Asthma and Posttraumatic Stress Symptoms 5 to 6 Years Following Exposure to the World Trade Center Terrorist Attack

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Context The World Trade Center Health Registry provides a unique opportunity to examine long-term health effects of a large-scale disaster.

Objective To examine risk factors for new asthma diagnoses and event-related posttraumatic stress (PTS) symptoms among exposed adults 5 to 6 years following exposure to the September 11, 2001, World Trade Center (WTC) terrorist attack.

Design, Setting, and Participants Longitudinal cohort study with wave 1 (W1) enrollment of 71 437 adults in 2003-2004, including rescue/recovery worker, lower Manhattan resident, lower Manhattan office worker, and passersby eligibility groups; 46 322 adults (68%) completed the wave 2 (W2) survey in 2006-2007.

Main Outcome Measures Self-reported diagnosed asthma following September 11; event-related current PTS symptoms indicative of probable posttraumatic stress disorder (PTSD), assessed using the PTSD Checklist (cutoff score ≥44).

Results Of W2 participants with no stated asthma history, 10.2% (95% confidence interval [CI], 9.9%-10.5%) reported new asthma diagnoses postevent. Intense dust cloud exposure on September 11 was a major contributor to new asthma diagnoses for all eligibility groups: for example, 19.1% vs 9.6% in those without exposure among rescue/recovery workers (adjusted odds ratio, 1.5 [95% CI, 1.4-1.7]). Asthma risk was highest among rescue/recovery workers on the WTC pile on September 11 (20.5% [95% CI, 19.0%-22.0%]). Persistent risks included working longer at the WTC site, not evacuating homes, and experiencing a heavy layer of dust in home or office. Of participants with no PTSD history, 23.8% (95% CI, 23.4%-24.2%) reported PTS symptoms at either W1 (14.3%) or W2 (19.1%). Nearly 10% (9.6% [95% CI, 9.3%-9.8%]) had PTS symptoms at both surveys, 4.7% (95% CI, 4.5%-4.9%) had PTS symptoms at W1 only, and 9.5% (95% CI, 9.3%-9.8%) had PTS symptoms at W2 only. At W2, passersby had the highest rate of PTS symptoms (23.2% [95% CI, 21.4%-25.0%]). Event-related loss of spouse or job was associated with PTS symptoms at W2.

Conclusion Acute and prolonged exposures were both associated with a large burden of asthma and PTS symptoms 5 to 6 years after the September 11 WTC attack.

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THE SEPTEMBER 11, 2001, TERRORist attack on the World Trade Center (WTC) killed thousands and exposed hundreds of thousands to horrific events and potentially harmful environmental conditions resulting from the collapsing towers and fires.[1-3] Studies have documented adverse respiratory and mental health conditions associated with direct exposure within 1 to 3 years following the event,[4-12] but most have focused on health effects in subgroups with common exposures, such as firefighters,[5,10,13] rescue/recovery workers,[6,9,11,14-17] or residents of lower Manhattan.[8,12,18-21] However, the longer-term impact on health is unclear, and the capacity to compare patterns of association across affected subgroups has been limited. Few studies have followed the health of rescue workers for more than 3 years after September 11,[16,22,23] and only 1 study of New York City residents reported the longitudinal course of probable posttraumatic stress disorder (PTSD) 3 years after the event.[24]

The World Trade Center Health Registry, the largest postdisaster exposure registry in US history, prospectively follows a cohort that reported a range of WTC disaster–associated

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exposures on September 11 and during its immediate aftermath. This study describes the cumulative burden of 2 of the most commonly reported health outcomes: asthma and posttraumatic stress (PTS) symptoms indicative of probable PTSD among adult enrollees 5 to 6 years after September 11. We also characterize disease severity, quality of life, and health care utilization and examine associations between September 11 exposures and outcomes.

METHODS

Study Population

The World Trade Center Health Registry, as described elsewhere,[7,25] was established to prospectively monitor the physical and mental health of persons with a high probability of direct exposure to the September 11 terrorist attack and its aftermath, including rescue/recovery workers, persons with a primary residence in lower Manhattan on September 11, and office workers and passersby present in lower Manhattan on the morning of September 11. The Centers for Disease Control and Prevention and New York City Health Department institutional review boards approved the registry protocols. A Federal Certificate of Confidentiality was obtained, as was oral informed consent.

Eligibility groups were categorized in a mutually exclusive, hierarchical order, with rescue/recovery workers first, followed by lower Manhattan residents, lower Manhattan office workers, and passersby on September 11. For example, a resident who was also a rescue/recovery worker was classified as a rescue/recovery worker only. Staff or student participants 18 years or older at wave 1 (W1) who were not also rescue/recovery workers or residents and who were not present south of Chambers Street on September 11 were excluded from specific eligibility group analyses (n=85 in wave 2 [W2]).

The number of persons eligible for the registry was estimated to be approximately 409 000, of whom 71 437 (17.4%) enrolled.[25] Outreach and multilingual media campaigns encouraged enrollment through a toll-free number or Web site (classified as "self-identified").[26] Lists of persons potentially exposed were provided by entities such as employers and governmental agencies (classified as "list-identified").[7] Final enrollment was 70% self-identified and 30% list-identified.

Wave 1 interviews were conducted September 2003 through November 2004; 95% were conducted using computer-assisted telephone interviews (CATIs), and the remainder used computer-assisted in-person interviews. Wave 1 included demographics, event-related exposures, and pre-event and postevent physical and mental health. The methods and findings of W1 have been previously published.[4,7,9,11,12,25,27]

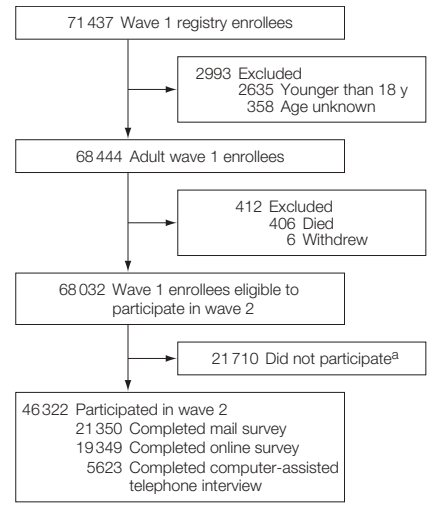
The potential impact of self-selection bias in W1 registry enrollment has been described in other reports. Wave 1 studies examining either asthma or probable PTSD included subanalyses of list-identified participants to measure self-selection influences.[9,11,12] In each, health effects were higher among self- vs list-identified participants. These conditions among list-identified participants remained elevated compared with available background levels, and in most cases the observed associations between September 11 exposures and health conditions remained significant. List-identified participants may still reflect some selection bias, but in one prior study among lower Manhattan residents, the most well-defined and geographically bounded of eligibility groups, a sensitivity analysis using raking ratio estimation and Census demographics found that estimated probable PTS symptoms did not decrease significantly after accounting for underrepresented resident groups.[12]

Data Collection

The W2 survey was developed to assess the health status of enrollees 5 to 6 years after the WTC attack. Enrollees 18 years or older (n=68 032) at the time of the W2 survey launch were included; those excluded were deceased enrollees (n=406), withdrawals (n=6), and those with unknown age (n=358) (FIGURE 1). Wave 2 was conducted from November 2006 through December 2007, using 2 initial data collection modes: an Internet-based survey and a mail survey. Enrollees with valid e-mail addresses (63%) received an electronic invitation to access the online survey, which was only available in English. Paper questionnaires were mailed to the remaining enrollees based on enrollees' W1 interview language. A reminder postcard and e-mail invitation were mailed 3 weeks after W2 launch. Six subsequent e-mails and 3 postcard reminders were sent. Two additional rounds of paper questionnaires were mailed to nonrespondents.

In the last 3 months of data collection, nonparticipants (Figure 1) were recontacted for CATI participation. At least 1 attempt was made to call nonrespondents with valid numbers, and as many as 30 call attempts were made to underrepresented enrollee groups (list-identified, those with household income less than $35 000, young adults, sanitation workers, Spanish and Chinese speakers, and lower Manhattan residents).

Figure 1. Sampling Stages of the World Trade Center Health Registry



[a]During the wave 2 survey period (September 2006 launch through December 31, 2007, completion), there were an additional 207 deaths reported and an additional 58 withdrawals among these 21 710 participants.

Study Variables

Wave 2 assessed current physical and mental health status, clarified reported W1 exposures, and measured health care utilization and quality of life. The primary respiratory outcome was a self-reported first lifetime diagnosis of asthma or reactive airways dysfunction syndrome after September 11, collectively referred to as "asthma."[28] Participants reported whether they were ever diagnosed by a physician as having asthma or reactive airways dysfunction syndrome, the year of diagnosis, and, if in 2001, whether diagnosis occurred before or after September 11. Postevent asthma was further categorized as early, late, or unknown date of diagnosis. "Early" was defined as an asthma diagnosis between September 11, 2001, and the end of 2003, corresponding to the approximate time frame of W1 initiation; "late" was defined as a diagnosis between January 2004 and December 2007. Participants reporting a new asthma diagnosis after September 11 but not reporting the year were categorized as postevent, date unknown. Asthma diagnoses established before September 11 were categorized as pre-event asthma. Treatment and severity of asthma were assessed with questions regarding use of an inhaler for asthma control, asthma attack, or asthma-related emergency department visit in the previous 12 months. Respiratory symptoms assessed in W1 included new or worsening wheezing, shortness of breath, and persistent cough after September 11. Wave 2 assessed whether participants experienced these same symptoms in the 30 days prior to survey.

