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Trends in respiratory diagnoses and symptoms of firefighters exposed to the World Trade Center disaster: 2005–2010

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ABSTRACT

Objectives. To compare the prevalence of self-reported respiratory diagnoses in World Trade Center-exposed Fire Department of New York City firefighters to the prevalence in demographically similar National Health Interview Survey participants by year; and, 2) to describe the prevalence of World Trade Center-related symptoms up to 9 years post-9/11.

Methods. We analyzed 45,988 questionnaires completed by 10,999 firefighters from 10/2/2001 to 9/11/2010. For comparison of diagnosis rates, we calculated 95% confidence intervals around yearly firefighter prevalence estimates and generated odds ratios and confidence intervals to compare the odds of diagnoses in firefighters to the National Health Interview Survey prevalence, by smoking status.

Results. Overall, World Trade Center-exposed firefighters had higher respiratory diagnosis rates than the National Health Interview Survey; Fire Department of New York City rates also varied less by smoking status. In 2009, bronchitis rates in firefighters aged 45–65 were 13.3 in smokers versus 13.1 in never-smokers while in the National Health Interview Survey, bronchitis rates were doubled for smokers: 4.3 vs. 2.1. In serial cross-sectional analyses, the prevalence of most symptoms stabilized by 2005, at ~10% for cough to ~48% for sinus.

Conclusions. We found generally higher rates of respiratory diagnoses in World Trade Center-exposed firefighters compared to US males, regardless of smoking status. This underscores the impact of World Trade Center exposure and the need for continued monitoring and treatment of this population.

Introduction

The 9/11 terrorist attacks on the World Trade Center (WTC) created a man-made disaster of devastating magnitude, resulting in the release of great volumes of dust and debris into the environment. It has been estimated that approximately 70% of the towers' structural components were pulverized during the collapse, producing small and large inhalable particulates (Lioy et al., 2002).

Adverse short-and medium-term respiratory effects in Fire Department of New York City (FDNY) first responders and others have been widely documented (Banauch et al., 2003; Levin et al., 2002; Lin et al., 2005, 2010; Reibman et al., 2005; Wheeler et al., 2007). Our FDNY team first reported WTC cough syndrome (Prezant et al., 2002) and more recently demonstrated that work-related exposures on and after 9/11 increased the odds of aerodigestive symptoms up to four years later (Webber et al., 2009). Others have reported persistent lower respiratory symptoms in moderately-exposed workers 5 years post-9/11 (Mauer et al., 2010), and in NYC residents 5 to 8 years post-9/11 (Reibman et al., 2009). Further, we documented a lack of recovery in pulmonary function in FDNY rescue/recovery workers 7 years post-9/11 (Aldrich et al., 2010). While the WTC Registry has reported an association between acute exposure and self-reports of doctor-diagnosed asthma (Brackbill et al., 2009), no study to date has reported on the full spectrum of doctor-diagnosed respiratory diseases post-9/11.

The goals of the current analyses are: 1) to compare the prevalence of specific self-reported diagnosed respiratory conditions in WTC-exposed FDNY firefighters to the prevalence in demographically similar participants in the National Health Interview Survey (NHIS) during the same year; and, 2) to describe the current prevalence of respiratory and gastroesophageal reflux symptoms (GERS) up to 9 years after 9/11.

Abbreviations: COPD, chronic obstructive pulmonary disease; FDNY, Fire Department of New York City; GERS, gastroesophageal reflux symptoms; LRS, lower respiratory symptoms; NHIS, National Health Interview Survey; RADS, reactive airways dysfunction syndrome; URS, upper respiratory symptoms; WTC, World Trade Center.

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Methods

Beginning in October of 2001, the FDNY Bureau of Health Services expanded their periodic medical examinations, performed at 12–18 month intervals, to include self-administered physical and mental health questionnaires. In 2005, questions were added to capture self-reports of doctor-diagnoses of upper and lower respiratory conditions and GERS. The study was approved by the Montefiore Medical Center Institutional Review Board and participation required written informed consent.

Participants

The original population consisted of 11,790 firefighters hired before July 25, 2002, the date the WTC site formally closed, and who arrived at the WTC site within 14 days of 9/11. We removed 791 non-white and 28 women firefighters from the analytic cohort to allow for comparison of doctor diagnoses in the firefighter cohort to diagnoses reported by the NHIS database for white males. The final FDNY population consisted of 10,999 WTC-exposed white male firefighters. We also evaluated 3545 unexposed white male firefighters, 90% hired after the WTC site closed, to use as a reference population for the WTC-exposed.

Data sources

Demographic data came from the FDNY employee database. All other information (e.g., ever/never smoking) came from the self-administered questionnaires.

