World Trade Center Related Health Among NYC Firefighters and EMS Workers

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Introduction

FDNY WTC Health Program: 2001–2016

On September 11, 2001 (9/11), the collapse of the World Trade Center (WTC) resulted in the loss of 343 Fire Department of the City of New York (FDNY) responders and exposed thousands more to a hazardous mix of inorganic dust, products of combustion and respirable particulates [1]. In response, FDNY Bureau of Health Services (FDNY-BHS) instituted a rigorous medical monitoring and treatment program for the nearly 16,000 FDNY firefighters and emergency medical service (EMS) workers who performed rescue/recovery work on 9/11 and during the subsequent 10-month recovery period at the WTC site. Concurrently, FDNY physicians and others documented the early health symptoms and conditions presented by the FDNY workforce, most notably respiratory and mental health symptoms, which were the most problematic immediately post-disaster. In 2005, the FDNY data center was established to institutionalize the collection and analysis of data on health conditions associated with WTC exposure.

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FDNY's multifaceted approach (monitoring, treatment, and research) has enabled us to document and ameliorate the health effects of 9/11. FDNY-BHS and its WTC Health Program (WTCHP) provided clinical care and referrals for services, while research studies from the FDNY data center identified trends and risk factors for WTC-related health conditions to improve our understanding of exposure-host interactions and, in so doing, to provide appropriate clinical services. In this report, which is an update from a previous review article [2], we describe FDNY's post-9/11 clinical care and health interventions and provide a summary of health outcomes that we have identified between 2001 and 2016.

Evolution of the FDNY WTC Health Program

FDNY's WTC treatment program began on 9/11, when FDNY-BHS physicians were deployed to the WTC site, some prior to the collapse, to provide triage and on-site treatment. Treatment continued and three weeks after 9/11, formal medical monitoring began, leveraging the existing health infrastructure already in place at FDNY-BHS at the time of the disaster. This occupational health service was established well before 9/11 to provide monitoring and treatment medical exams for active FDNY firefighters and EMS workers, primarily to assess and improve their fitness to perform work-related activities. The early WTCHP incorporated FDNY-BHS routine exams that included physical examinations by FDNY physicians, self-administered health questionnaires (rapidly updated to include WTC-related questions), pulmonary function tests, chest x-rays, cardiograms, audiograms, and the collection of blood and urine samples for testing. Since then, the WTCHP, based in Brooklyn, NY, has added satellite locations in Queens, NY, Staten Island, NY, and Suffolk and Orange counties to increase access to care. It has also expanded to include more in-depth clinical exams and physical and mental health monitoring exams as well as free treatment services.

Free treatment services for WTC-related health conditions are offered to all active and retired WTC-exposed FDNY responders. FDNY-WTCHP provides on-site diagnosis and treatment of WTC-related physical health conditions (e.g., lower and upper respiratory diseases and gastroesophageal reflux disease [GERD]), mental health conditions (post-traumatic stress disorder [PTSD], depression, anxiety, prolonged grief, and substance abuse [primarily alcohol and tobacco use]), and when necessary referrals to an extensive network of specialty providers conveniently located in the New York metropolitan area. Referrals are provided for diagnostic procedures and treatment. After epidemiological findings from FDNY and others demonstrating a link between WTC exposure and cancer [3–5], and the subsequent addition of cancers as a WTC-covered condition in 2012 under the James Zadroga 9/11 Health and Compensation Act of 2010 Act [6], FDNY-WTCHP expanded to provide diagnostic evaluations for WTC-related cancers and added providers such as the Memorial Sloan Kettering Cancer Center to its external network for cancer treatment. Program expansion also included adding an FDNY case management unit primarily to provide care coordination for patients with cancer and other severe diseases, cancer screening for early diagnosis, and, for patients unresponsive to treatment, end-of-life care through hospice referrals.

WTC Health Program Utilization

There are 15,634 FDNY WTC-exposed responders enrolled in the FDNY-WTCHP. Since the inception of FDNY-WTCHP, 15,245 (98%) received at least one monitoring exam, and to date (December 1, 2016), 10,971 (70%) have received at least eight monitoring exams. Participation rates remain high; in the last 12 months, 10,818 (69%) enrolled members received an FDNY WTC monitoring exam.

