

Longitudinal Study of Probable Post-Traumatic Stress Disorder in Firefighters Exposed to the World Trade Center Disaster

Amy Berninger, MPH,^{1,2} Mayris P. Webber, DrPH, MPH,^{2,3*} Justin K. Niles, MA,^{1,2}
Jackson Gustave, MPH,² Roy Lee, BS,² Hillel W. Cohen, DrPH, MPH,³ Kerry Kelly, MD,²
Malachy Corrigan, PhD, RN,² and David J. Prezant, MD^{1,2,4}

Background Symptoms of post-traumatic stress disorder (PTSD) have been reported even years after the terrorist attacks of September 11, 2001 (9/11).

Methods We used screening tools to assess the prevalence of probable PTSD in 9/11-exposed firefighters at two time points, within 6 months of 9/11 (baseline) and 3–4 years post-disaster (follow-up).

Results Five thousand six hundred fifty-six individuals completed assessments at both times. 15.5% reported probable PTSD post-9/11, 8.6% at baseline and 11.1% at follow-up, on average 2.9 (SD 0.5) years later. Analyses revealed that nearly half of all probable PTSD occurred as delayed onset (absent baseline, present follow-up). Compared with the resilient group (no probable PTSD at either time), probable PTSD at baseline, and delayed onset at follow-up were each associated with concomitant functional impairment (OR 19.5 and 18.9), respectively.

Conclusion Similar percentages of firefighters met criteria for baseline and delayed onset probable PTSD at follow-up, years later. Both were associated with substantial functional impairment. Early risk identification could provide opportunities for mental health interventions before symptoms compromise work and social relationships. *Am. J. Ind. Med.* 53:1177–1185, 2010. © 2010 Wiley-Liss, Inc.

KEY WORDS: World Trade Center; mental health; occupational medicine; post-traumatic stress; firefighters

BACKGROUND

On September 11, 2001 (9/11), the terrorist attacks on the World Trade Center (WTC) killed 2,974 people and

destroyed the WTC towers and adjacent buildings. The hazardous conditions created a site that not only produced physical health and safety concerns, but also psychological ones [Lioy et al., 2002; Edelman et al., 2003; McGee et al., 2003; Landrigan et al., 2004]. The attack on the WTC directly affected the Fire Department of the City of New York (FDNY), killing 343 FDNY rescue workers and injuring 100s more. Nearly every FDNY firefighter worked for some time at the WTC site, suffering great exposure to potentially life-threatening situations during the first month, and additional exposures to the injured, the dead, and human remains in the first 6 months.

After the WTC attack, several studies using different screening questionnaires among different groups of rescue and recovery workers, observed similar percentages of exposed individuals reporting symptoms consistent with

¹Montefiore Medical Center, Department of Medicine, Bronx, New York

²Bureau of Health Services, Fire Department of the City of New York, Brooklyn, New York

³Department of Epidemiology and Population Health, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, New York

⁴Department of Medicine, Albert Einstein College of Medicine, Bronx, New York

Contract grant sponsor: National Institute for Occupational Safety and Health (NIOSH); Contract grant number: R01-OH07350.

*Correspondence to: Mayris P. Webber, New York City Fire Department, Bureau of Health Services, 9 Metrotech Center, Brooklyn, NY 11201. E-mail: webberm@fdnynyc.gov

Accepted 28 July 2010

DOI 10.1002/ajim.20894. Published online 22 September 2010 in Wiley Online Library (wileyonlinelibrary.com).

post-traumatic stress disorder (PTSD), including 12–17% of firefighters in the WTC Registry (FDNY and non-FDNY) [Perrin et al., 2007], 12–13% of FDNY firefighters [Corrigan et al., 2009], and 11–20% of non-FDNY rescue and recovery workers in the NY/NJ-WTC-Consortium [Stellman et al., 2008].

There have been conflicting reports about the evolution of PTSD symptoms in WTC-exposed populations. Several serial cross-sectional studies examining prevalence at two time points have reported declines in PTSD over time [Galea et al., 2003; Stellman et al., 2008], while our previous work, and that of others, have reported increases [Brackbill et al., 2009; Berninger et al., 2010]. Recent longitudinal studies tracked PTSD in individuals over an extended follow-up period. The prevalence of symptoms consistent with probable PTSD in a population-based cohort of 2,752 NYC residents was relatively stable, averaging between 12% and 14% during follow-up which ended approximately 4 years post-9/11 [Galea et al., 2008]. The other, a large heterogeneous sample of 21,605 rescue/recovery workers and volunteers from the WTC Registry, found that the prevalence of probable PTSD increased from 12.1% during 2003–2004 to 19.5% during 2006–2007 [Brackbill et al., 2009].

The current study reports on the evolution of delayed onset probable PTSD (defined as absent at baseline, present at follow-up) in a large, highly exposed cohort of 5,656 FDNY firefighters with baseline evaluation between 1 and 6 months after 9/11 and with prospective follow-up 3–4 years post-disaster. This study is the first to look at delayed onset probable PTSD in the FDNY cohort that remained part of the active workforce. We also examined potential risk factors and correlates of probable PTSD [Corrigan et al., 2009; Berninger et al., 2010] identified in previous studies of our and other populations [Perrin et al., 2007] including WTC exposures, work-related stressors, alcohol use, and the presence of specific symptom domains as defined in the DSM-IV-TR[®] diagnostic criteria for PTSD. We examined the associations of the same potential risk factors and correlates with delayed onset probable PTSD in relation to the group deemed “resilient” that did not exhibit sufficient symptom loads to be considered probable PTSD at baseline or follow-up.