Doctor diagnoses of respiratory illnesses — FDNY comparison to US white males National Health Interview Survey (NHIS)

The NHIS is a household, multi-stage probability sample survey conducted annually by the National Center for Health Statistics and fielded by the US Census Bureau for the Centers for Disease Control and Prevention's National Center for Health Statistics (US Dept. of Health and Human Services). We calculated NHIS rates of self-reported doctor-diagnosed sinusitis, asthma, chronic obstructive pulmonary disease (COPD)/emphysema, and bronchitis for white males ages 18–44 and 45–65 and compared rates to FDNY rates for white males in similar age groups during the same year. Five FDNY questions mirrored those asked in the NHIS questionnaire. For example, to determine sinusitis rates, our questionnaire asked, "In the past 12 months, has a doctor or health professional told you that you have sinusitis/rhinitis?" This compares to the NHIS survey question of "Had you been told by a doctor or other health professional in the past 12 months that you had sinusitis?" For asthma, the NHIS asked if the respondent had ever been told by a doctor or other health professional that they had asthma. Respondents who had been told they had asthma were asked if they still had asthma. FDNY questions asked "has a doctor or health professional told you that you have asthma/RADS (Reactive Airways Dysfunction Syndrome)?" Respondents were then asked if their current asthma had resolved. If not, we considered them as having current asthma. We could not compare doctor diagnoses of gastroesophageal disease with the NHIS reference group because it was not available in the NHIS database.

FDNY symptom prevalence

Upper respiratory symptoms (URS) included nasal/sinus drip/congestion or sore/hoarse throat. Lower respiratory symptoms (LRS) included dyspnea or wheezing. GERS included acid reflux, chest burning/tightness, heartburn or associated nausea. To determine the presence of current URS or LRS, participants who indicated they had any of these symptoms post-9/11 were asked to check off the most accurate description of each current symptom from choices which included: "Currently, has your symptom resolved", "feel normal when on medication/treatment", "improved", "stayed the same" and "worsened". If the participant indicated any response except "resolved", the symptom was considered "current". To determine the presence of current cough, we asked participants "In the past 12 months, apart from when you had a cold, have you had a regular or usual cough? (At least 4 times per day, 4 days per week, 4 consecutive weeks per year.)" If participants answered 'yes' they were then asked, "In the past 4 weeks, how often have you had a regular or usual cough while you were awake?" We required the response of "daily or almost daily (apart from cold)" to have current cough. GERS were estimated based on a positive response to "chest tightness", "chest pain", "chest pressure", "chest stabbing", or "chest burning" since 9/11. If "yes", participants were then asked "Currently, has your acid reflux, regurgitation, heartburn, indigestion, and/or nausea: Resolved; feel normal when on medication/treatment; improved; stayed the same; worsened?" If the participant indicated any response except "resolved", the participant was considered to have current GERS.

Cross-sectional time periods

For analyses of current symptoms, we included data from 45,988 questionnaires, analyzing each one-year time period separately. If persons completed more than one questionnaire during any one year, only data from the first were used. We included questionnaires administered from 10/2/01 to 9/11/02 (N = 8340) as Year 1; questionnaires from 9/12/02 to 9/11/03 (N = 1118) as Year 2; questionnaires from 9/12/03 to 9/11/04 (N = 2693) as year 3; questionnaires from 9/12/04 to 9/11/05 (N = 4173) as Year 4; questionnaires from 9/12/05 to 9/11/06 (N = 5226) as Year 5; questionnaires from 9/12/06 to 9/11/07 (N = 5078) as Year 6; questionnaires from 9/12/07 to 9/11/08 (N = 5827) as Year 7; questionnaires from 9/12/08 to 9/11/09 (N = 6589) as Year 8, and questionnaires from 9/12/09 to 9/11/10 (N = 6944) as Year 9.

Statistical analysis

For comparison with NHIS national prevalence data, we calculated 95% confidence intervals (CI) around yearly prevalence estimates of diagnoses and generated odds ratios (OR) and CIs to compare the odds of diagnoses in study participants to the NHIS prevalence for white males in a similar age group. The NHIS estimates, and the odds ratios of FDNY to NHIS, were computed using the sampling weights in the NHIS complex sampling design and for non-response in NHIS. We also computed rates for FDNY and NHIS stratified by smoking status. To demonstrate the disparity in respiratory diagnoses, we calculated prevalence ratios between NHIS and firefighters in both age groups, again taking into account the sampling design. The Taylor series (linearization) method was used to estimate parameter variances taking into account the complex sampling design (Krewski and Rao, 1981). Analyses were performed using SAS, version 9.2 (SAS Institute, Inc., Cary, NC, USA, http://www.sas.com).