Between 9/11 and 12/1/2016, not including monitoring, 14,028 (90%) individuals visited an FDNY-WTCHP physician for diagnosis and treatment of a physical health problem. Many of these conditions, initially acute, have evolved to become chronic illnesses requiring ongoing treatment. To date, 10,433 persons have been certified by the National Institute for Occupational Safety and Health (NIOSH) as having at least one WTC-related health condition, and 9484 (61% of enrolled members) have filled at least one medication under this program (Table 1). Over the last 12 months, 7718 (49%) enrolled members with at least one certified WTC-related illness have presented for treatment of a physical or mental health problem at the FDNY-WTCHP. The most common types of medications for physical health conditions were proton pump inhibitors for those certified with GERD; saline wash and nasal anti-inflammatory steroids for those certified with upper airway diseases, predominantly chronic rhinosinusitis (CRS); and beta-adrenergic agents and inhaled

Table 1 Selected characteristics of WTC-exposed firefighters and EMS workers enrolled in the FDNY World Trade Center Health Program[a]

	Firefighters		EMS workers		Total	
Characteristics	*N*	%	*N*	%	*N*	%
Total	13195	100	2439	100	15634	100
WTC arrival group						
Arrival on the morning of 9/11	1812	13.7	459	18.8	2271	14.5
Arrival during the afternoon of 9/11	6094	46.2	719	29.5	6813	43.6
Arrival on 9/12/2001	2442	18.5	293	12.0	2735	17.5
Arrival any day between 9/13/2001 and 9/24/2001	2042	15.5	603	24.7	2645	16.9
Arrival after 9/24/2001	265	2.0	215	8.8	480	3.1
Undefined exposure	540	4.1	150	6.2	690	4.4
Duration—months at the WTC						
Median [IQR range]	3 [1–5]		2 [1–5]		2 [1–5]	
Age on 9/11 *years*						
Median [IQR range]	40.6 [34.0–46.7]		34.9 [28.2–41.0]		39.6 [33.0–46.0]	
Gender						
Male	13165	99.8	1956	80.2	15121	96.7
Female	30	0.2	483	19.8	513	3.3
Race						
White	12340	93.5	1267	52.0	13607	87.0
Nonwhite	855	6.5	1172	48.1	2027	13.0

(continued)

Table 1 (continued)

Characteristics	Firefighters		EMS workers		Total	
	N	%	*N*	%	*N*	%
Total	13195	100	2439	100	15634	100
Current smoking status[a,b]						
Current	652	4.9	319	13.1	971	6.2
Former	4580	34.7	895	36.7	5475	35.0
Never	7680	58.2	1189	48.8	8869	56.7
Retirement status[a]						
Retired	8735	66.2	1304	53.5	10039	64.2
Not retired	4460	33.8	1135	46.5	5595	35.8
*Post-*9/11 *prevalence of respiratory health diagnoses*[c]						
Chronic rhinosinusitis	4618	35.0	357	14.6	4975	31.8
Gastroesophageal reflux disease	4396	33.3	379	15.5	4775	30.5
Obstructive airways disease	3733	28.3	334	13.7	4067	26.0
Asthma	2920	22.1	274	11.2	3194	20.4
Chronic bronchitis	1408	10.7	88	3.6	1496	9.6
Chronic obstructive pulmonary disease	256	1.9	19	0.8	275	1.8
At least one of the above respiratory diagnoses[c]	7202	54.6	665	27.3	7867	50.3
Prevalence of probable mental health conditions in year 15[d]						
PTSD	720	8.0	100	6.8	820	7.8
Depression	1395	15.4	223	15.1	1618	15.4
At least one medication fill under FDNY-WTCHP	8617	65.3	867	35.5	9484	60.6

[a]As of December 1, 2016
[b]*N* = 319 had unknown current smoking status
[c]Between 2001 and 2016
[d]Percentages of *N* = 10,538 who completed a mental health questionnaire in 9/11 year, year 15

corticosteroids for those certified with obstructive airways diseases (OAD) including asthma, reactive airways dysfunction syndrome (RADS), chronic bronchitis, and emphysema. The three most common types of medications for those certified with mental health conditions, predominantly PTSD, depression, and anxiety were selective serotonin reuptake inhibitors, anti-anxiety drugs, and norepinephrine and dopamine reuptake inhibitors.

WTC exposure

We use two measures to characterize WTC-exposure in our research studies: initial arrival time and duration of work at the WTC site. Initial arrival time was obtained from the earliest post-9/11 questionnaire, which was completed a median of four months after 9/11. Initial arrival time is categorized from highly exposed to

least exposed as follows: arriving on the morning of 9/11 (highest exposure level); arriving during the afternoon of 9/11; arriving on 9/12/2001; arriving any day between 9/13/2001 and 9/24/2001; and arriving after 9/24/2001 (lowest exposure level). Duration of work was added to later questionnaires and was obtained a median of four years post-9/11. Duration of work is a summation of each calendar month that an individual worked for at least one day at the WTC site (range 1–10 months). For most analyses, we did not have a non-WTC-exposed group, as virtually all active FDNY members worked at the WTC site. Table 1 shows that close to 14% of firefighters and 19% of EMS workers arrived at the WTC site during the morning of 9/11, although most firefighters (46%) and EMS workers (30%) arrived during that afternoon. The median duration of time worked at the site was three months for firefighters and two months for EMS workers. The FDNY-WTC rescue/recovery cohort was mostly white (87%), was male (97%), and had a median age of 40 years (IQR range: 33–46 years) on 9/11.