The primary mental health outcome was current event-related PTS symptoms indicative of probable PTSD. This was assessed with the stressor-specific PTSD Checklist (PCL),[29] a 17-item self-report instrument based on *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) criteria[30] and linked to a specific traumatic exposure (ie, "the events of September 11"). Respondents scored each symptom experienced during the past 30 days on a 5-point scale; a score of 44 or greater was indicative of probable PTSD. Psychometric properties of the PCL used in this manner have been reported by others in a variety of settings and traumas, with sensitivity ranging from 0.94 to 0.97, specificity from 0.86 to 0.99, positive predictive value from 0.70 to 0.97, and diagnostic efficiency from 0.83 to 0.96.[29,31-33]

Participants also reported whether they had been diagnosed with PTSD or depression by a health professional before or after September 11 and whether they had received counseling or used prescription medication for mental health in the past 12 months. For both physical and mental health, quality of life was measured by self-report of health not being good for 14 or more of the past 30 days and whether poor health prevented usual activities for 14 or more of the past 30 days.[34]

Disaster-related exposures were defined by common experiences and by exposures unique to subgroups.[7] Dust cloud exposure on September 11 has been associated with adverse physical as well as mental health outcomes.[4,7,9,11,12,21] This exposure was stratified into "some" vs "intense" exposure. Intense dust cloud exposure was defined as answering "yes" to being caught in the dust or debris cloud on September 11 in W1 and answering "yes" to any of the 5 additional W2 questions (could not see a couple of feet in front of me; had trouble walking or finding my way because the dust was so thick; had to find shelter such as under a car or in a doorway; was covered from head to toe with dust or debris; could not hear anything).[7] "Some" dust cloud exposure was defined as answering "yes" to being caught in the dust or debris cloud on September 11 and reporting a geocodable location in lower Manhattan, as previously described.[7]

Postevent exposure varied by eligibility group. For rescue/recovery workers, additional variables included number of days worked at the WTC site between the attack and when recovery operations ceased on June 30, 2002. Start date for WTC work was categorized according to pile work on September 11, another WTC site on September 11, and a WTC site between September 12 and September 17, 2001, or between September 18, 2001, and June 2002. For residents, measures included whether they evacuated from home and the extent of home damage (none, damage without heavy layer of dust, or a heavy layer of dust with or without damage). For office workers, extent of damage to the office was measured analogously. Exposure variables examined for association with asthma were limited to disaster-related respiratory exposures.

For PTS symptoms, potential peri-event risk factors included personally witnessing horror on September 11 (eg, individuals jumping or falling from buildings), being injured on September 11, and evacuation of or damage to home or office. Postevent risk factors included knowing someone killed in the September 11 attack, little or no social support, and job loss.

Covariates included sociodemographic characteristics, W1 smoking status, W1 source (self- vs list-identified), and W2 survey mode (paper, Web, or telephone).

Data Analysis

Enrollees 18 years or older at W1 and who completed W2 were included in the current analyses. SAS version 9.1 (SAS Institute Inc, Cary, North Carolina) was used to compare W2 participants and nonparticipants by demographics, eligibility group, exposures, and W1 health outcome responses, using χ^2 tests. For all analyses, P values involved hypothesis tests against a 2-sided alternative and were considered significant when $P < .05$. Given the large number of statistical tests, some significant findings could arise by chance. We attempted to limit this by focusing testing on epidemiologically plausible associations suggested by previous reports and examining for dose-related associations.

To measure incidence of postevent asthma diagnoses, persons who re-

ported pre-event asthma diagnoses were excluded. For persons with available year of diagnosis at W2, the annualized rate of new asthma diagnoses between 2001 and 2006 was calculated. For 2001, the number of cases diagnosed between September 11 and December 31, 2001, was multiplied by 3.25 to calculate the annualized rate for that year. To measure PTS symptoms, persons with a pre-event diagnosis of PTSD were excluded. Symptom course was characterized by combining results from the 2 time points: no symptoms indicative of probable PTSD (PCL score <44 at both W1 and W2), resolved symptoms (≥44 at W1 only), late-onset symptoms (≥44 at W2 only), and chronic symptoms (≥44 at both W1 and W2).[29]

Multivariable logistic regression was used to ascertain the independent association between exposures of interest and the 2 main health outcomes (postevent asthma and PTS symptoms at W2). Because of potential biases associated with self- vs list-identification in W1 and survey mode in W2, these variables were included in all models. Demographic covariates were included in the multivariable models.

Using previously published methods,[7] a range of the burden of postevent asthma and PTS symptoms was derived for the 409 000 persons estimated to be eligible for the registry.[25] Disease rates for self- and list-identified enrollees from W2 were multiplied by the respective estimated population exposed. To address potential selection bias attributable to the higher prevalence of disease among self- vs list-identified persons, the midpoint estimate was based on disease rates among list-identified enrollees only. An upper bound estimate was calculated using rates among self-identified enrollees, and a lower bound estimate was calculated assuming that, even among those list-identified, those who were sick were 50% more likely to enroll than others. Calculations were performed by eligibility group, and the results were summed. Estimates were rounded to the nearest hundred.

RESULTS

Response Rates

A total of 46 322 participants 18 years or older at W1 participated in W2 and were included in this analysis (68.1% response rate). Mail surveys accounted for 46.1% of completed questionnaires, followed by Web surveys (41.8%) and CATIs (12.1%). At the time of CATI initiation, the response rate to mail and Web surveys was 59%. The CATI-specific response rate among mail/Web nonresponders was 21%.

Online eTable 1 (available at http://www.jama.com) compares W1 characteristics of participants and nonparticipants. Response rates were higher among self-identified participants, English speakers, men, persons aged 45 through 64 years, non-Hispanic whites, those with higher household income, and former smokers. Responses were highest for rescue/recovery workers (71.0%) and lowest for residents (60.2%). Response rates did not vary by type of exposure. Wave 2 participants had a slightly higher incidence of newly diagnosed asthma at W1 than W2 nonrespondents (3.0% [95% confidence interval {CI}, 2.8%-3.1%] vs 2.7% [95% CI, 2.4%-2.9%], $P=.02$) and a significantly lower prevalence of PTS symptoms at W1 (14.4% [95% CI, 14.1%-14.7%] vs 18.2% [95% CI, 17.7%-18.7%], $P<.001$).

Asthma

The reported cumulative lifetime prevalence of asthma prior to September 11 was 11.1% (95% CI, 10.8%-11.3%) (TABLE 1) and varied by demographic group, with the highest rates among women, those of youngest age, and Hispanics. Overall postevent incidence among those without a prior history of asthma was 10.2% (95% CI, 9.9%-10.5%). Incidence varied significantly across eligibility groups. Rescue/recovery workers had higher postevent asthma diagnosis rates than the next highest group, passersby on September 11 (12.2% [95% CI, 11.8%-12.7%] vs 8.6% [95% CI, 7.3%-9.8%]).

For all eligibility groups combined, intense dust cloud exposure was associated with postevent diagnoses of asthma (13.5% [95% CI, 12.9%-14.1%] vs 8.4% [95% CI, 8.0%-8.8%] for no dust cloud exposure) (Table 1). Thirty-nine percent (n=1604/4098) of all respondents reporting postevent diagnoses of asthma also reported intense dust cloud exposure.

At the time of W2, respondents with asthma diagnosed after September 11 were more symptomatic, required more treatment, and reported a lower quality of life than those with asthma diagnosed before September 11 (TABLE 2).

Among respondents reporting asthma diagnosed after September 11, symptom or severity differences were examined for those diagnosed early (2001-2003) and late (2004-2006) and for those whom year of diagnosis could not be determined. Across all 3 groups, there were notable differences in prevalence of symptoms at W1 in 2003. Adults with early diagnosed asthma had the highest prevalence of respiratory symptoms at W1 (wheezing, 89.7% [95% CI, 88.1%-91.3%]; shortness of breath, 91.2% [95% CI, 89.7%-92.7%]; and persistent cough, 78.7% [95% CI, 76.5%-80.8%]). Adults for whom year of asthma diagnosis could not be determined had a prevalence of respiratory symptoms nearly comparable to the early diagnosis group at W1 (wheezing, 79.5% [95% CI, 77.5%-81.5%]; shortness of breath, 80.6% [95% CI, 78.6%-82.5%]; and persistent cough, 67.1% [95% CI, 64.8%-69.4%]). Adults with late asthma diagnosis had a prevalence less than the early diagnosis group but generally higher than the pre-event diagnosis group (wheezing, 56.9% [95% CI, 54.0%-59.9%]; shortness of breath, 59.8% [95% CI, 56.9%-62.7%]; and persistent cough, 53.2% [95% CI, 50.3%-56.2%]).

FIGURE 2 shows the annualized incidence of postevent asthma diagnoses by year for adults with reliable dates (2483/4098 [60.6%]). Diagnosis rates were especially high during the final months of 2001, with rapid tapering and stabilization of new asthma diagnoses by 2003.