Results

Characteristics of the population

From October 2, 2001 to September 11, 2009, 45,988 surveys were collected from the 10,999 WTC-exposed firefighters. Participants' mean (±SD) age on 9/11 was 41.0 (±8.4) years and 63.7% never smoked. Overall, 15.1% were in arrival group 1, 60.8% in arrival group 2; 14.0% in arrival group 3 and 10.1% in arrival group 4. The overall mean duration of work at the WTC site was 4.1 (±2.8) months. In the last study year (year 9), 30.0% were in the 18–44 age group, 64% in the 45–65 age group, and 6.1% were over the age of 65 and not included in the NHIS comparison analyses. We collected 9729 surveys from 3545 WTC-unexposed firefighters. Their mean (±SD) age on 9/11 was 23.2 (±4.0) and 66.6% never smoked.

Respiratory diagnoses: FDNY firefighters compared to US males (NHIS)

In post-9/11 year 5, the first year we obtained information about doctor-diagnoses, the prevalence of doctor-diagnosed sinusitis/rhinitis, bronchitis, and COPD/emphysema was similar to or higher in the WTC-exposed FDNY population compared to population rates for US white males, except for asthma diagnoses in those below age 45 (Table 1). The discrepancy became larger in bronchitis and COPD/emphysema, as rates in the WTC-exposed increased, while national rates remained relatively stable. By 2009, the prevalence in WTC-exposed firefighters, regardless of age, was highest for ever asthma, followed by sinusitis/rhinitis, and lowest for COPD/emphysema. Prevalence ratios, comparing FDNY to NHIS rates, were highest for COPD/emphysema and bronchitis.

Table 1
Prevalence and odds ratios of self-reported respiratory diagnoses — by year and age group in WTC-exposed FDNY and NHIS populations 2005–2009.

2005	FDNY WTC-exposed prevalence (95% CI)	NHIS data prevalence (95% CI)	Odds ratio (95% CI)[a]
Sinusitis/rhinitis			
18–44	10.1 (9.0–11.2)	8.9 (8.1–9.8)	1.2 (0.98–1.4)
45–65	12.0 (10.7–13.4)	10.8 (9.7–12.0)	1.1 (0.95–1.3)
Asthma ever			
18–44	6.9 (6.0–7.9)	9.5 (8.6–10.5)	0.7 (0.6–0.8)
45–65	13.9 (12.5–15.4)	7.9 (7.0–8.9)	1.9 (1.6–2.2)
Asthma current			
18–44	3.3 (2.7–4.0)	5.1 (4.5–5.8)	0.6(0.5–0.8)
45–65	8.9 (7.8–10.1)	4.9 (4.2–5.7)	1.9(1.5–2.4)
Bronchitis			
18–44	8.0 (7.1–9.1)	2.1 (1.7–2.6)	4.1 (3.2–5.3)
45–65	8.7 (7.7–10.0)	3.1 (2.5–3.8)	3.0 (2.3–3.9)
COPD/emphysema			
18–44	0.5 (0.3–0.8)	0.4 (0.2–0.6)	1.2 (0.6–2.4)
45–65	3.5 (2.8–4.3)	2.4 (1.9–3.0)	1.5 (1.1–2.1)
2006	FDNY	NHIS	
Sinusitis/rhinitis			
18–44	15.0 (13.7–16.4)	9.0 (8.0–10.2)	1.8 (1.5–2.1)
45–65	15.8 (14.3–17.3)	12.6 (11.1–14.2)	1.3 (1.1–1.6)
Asthma ever			
18–44	10.4 (9.3–11.6)	9.9 (8.8–11.1)	1.1 (0.9–1.3)
45–65	17.2 (15.7–18.8)	8.8 (7.7–10.1)	2.1 (1.8–2.5)
Asthma current			
18–44	7.0 (6.1–8.0)	5.3 (4.5–6.3)	1.3 (1.1–1.7)
45–65	13.1 (11.7–14.5)	5.8 (4.8–6.9)	2.5 (2.0–3.1)
Bronchitis			
18–44	12.1 (10.9–13.4)	1.7 (1.3–2.1)	8.2 (6.2–10.8)
45–65	11.7 (10.5–13.1)	3.4 (2.7–4.3)	3.8 (2.9–5.0)
COPD/emphysema			
18–44	1.0 (0.7–1.4)	0.3 (0.1–0.5)	3.8 (1.7–8.1)
45–65	4.5 (3.7–5.4)	3.4 (2.6–4.3)	1.4 (0.98–1.9)
2007	FDNY	NHIS	
Sinusitis/rhinitis			
18–44	14.4 (13.1–15.8)	8.1 (7.0–9.3)	1.9 (1.6–2.3)
45–65	16.3 (15.0–17.7)	11.9 (10.3–13.6)	1.5 (1.2–1.7)
Asthma ever			
18–44	10.6 (9.5–11.9)	11.3 (10.1–12.5)	1.0 (0.8–1.1)
45–65	17.5 (16.2–18.9)	8.9 (7.7–10.2)	2.2 (1.8–2.6)
Asthma current			
18–44	5.9 (5.0–6.9)	5.6 (4.7–6.6)	1.1 (0.8–1.4)
45–65	11.7 (10.6–12.9)	5.3 (4.4–6.4)	2.4 (1.9–3.0)
Bronchitis			
18–44	13.2 (11.9–14.6)	1.5 (1.1–2.1)	9.7 (6.9–13.7)
45–65	13.8 (12.6–15.1)	2.8 (2.1–3.6)	5.6 (4.2–7.5)
COPD/emphysema			
18–44	1.0 (0.7–1.5)	0.2 (0.1–.6)	4.3 (1.5–12.3)
45–65	5.4 (4.6–6.2)	2.8 (2.1–3.6)	2.0 (1.5–2.7)
2008	FDNY	NHIS	
Sinusitis/rhinitis			
18–44	16.4 (14.9–17.9)	8.5 (7.5–9.7)	2.1 (1.8–2.5)
45–65	19.3 (18.1–20.6)	10.9 (9.6–12.4)	2.0 (1.7–2.3)
Asthma ever			
18–44	11.8 (10.5–13.2)	12.1 (10.8–13.5)	0.97 (0.8–1.2)
45–65	21.8 (20.6–23.1)	9.2 (8.0–10.5)	2.8 (2.3–3.3)
Asthma current			
18–44	6.0 (5.1–7.1)	5.4 (4.4–6.4)	1.1 (0.9–1.5)
45–65	14.0 (12.9–15.1)	5.7 (4.8–6.7)	2.7 (2.2–3.3)