WTC Health Findings

To describe various health conditions, we use both self-reported symptoms from monitoring questionnaires and physician diagnoses from FDNY medical records. Pulmonary function was analyzed using forced vital capacity (FVC) and the forced expiratory volume in the first second (FEV_1) results from routine spirometry. Bronchial reactivity information was obtained from methacholine challenge tests.

Pulmonary Function and Lower Respiratory

Among 12,781 WTC-exposed firefighters and EMS workers who had 61,746 spirometry measurements, [7] reported accelerated lung function decline from serial FEV_1 measurements, which averaged 372 ml over the first year after 9/11, the equivalent of 10–12 years of normal, age-related loss. During the subsequent six years post-disaster, there was little to no recovery. In updated studies extending follow-up time up to 14 years after 9/11, most firefighters and EMS workers continued to show a lack of lung function recovery [8, 9]. The dose-response association of WTC exposure in relation to lung function remained: firefighters who arrived during the morning of 9/11 averaged lower lung function than did lesser exposed firefighters, a difference that remained statistically significant during most of the follow-up [10].

Methacholine challenge tests identify individuals with bronchial hyperreactivity (BHR), a hallmark of asthma/RADS. At six months post-9/11, firefighters who arrived during the morning of 9/11 were 6.8 times more likely to experience BHR than those who arrived later (odds ratio [OR]: 6.8; 95% CI: 1.8–25.2) [11]. Further, in a recent follow-up study, we found that for many, BHR did not resolve with removal from the noxious exposure, even more than one decade post-9/11, and that persistent BHR predicted an accelerated decline in lung function [10].

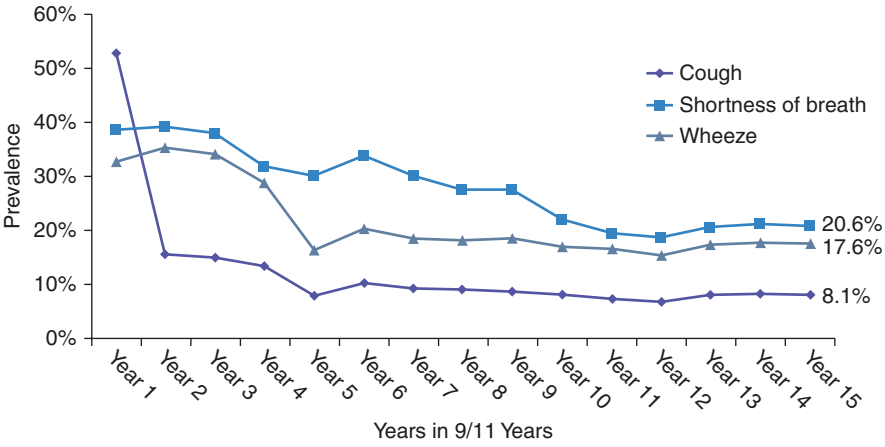

Fig. 1 Prevalence of lower respiratory symptoms by FDNY-WTC responders

Figure 1 shows that immediately after 9/11, cough was the most common respiratory symptom reported by 53% of the FDNY-WTC rescue/recovery cohort, followed by shortness of breath (38%) and wheezing (33%). In the first published post-9/11 study on respiratory health, [1] described "World Trade Center cough syndrome" in an initial sample of 332 WTC-exposed firefighters who were evaluated 6 months after 9/11. WTC cough syndrome was characterized by a constellation of symptoms including a persistent cough and upper respiratory and lower respiratory symptoms (e.g., nasal congestion, nasal drip, sore throat, bronchial hyperreactivity, and/or GERD symptoms). In this sample of 332, the prevalence of this syndrome was greatest in those arriving earliest at the WTC site, on the morning of 9/11 [1].

Subsequent studies confirmed the association between WTC-exposure intensity (as measured by arrival time) and lower respiratory conditions, such as OAD. OAD includes the following physician diagnoses from FDNY medical records: asthma/RADS, chronic obstructive pulmonary disease/emphysema, and chronic bronchitis. In a sample of 8930 firefighters, those who arrived during the morning of 9/11 had four times the OAD diagnosis rate (relative rate, 3.96; 95% CI, 2.51–6.26) of later-arriving firefighters during the first 15 months after 9/11 [12]. Similarly, EMS workers with the earliest arrival time have more than twice the risk (relative risk, 2.4; 95% CI, 1.7–3.6) of being diagnosed with OAD compared with their unexposed counterparts [13]. By 2016, the prevalence of FDNY physician-diagnosed OAD was 26%, with asthma at 20% as the most common diagnosis (Table 1).