METHODS

After 9/11, a formal Medical Monitoring Program (FDNY-WTC-MMP) was implemented to screen FDNY rescue workers who were exposed to the WTC disaster. These exams, which are on-going and scheduled every 12–18 months, include a physical examination and completion of self-administered questionnaires, which collect information on exposure to the WTC site and physical and mental health symptoms using touch screen computers. Trained personnel were available to answer questions. Participation

in the current study required written consent and was approved by the Institutional Review Board at Montefiore Medical Center.

Participants

The FDNY WTC rescue workforce consisted of 13,441 firefighters and Emergency Medical Service (EMS) workers who were hired before the close of the WTC site on July 25, 2002. The following were excluded from this analytic cohort: 2,417 EMS workers and 206 fire marshals due to differences in job tasks these groups performed at the site; 1,977 firefighters who retired during the study period resulting in high loss to follow-up rates in retirees prior to outreach, which began in December, 2005; 1,310 individuals without a baseline exam within 6 months of 9/11; 724 firefighters who arrived at the disaster site more than 14 days after the rescue/recovery effort began resulting in different exposures to horrific and dangerous events as well as demographic differences between the late comers and the rest of the firefighter group; and 20 female firefighters due to small numbers. This left 6,787 firefighters eligible for inclusion in the study. As our goal was to examine delayed onset probable PTSD status between baseline and 3–4 years of follow-up, we excluded an additional 1,131 without an exam during the follow-up time period.

Comparing those included in the analytic cohort to those excluded only due to lack of a follow-up exam, there were small but statistically significant differences in mean age (37.8 ± 6.5 vs. 39.4 ± 6.6 years, $P < 0.01$); the proportion of most-exposed individuals in Arrival Group 1 (see below for definition): (15.8% vs. 17.2%, $P < 0.01$); and mean PTSD symptom counts (3.5 ± 3.5 vs. 4.1 ± 3.8 , $P < 0.0001$). The baseline prevalence of probable PTSD (8.6% vs. 11.7%; $P < 0.0001$) was lower in the analytic cohort.

Data Sources

Demographic and retirement status data were obtained from the FDNY employee database. All other information was obtained from the FDNY-WTC-MMP questionnaires.

WTC Exposure

Exposure to the WTC site was determined using the previously described FDNY-WTC-MMP Exposure Intensity Index based on initial arrival time to the WTC site [Prezant et al., 2002]. Those who first arrived during the morning of 9/11 (day 1) and were present during the tower collapses were categorized as “Arrival Group 1”; those arriving during the afternoon of 9/11 were categorized as “Arrival Group 2”; those arriving on day 2 were categorized as “Arrival Group 3”; and those who arrived at any time from days 3 to 14 were categorized as “Arrival Group 4.” A duration variable was

created by summing the number of months that an individual reported working at the site.

Probable PTSD

Details of the FDNY-modified PTSD Checklist (PCL-m) have been previously described [Corrigan et al., 2009] and are included in Figure 1. Briefly, in the FDNY version, 14 psychological questions were modified to fit the context of 9/11. For example, at both time points participants were asked: “Since the disaster, have you experienced any of the following...” Additionally, answer choices were binary (“yes”/“no”) for simplicity and speed in self-administration. In our previous work, we found the PCL-m was associated with self-referral to counseling services, impaired work performance and mental health-related medical leave [Corrigan et al., 2009].

A formal PTSD diagnosis cannot be determined solely from questionnaire responses. Since our outcome measure was based only on the PCL-m, we refer to those scoring positive as having “probable PTSD,” consistent with previous literature [Perrin et al., 2007]. We required that two different conditions be satisfied to score positive. The first was based on the DSM-IV-TR[®] diagnostic criteria and required at least two affirmative responses in the Arousal domain, at least one affirmative response in the Re-experiencing domain, and at least three affirmative responses in the Avoidance/Numbing domain. The second method was based on a total score of at least nine affirmative responses which we previously determined to be an appropriate threshold for probable PTSD in this population [Corrigan et al., 2009]. Thus, individuals with probable PTSD met the

most conservative definition, satisfying both the domain criteria and scored ≥ 9 on the PCL-m. A sub-threshold probable PTSD score of 5–8 was based on the upper quartile of the sum of affirmative responses below the threshold for probable PTSD and also includes firefighters who had scores ≥ 9 but did not fulfill the individual domain requirements.

We have chosen to refer to those firefighters who did not meet the criteria for probable PTSD in their baseline questionnaire, but did meet the criteria at follow-up as delayed onset probable PTSD. This is a descriptive and not diagnostic term that has been used in previous literature [Adams and Boscarino, 2006; Andrews et al., 2009]. This group was examined in relation to the group deemed “resilient” that did not exhibit sufficient symptom loads to be considered probable PTSD at either time point.