Table 1. Asthma Diagnosed Before September 11 and Incident Diagnoses of Asthma Since September 11, 2001, by WTCHR Wave 1 Characteristics and Event-Related Exposures

Wave 1 Characteristic	Adult Participants, Wave 2 Survey, No.[a]	Pre–September 11 Asthma, No. (% [95% CI])	Participants Asthma-Free Prior to Event, No.	Newly Diagnosed Asthma Since Event, No. (% [95% CI])
Total adults	46 322	5123 (11.1 [10.8-11.3])	40 224	4098 (10.2 [9.9-10.5])
Source of interview				
Self-identified	34 124	3940 (11.5 [11.2-11.9])	29 425	3381 (11.5 [11.1-11.9])
List-identified	12 198	1183 (9.7 [9.1-10.2])	10 799	717 (6.6 [6.2-7.1])
Sex[a]				
Male	28 339	2600 (9.2 [8.8-9.5])	25 195	2419 (9.6 [9.2-10.0])
Female	17 982	2523 (14.0 [13.5-14.5])	15 028	1679 (11.2 [10.7-11.7])
Age at wave 1 interview, y				
18-24	1427	224 (15.7 [13.8-17.6])	1168	95 (8.1 [6.6-9.7])
25-44	22 001	2541 (11.5 [11.1-12.0])	19 001	1987 (10.5 [10.0-10.9])
45-64	20 691	2176 (10.5 [10.1-10.9])	18 089	1895 (10.5 [10.0-10.9])
≥65	2203	182 (8.3 [7.1-9.4])	1966	121 (6.2 [5.1-7.2])
Race/ethnicity				
Non-Hispanic white	32 193	3312 (10.3 [10.0-10.6])	28 296	2683 (9.5 [9.1-9.8])
Non-Hispanic black	4725	578 (12.3 [11.3-13.2])	4042	418 (10.3 [9.4-11.3])
Hispanic	5287	795 (15.0 [14.1-16.0])	4351	644 (14.8 [13.7-15.9])
Asian	2578	239 (9.3 [8.2-10.4])	2265	209 (9.2 [8.0-10.4])
Other	1539	199 (12.9 [11.3-14.6])	1270	144 (11.3 [9.6-13.1])
Total household income at wave 1, $				
<25 000	3766	454 (12.1 [11.0-13.1])	3179	404 (12.7 [11.6-13.9])
25 000-<50 000	8236	984 (11.9 [11.2-12.6])	7073	776 (11.0 [10.2-11.7])
50 000-<75 000	9104	972 (10.7 [10.0-11.3])	7956	862 (10.8 [10.2-11.5])
75 000-<150 000	15 465	1591 (10.3 [9.8-10.8])	13 596	1379 (10.1 [9.6-10.7])
≥150 000	5241	621 (11.8 [11.0-12.7])	4531	337 (7.4 [6.7-8.2])
Missing	4510	501 (11.1 [10.2-12.0])	3889	340 (8.7 [7.9-9.6])
Smoking status at interview[a]				
Never	26 087	2897 (11.1 [10.7-11.5])	22 643	2330 (10.3 [9.9-10.7])
Former	13 149	1467 (11.2 [10.6-11.7])	11 435	1158 (10.1 [9.6-10.7])
Current	6822	723 (10.6 [9.9-11.3])	5956	595 (10.0 [9.2-10.8])
Eligibility groups				
Rescue/recovery workers and volunteers	21 605	2009 (9.3 [8.9-9.7])	19 161	2347 (12.2 [11.8-12.7])
Lower Manhattan residents	6590	823 (12.5 [11.7-13.3])	5594	445 (8.0 [7.2-8.7])
Lower Manhattan office workers	15 759	1960 (12.4 [11.9-13.0])	13 489	1137 (8.4 [8.0-8.9])
Passersby on September 11	2283	315 (13.8 [12.4-15.2])	1913	164 (8.6 [7.3-9.8])
Dust cloud exposure[a]				
None	24 350	2628 (10.8 [10.4-11.2])	21 256	1787 (8.4 [8.0-8.8])
Some	6421	731 (11.4 [10.6-12.2])	5542	496 (9.0 [8.2-9.7])
Intense	13 770	1572 (11.4 [10.9-11.9])	11 887	1604 (13.5 [12.9-14.1])
Rescue/recovery workers and volunteers				
No. of days worked at WTC site				
1-7	6949	801 (11.5 [10.8-12.3])	5997	548 (9.1 [8.4-9.9])
8-30	5977	493 (8.2 [7.6-8.9])	5374	646 (12.0 [11.2-12.9])
31-90	3436	268 (7.8 [6.9-8.7])	3104	466 (15.0 [13.8-16.3])
>90	3426	267 (7.8 [6.9-8.7])	3088	533 (17.3 [15.9-18.6])
Time of arrival for rescue/recovery workers				
September 11, on pile	3179	175 (5.5 [4.7-6.3])	2931	600 (20.5 [19.0-22.0])
September 11, other WTC site location	2912	302 (10.4 [9.3-11.5])	2556	330 (12.9 [11.6-14.2])
September 12-17, any WTC site	8551	808 (9.4 [8.8-10.1])	7576	941 (12.4 [11.7-13.2])
September 18, 2001, to June 2002, any WTC site	6141	635 (10.3 [9.6-11.1])	5381	422 (7.8 [7.1-8.6])

(continued)

Table 1. Asthma Diagnosed Before September 11 and Incident Diagnoses of Asthma Since September 11, 2001, by WTCHR Wave 1 Characteristics and Event-Related Exposures (continued)

Wave 1 Characteristic	Adult Participants, Wave 2 Survey, No.[a]	Pre–September 11 Asthma, No. (% [95% CI])	Participants Asthma-Free Prior to Event, No.	Newly Diagnosed Asthma Since Event, No. (% [95% CI])
Lower Manhattan residents				
Evacuation of home				
Did not evacuate	2302	275 (11.9 [10.6-13.3])	1941	183 (9.4 [8.1-10.7])
Evacuated	4281	548 (12.8 [11.8-13.8])	3646	261 (7.2 [6.3-8.0])
Damage to home				
None	4744	582 (12.3 [11.3-13.2])	4030	293 (7.3 [6.5-8.0])
Damage without heavy layer of dust	795	104 (13.0 [10.7-15.4])	675	61 (9.0 [6.9-11.2])
Heavy layer of dust with or without damage	1043	135 (12.9 [10.9-15.0])	883	91 (10.3 [8.3-12.3])
Lower Manhattan office workers				
No office damage	11 850	1475 (12.4 [11.9-13.0])	10 165	790 (7.8 [7.3-8.3])
Damage without heavy layer of dust	2289	274 (12.0 [10.6-13.3])	1962	175 (8.9 [7.7-10.2])
Heavy layer of dust with or without damage	1602	206 (12.9 [11.2-14.5])	1349	171 (12.7 [10.9-14.5])

Abbreviations: CI, confidence interval; WTCHR, World Trade Center Health Registry.
[a] Does not sum to total because of missing values (1 [sex], 264 [smoking status], 1781 [dust cloud exposure]).

Using multivariable analyses, the independent effects of different exposure factors were examined, adjusting for demographics, W1 recruitment source, and W2 mode of response (TABLE 3, TABLE 4, and TABLE 5; full models in online eTables 2 and 3). These analyses confirm that intense dust cloud exposure was associated with new asthma diagnoses for each eligibility group, including the 1913 passersby who only had exposure to the area air and dust on September 11 (10.3% with intense dust cloud exposure vs 7.0% with no exposure; adjusted OR [OR], 1.4 [95% CI, 1.0-2.0]). Most other risk factors identified in bivariate analyses persisted across eligibility groups after controlling for dust cloud exposure. Among rescue/recovery workers, risk for asthma was highest among those who worked on the pile on September 11 (20.5% vs 7.8%; adjusted OR, 2.2 [95% CI, 1.9-2.6]), with risk diminishing with later start dates. Independent of date of arrival at the WTC site, risk of asthma increased with length of time worked (17.3% vs 9.1%; adjusted OR for >90 days, 1.9 [95% CI, 1.6-2.1]). Asthma risk also was independently associated with some damage to home or office, and risk was highest if there was a heavy coating of dust at home (10.3% vs 7.3% with no home damage; adjusted OR, 1.5 [95% CI, 1.1-1.9]) or at the office (12.7% vs 7.8% with no office damage; adjusted OR, 1.5 [95% CI, 1.3-1.8]). Among residents, those who did not evacuate reported higher rates of asthma than those who did (9.4% vs 7.2%; adjusted OR, 1.4 [95% CI, 1.1-1.7]).

Analyses using only those cases for which diagnosis year was provided showed that the association with intense dust cloud exposure for all groups combined diminished over time from an adjusted OR of 1.6 (95% CI, 1.4-1.8) to 1.2 but remained significant (95% CI, 1.1-1.4) (eTable 4). The cumulative incidence of late-diagnosed asthma in all persons without any respiratory symptoms at W1 was 1.3% (95% CI, 1.2%-1.5% [n=236/17 784]), compared with 4.7% (95% CI, 4.4%-5.0% [n=864/18 342]) in those with at least 1 W1 symptom.

Among respondents who reported postevent asthma, those who also reported intense dust cloud exposure were more likely to have respiratory symptoms, need treatment, and have a lower quality of life than those who reported some or no dust cloud exposure (wheezing in the past 30 days: 69.2% [95% CI, 66.9%-71.5%] [n=1077/1557] vs 58.5% [95% CI, 56.5%-60.6%] [n=1291/2206]; having ≥2 emergency department visits for asthma in the past year: 14.4% [95% CI, 12.7%-16.1%] [n=231/1604] vs 9.3% [95% CI, 8.1%-10.5%] [n=213/2283]; and ≥14 days of poor physical health in the past month: 49.2% [95% CI, 46.3%-52.2%] [n=542/1101] vs 40.7% [95% CI, 38.1%-43.3%] [n=549/1349]).