Interstitial Lung Diseases

Interstitial lung diseases (ILD) such as sarcoidosis, pulmonary fibrosis, and bronchiolitis obliterans remain far less common than OAD in our cohort, and, with the exception of sarcoidosis, are extremely rare. In the first 14 years post-9/11, we

identified 75 FDNY-WTC responders with new incident sarcoidosis. Pre-9/11, all had normal chest X-rays and normal spirometry and were asymptomatic [14]. This post-9/11 sarcoidosis rate of ~22/100,000 was considerably higher than the average pre-9/11 incidence rate of ~15/100,000. Further, in contrast to pre-9/11 sarcoidosis cases, many FDNY sarcoidosis cases diagnosed post-9/11 were not only symptomatic due primarily to OAD (69%) [14] but also upon further workup, had evidence of cardiac involvement (12%) [15] and/or rheumatologic involvement (15%) [16], the latter often requiring biologicals for disease control.

Upper Respiratory

While not as immediately obvious as a cough and other lower respiratory symptoms, CRS symptoms were also commonly reported by FDNY firefighters and EMS workers. From the first post-9/11 year to 15 years post-9/11, CRS symptoms consistently affected about 40% of the FDNY-WTC rescue/recovery cohort (Fig. 2), in contrast to pre-9/11 reports of frequent rhinosinusitis by 4.4% of FDNY firefighters [17]. Rhinosinusitis symptoms four years post-9/11 were still associated with WTC exposure as measured by both arrival time and duration of work [17].

Examining FDNY medical records, the post-9/11 prevalence of physician-diagnosed CRS increased from 11% in 2005 [18] to 32% in 2016 (Table 1) and was highest in FDNY-WTC responders who arrived either during the morning (36%; Fig. 3) or afternoon of 9/11 (35%). Recent studies confirmed the risk of CRS among early arriving FDNY-WTC responders: firefighters with the earliest arrival time had almost twice the rate of physician-diagnosed CRS when compared with later-arriving firefighters (relative rate: 1.99; 95% CI: 1.64–2.41) [19], and EMS workers with the earliest arrival time had nearly four times the risk of being diagnosed with CRS compared with their unexposed counterparts (relative risk, 3.7; 95% CI, 2.2–6.0) [13].

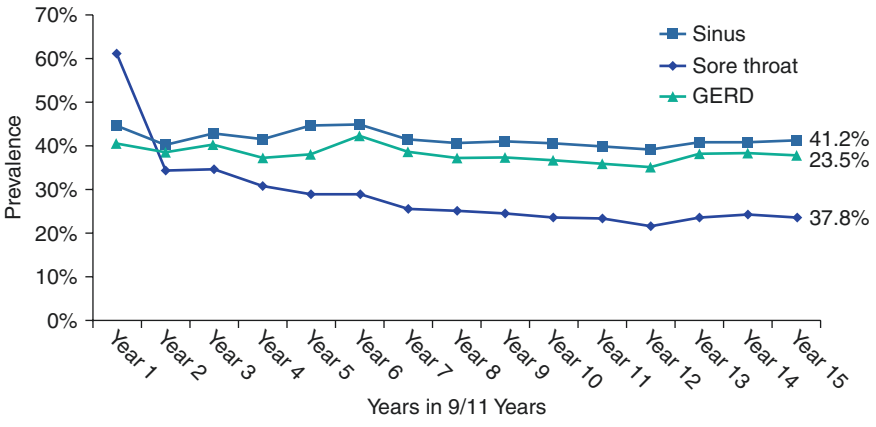

Fig. 2 Prevalence of upper respiratory symptoms by FDNY-WTC responders

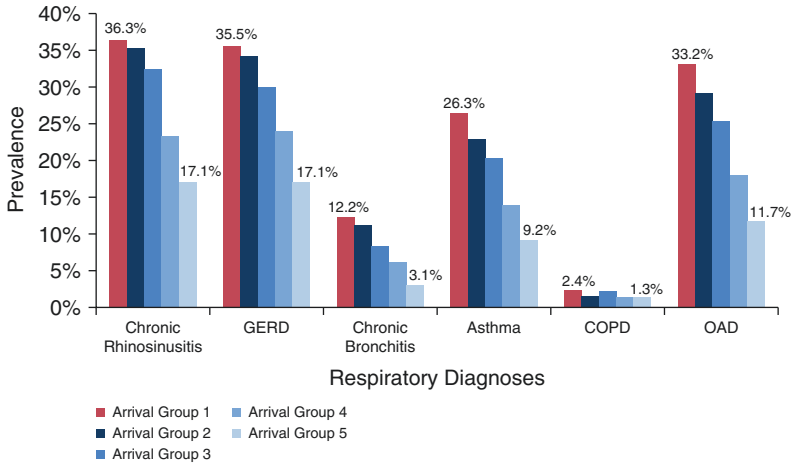

Fig. 3 Post-9/11 prevalence of respiratory health and GERD diagnoses between 2002 and 2015. Note: Arrival Group 1 arrived on the morning of 9/11, Arrival Group 2 arrived during the afternoon of 9/11, Arrival Group 3 arrived on 9/12/2001, Arrival Group 4 arrived any day between 9/13/2001 and 9/24/2001, and Arrival Group 5 arrived after 9/24/2001