Functional Impairment

Two questions on functional impairment at work or at home were not part of the scoring algorithm because they are not part of the standard PCL for predicting PTSD risk, but were used in bivariate analyses as they provide insight as to whether probable PTSD is associated with functional impairment. The questions used both at baseline and follow-up were part of a list where participants could check off one or more items, as applicable: “Since the disaster, have you experienced any of the following?” Responses included “no problems”, “difficulty functioning at home”, or “difficulty functioning at work”. A positive response to either functioning symptom was termed “difficulty functioning.”

Alcohol Use

Time constraints during the baseline questionnaire limited our alcohol use assessment to a single question. Although similar in concept to studies assessing increased use in alcohol [Vetter et al., 2008], the exact wording was unique. Data on alcohol use was based on the following question: “Has your average alcohol use changed since the disaster?” Response options included “do not use alcohol,” “no change in alcohol use,” “decreased alcohol use,” and “increased alcohol use.” At baseline, individuals were considered to have an increase in alcohol use if they responded “increased alcohol use.” We also analyzed separately those who reported “increased alcohol use” at follow-up and did not report “increased alcohol use” at baseline.

Data Analysis

Demographic and other potential risk factors were analyzed in relation to probable PTSD, as previously defined, using the chi-squared test with unadjusted odds ratios (OR) and 95% confidence intervals (95% CI) in bivariate analyses. Multivariable logistic regression models were used to

“Since the disaster, have you experienced any of the following...”
Re-experiencing
Flashback memories of the disaster (repeated disturbing images)
Nightmares or bad dreams related to WTC
Avoidance and numbing
Distant from other people
Distant from friends or family
I feel numb
Dazed or detached from surroundings
Avoiding things or people that remind you of the disaster
Difficulty remembering details of the disaster
Arousal
Difficulty getting a good night's sleep
Difficulty falling asleep or staying asleep
Unusual irritability
Feeling anxious or unusually restless
Difficulty concentrating
Unusual anger

FIGURE 1. FDNY PCL-m.

examine associations between questionnaire and other data (including individual PTSD domains) with the dichotomous model outcomes of exhibiting probable PTSD on one or both questionnaires (Table I) and delayed onset probable PTSD (Table II). Interaction terms including Arrival Group and number of months worked at the site were individually tested

[Perrin et al., 2007]. Variables were retained in final models after assessment of their impact on other variables in the model or if they were statistically significant at $P < 0.05$. Models were adjusted for Arrival Group (either as reference group 4 or combining arrival groups 3 and 4 as the reference when there were small numbers), months of work at the WTC

TABLE I. Population Characteristics

	Total (%)	Ever probable PTSD (%)	Never probable PTSD (%)	Unadjusted odds ratios (95% CI)
Total	5,656	878 (16)	4,778 (84)	—
Sociodemographics				
Age on 9/11				
20–29	643 (11)	101 (11)	542 (11)	—
30–39	2,980 (53)	463 (53)	2,517 (53)	1.0 (0.8–1.3)
40–49	1,868 (33)	297 (34)	1,571 (33)	1.0 (0.8–1.3)
50–59	161 (3)	17 (2)	144 (3)	0.6 (0.4–1.1)
60+	4 (0)	0 (0)	4 (0)	<0.01 (<0.01–>100)
Education ^a				
High School	1,370 (24)	197 (22)	1,173 (25)	—
Some College	2,627 (46)	416 (48)	2,211 (46)	1.1 (0.9–1.3)
College	1,265 (22)	198 (23)	1,067 (22)	1.1 (0.9–1.3)
Post-College	184 (3)	32 (4)	152 (3)	1.2 (0.8–1.8)
Living with a partner				
Yes	4,498 (80)	691 (79)	3,807 (80)	—
No	1,158 (20)	187 (21)	971 (20)	1.06 (0.89–1.27)
WTC exposures				
Arrival Group				
Morning of 9/11	893 (16)	236 (27)	657 (14)	4.8 (3.0–7.5)
Afternoon of 9/11	3,852 (68)	564 (64)	3,288 (69)	2.3 (1.5–3.5)
Day 2	598 (11)	56 (6)	542 (11)	1.4 (0.8–2.3)
Days 3–14	313 (6)	22 (3)	291 (6)	—
Prolonged work at the WTC site (≥ 4 months) ^b				
≥ 4 months	2,395 (43)	493 (57)	1,902 (40)	2.0 (1.7–2.3)
< 4 months	3,194 (57)	375 (43)	2,819 (60)	—
Work-related variables				
Rank				
Firefighter	3,509 (62)	527 (60)	2,982 (62)	—
Line officer	1,780 (31)	293 (33)	1,487 (31)	1.1 (0.95–1.30)
Chiefs	341 (6)	50 (6)	291 (6)	0.96 (0.70–1.32)
Number of deaths in firehouse				
0	4,705 (83)	663 (76)	4,042 (85)	—
1–3	571 (10)	112 (13)	459 (10)	1.5 (1.2–1.9)
4+	380 (7)	103 (12)	277 (6)	2.3 (1.8–2.9)
Supervising responsibilities during the collapse				
Yes	287 (5)	80 (9)	207 (4)	2.2 (1.7–2.9)
No	5,369 (95)	798 (91)	4,571 (96)	—
Previous disaster experience				
Yes	1,492 (26)	281 (32)	1,211 (25)	1.4 (1.2–1.6)
No	4,164 (74)	597 (68)	3,567 (75)	—

^aEducation information missing on 210 individuals.