PTS Symptoms

Of the 43 032 adults without a diagnosis of PTSD before September 11, 23.8% (95% CI, 23.4%-24.2%) screened positive for PTS symptoms indicative of probable PTSD at either W1 (14.3% [95% CI, 13.9%-14.6%]) or W2 (19.1% [95% CI, 18.7%-19.5%]) (TABLE 6). The prevalence of PTS symptoms increased from W1 to W2 in every eligibility group, with the greatest increase occurring among rescue/recovery workers (12.1% [95% CI, 11.7%-12.6%] at W1 vs 19.5% [95% CI, 18.9%-20.0%] at W2). Still, at W2, passersby had the highest levels of symptoms (23.2% [95% CI, 21.4%-25.0%]), while residents had the lowest (16.3% [95% CI, 15.4%-17.2%]).

TABLE 7 displays the distribution of participant characteristics by PTS symptom course (chronic, late-onset, resolved, no symptoms indicative of probable PTSD). Among participants with PTS measured at W1 and W2, 9.6% (95% CI, 9.3%-9.8%) had chronic symptoms, 9.5% (95% CI, 9.3%-9.8%) had late-onset symptoms, and

4.7% (95% CI, 4.5%-4.9%) had symptoms that had resolved. Participants with chronic symptoms had significantly higher mean PCL scores at W1 than those whose symptoms later resolved (56.5 vs 50.9, $t=26.6$, $P<.001$). Also, participants with late-onset PTS symptoms reported significantly higher mean PCL scores at W1 than those who never screened positive (32.9 vs 24.8, $t=72.8$, $P<.001$). At W2, participants with chronic symptoms had significantly higher scores than those with late-onset symptoms (59.5 vs 52.9, $t=32.8$, $P<.001$), and those whose symptoms resolved continued to have higher scores than those who never screened positive (33.6 vs 25.4, $t=50.3$, $P<.001$).

Across eligibility groups, passersby had the highest prevalence of chronic PTS symptoms (13.2% [95% CI, 11.8%-14.7%]), and office workers had the highest prevalence of resolved symptoms (6.1% [95% CI, 5.7%-6.5%]). Rescue/recovery workers had the highest prevalence of late-onset symptoms (10.8% [95% CI, 10.4%-11.2%]).

With regard to mental health diagnoses, 13.6% (95% CI, 13.2%-13.9%) of all participants previously free of PTSD reported receiving a PTSD diagnosis from a mental health professional since September 11, 14.0% (95% CI, 13.6%-14.3%) reported receiving a depression diagnosis, and 7.4% (95% CI, 7.2%-7.7%) reported receiving both. A much higher proportion of those with chronic PTS symptoms reported that they had received a professional diagnosis for PTSD (46.1% [95% CI, 44.6%-47.6%]) than those with late-onset symptoms (28.6% [95% CI, 27.2%-30.0%]) or resolved symptoms

Table 2. Symptoms, Severity, Treatment History, and Quality of Life Among WTCHR Registrants With Asthma, by Time of Diagnosis

	No. (% [95% CI])					
		New Asthma Diagnosis Since September 11				
Characteristic	Total	Early Diagnosis (2001-2003)	Late Diagnosis (2004-2006)	Undetermined Date of Diagnosis	Pre-Event Asthma Diagnosis	No Asthma[a]
Total adults, No.	4098	1382	1101	1615	5123	36 126
New-onset respiratory symptoms since wave 1						
Wheezing	3151 (76.9 [75.6-78.2])	1240 (89.7 [88.1-91.3])	627 (56.9 [54.0-59.9])	1284 (79.5 [77.5-81.5])	2787 (54.4 [53.0-55.8])	11 099 (30.7 [30.2-31.2])
Shortness of breath	3219 (78.6 [77.3-79.8])	1260 (91.2 [89.7-92.7])	658 (59.8 [56.9-62.7])	1301 (80.6 [78.6-82.5])	2734 (53.4 [52.0-54.7])	12 672 (35.1 [34.6-35.6])
Persistent cough	2757 (67.3 [65.8-68.7])	1087 (78.7 [76.5-80.8])	586 (53.2 [50.3-56.2])	1084 (67.1 [64.8-69.4])	1983 (38.7 [37.4-40.0])	11 835 (32.8 [32.3-33.2])
None	421 (10.3 [9.3-11.2])	36 (2.6 [1.8-3.4])	237 (21.5 [19.1-24.0])	148 (9.2 [7.8-10.6])	1740 (34.0 [32.7-35.3])	17 784 (49.2 [48.7-49.7])
Respiratory symptoms in last 30 d (wave 2)						
Wheezing	2513 (61.3 [59.8-62.8])	879 (63.6 [61.1-66.1])	650 (59.0 [56.1-61.9])	984 (60.9 [58.5-63.3])	2221 (43.4 [42.0-44.7])	5170 (14.3 [13.9-14.7])
Shortness of breath	2943 (71.8 [70.4-73.2])	1034 (74.8 [72.5-77.1])	771 (70.0 [67.3-72.7])	1138 (70.5 [68.2-72.7])	2530 (49.4 [48.0-50.8])	8727 (24.2 [23.7-24.6])
Persistent cough	2057 (50.2 [48.7-51.7])	748 (54.1 [51.5-56.8])	544 (49.4 [46.5-52.4])	765 (47.4 [44.9-49.8])	1407 (27.5 [26.2-28.7])	7955 (22.0 [21.6-22.4])
None	688 (16.8 [15.6-17.9])	205 (14.8 [13.0-16.7])	181 (16.4 [14.3-18.6])	302 (18.7 [16.8-20.6])	1988 (38.8 [37.5-40.1])	22 597 (62.6 [62.1-63.0])
Severity and treatment (wave 2)						
Had asthma attack in last 12 mo	2406 (58.7 [57.2-60.2])	850 (61.5 [58.9-64.1])	661 (60.0 [57.1-62.9])	895 (55.4 [53.0-57.8])	2282 (44.5 [43.2-45.9])	NA
Used an inhaler for asthma in last 12 mo	2659 (64.9 [63.4-66.3])	908 (65.7 [63.2-68.2])	760 (69.0 [66.3-71.8])	991 (61.4 [59.0-63.7])	2604 (50.8 [49.5-52.2])	NA
Visited ED 2 or more times in last 12 mo	494 (12.1 [11.1-13.1])	181 (13.1 [11.3-14.9])	113 (10.3 [8.5-12.1])	200 (12.4 [10.8-14.0])	411 (8.0 [7.3-8.8])	NA
Quality of life (wave 2)						
Physical health not good ≥14 d	1170 (28.6 [27.2-29.9])	442 (32.0 [29.5-34.4])	293 (26.6 [24.0-29.2])	435 (26.9 [24.8-29.1])	787 (15.4 [14.4-16.3])	3897 (10.8 [10.5-11.1])
Poor health prevented activities ≥14 d	1019 (24.9 [23.5-26.2])	403 (29.2 [26.8-31.6])	239 (21.7 [19.3-24.1])	377 (23.3 [21.3-25.4])	664 (13.0 [12.0-13.9])	3282 (9.1 [8.8-9.4])
Both	730 (17.8 [16.6-19.0])	295 (21.3 [19.2-23.5])	174 (15.8 [13.6-18.0])	261 (16.2 [14.4-18.0])	400 (7.8 [7.1-8.5])	1904 (5.3 [5.0-5.5])

Abbreviations: CI, confidence interval; ED, emergency department; NA, not applicable.
[a] Nine hundred seventy-five persons had missing information on asthma status.

(22.2% [95% CI, 20.4%-24.0%]), and one-third of individuals with chronic symptoms reported dual diagnoses of PTSD and depression. Twenty-one percent of participants (95% CI, 20.5%-21.3%) reported seeing a mental health professional in the past 12 months, and 14.2% (95% CI, 13.9%-14.5%) reported taking prescription medication for a mental health condition. Participants with chronic PTS symptoms were more likely to report receiving any form of mental health care in the last 12 months than those with late-onset PTS symptoms (53.4% [95% CI, 51.9%-54.9%] vs 41.9% [95% CI, 40.4%-43.4%]).

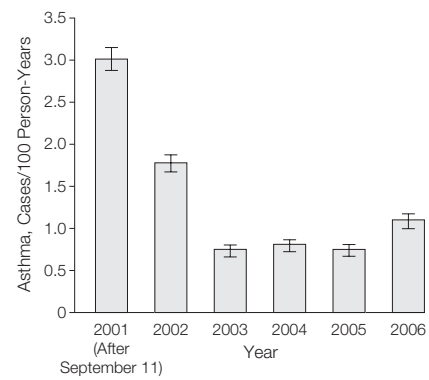
Of the W2 participants, 18.3% (95% CI, 17.9%-18.7%) reported poor mental health on at least 14 of 30 days prior to W2, and 10.5% (95% CI, 10.3%-10.8%) reported limited activity owing to poor health. Quality of life was worst for participants with chronic and late-onset PTS symptoms: 60.9% (95% CI, 59.4%-62.4%) with chronic symptoms and 48.3% (95% CI, 46.8%-49.8%) with late-onset symptoms reported 14 or more days of poor mental health in the 30 days prior to W2.