GERD

Before 9/11, symptoms consistent with GERD (acid reflux, sore throat, chest burning/tightness, and difficulty swallowing) were reported by 5.2% of FDNY firefighters [17]. However, in the first year post-9/11, 41% reported GERD symptoms, of which sore throat symptoms were the most prevalent (61%; Fig. 2). GERD symptoms, previously shown to be significantly associated with WTC arrival time and duration of work [17], consistently affected about 40% of the FDNY-WTC rescue/recovery cohort (Fig. 2).

The prevalence of FDNY physician-diagnosed GERD was 31% in 2016 (Table 1) and was highest among FDNY-WTC responders with the earliest arrival time (36%; Fig. 3). Firefighters with the earliest arrival time had 1.5 times the rate of having a GERD diagnosis than later-arriving firefighters (relative rate, 1.48; 95% CI, 1.27–1.73) [20], and EMS workers who arrived during the morning of 9/11 had nearly four times the risk of being diagnosed with GERD compared with unexposed EMS (relative risk, 3.8; 95% CI, 2.4–6.1) [13].

Obstructive Sleep Apnea

In 2011, we showed that early arrival time at the WTC site was significantly associated with scoring at high risk for obstructive sleep apnea (OSA) using an adapted Berlin screening survey [21]. In a later study, we confirmed that 81% of 636

participants who scored high risk for OSA had polysomnogram-confirmed OSA [22]. We also found that FDNY responders who arrived at the WTC during the morning of 9/11 had almost twice the odds (OR, 1.91; 95% CI, 1.15–3.17) of polysomnogram-confirmed OSA than those with lower levels of WTC exposure.

Cancer

We showed that seven years after 9/11, FDNY-WTC-exposed firefighters had a 10% higher overall cancer incidence rate (standardized incidence ratio [SIR], 1.10; 95% CI, 0.98–1.25) than the general US male population and a 32% higher rate than in unexposed FDNY firefighters (SIR, 1.32; 95% CI, 1.07–1.62), the latter reaching statistical significance [23]. WTC-exposed firefighters had significantly higher rates for some specific cancers when compared with the general US male population (e.g., prostate [SIR, 1.49; 95% CI, 1.20–1.85] and thyroid [SIR, 3.07; 95% CI, 1.86–5.08]) [23]. In contrast, lung cancer incidence in WTC-exposed firefighters was significantly lower than expected (SIR, 0.42; 95% CI, 0.20–0.86) in the general US male population, likely due to lower smoking rates and the short follow-up period of seven years post-9/11. Two other WTC-exposed cohorts, the WTC Health Consortium and the WTC Health Registry, showed results generally consistent with our findings [4, 5, 24].

Recently, we compared cancer incidence in FDNY-WTC-exposed firefighters to incidence in a combined cohort of career firefighters from Chicago, Philadelphia, and San Francisco [25]. This comparison to firefighters, rather than to the US general population, demonstrated similar, rather than increased, rates of all cancers combined, although rates for thyroid cancer and late-onset prostate cancer remained significantly elevated, similar to our previous results [23].

Autoimmune Diseases

Between 2001 and 2013, we identified 59 FDNY-WTC responders with rheumatologist-confirmed systematic autoimmune disease (SAIDs), of whom 37% had rheumatoid arthritis [26]. In a case-control study, prolonged work at the WTC site was significantly associated with SAIDs: the odds for incident SAIDs increased by 13% (conditional OR, 1.13; 95% CI, 1.02–1.26) for each additional month worked at the site [26].

In a later study, we identified 63 rheumatologist-confirmed cases of SAIDs, but also included 34 additional “probable” cases, that, according to two rheumatologists, likely had SAIDs [27]. Although we found that overall SAIDs rates were not significantly different from expected rates (SIR, 0.97; 95% CI, 0.77–1.21), based on comparison with incident cases from Rochester Epidemiology Project (REP) participants, highly WTC-exposed FDNY responders had an excess of 7.7 cases of SAIDs, while lesser exposed workers had 9.9 fewer cases than expected.