^bDuration information missing on 67 individuals, presented here as a median split.

TABLE II. Multivariable Models of Symptom Patterns

	Adjusted odds ratio (95% CI)	P-value
Delayed onset probable PTSD++		
Age on 9/11	0.98 (0.97–1.00)	0.04
Arrival Group 1—Morning of 9/11	2.0 (1.3–2.9)	<0.01
Arrival Group 2—Afternoon of 9/11	1.1 (0.8–1.5)	0.74
Duration of work at WTC site (per month)	1.1 (1.1–1.2)	<0.01
Reported increase in alcohol-baseline	1.3 (1.0–1.7)	0.06
Baseline sub-threshold probable PTSD	5.6 (4.4–7.0)	<0.01

Arrival Group, duration of work at the WTC site, and age on 9/11 were controlled for. Baseline is the initial interview period within 6 months of 9/11. ++ reference group is resilient individuals.

site, and age on 9/11. No interaction terms met the criteria for model inclusion. All statistical analyses were performed using SAS Version 9.1 (The SAS Institute, Cary, NC).

RESULTS

Progression of Probable PTSD

Five thousand six hundred fifty-six firefighters completed questionnaires at baseline and follow-up, on average, 2.9 (SD 0.5) years apart (range = 1.6–3.8 years). Combining data from both assessments, 15.5% had probable PTSD on one or both questionnaires (Table I). There were 487 firefighters (8.6%) with probable PTSD at baseline and 11.1% at follow-up; 391 (44.5%) of all probable PTSD cases were as a result of delayed onset. There were also 252 cases who met the criteria at baseline but not at follow-up. The mean number of symptoms reported by individuals with delayed onset increased from 5.5 (SD 2.8) at baseline to 11.2 (SD 1.6) at follow-up. The mean number of symptoms reported by the resilient (below symptom threshold definition) group was 2.6 (SD 2.6) at baseline and 2.4 (SD 2.7) at follow-up. There was a statistically significant exposure gradient by arrival group in prevalence of probable PTSD at baseline and in delayed onset probable PTSD (shown in Fig. 2).

Probable PTSD Domains

The DSM-IV-TR[®] criteria for a diagnosis of PTSD required symptoms in each of three domains—arousal, re-experiencing, and avoidance/numbing. We examined each domain of the DSM-IV-TR[®] at baseline and found Arousal was most common, endorsed by 50.2%. Re-experiencing was the second most common, endorsed by 38.0% and avoidance/numbing was the least common, endorsed by 14.8% at baseline. We found that the least prevalent domain had the greatest association with probable PTSD (i.e., had the greatest positive predictive value). Compared to the resilient

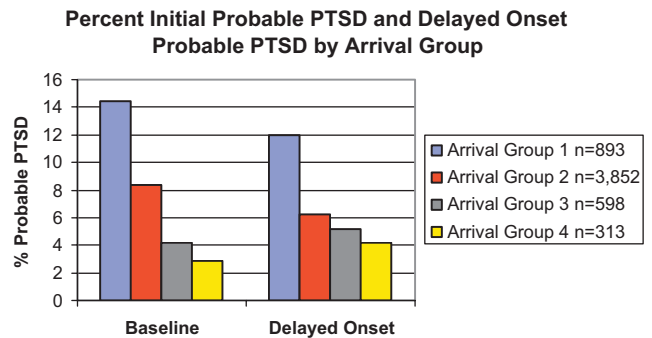


FIGURE 2. Percent initial probable PTSD and delayed onset probable PTSD by Arrival Group. Note: Baseline: 9/11/01–3/10/02. Delayed onset is absence of probable PTSD at baseline, presence at follow-up. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

group, those with delayed onset probable PTSD were more likely to have met the criteria for the arousal domain (OR = 5.2, 95% CI: 4.0–6.7, $P < 0.01$), the re-experiencing domain (OR = 3.4, 95% CI: 2.7–4.2, $P < 0.01$), and the avoidance/numbing domain (OR = 3.2, 95% CI: 2.4–4.3, $P < 0.01$) at baseline in separate logistic models.

Impaired Function

At baseline, 15.2% of the analytic cohort reported functional impairment at work or at home. Those with probable PTSD at baseline were far more likely to concurrently report functional impairment than those in the resilient group (OR = 19.5; 95% CI: 15.8–24.1). Those with delayed onset probable PTSD were also more likely to report functional impairment than the resilient group, both at baseline (OR = 3.5; 95% CI: 2.8–4.5) and especially at follow-up (OR = 18.9, 95% CI: 15.0–23.8).