After adjusting for a pre-event diagnosis of depression and demographic and survey characteristics (TABLE 8, TABLE 9, and TABLE 10), intense dust cloud exposure was associated with current PTS symptoms indicative of probable PTSD at W2 across groups (rescue/recovery workers: 32.4% vs 14.2%; adjusted OR, 1.5 [95% CI, 1.3-1.6]; residents: 29.8% vs 10.1%; adjusted OR, 2.0 [95% CI, 1.6-2.4]; office workers: 26.8% vs 12.2%; adjusted OR, 1.7 [95% CI, 1.5-1.9]; and passersby: 33.1% vs 14.8%; adjusted OR, 1.8 [95% CI, 1.4-2.3]). Witnessing horror was also associated with PTS symptoms (adjusted ORs ranged from 1.3 [95% CI, 1.2-1.5] in rescue/recovery workers [25.1% vs 12.9%] to 2.2 [95% CI, 1.7-2.8] in residents [19.4% vs 7.2%,]), as was sustaining an injury. The risk for PTS symptoms was greater for participants who reported loss of a spouse, other family member, coworker, or acquaintance as a result of the terrorist attack, with the loss of a spouse associated with greatest risk (eg, 50.0% vs 13.4%; adjusted OR, 3.6 [95% CI, 1.6-8.1] among office workers).

Regarding peri-event risk factors for PTS symptoms at W2, rescue/recovery workers who worked longer periods (>90 days) were at increased risk (28.3% vs 16.3%; adjusted OR, 1.6 [95% CI, 1.4-1.8]). Also, workers who began work on September 11 were at greater risk than those who arrived after September 18 (28.0% vs 12.4%; adjusted OR, 1.3 [95% CI, 1.1-1.5]). Residents who reported heavy dust in the home were at higher risk for PTS symptoms than those who reported no damage or no heavy dust layer (28.5% vs 12.3%; adjusted OR, 2.2 [95% CI, 1.8-2.6]). Among office workers, a heavy layer of dust in the workplace similarly increased risk (33.8% vs 16.4%; adjusted OR, 2.0 [95% CI, 1.8-2.3]).

Postevent risk factors produced the greatest risks for PTS symptoms at W2. Job loss related to the event produced adjusted ORs ranging from 2.4 (95% CI, 1.9-3.1 [36.1% vs 11.7%]) among residents to 4.6 (95% CI, 4.0.-5.3 [56.4% vs 16.1%]) among rescue/recovery workers. Social support was also inversely related to risk. The greatest effect was observed among rescue/recovery workers who reported no sources of social support compared with those who reported 4 or 5 sources (49.7% vs 9.9%; adjusted OR, 6.9 [95% CI, 5.7-8.3]).

Figure 2. Asthma Newly Diagnosed Since the September 11, 2001, World Trade Center Terrorist Attack, by Year of Diagnosis (n=2483)



Error bars indicate 95% confidence intervals.

Table 3. Multivariable Analysis of Dust Cloud Exposure and Asthma Diagnosed Since September 11, 2001, by WTCHR Eligibility Group

	Rescue/Recovery Workers and Volunteers (n = 19 161)			Lower Manhattan Residents (n = 5594)			Lower Manhattan Office Workers (n = 13 489)			Passersby on September 11 (n = 1913)		
Risk Factor	Asthma, No. (%)[a]	Crude OR (95% CI)	Adjusted OR (95% CI)[b]	Asthma, No. (%)[a]	Crude OR (95% CI)	Adjusted OR (95% CI)[b]	Asthma, No. (%)[a]	Crude OR (95% CI)	Adjusted OR (95% CI)[b]	Asthma, No. (%)[a]	Crude OR (95% CI)	Adjusted OR (95% CI)[b]
Total adults	2347 (12.2)			445 (8.0)			1137 (8.4)			164 (8.6)		
Dust cloud exposure												
None	1208 (9.6)	1 [Ref]	1 [Ref]	217 (7.2)	1 [Ref]	1 [Ref]	303 (6.2)	1 [Ref]	1 [Ref]	56 (7.0)	1 [Ref]	1 [Ref]
Some	200 (12.3)	1.3 (1.1-1.5)	1.0 (0.8-1.2)	76 (7.3)	1.0 (0.8-1.3)	1.0 (0.8-1.3)	185 (7.5)	1.1 (0.9-1.4)	1.1 (0.9-1.3)	33 (8.4)	1.2 (0.7-1.8)	1.2 (0.7-1.8)
Intense	807 (19.1)	2.1 (1.9-2.3)	1.5 (1.4-1.7)	130 (10.1)	1.4 (1.1-1.8)	1.4 (1.1-1.8)	599 (10.5)	1.7 (1.4-1.9)	1.5 (1.3-1.7)	68 (10.3)	1.5 (1.0-2.1)	1.4 (1.0-2.0)

Abbreviations: CI, confidence interval; OR, odds ratio; Ref, reference group; WTCHR, World Trade Center Health Registry.
[a] Percentages are strata-specific prevalences of postevent asthma by eligibility group.
[b] Odds ratios are adjusted for mode of recruitment at wave 1, mode of interview at wave 2, sex, age group, race/ethnic group, income, current smoking, and other exposure factors shown in Tables 4 and 5.

Co-occurrence of postevent asthma and PTS symptoms at W2 was common. Among enrollees with postevent asthma, 36% (95% CI, 34.4%-37.5% [n=1367/3800]) had PTS symptoms; among enrollees with these symptoms at W2, 19% (95% CI, 18.2-20.0 [n=1367/7164]) reported a new diagnosis of asthma after September 11.

eTables 5-8 present the full models, as well as models stratified by recruitment mode (self- vs list- identified) for diagnosed asthma and PTS symptoms. Stratification shows that recruitment mode did not modify observed effects.

Estimated Burden in Directly Exposed Adults

Applying reported outcome rates from the W2 survey results to the potential universe of approximately 409 000 exposed persons, roughly 25 500 adults (range, 17 400-40 000) are estimated to have experienced postevent asthma, and 61 000 (range, 43 000-88 600) are estimated to have experienced symptoms indicative of probable PTSD at W2.

COMMENT

This longitudinal study of more than 46 000 enrollees demonstrates that large numbers of individuals reported adverse health conditions 5 to 6 years after the September 11, 2001, WTC attack. Respiratory health effects, while most apparent among rescue/recovery workers, also affected residents, office workers, and passersby, and our estimates suggest that more than 25 000 directly exposed adults may have received new asthma diagnoses since the event. The burden of mental health trauma was larger and developed late for many. While pathogenesis mechanisms may have varied, the 2 conditions frequently co-occurred and shared common event-related risk factors, such as intense exposure to the dust cloud, timing and duration of rescue and recovery work, and sustaining damage to home or workplace. Efforts to address ongoing event-related health consequences require coordinated physical and mental health care.[35]

In our cohort, the annualized rate of asthma diagnoses in the 4 months immediately following the attacks was at least 6 times higher than the estimated annual national adult rate of 0.5% for 2002,[36] and in subsequent years it remained at least 2 times higher than national estimates. By contrast, the 3-year asthma diagnosis rate from 2004-2006 in those with no symptoms at W1 was 1.3%, similar to what would be expected if the terrorist event had not happened. Thus, there appears to have been a sizable increased risk of asthma in this directly exposed cohort. Indeed, early postevent asthma diagnoses in the registry population are underestimated here, because they exclude the 40% of new diagnoses with unknown date of diagnosis but with W1 characteristics suggesting that they were largely early cases and mostly event-related.

Several factors were associated with postevent asthma. Rates were nearly as high in passersby as in persons who returned to live or work in the area, suggesting that much postevent asthma resulted from intensive respiratory exposure to particulates and fumes released by the collapse of the WTC towers, similar to occupational exposures that can result in reactive airways dysfunction syndrome.[37,38] However, these

Table 4. Multivariable Analysis of Days Worked and Time of Arrival as Risk Factors for Asthma Diagnosed Since September 11, 2001, Among World Trade Center (WTC) Rescue/Recovery Workers and Volunteers (n = 19 161)[a]

Risk Factor	Asthma, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
No. of days worked at any WTC site			
1-7	548 (9.1)	1 [Reference]	1 [Reference]
8-30	646 (12.0)	1.3 (1.2-1.5)	1.3 (1.1-1.4)
31-90	466 (15.0)	1.7 (1.5-2.0)	1.4 (1.3-1.6)
>90	533 (17.3)	2.0 (1.8-2.3)	1.9 (1.6-2.1)
Time of arrival			
September 11, on pile	600 (20.5)	3.0 (2.7-3.5)	2.2 (1.9-2.6)
September 11, other WTC site	330 (12.9)	1.8 (1.5-2.0)	1.4 (1.2-1.6)
September 12-17, any WTC site	941 (12.4)	1.7 (1.5-1.9)	1.6 (1.4-1.8)
September 18, 2001, to June 2002, any WTC site	422 (7.8)	1 [Reference]	1 [Reference]

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] See notes a and b in Table 3.

Table 5. Multivariable Analysis of Home/Office Evacuation and Damage as Risk Factors for Asthma Diagnosed Since September 11, 2001, Among Lower Manhattan Residents and Office Workers[a]

Risk Factor	Asthma, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
Residents (n = 5594)			
Evacuation of home			
Evacuated	261 (7.2)	1 [Reference]	1 [Reference]
Did not evacuate	183 (9.4)	1.4 (1.1-1.6)	1.4 (1.1-1.7)
Damage to home			
None	293 (7.3)	1 [Reference]	1 [Reference]
Damage without heavy layer of dust	61 (9.0)	1.3 (1.0-1.7)	1.3 (1.0-1.8)
Heavy layer of dust with or without damage	91 (10.3)	1.5 (1.1-1.9)	1.5 (1.1-1.9)
Office workers (n = 13 489)			
No office damage	790 (7.8)	1 [Reference]	1 [Reference]
Damage without heavy layer of dust	175 (8.9)	1.2 (1.0-1.4)	1.1 (0.9-1.3)
Heavy layer of dust with or without damage	171 (12.7)	1.7 (1.4-2.1)	1.5 (1.3-1.8)

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] See notes a and b in Table 3.

data also suggest that ongoing exposure to WTC dust (and the chemicals or allergens in it) introduced additional risks. Risk of asthma increased with length of time worked at the site. Residents who did not evacuate were at higher risk than those who did. Those who reported a heavy layer of dust in their home or office had higher asthma diagnosis rates, independent of dust cloud exposure.