Mental Health

Immediately after 9/11, FDNY-WTC monitoring questionnaires included screening questions for PTSD. In 2005, mental health screening questionnaires were improved and expanded to include validated instruments to assess symptoms consistent with common mental health conditions. The PTSD Checklist (PCL-17) [28] and Center for Epidemiological Studies-Depression scale (CES-D) [29] were used to assess probable PTSD and probable depression, respectively. Before 2005, FDNY assessed probable PTSD using a modified version of the PCL [30]. Alcohol Use Disorders Identification Test (AUDIT) [31] was used to assess harmful alcohol use. Details and scoring of the screening instruments have been previously described [3, 13]. Information from these instruments identified at-risk individuals who were referred to FDNY-CSU. Analyses of these screeners also helped describe the prevalence of probable PTSD, probable depression, and harmful alcohol use and its association with WTC exposure.

Between 2002 and 2005 (years 1 through 4 on Fig. 4), the highest prevalence of probable PTSD was found immediately post-9/11 (10%; Fig. 4) and was especially high among workers with the earliest arrival (25%; data not shown). In fact, this rate of 25% is similar to that reported in survivors of the WTC collapse [32]. In year 15, probable PTSD prevalence was 8% and continued to be higher among workers with the earliest arrival (13%; data not shown). Previous analyses have consistently found an association between PTSD and earliest arrival at the WTC site [13, 30, 33]. Notably, firefighters who arrived during the morning of 9/11 had six times the odds (OR, 6.0; 95% CI, 4.4–8.3) of screening positive for PTSD [33] and EMS workers who arrived during the morning had seven times the risk (OR, 7.0; 95% CI, 3.6–13.5) of screening positive for PTSD [13].

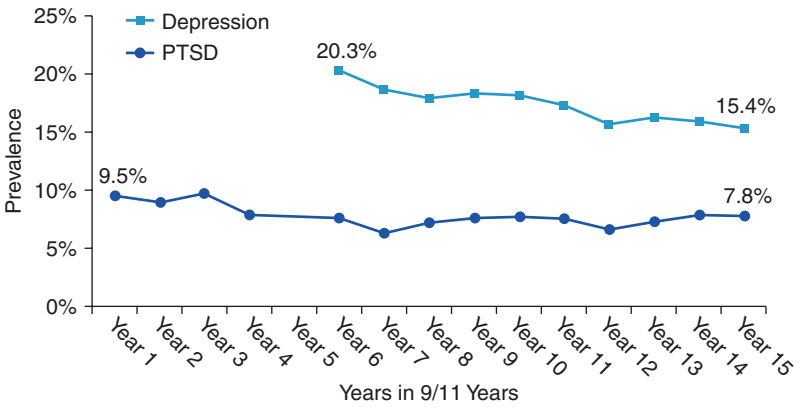

Fig. 4 Probable depression and post-traumatic stress disorder (PTSD) in FDNY-WTC responders. Footnote: PTSD data is unavailable in year 5

High prevalence of probable depression is also documented among FDNY-WTC responders, ranging from 20% in year 6 to 15% in 15 (Fig. 4), and is highest among those with the earliest arrival (20% in year 15; data not shown).

Health Comorbidities

Very substantial comorbidities exist between mental health conditions. Figure 5a shows that, among those who had a mental health questionnaire in year 15, 7% (N = 744) screened positive for both probable PTSD and probable depression. Further, among FDNY-WTC responders with probable PTSD (N = 820), 91% also screened positive for probable depression, and among those with probable depression (N = 1618), 46% also screened positive for probable PTSD. FDNY-WTC responders with harmful alcohol use were twice as likely to screen positive for either PTSD (OR, 2.4; 95% CI, 1.9–4.3) or depression (OR, 1.9; 95% CI, 1.5–2.4) [3].

Physical health conditions also commonly co-occur, such as between WTC cough syndrome and GERD [1] and between CRS, OAD, and GERD [13, 20] (Fig. 5b). By 2016, 1617 (10%) of FDNY-WTC responders had been diagnosed with all three health conditions: CRS, OAD, and GERD (Fig. 5b). Further, 1199 (8%) had both CRS and GERD, 825 (5%) had CRS and OAD, and 692 (4%) had GERD and OAD (Fig. 5b).