Fulfillment of the avoidance/numbing domain, with or without probable PTSD, was strongly associated with impaired function. Those fulfilling the avoidance/numbing domain were 12 times more likely (OR = 12.2; 95% CI: 10.3–14.4, $P < 0.0001$) to report difficulty functioning at baseline. Those who did not fulfill the avoidance/numbing domain at baseline, but did at follow-up were three times more likely (OR = 3.1; 95% CI: 2.5–4.0, $P < 0.01$) to have reported difficulty functioning at baseline and nearly 16 times more likely (OR = 15.9; 95% CI: 12.9–19.7) at follow-up. Patterns were unchanged when difficulty functioning was analyzed as either “at home” or “at work” (data not shown).

Increased Alcohol Use

In a baseline univariate model, an increase in alcohol use was associated with probable PTSD (OR = 4.0, 95% CI: 3.2–4.9, $P < 0.01$). When compared to the resilient group, increased alcohol use at baseline was a significant predictor of delayed onset probable PTSD (OR = 2.3, 95% CI: 1.8–

3.0, $P < 0.01$). In multivariable models, however, increased alcohol use at baseline was of borderline significance in predicting delayed onset probable PTSD (OR 1.3, 95% CI: 1.0–1.7, $P = 0.06$).

Multivariable Analyses

We used multivariable logistic regression models to identify independent predictors of probable PTSD and delayed onset probable PTSD. In all models, number of months of work at the WTC site (used as a continuous variable) was a significant predictor of probable PTSD. In one multivariable model, firefighters with delayed onset probable PTSD were more likely than the resilient group to have met the threshold for the avoidance/numbing domain (OR = 2.1; 95% CI: 1.5–2.9), the arousal domain (OR = 3.4; 95% CI: 2.6–4.5), and the re-experiencing domain (OR = 2.1; 95% CI: 1.7–2.7) at baseline. A sub-threshold PTSD score on the FDNY-PCL-m at baseline performed as well or better than any of these domains predicting delayed onset probable PTSD (OR = 5.6; 95% CI: 4.4–7.0). For simplicity, we present the model with a sub-threshold PTSD score in Table II. Reporting an increase in alcohol use at baseline was a borderline significant predictor of delayed onset probable PTSD (Table II).

DISCUSSION

This study reports the prevalence of probable PTSD over time in a large, highly exposed cohort of more than 5,600 firefighters who experienced great risk to life and worked for many months at the WTC site. We found that 8.6% reported probable PTSD within the first 6 months of 9/11, a rate which increased to 11.1%, on average 3 years later (including 391 firefighters with delayed onset probable PTSD). Our rates are lower than those reported for rescue/recovery and volunteers in the WTC registry, where rates increased from 12.1% to 19.5%. Some of this discrepancy may have been due to the disproportionate participation of symptomatic rescue/recovery workers and volunteers in other studies [Brackbill et al., 2009] or to the conservative scoring method that we used, requiring both a minimum score and a minimum number of symptoms in each domain. Alternatively, our lower rates may reflect lower probable PTSD in the population that fulfilled the entry criteria for the analytic cohort, that is, active firefighters who took monitoring exams during the appropriate time intervals. In any case, both our study and Brackbill et al. reported new cases of probable PTSD well after the event.

There has been controversy over the prevalence and even the existence of delayed onset PTSD [Andrews et al., 2007]. The DSM-IV-TR[®] describes delayed onset as “at least 6 months . . . between the traumatic event and the onset of symptoms.” Thus, if one interprets the “onset of symptoms”

as onset of symptoms of sufficient severity to warrant a diagnosis of PTSD, or for studies like ours using screening estimates to warrant a classification of “probable PTSD,” then our categorization of “delayed onset” is consistent with the DSM-IV-TR[®] definition. Using the alternative definition (no symptoms at baseline and probable PTSD at follow-up) “delayed onset” probable PTSD would have been exceedingly rare because only 32 firefighters with probable PTSD at follow-up reported no symptoms at baseline. As it is common for individuals to initially report at least one symptom after exposure to a traumatic event (73.3% in our cohort at baseline), we believe the gradual onset interpretation is more appropriate.

The usual concept of “delayed onset” fits more readily with reactions of limited time exposure to a specific traumatic event like the Oklahoma City bombing, but may be an imperfect fit under circumstances of extended exposure. Unlike disaster workers and survivors in other situations, FDNY firefighters had ongoing exposures to the WTC site because recovery efforts lasted for 10 months. While it is true that nearly 75% (292) of the 391 individuals classified as having delayed onset probable PTSD continued working at the WTC site after their baseline interview, all were interviewed only after the first month when exposure to life-threatening danger was no longer an issue and exposure to dead bodies or body parts had become increasingly rare. Individuals were also exposed to additional traumatic reminders and stressors through multiple funerals and memorial services during the first year and department ceremonies that continue to this day. Thus “delayed onset symptoms” could depend on when individuals completed their first assessment relative to when they completed work at the WTC site.

Stress reactions in WTC-exposed firefighters could more closely mimic those of soldiers in combat, where delayed onset has been reported with many developing symptoms only after returning home [Andreasen, 2004]. A longitudinal study of 88,000 US soldiers returning from Iraq concluded that mental health screening immediately upon return from deployment seriously underestimated the mental health burden detected 3–6 months later, which for PTSD increased from 11.8% to 16.7% [Milliken et al., 2007]. While additional follow-up of this group is not available at this time, it seems like the prevalence of PTSD, especially in cases of delayed onset, could be in part definitional.