While symptoms varied substantially among those who reported asthma, the data suggest that asthma associated with intense dust cloud exposure may be more severe than new asthma occurring for other reasons. This finding persisted when controlling for demographic and socioeconomic factors or when restricted to list-identified enrollees only, who may have been less affected by self-selection biases.

While dust cloud exposure and heavy layer of dust in the home or office were risk factors for early and late postevent asthma, our analysis suggests that risk for new diagnosis of asthma associated with WTC exposures has waned, although it may not be over. The epidemic curve flattened for 3 years following 2002. The increase in 2006 is likely attributable to recall bias associated with W2 administration. The association with dust cloud exposure has decreased over time, and asthma developing later in previously symptom-free persons appears to be occurring at a rate comparable to what would be expected had there been no September 11 disaster, about 0.5% per year. Similarly, in a longitudinal study of rescue/recovery workers, the prevalence of spirometric abnormalities did not increase over the 5-year interval, and the change in lung function was compatible with normal aging.[16]

In addition, the high prevalence of wheezing, shortness of breath, and cough at W1 among persons with a late postevent diagnosis of asthma suggests that many may already have developed event-related asthma early but had a delayed diagnosis. Given that apparent late diagnoses of probable event-related asthma continued to occur through 2006 and a sizable number of

Table 6. PTSD Diagnosed Before September 11, 2001, and Event-Related Posttraumatic Stress Symptoms Since September 11, by World Trade Center Health Registry Wave 1 Characteristics and Event-Related Exposures

Wave 1 Characteristic	Wave 2, PTSD-Free Prior to Event, No.[a]	September 11–Related Probable PTSD, No. (% [95%CI])		
		Total	Wave 1 PTSD	Wave 2 PTSD
Total adults	43 032	10 242 (23.8 [23.4-24.2])	6141 (14.3 [13.9-14.6])	8212 (19.1 [18.7-19.5])
Source of interview				
Self-identified	31 814	8232 (25.9 [25.4-26.4])	4972 (15.6 [15.2-16.0])	6627 (20.8 [20.4-21.3])
List-identified	11 218	2010 (17.9 [17.2-18.6])	1169 (10.4 [9.9-11.0])	1585 (14.1 [13.5-14.8])
Sex				
Male	26 610	5860 (22.0 [21.5-22.5])	3154 (11.9 [11.5-12.2])	4891 (18.4 [17.9-18.8])
Female	16 422	4382 (26.7 [26.0-27.4])	2987 (18.2 [17.6-18.8])	3321 (20.2 [19.6-20.8])
Age at interview, y				
18-24	1382	270 (19.5 [17.4-21.6])	144 (10.4 [8.8-12.0])	211 (15.3 [13.4-17.2])
25-44	20 939	4935 (23.6 [23.0-24.1])	2848 (13.6 [13.1-14.1])	4002 (19.1 [18.6-19.6])
45-64	18 883	4748 (25.1 [24.5-25.8])	2964 (15.7 [15.2-16.2])	3784 (20.0 [19.5-20.6])
≥65	1828	289 (15.8 [14.1-17.5])	185 (10.1 [8.7-11.5])	215 (11.8 [10.3-13.2])
Race/ethnicity				
Non-Hispanic white	30 468	6093 (20.0 [19.5-20.4])	3253 (10.7 [10.3-11.0])	5058 (16.6 [16.2-17.0])
Non-Hispanic black	4248	1325 (31.2 [29.8-32.6])	960 (22.6 [21.3-23.9])	941 (22.2 [20.9-23.4])
Hispanic	4820	1888 (39.2 [37.8-40.5])	1329 (27.6 [26.3-28.8])	1484 (30.8 [29.5-32.1])
Asian	2227	515 (23.1 [21.3-24.9])	316 (14.2 [12.7-15.6])	388 (17.4 [15.8-19.0])
Other	1269	421 (33.2 [30.6-35.8])	283 (22.3 [20.0-24.6])	341 (26.9 [24.4-29.3])
Total household income at interview, $				
<25 000	3201	1284 (40.1 [38.4-41.8])	965 (30.1 [28.6-31.7])	1028 (32.1 [30.5-33.7])
25 000-<50 000	7531	2374 (31.5 [30.5-32.6])	1598 (21.2 [20.3-22.1])	1838 (24.4 [23.4-25.4])
50 000-<75 000	8567	2126 (24.8 [23.9-25.7])	1259 (14.7 [13.9-15.4])	1681 (19.6 [18.8-20.5])
75 000-<150 000	14 740	2973 (20.2 [19.5-20.8])	1501 (10.2 [9.7-10.7])	2492 (16.9 [16.3-17.5])
≥150 000	5025	715 (14.2 [13.3-15.2])	375 (7.5 [6.7-8.2])	575 (11.4 [10.6-12.1])
Missing	3968	770 (17.9 [16.7-19.1])	443 (11.2 [10.2-12.1])	598 (15.1 [14.0-16.2])
Eligibility groups				
Rescue/recovery workers and volunteers	20 294	4656 (22.9 [22.4-23.5])	2465 (12.1 [11.7-12.6])	3950 (19.5 [18.9-20.0])
Lower Manhattan residents	5852	1248 (21.3 [20.3-22.4])	770 (13.2 [12.3-14.0])	954 (16.3 [15.4-17.2])
Lower Manhattan office workers	14 718	3712 (25.2 [24.5-25.9])	2494 (16.9 [16.3-17.6])	2814 (19.1 [18.5-19.8])
Passersby	2087	610 (29.2 [27.3-31.2])	402 (19.3 [17.6-21.0])	484 (23.2 [21.4-25.0])

Abbreviations: CI, confidence interval; PTSD, posttraumatic stress disorder.
[a] Restricted to 43 032 persons without a pre-event diagnosis of PTSD and with complete PTSD measures at both wave 1 and wave 2.

additional registrants with respiratory symptoms at W1 also reported recent respiratory symptoms at W2 but no asthma diagnosis, it is likely that late diagnoses of event-related asthma will continue but diminish in the future. Continued tracking may help determine the extent to which late diagnoses continue to occur and can help clarify the observed increase in 2006. It also remains unclear whether asthma associated with exposure to the dust cloud will remain more severe than other postevent asthma.

Our findings on the prevalence of event-related current PTS symptoms also shed new light on the long-term mental health effects of the WTC disaster. Prevalences among exposed groups were considerably higher than those previously reported in serial cross-sectional studies of the general population within 6 months after September 11.[20] To our knowledge, only 1 study of New York City adults (n=2752) used a longitudinal study design.[24] The authors of that study found a 14% prevalence of probable PTSD up to 4 years postevent, similar to our results. Our estimates are also comparable to long-term findings on highly exposed individuals from other studies of terrorist events. Probable PTSD prevalences were 17% and 19% among survivors 1 to 3 years after a mass shooting in Texas,[39] 31% among survivors 3 years after the Oklahoma City bombing,[40] and 31% among civilian survivors 2 to 3 years after the 1995-1996 bombings in France.[41] Few studies have tracked PTS symptoms in directly exposed individuals for more than 3 years postevent.

Results from W1 and W2 surveys clarified the course of PTS symptoms among highly exposed groups. Roughly 10% of participants were categorized as having chronic symptoms, and another 10% developed late-onset symptoms. One in 20 (4.7%) had symptoms at W1 that resolved to levels not indicative of probable PTSD. Higher PCL scores at W1 were correlated with greater risk of chronicity, suggesting that the magnitude of PCL scores warrants attention.[42]

Table 7. September 11–Related Posttraumatic Stress Symptoms, Comorbidity, Mental Health Care Utilization, and Quality of Life