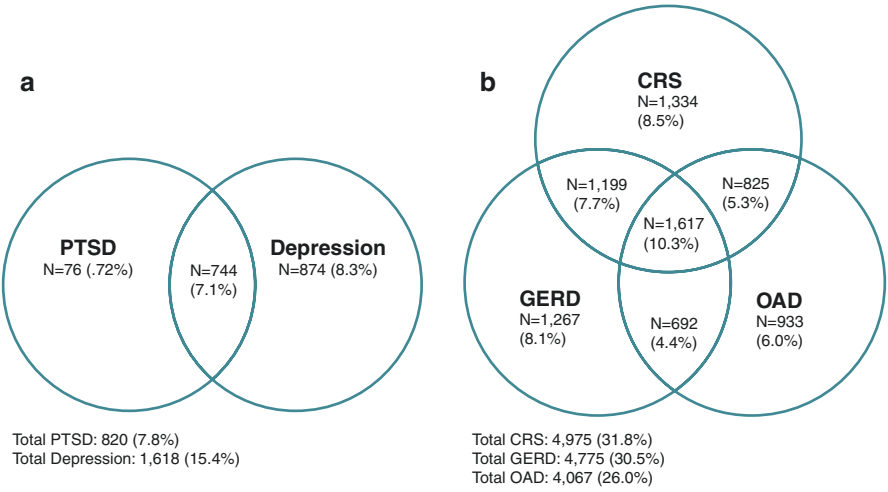

Fig. 5 Mental health (**a**) and physical health (**b**) comorbidities in FDNY-WTC responders. Footnote: Percentages of probable PTSD and probable depression were among N = 10,538 who completed a mental health questionnaire in 9/11 year, year 15 (9/11/2015–9/11/2016). Percentages of CRS, GERD, and OAD were among N = 15,634

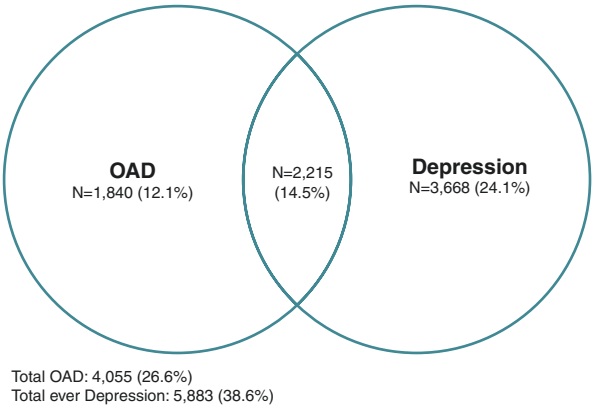

Fig. 6 Obstructive airways disease and probable depression comorbidity. Footnote: Percentages were among $N = 15{,}235$ who ever had a mental health questionnaire

Importantly, we found that an OAD diagnosis increased the risk of additional diagnoses: firefighters with an OAD diagnosis were more than four times more likely to have a CRS diagnosis (relative rate, 4.15; 95% CI, 3.70–4.66) and more than three times more likely to have a GERD diagnosis (relative rate, 3.18; 95% CI, 2.90–3.48) [20].

Finally, physical and mental health conditions also frequently occur in the same individuals: 15% of those who ever had a mental health questionnaire had both a diagnosis of OAD and reported symptoms consistent with depression (Fig. 6). Nearly 38% of 5883 FDNY-WTC responders who ever screened positive for probable depression also had an OAD diagnosis, and 55% of 4055 workers who had OAD at any time also had probable depression. In another study, we found that firefighters who had probable PTSD shortly after 9/11 had increased odds of WTC cough syndrome up to four years post-9/11 (OR: 1.56; 95% CI: 1.23–1.99) [34]. And among EMS workers who screened positive for PTSD, depression, or harmful alcohol use, 35% had at least one respiratory condition: CRS, GERD, or OAD [13].

Discussion

This report showed that FDNY firefighters and EMS workers with the highest levels of WTC exposure had the greatest risk for adverse health conditions ranging from OAD to PTSD and that, over time, this disproportionate health burden remained. To date, the most highly exposed continue to have the highest prevalence of physician-diagnosed respiratory health conditions such as OAD (33% vs. overall 26%), CRS (36% vs. overall 32%), and GERD (36% vs. overall 31%); 15 years after 9/11, they have the highest prevalence of mental health conditions such as probable PTSD (13% vs. overall 8%) and probable depression (20% vs. overall 15%).

A substantial number of FDNY-WTC responders exhibited impaired pulmonary function. Most of those who experienced an unprecedented decline in lung function shortly after 9/11 continue to show either lack of recovery or only a partial recovery

up to 15 years later. Symptoms or diagnoses of respiratory health conditions were rare before 9/11; by 2016, half of the FDNY-WTC rescue/recovery cohort had at least one of the following physician diagnoses: OAD, CRS, or GERD.

The pathophysiological causes of these respiratory conditions, which frequently co-occur in the same individuals, are a topic of intense investigation. Inhalation injuries of toxic, highly alkaline dust at the WTC site, and the lack of personal protective respirators, likely triggered upper and lower respiratory tract injury, inflammation, and symptoms [35]. For the majority of those affected, this has resulted in airways obstruction, as indicated by pulmonary function and methacholine challenge tests and chest CT scans [36]. As for the high incidence of GERD symptoms, ingestion of WTC dust, and other hazardous substances, along with risk factors such as stress in general and PTSD specifically, poor diet, side effects from medications prescribed for WTC-related conditions, and weight gain likely irritated the gastroesophageal tract [1, 35]. Given the observed high comorbidity between GERD, CRS, and OAD, it is unknown whether GERD causes respiratory symptoms or contributes to the persistence of airway inflammation [1, 35]. Nonetheless, WTC treatment guidelines stress that successful management of respiratory conditions is linked to successful treatment of GERD symptoms [35]. It is also important to consider evaluation of possible mental health problems such as PTSD in the treatment of persistent respiratory and GERD conditions, especially given the high comorbidities in this cohort.