Another explanation is that delayed onset probable PTSD was in fact persistent probable PTSD that went unrecognized initially because the threshold score determined from our initial validation study was too high. In consideration of this, we defined a sub-threshold PTSD score (5–8) based on the upper quartile of the sum of affirmative responses below the threshold for probable risk. We also included those who met either definition of probable PTSD at baseline but did not fulfill the criteria for both methods. At

baseline, our group of delayed onset individuals had mean symptom scores less than half of the scores of those with baseline probable PTSD (5.5 ± 2.8 vs. 11.2 ± 1.6 ; $P < 0.01$), but approximately double the scores of those in the resilient group (2.6 ± 2.6). About one-third (34%) of those with delayed onset probable PTSD had sub-threshold PTSD scores, supporting the importance of baseline symptoms in the evolution of delayed onset probable PTSD, as other studies have also shown [Smid et al., 2009]. In the multivariate model, sub-threshold probable PTSD scores at baseline were more strongly associated with delayed onset probable PTSD, than any other variable in the model. In our cohort, 18.9% (258/1,366) of those with a sub-threshold score at baseline progressed to probable PTSD at follow-up. Thus, while this group may or may not be called “sub-threshold,” we suggest that it may represent individuals whose probable PTSD was evolving, perhaps based on chronic re-exposure to the WTC site during the first year after 9/11.

By examining difficulty functioning, we found further evidence for delayed onset probable PTSD as an evolving condition. Compared to the resilient group, there was a strong association between difficulty functioning at baseline and probable PTSD at baseline (OR = 19.5; 95% CI: 15.8–24.1). There was a weaker association between difficulty functioning at baseline and delayed onset probable PTSD (OR = 3.5; 95% CI: 2.8–4.5). In contrast, the association between difficulty functioning at follow-up and delayed onset probable PTSD increased substantially (OR = 18.9; 95% CI: 15.0–23.8). This again suggests that those who went on to have “delayed onset” probable PTSD had evolving rather than unrecognized probable PTSD at baseline. It has also been suggested that those with delayed onset probable PTSD developed a heightened sensitivity to further exposures or an inability to adapt to these exposures [Andrews et al., 2009], which is also consistent with our findings.

Another focus of our work was to examine whether any individual domain had a disproportionate impact on probable PTSD at baseline or on delayed onset probable PTSD [North et al., 2004]. Consistent with earlier work, we found that a greater proportion of individuals endorsing the avoidance/numbing domain met our definition of probable PTSD compared to other individual domains at baseline [Corrigan et al., 2009]. At follow-up, however, multivariable analyses predicting delayed onset probable PTSD indicated that endorsement of the arousal domain had a stronger magnitude of association than the avoidance/numbing domain at baseline. This may be a function of the frequency of arousal symptoms versus avoidance symptoms and our definition of probable PTSD. When delayed onset risk is modeled using only the domain method for determining probable PTSD as the outcome, the avoidance/numbing domain is the most important predictor, whereas when only the PCL-m scoring method is used, arousal is most important. Since avoidance/

numbing symptoms are the least commonly reported, they play a larger role in predicting probable PTSD using the domain method whereas the number of arousal symptoms, which are the most commonly reported, play a larger role in crossing the PCL-m threshold.

Difficulty functioning is included in the DSM-IV-TR[®] Diagnostic Criteria for PTSD, but is not included in the PCL-17 and was therefore not part of the PCL-m scoring methodology. We found significant relationships between difficulty functioning and endorsement of the avoidance/numbing domain as well as between difficulty functioning and probable PTSD. The strong association between probable PTSD and difficulty functioning highlights the need for clinical services and treatment options in this and similarly affected populations.

We confirmed the association of probable PTSD with previously identified factors including early arrival and prolonged work at the WTC site [Fullerton et al., 2004; Perrin et al., 2007; DiGrande et al., 2008]. Compared to the resilient group, the delayed onset group was more likely to have arrived earlier and worked longer at the WTC site, to be younger, to report an increase in alcohol use at baseline, and have sub-threshold probable PTSD at baseline.

Our study was not designed to determine whether increased alcohol use is a consequence or predictor of probable PTSD. However, we found that among those who did not report increased post-9/11 alcohol use at baseline, those with probable PTSD were 2.2 times more likely to report an increase in alcohol use at follow-up, suggesting that some of those with probable PTSD may have increased their alcohol use as a form of self-medication (data not shown), as others have also reported [Adams et al., 2006; Hien et al., 2010]. Alternatively, increased alcohol use at baseline may have increased firefighters' vulnerability for developing probable PTSD. In a univariate model, increased alcohol use at baseline was a significant predictor of delayed onset probable PTSD (OR = 2.3, 95% CI: 1.8–3.0, $P < 0.01$), similar to the results found in other studies [Andrews et al., 2007]. In multivariable models, however, increased alcohol use at baseline was of borderline significance in predicting delayed onset probable PTSD (OR = 1.3, 95% CI: 1.0–1.7, $P = 0.06$). Further study of the longitudinal effects of alcohol use, PTSD, and other mental health disorders is necessary.