Characteristic	No. (%)				
	Wave 2, PTSD-Free Pre-Event[b]	September 11–Related Probable PTSD Status at Wave 2[a]			
		Chronic	Late-Onset	Resolved	None
Total adults	43 032	4111	4101	2030	32 790
Eligibility group					
Rescue/recovery workers and volunteers	20 294 (47.2 [46.7-47.6])	1759 (42.8 [41.3-44.3])	2191 (53.4 [51.9-55.0])	706 (34.8 [32.7-36.9])	15 638 (47.7 [47.2-48.2])
Residents	5852 (13.6 [13.3-13.9])	476 (11.6 [10.6-12.6])	478 (11.7 [10.7-12.6])	294 (14.5 [13.0-16.0])	4604 (14.0 [13.7-14.4])
Lower Manhattan office workers	14 718 (34.2 [33.8-34.7])	1596 (38.8 [37.3-40.3])	1218 (29.7 [28.3-31.1])	898 (44.2 [42.1-46.4])	11 006 (33.6 [33.1-34.1])
Passersby	2087 (4.9 [4.6-5.1])	276 (6.7 [5.9-7.5])	208 (5.1 [4.4-5.7])	126 (6.2 [5.2-7.3])	1477 (4.5 [4.3-4.7])
Mental health diagnoses since September 11					
PTSD	5831 (13.6 [13.2-13.9])	1896 (46.1 [44.6-47.6])	1172 (28.6 [27.2-30.0])	451 (22.2 [20.4-24.0])	2312 (7.1 [6.8-7.3])
Depression	6010 (14.0 [13.6-14.3])	1933 (47.0 [45.5-48.5])	1276 (31.1 [29.7-32.5])	424 (20.9 [19.1-22.7])	2377 (7.2 [7.0-7.5])
Both depression and PTSD	3188 (7.4 [7.2-7.7])	1375 (33.4 [32.0-34.9])	747 (18.2 [17.0-19.4])	236 (11.6 [10.2-13.0])	830 (2.5 [2.4-2.7])
Mental health care utilization <12 mo					
Seen professional	8980 (20.9 [20.5-21.3])	1944 (47.3 [45.8-48.8])	1504 (36.7 [35.2-38.1])	480 (23.6 [21.8-25.5])	5052 (15.4 [15.0-15.8])
Prescription medication	6104 (14.2 [13.9-14.5])	1541 (37.5 [36.0-39.0])	1103 (26.9 [25.5-28.3])	336 (16.6 [14.9-18.2])	3124 (9.5 [9.2-9.8])
Any mental health care	10 480 (24.4 [23.9-24.8])	2196 (53.4 [51.9-54.9])	1719 (41.9 [40.4-43.4])	577 (28.4 [26.5-30.4])	5988 (18.3 [17.8-18.7])
Both	4604 (10.7 [10.4-11.0])	1289 (31.4 [29.9-32.8])	888 (21.7 [20.4-22.9])	239 (11.8 [10.4-13.2])	2188 (6.7 [6.4-6.9])
Quality of life <30 d					
Poor mental health ≥14 d	7875 (18.3 [17.9-18.7])	2502 (60.9 [59.4-62.4])	1981 (48.3 [46.8-49.8])	439 (21.6 [19.8-23.4])	2953 (9.0 [8.7-9.3])
Limited activity ≥14 d	4537 (10.5 [10.3-10.8])	1564 (38.0 [36.6-39.5])	1067 (26.0 [24.7-27.4])	206 (10.1 [8.8-11.5])	1700 (5.2 [4.9-5.4])
Both	3163 (7.4 [7.1-7.6])	1384 (33.7 [32.2-35.1])	899 (21.9 [20.7-23.2])	132 (6.5 [5.4-7.6])	748 (2.3 [2.1-2.4])

Abbreviations: CI, confidence interval; PTSD, posttraumatic stress disorder.
[a] Chronic indicates a positive screen result at both wave 1 and wave 2; late-onset, a negative result at wave 1 and a positive result at wave 2; resolved, a positive result at wave 1 and a negative result at wave 2; and none, a negative result at both wave 1 and wave 2.
[b] Restricted to 43 032 persons without a pre-event diagnosis of PTSD with complete PTSD measures at both wave 1 and wave 2.

Participants with chronic or late-onset PTS symptoms were most likely to report postevent mental health care utilization and diagnoses, although the former reported poorer quality of life. These results highlight the importance of ongoing mental health surveillance after disasters. Rescue/recovery workers were most

Table 8. Multivariable Analysis of Risk Factors of September 11–Related Probable PTSD at WTCHR Registry Wave 2 by Eligibility Group[a]

Characteristic	Rescue/Recovery Workers and Volunteers (n = 20 294)			Lower Manhattan Residents (n = 5852)			Lower Manhattan Office Workers (n = 14 718)			Passersby on September 11 (n = 2087)		
	PTSD at Follow-up, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)[b]	PTSD at Follow-up, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)[b]	PTSD at Follow-up, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)[b]	PTSD at Follow-up, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)[b]
Pre-event mental health diagnosis (depression)												
Yes	204 (23.0)	1.2 (1.1-1.5)	1.5 (1.2-1.8)	147 (25.3)	1.9 (1.5-2.3)	1.8 (1.4-2.3)	244 (26.6)	1.6 (1.4-1.8)	1.8 (1.5-2.1)	48 (25.7)	1.2 (0.8-1.6)	1.2 (.8-1.8)
No	3746 (19.3)	1 [Ref]	1 [Ref]	807 (15.3)	1 [Ref]	1 [Ref]	2570 (18.6)	1 [Ref]	1 [Ref]	436 (23.0)	1 [Ref]	1 [Ref]
Dust cloud exposure												
None	1887 (14.2)	1 [Ref]	1 [Ref]	316 (10.1)	1 [Ref]	1 [Ref]	650 (12.2)	1 [Ref]	1 [Ref]	128 (14.8)	1 [Ref]	1 [Ref]
Some	347 (20.0)	1.4 (1.2-1.6)	1.0 (.8-1.1)	160 (14.6)	1.3 (1.1-1.6)	1.0 (.8-1.3)	377 (14.1)	1.1 (0.9-1.2)	1.0 (0.9-1.2)	85 (19.9)	1.2 (.9-1.6)	1.1 (.8-1.5)
Intense	1446 (32.4)	2.7 (2.5-2.9)	1.5 (1.3-1.6)	403 (29.8)	3.3 (2.8-3.8)	2.0 (1.6-2.4)	1672 (26.8)	2.4 (2.2-2.7)	1.7 (1.5-1.9)	240 (33.1)	2.4 (1.9-3.0)	1.8 (1.4-2.3)
Witnessed traumatic or horrific event on September 11												
Yes	2639 (26.1)	2.4 (2.2-2.6)	1.3 (1.2-1.5)	846 (19.4)	3.1 (2.5-3.8)	2.2 (1.7-2.8)	2726 (20.2)	3.3 (2.6-4.1)	2.1 (1.6-2.6)	460 (23.9)	1.8 (1.1-2.8)	1.5 (.9-2.4)
No	1306 (12.9)	1 [Ref]	1 [Ref]	107 (7.2)	1 [Ref]	1 [Ref]	83 (7.2)	1 [Ref]	1 [Ref]	24 (15.1)	1 [Ref]	1 [Ref]
Sustained injury on September 11												
Yes	1125 (36.5)	2.9 (2.7-3.2)	1.9 (1.7-2.1)	156 (41.8)	4.2 (3.4-5.2)	1.9 (1.4-2.4)	774 (39.5)	3.4 (3.1-3.8)	2.3 (2.0-2.6)	114 (47.7)	3.6 (2.8-4.8)	2.3 (1.7-3.2)
No	2825 (16.4)	1 [Ref]	1 [Ref]	798 (14.6)	1 [Ref]	1 [Ref]	2040 (16.0)	1 [Ref]	1 [Ref]	370 (20.0)	1 [Ref]	1 [Ref]
Loss/death of other on September 11												
None	1002 (12.3)	1 [Ref]	1 [Ref]	407 (11.9)	1 [Ref]	1 [Ref]	717 (13.4)	1 [Ref]	1 [Ref]	177 (16.1)	1 [Ref]	1 [Ref]
Spouse	57 (47.5)	6.0 (4.2-8.6)	2.7 (1.8-4.0)	4 (80.0)	28.5 (3.2-254.7)	30.9 (2.9-327.6)	18 (50.0)	6.2 (3.2-11.9)	3.6 (1.6-8.1)	4 (80.0)	20.1 (2.2-181.0)	13.5 (1.2-150.5)
Other family member	196 (29.0)	2.7 (2.3-3.2)	2.2 (1.8-2.6)	33 (31.1)	3.2 (2.1-4.9)	2.9 (1.8-4.7)	135 (30.8)	2.7 (2.2-3.4)	2.9 (2.3-3.7)	26 (40.6)	3.4 (2.0-5.8)	3.4 (1.8-6.1)
Coworker	1206 (24.3)	2.1 (1.9-2.3)	1.5 (1.3-1.9)	78 (25.3)	2.4 (1.8-3.2)	2.2 (1.6-3.0)	779 (24.8)	2.0 (1.8-2.3)	2.2 (1.9-2.4)	72 (34.8)	2.7 (1.9-3.7)	2.9 (2.0-4.2)
Acquaintance	1372 (22.8)	2.0 (1.8-2.1)	1.7 (1.5-1.8)	405 (21.3)	1.9 (1.7-2.1)	1.8 (1.6-2.9)	1112 (19.9)	1.5 (1.4-1.7)	1.7 (1.5-1.9)	195 (28.6)	2.0 (1.6-2.5)	2.0 (1.5-2.6)
Postevent job loss												
None	2612 (16.1)	1 [Ref]	1 [Ref]	399 (11.7)	1 [Ref]	1 [Ref]	1715 (15.4)	1 [Ref]	1 [Ref]	247 (18.6)	1 [Ref]	1 [Ref]
Event-related	602 (56.4)	6.7 (5.9-7.6)	4.6 (4.0-5.3)	163 (36.1)	3.5 (2.9-4.3)	2.4 (1.9-3.1)	630 (42.7)	4.0 (3.6-4.5)	2.8 (2.4-3.2)	88 (56.1)	5.3 (3.8-7.4)	4.9 (2.7-5.9)
Not related	455 (32.9)	2.5 (2.2-2.9)	2.4 (2.1-2.7)	123 (21.5)	1.7 (1.4-2.1)	1.7 (1.4-2.2)	420 (21.6)	1.5 (1.3-1.7)	1.6 (1.4-1.8)	61 (28.8)	1.7 (1.2-2.3)	1.6 (1.1-2.2)
Postevent social support sources												
None	350 (49.7)	9.0 (7.7-10.7)	6.9 (5.7-8.3)	78 (37.3)	4.6 (3.3-6.3)	4.8 (3.3-7.1)	176 (46.4)	6.4 (5.1-8.0)	5.3 (4.1-6.8)	36 (54.6)	6.1 (3.6-10.4)	4.3 (2.3-7.8)
1 or 2	2251 (24.7)	3.0 (2.7-3.3)	2.4 (2.2-2.7)	552 (17.4)	1.6 (1.4-1.9)	1.7 (1.4-22.1)	1719 (22.7)	2.2 (1.9-2.4)	2.0 (1.8-2.3)	267 (26.0)	1.8 (1.4-2.3)	1.6 (1.2-2.1)
3	653 (19.2)	2.2 (1.9-2.4)	1.8 (1.6-2.0)	138 (15.9)	1.4 (1.1-1.8)	1.3 (1.0-1.7)	405 (16.4)	1.4 (1.3-1.7)	1.4 (1.2-1.6)	75 (21.8)	1.4 (1.0-2.0)	1.2 (.8-1.8)
4 or 5	696 (9.9)	1 [Ref]	1 [Ref]	186 (11.6)	1 [Ref]	1 [Ref]	514 (12.0)	1 [Ref]	1 [Ref]	106 (16.3)	1 [Ref]	1 [Ref]

