (35.2)	1.08 (0.97, 1.22)
Post-9/11 trauma				
No	500 (57.2)		374 (42.8)	1.00 (ref)
Yes	994 (70.9)		407 (29.1)	0.79 (0.71, 0.89)
Chronic disease at Wave 4 ^{e,f}				
No	445 (59.6)		302 (40.4)	1.00 (ref)
Yes	1006 (69.1)		449 (30.9)	0.86 (0.77, 0.97)

Abbreviations: PTSD: posttraumatic stress disorder.

^a Depression at Wave 3 and not at Wave 4.^b Excludes those with pre-9/11 depression or PTSD diagnoses, those with missing information on diagnosed depression or PTSD, those missing PHQ-8 items at Waves 3 and 4, those missing PCL-17 items at any Wave 1–4, those < 18 at Wave 1; in addition to: those who never had depression (n = 2202) or had depression at Wave 4 only (n = 628), and those missing depression status (PHQ-8 items) at Wave 3 (n = 140) or Wave 4 (n = 217).^c Depression at Waves 3 and 4.^d Compared with persistent depression (depression at Wave 3 and Wave 4) and adjusted for all variables in table as well as sex, age, race, education, and marital status.^e N = 94 missing income; N = 14 missing education; N = 19 missing marital status; N = 37 missing employment; N = 26 missing eligibility criteria; N = 66 missing social integration; N = 47 missing social support; N = 113 missing pre-9/11 trauma; N = 73 missing chronic disease status.^f Chronic disease includes heart attack or heart disease, asthma, GERD, and/or cancer.

data on mental health conditions, including both PTSD and depression. This allowed us to evaluate relationships over time as well as identify predictors of transient (vs. persistent) depression. However, the instrument measuring PTSD symptoms referenced the events of 9/11 in the re-experiencing and avoidance domains, which may have impeded our ability to identify all PTSD cases. It is therefore possible that the reported prevalence may underestimate the total burden of PTSD in this population. In addition, the predictors of depression across the two PTSD strata may have differed if we had been able to identify all PTSD cases, which may make our findings more specific to 9/11 or other severe trauma-exposed populations. Another strength of this study was our large sample size allowed us to implement log binomial models, yielding risk ratios. This was particularly important among those who had a history of PTSD, due to the high prevalence of depression (56%) in that stratum. It is well known that the odds ratio overestimates the risk ratio, especially in the case where disease is not rare (Greenland, 1987), and thus we implemented a statistical approach appropriate for our data structure. Finally, questionnaires assessed mental health symptoms based on validated instruments that are widely used, which

allows for easy comparisons to other studies and populations. However, we used scales that relied on *DSM-IV* diagnostic criteria which differ from those in the *DSM-V* (Kilpatrick et al., 2013). Although it was important that we maintain consistency over time to ensure internal validity, these recent changes may affect our ability to compare results with other studies that use instruments based on the *DSM-V* criteria, such as the PCL-5 (Blevins et al., 2015). In addition, while the use of these scales is not the same as psychiatric evaluations and diagnoses (North and Pfefferbaum, 2002), in the setting of population-based research, it allows for classification of individuals regardless of their care-seeking behavior.

However, we also had some limitations. First, this study was conducted among enrollees of the World Trade Center Health Registry who completed all four major follow-up waves, through 15–16 years post-disaster. There has been substantial attrition since Wave 1: 71,427 individuals were enrolled at Wave 1; 28,250 participants completed all four waves; and 21,258 were included in this study after exclusions. These individuals who participated in all four waves are different than those who participated in just Wave 1. Previous investigation of this

issue has shown that this loss to follow-up led to decreases in the prevalence of PTSD, which is likely also the case for depression (Yu et al., 2015). However, Yu et al. also reported that questionnaire non-response did not bias measures of association between 9/11 and several health conditions because non-response was not related to 9/11-related exposures (i.e., dust cloud intensity). However, we cannot rule out the potential role of selection bias in our study, especially because we had various predictors of interest. Another issue is that we were not able to examine resolution of depression over time among those without a history of PTSD due to insufficient sample size. This was due to the high degree of correlation between PTSD and depression; thus, there were not enough people who had never experienced PTSD, but had depression at Wave 3 to assess their potential for recovery. This is likely to occur in other studies of trauma-exposed populations, where PTSD is common and much of the depression burden may stem from that. Lastly, questionnaires at Waves 1 and 2 did not include measures of depression, which precluded us from evaluating an even longer-term longitudinal course of depressive symptoms. Furthermore, this design may have also affected our ability to capture the total burden of depression. For example, it is possible that individuals experienced depression shortly after 9/11 but it resolved before our first PHQ-8 assessment at Wave 3. Similarly, we were not able to distinguish between individuals who had persistent depression (e.g., since Wave 1) and those with newly developed depression at Wave 3, who likely had distinct sets of risk factors. However, despite this, we were still able to identify predictors of depression, as well as its persistence over several years.

The results of this study build upon the existing knowledge from other longitudinal studies on PTSD and depression (Bowler et al., 2016; Ginzburg et al., 2010; Horesh et al., 2017) by conducting an analysis focused on determinants of depression in two distinct subpopulations based on long-term PTSD symptomology, as well as identifying predictors of resolved depression compared with persistent depression over time. These contributions have important clinical and public health practice implications because they may inform potential interventions.

5. Conclusions

In a cohort of individuals exposed to the 9/11 attacks up to 15 years post-disaster, there was a substantial burden of depression overall and especially among those who had a history of PTSD. Among those with and without a history of PTSD, low income, unemployment, low social integration and support, recent traumatic life events, and chronic physical disease were associated with an increased risk of depression. These same factors were identified as predictors of persistent depression compared with resolved depression. This work may have implications for targeting public health interventions and clinical care.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.jad.2017.12.105>

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