There are several limitations to our study. First, we used a screening tool to determine probable PTSD that, although based on the PCL-17, has not been validated in populations other than FDNY [Corrigan et al., 2009]. Yet, a considerable strength is our use of the same tool and method of administration at both times and reported prevalence estimates that were consistent with other studies [Perrin et al., 2007]. Second, because the wording of our questions, which started with the phrase “since the disaster” did not specify a time period, we could not be sure what time period (baseline or follow-up) a respondent who answered yes on both occasions

was referring to. However, judging by the number of firefighters with decreased symptoms at follow-up, it seems likely that individuals understood this to mean a more proximate time frame. Regardless of the interpretation, the definition of “delayed onset” remains the same.

Third, the cohort excluded 1,131 of 6,787 (16.7%) firefighters who were otherwise eligible for participation but lacked a follow-up interview within the designated time frame. Although demographic characteristics between cohort and non-cohort firefighters were largely similar, there were significant, albeit small, differences—particularly in the baseline prevalence of probable PTSD, the proportion of those arriving during the collapse, and age on 9/11. Fourth, we do not know the proportion of participants that were being treated for mental health symptoms, which could have impacted on our prevalence estimates. Fifth, non-health issues may have led to either under- or overestimation of our rates. Rates could have been overestimated if symptoms were exaggerated due to an interest in workers compensation, retirement disability, and civil litigation. This is unlikely, since mental health problems have rarely received financial compensation pre- or post-9/11. Rates might have been underestimated due to cultural factors in a uniformed workforce such as FDNY that discourages reporting mental health symptoms. Workers may also have been reluctant to report mental health symptoms and functional impairment at home or at work due to job-related concerns.

Finally, unknown stressors may have occurred between assessments and impacted on the prevalence of probable PTSD at follow-up. While one might presume that firefighting itself may be a repeated stressor, our experience with this workforce strongly argues the opposite—firefighting is considered a normal event and therefore not a stressor; only the unusual (e.g., terrorist event or a fire with high-death counts or the death of a child or co-worker) is a stressor. For this reason, we also do not presume that normal work as a firefighter made the cohort more susceptible to probable PTSD due to ongoing stressors. We do not have individual-level data to support this, but note that during the time interval between the first and second examinations, FDNY experienced no terrorist events or fires with high-death counts and exposure to fires with the death of a child or co-worker was rare. There may have been other stressors, not related to work such as a death in the family that could have impacted outcomes, but, again, we do not have data to support this.

We believe that the strengths of this work outweigh its limitations. This is the first study to report on delayed onset probable PTSD in the FDNY population, a large, homogeneous group with severe and prolonged exposures to the WTC. Because active FDNY firefighters are routinely screened at regularly scheduled exams, our population is less likely to be self-selected compared with other studies. We confirmed exposure-response gradients based on Arrival

Group and work duration at the WTC site, and reported strong associations between probable PTSD and functional impairment. We also found that the prevalence of probable PTSD increased over time. Early identification of those with sub-threshold PTSD, high-risk exposure or increased alcohol use at an early screening may present an opportunity to offer mental health services before symptoms become chronic and compromise work and social relationships.

REFERENCES

- Adams RE, Boscarino JA. 2006. Predictors of PTSD and delayed PTSD after disaster: The impact of exposure and psychosocial resources. *J Nerv Ment Dis* 194(7):485–493.
- Adams RE, Boscarino JA, Galea S. 2006. Alcohol use, mental health status and psychological well-being 2 years after the World Trade Center attacks in New York City. *Am J Drug Alcohol Abuse* 32(2):203–224.
- Andreasen NC. 2004. Acute and delayed posttraumatic stress disorders: A history and some issues. *Am J Psychiatry* 161:1321–1323.
- Andrews B, Brewin CR, Philpott R, Stewart L. 2007. Delayed-onset posttraumatic stress disorder: A systematic review of the evidence. *Am J Psychiatry* 164:1319–1326.
- Andrews B, Brewin CR, Stewart L, Philpott R, Hejdenberg J. 2009. Comparison of immediate-onset and delayed-onset posttraumatic stress disorder in military veterans. *J Abnorm Psychol* 118(4):767–777.
- Berninger A, Webber MP, Cohen HW, Gustave J, Lee R, Niles JK, Chiu S, Zeig-Owens R, Kelly K, Prezant DJ. 2010. Trends of elevated PTSD risk in firefighters exposed to the World Trade Center disaster: 2001–2005. *Public Health Rep* 125(4):556–566.
- Brackbill RM, Hadler JL, DiGrande L, Ekenga CC, Farfel MR, Friedman S, Perlman SE, Stellman SD, Walker DJ, Wu D, Yu S, Thorpe LE. 2009. Asthma and posttraumatic stress symptoms 5 to 6 years following exposure to the World Trade Center terrorist attack. *JAMA* 302:502–516.
- Corrigan M, McWilliams R, Kelly KJ, Niles J, Cammarata C, Jones K, Glass L, Wartenberg D, Halliman W, Kipien H, Schorr J, Prezant DJ. 2009. Mental health outcomes in the FDNY firefighter World Trade Center cohort—A study based on a self-administered, computerized survey with 2.5 years of follow-up. *Am J Public Health* 99(Suppl 3):S702–S709.
- DiGrande L, Perrin MA, Thorpe LE, Thalji L, Murphy J, Wu D, Farfel M, Brackbill RM. 2008. Posttraumatic stress symptoms, PTSD, and risk factors among lower Manhattan residents 2–3 years after the September 11, 2001 terrorist attacks. *J Trauma Stress* 21:264–273.
- Edelman P, Osterloh J, Pirkle J, Caudill SP, Grainger J, Jones R, Blount B, Calafat A, Turner W, Feldman D, Baron S, Bernard B, Lushniak BD, Kelly K, Prezant D. 2003. Biomonitoring of chemical exposure among New York City firefighters responding to the World Trade Center fire and collapse. *Environ Health Perspect* 111:1906–1911.
- Fullerton CS, Ursano RJ, Wang L. 2004. Acute stress disorder, posttraumatic stress disorder, and depression in disaster or rescue workers. *Am J Psychiatry* 161:1370–1376.
- Galea S, Vlahov D, Resnick H, Ahern J, Susser E, Gold J, Bucuvalas M, Kilpatrick D. 2003. Trends of probable post-traumatic stress disorder in New York City after the September 11 terrorist attacks. *Am J Epidemiol* 158:514–524.
- Galea S, Ahern J, Tracy M, Hubbard A, Cerda M, Goldmann E, Vlahov D. 2008. Longitudinal determinants of posttraumatic stress in a population-based cohort study. *Epidemiology* 19:47–54.