Abbreviations: CI, confidence interval; OR, odds ratio; PTSD, posttraumatic stress disorder; Ref, reference group; WTCHR, World Trade Center Health Registry.
[a] Analyses restricted to persons without a pre-event diagnosis of PTSD and with complete PTSD measures at both wave 1 and wave 2.
[b] Odds ratios are adjusted for mode of recruitment at wave 1, mode of interview at wave 2, sex, age group, race/ethnic group, income, and other factors in this table and in Tables 9 and 10.

likely to have delayed symptoms, consistent with other reports on rescue workers' development of probable PTSD after experiencing subsyndromal reactions.[43]

Our findings on pre-event, peri-event, and postevent risk factors are consistent with research on the mental health impacts of disasters,[44,45] although few studies have explored[9,12,27] detailed peri-event experiences by exposure group. Intense dust cloud exposure, injury, and personally witnessing horror were more strongly associated with long-term PTS symptom risk than were any eligibility group–specific exposures. However, postevent experiences were the strongest risk factors; the effects of job loss and low social support were consistent with findings from studies of the postevent general population and from veteran studies.[24,46,47] These findings confirm the general understanding that, over time, evaluation and treatment of individuals with long-term PTSD must address social factors that moderate predisaster and peri-disaster experiences. The role of postevent resource loss is also important for planning interventions for future disasters.[48]

Approximately one-quarter (24.4%) of participants reported accessing mental health care in the year prior to W2. However, at least half (52.4%) with chronic or late-onset PTS symptoms reported no mental heath care utilization in the year prior to W2, and many did not report a diagnosis of PTSD. Given that untreated PTSD can be debilitating, policy makers and mental health professionals must better understand and address barriers to care.[49]

It is important to recognize that resilience is the most commonly observed reaction, even among direct survivors. Nearly 8 of 10 participants (76.2%) did not screen positive for stress symptoms indicative of probable PTSD at W1 or W2, similar to those with high event exposure in the general population.[50] Researchers have also identified positive outcomes related to disaster, including personal ability to handle crises effectively, reprioritization of goals and values, and community closeness.[51]

The voluntary nature of the WTC Health Registry may have resulted in systematic underrepresentation of some populations. To address the fact that participants who volunteered may not have been representative of the true exposed population, we adjusted for self- vs list-identification to account for potential self-selection bias and also examined findings among list-identified enrollees alone. Residual self-selection bias, even among list-identified participants, may nonetheless have influenced observed disease rates. We found that multimode data gathering affected absolute estimates of symptoms of PTSD but not asthma prevalence and had little impact on multivariable-adjusted estimates of the association between risk factors and either outcome. Prevalences remained high, and all major independent associations between September 11 exposures and either asthma or PTS remained statistically significant. Persons with PTS symptoms at W1 were less likely to complete the W2 survey, potentially related to avoidance tendencies,

Table 9. Multivariable Analysis of Days Worked and Time of Arrival as Risk Factors for September 11–Related Probable PTSD at WTCHR Wave 2 Among Rescue/Recovery Workers and Volunteers (n = 20 294)[a]

Risk Factor	PTSD at Follow-up, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
No. of days worked at any WTC site			
1-7	1061 (16.3)	1 [Reference]	1 [Reference]
8-30	978 (17.2)	1.1 (1.0-1.2)	1.1 (1.0-1.2)
31-90	736 (22.7)	1.5 (1.4-1.7)	1.3 (1.1-1.4)
>90	898 (28.3)	2.0 (1.8-2.2)	1.6 (1.4-1.8)
Time of arrival			
September 11, on pile	847 (28.0)	2.8 (2.5-3.1)	1.3 (1.1-1.5)
September 11, other WTC site location	632 (23.3)	2.2 (1.9-2.4)	1.2 (1.1-1.4)
September 12-17, any WTC site	1662 (20.8)	1.9 (1.7-2.0)	1.4 (1.3-1.6)
September 18, 2001, to June 2002, any WTC site	717 (12.4)	1 [Reference]	1 [Reference]

Abbreviations: CI, confidence interval; OR, odds ratio; PTSD, posttraumatic stress disorder; WTC, World Trade Center; WTCHR, WTC Health Registry.
[a] See notes a and b in Table 8.

Table 10. Multivariable Analysis of Home or Office Evacuation and Damage as Risk Factors for September 11–Related Probable PTSD at WTCHR Wave 2 Among Lower Manhattan Residents (n = 5852) and Office Workers (n = 14 718)[a]

Risk Factor	PTSD at Follow-up, No. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
Residents			
Evacuation of home			
Did not evacuate	307 (16.1)	1 [Reference]	1 [Reference]
Evacuated	645 (16.4)	1.0 (0.9-1.2)	1.0 (0.8-1.2)
Damage to home			
None	518 (12.3)	1 [Reference]	1 [Reference]
Damage without heavy layer of dust	167 (23.8)	2.2 (1.8-2.7)	1.9 (1.5-2.4)
Heavy layer of dust with or without damage	267 (28.5)	2.8 (2.4-3.4)	2.2 (1.8-2.6)
Office workers			
No office damage	1823 (16.4)	1 [Reference]	1 [Reference]
Damage without heavy layer of dust	493 (23.1)	1.5 (1.4-1.7)	1.5 (1.3-1.7)
Heavy layer of dust with or without damage	498 (33.8)	2.6 (2.3-2.9)	2.0 (1.8-2.3)

Abbreviations: CI, confidence interval; OR, odds ratio; PTSD, posttraumatic stress disorder; WTCHR, World Trade Center Health Registry.
[a] See notes a and b in Table 8.

suggesting the possibility of underestimation, whereas persons with asthma, the less common of the 2 health conditions examined, were slightly more likely to complete W2. Notably, however, September 11 experiences were not associated with participation.

The registry's asthma data are self-reported, with no objective measures of airway dysfunction or validation of diagnosis by review of medical records. However, nationally validated questions were used. In addition, reported symptoms and quality of life were consistent with reported asthma diagnosis. Similarly, although the PCL is a widely used measure for self-report of PTS, it is not a clinical assessment and excludes information necessary for a PTSD diagnosis. Specifically, the checklist lacks questions to ascertain actual or perceived life threat (*Diagnostic and Statistical Manual of Mental Disorders* [Fourth Edition] criterion A), duration of disturbance (criterion E), or significant impairment in social, occupational, or other functioning (criterion F). Thus, we reiterate that registry instruments measured stress symptoms indicative of probable PTSD, not PTSD itself. Furthermore, lack of information on intervening life stressors and traumatic events made it difficult to fully describe the etiology of late-onset symptoms compared with chronic and resolved symptoms, particularly with respect to timing of symptom onset. Despite these limitations, our findings document longitudinal symptom course, largely unexplored in September 11 literature.

Exposure assessments also were subject to a few limitations. First, the absence of information on new traumas and environmental exposures after the event may have resulted in an overestimate of disease associated with September 11 exposures. Second, assessment of exposure occurred 2 to 3 years after the event, and symptomatic persons may have recalled event-related exposures differently from asymptomatic persons. To improve the measurement of dust cloud exposure, we augmented self-report of dust cloud exposure with individual reports of exact location and experiences, such as being covered with dust from head to toe. Significant graded associations between asthma and exposure variables (dust cloud exposure, home and office heavy dust, and others) provide face validity for our findings.

CONCLUSIONS

Acute intense exposures as well as prolonged exposures resulted in a large burden of asthma and PTS symptoms 5 to 6 years after the September 11, 2001, WTC terrorist attack. Care through federally funded Centers of Excellence for persons with September 11–related physical and mental conditions exists, as do September 11–specific clinical guidelines, which call for coordinated treatment of physical and mental health conditions.[35] Following future disasters, we recommend short- and long-term interventions, including immediate outreach, screening, and evidence-based treatments. For example, there was outreach and active referral to mental health treatment after the 2005 London bombings.[52] Our findings confirm that, after a terrorist attack, mental health conditions can persist if not identified and adequately treated and that a substantial number of exposed persons may develop late-onset symptoms. Our study highlights the need for surveillance, outreach, treatment, and evaluation of efforts for many years following a disaster to prevent and mitigate health consequences.

Author Contributions: Dr Brackbill and Ms Ekenga had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Brackbill, DiGrande, Farfel, Friedman, Stellman, Thorpe.
Acquisition of data: Brackbill, DiGrande, Farfel, Friedman, Walker, Wu, Yu, Thorpe.
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