Persistence of disease is likely the result of chronic inflammation initiated by exposure to the dust and potentiated by host characteristics as demonstrated by induced sputum studies showing significantly increased percentages of inflammatory biomarkers, neutrophils, and eosinophils in those with high WTC exposure [37] and by serum studies from blood drawn within six months of 9/11 showing elevated levels of known inflammatory biomarkers, such as macrophage-derived chemokines, that were associated with increased risk of subsequent abnormal pulmonary function [38]. The protease/anti-protease imbalance defined by mild to moderate genetic deficiency of alpha-1 antitrypsin deficiency [39] and the elevated set points of eosinophils and IgE levels observed in those with non-resolving upper and lower airways inflammation [40, 41] are intrinsic characteristics of patients that can be assessed repeatedly using inexpensive, commercially available techniques. The ultimate goal of this line of investigation is to develop risk stratification models that allow for more intensive monitoring and treatment of those individuals at the highest risk for WTC-related health effects based not only on WTC-exposure intensity but also on host sensitivity. In so doing, it may also identify targets for more effective therapeutic agents in those with poorly controlled symptoms.

Strengths and Limitations

As described elsewhere [3, 13], our studies may have limitations. First, some of our results may be affected by surveillance bias because the WTCHP schedules periodic monitoring evaluations and provides free treatment for FDNY-WTC responders.

As such, FDNY-WTC responders have increased access to care than the general population. However, we consistently make efforts to address this potential bias. For example, in our cancer studies, we delayed the recorded cancer diagnosis date by two years or more in some analyses and found results similar to those uncorrected for surveillance bias [23, 25].

Another limitation is the lack of a suitable comparison group to WTC-exposed FDNY firefighters. Nearly 99% of the active firefighter workforce participated in the WTC rescue/recovery efforts either on the day of the collapse or in subsequent months. The small minority of firefighters who never worked at the WTC site were older on 9/11 and had worse pre-9/11 health status compared with those who worked at the site, rendering the two groups dissimilar. For that reason, many of our analyses have used external comparison groups including the general US population, REP participants [26], and more recently, NIOSH 3-cities firefighter cohort [25]. Because FDNY-WTC responders had stringent pre-hire health requirements, and were routinely screened post-hire, previous comparisons with the general US male population and REP participants may be limited by dissimilar health status at baseline [3, 27]. The NIOSH 3-cities firefighter cohort, a group more similar to FDNY WTC firefighters, is limited by data that ends in 2009 [25, 42] and an absence of data on smoking status and other potential confounders.

In addition, for mental health conditions, our research studies used validated screening tools rather than physician diagnoses. The use of screeners taken as part of routine monitoring exams, however, may have yielded more in-depth information about the size of the at-risk population. Finally, we acknowledge limited generalizability of our findings to women and minorities and to individuals with lower levels of WTC exposure. The FDNY WTC-exposed cohort is highly exposed and comprised predominantly of white males.

Despite these limitations, FDNY-WTCHP has strengths that enabled us to identify new health conditions and to make causal inferences about the role of WTC exposure in their development. These strengths result from the fact that this cohort existed prior to 9/11, minimizing selection bias, and was served by a pre-existing health infrastructure that had the confidence of both FDNY responders and their leaders to continue serving in this capacity after 9/11. First, because the cohort existed prior to 9/11, we avoided self-selection bias into the FDNY-WTC cohort. Second, because FDNY members had routine health assessments by BHS starting years before 9/11, we have pre-9/11 health information on nearly all of the enrollees, which has allowed us to document the temporal order of disease development in relation to WTC exposure. Third, for physical health conditions, we have direct access to FDNY medical records, which contain FDNY physician diagnoses and clinical data from pulmonary and radiographic tests. Finally, because retirees are included in the program for both monitoring and treatment, the FDNY-WTCHP has minimal longitudinal dropout, thereby allowing health surveillance epidemiologic studies to be more representative of the entire FDNY rescue/recovery cohort.

Conclusion

The collective experience of FDNY-WTCHP physicians and researchers has contributed greatly to the identification and treatment of WTC-related health conditions. FDNY and the FDNY-WTCHP remain committed to providing effective medical care and documenting existing and emergent health conditions for the FDNY-WTC rescue/recovery cohort and, by extension, for all affected individuals in the NYC community and beyond.

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