- Hien DA, Jiang H, Campbell AN, Hu MC, Miele GM, Cohen LR, Brigham GS, Capstick C, Kulaga A, Robinson J, Suarez-Morales L, Nunes EV. 2010. Do treatment improvements in PTSD severity affect substance use outcomes? A secondary analysis from a randomized clinical trial in NIDA's Clinical Trials Network. *Am J Psychiatry* 167(1):95–101.
- Landrigan PJ, Lioy PJ, Thurston G, Berkowitz G, Chen LC, Chillrud SN, Gavett SH, Georgopoulos PG, Geyh AS, Levin S, Perera F, Rappaport SM, Small C. 2004. Health and environmental consequences of the World Trade Center disaster. *Environ Health Perspect* 112:731–739.
- Lioy PJ, Weisel CP, Millette JR, Eisenreich S, Vallero D, Offenber J, Buckley B, Turpin B, Zhong M, Cohen MD, Prophete C, Yang I, Stiles R, Chee G, Johnson W, Porcja R, Alimokhtari S, Hale RC, Weschler C, Chen LC. 2002. Characterization of the dust/smoke aerosol that settled east of the World Trade Center (WTC) in lower Manhattan after the collapse of the WTC 11 September 2001. *Environ Health Perspect* 110:703–714.
- McGee JK, Chen LC, Cohen MD, Chee GR, Prophete CM, Haykal-Coates N, Wasson SJ, Conner TL, Costa DL, Gavett SH. 2003. Chemical analysis of World Trade Center fine particulate matter for use in toxicologic assessment. *Environ Health Perspect* 111:972–980.
- Milliken CS, Auchterlonie JL, Hoge CW. 2007. Longitudinal assessment of mental health problems among active and reserve component soldiers returning from the Iraq war. *JAMA* 298:2141–2148.
- North CS, Pfefferbaum B, Tivis L, Kawasaki A, Reddy C, Spitznagel EL. 2004. The course of posttraumatic stress disorder in a follow-up study of survivors of the Oklahoma City bombing. *Ann Clin Psychiatry* 16:209–215.
- Perrin MA, DiGrande L, Wheeler K, Thorpe L, Farfel M, Brackbill R. 2007. Differences in PTSD prevalence and associated risk factors among World Trade Center disaster rescue and recovery workers. *Am J Psychiatry* 164:1385–1394.
- Prezant DJ, Weiden M, Banauch GI, McGuinness G, Rom WN, Aldrich TK, Kelly KJ. 2002. Cough and bronchial responsiveness in firefighters at the World Trade Center site. *N Engl J Med* 347:806–815.
- Smid GE, Mooren TT, van der Mast RC, Gersons BP, Kleber RJ. 2009. Delayed posttraumatic stress disorder: Systematic review, meta-analysis, and meta-regression analysis of prospective studies. *J Clin Psychiatry* 70(11):1572–1582.
- Stellman JM, Smith RP, Katz CL, Sharma V, Charney DS, Herbert R, Moline J, Luft BJ, Markowitz S, Udasin I, Harrison D, Baron S, Landrigan PJ, Levin SM, Southwick S. 2008. Enduring mental health morbidity and social function impairment in World Trade Center rescue, recovery, and cleanup workers: The psychological dimension of an environmental health disaster. *Environ Health Perspect* 116:1248–1253.
- Vetter S, Rossegger A, Rossler W, Bisson JI, Endrass J. 2008. Exposure to the tsunami disaster, PTSD symptoms and increased substance use—An Internet based survey of male and female residents of Switzerland. *BMC Public Health* 8:92.