Table 1 (*continued*)

2008	FDNY	NHIS	
Bronchitis			
18–44	13.8 (12.4–15.3)	2.0 (1.5–2.6)	8.0 (5.8–11.1)
45–65	14.6 (13.5–15.7)	3.9 (3.2–4.8)	4.2 (3.3–5.3)
COPD/emphysema			
18–44	1.5 (1.1–2.1)	0.3 (0.1–0.6)	5.8 (2.2–15.0)
45–65	7.2 (6.5–8.1)	2.2 (1.7–3.0)	3.5 (2.5–4.7)
2009	FDNY	NHIS	
Sinusitis/rhinitis			
18–44	17.2 (15.6–18.8)	8.4 (7.3–9.7)	2.3 (1.9–2.7)
45–65	19.5 (18.4–20.7)	12.2 (10.8–13.7)	1.8 (1.5–2.1)
Asthma ever			
18–44	13.1 (11.7–14.6)	13.0 (11.6–14.4)	1.0 (0.9–1.2)
45–65	24.5 (23.3–25.8)	9.0 (7.9–10.1)	3.3 (2.8–3.8)
Asthma current			
18–44	6.3 (5.3–7.4)	5.8 (4.9–6.7)	1.1 (0.9–1.4)
45–65	14.9 (13.8–15.9)	4.9 (4.1–5.8)	3.4 (2.8–4.2)
Bronchitis			
18–44	13.0 (11.6–14.5)	2.1 (1.5–2.7)	7.1 (5.2–9.8)
45–65	13.2 (12.2–14.2)	3.3 (2.7–4.1)	4.4 (3.5–5.5)
COPD/emphysema			
18–44	1.5 (1.1–2.1)	0.3 (0.2–0.7)	4.4 (2.1–9.1)
45–65	7.6 (6.9–8.4)	3.2 (2.6–3.9)	2.5 (2.0–3.2)

WTC, World Trade Center; FDNY, Fire Department of the City of New York, New York, New York, USA; NHIS, National Health Interview Survey, USA; COPD, chronic obstructive pulmonary disease; CI, confidence interval.

[a] Odds ratios represent the comparison of WTC-exposed to NHIS males in the same age group.

Bronchitis was nearly six-fold higher in young WTC-exposed firefighters and nearly four-fold higher in older firefighters (Figs. 1 and 2).

After stratification by smoking status, we found little difference between FDNY ever-smokers and never-smokers for all diagnoses. There were, however, substantial differences in bronchitis rates by WTC exposure (Fig. 4). The effect of WTC exposure was similar for COPD/emphysema rates (not shown), although these rates were based on few cases, both in FDNY and in the NHIS populations.

Compared to NHIS rates, increases in rates of diagnosis are limited to WTC-exposed firefighters, regardless of smoking status. In unexposed firefighters ages 18–44, the asthma rate was 0.06% in year 5 and 0.04% in year 9. Sinusitis/rhinitis rates were 1.3% in year 5 and 1.7% in year 9. Bronchitis rates were 1.4% in year 5 and 2.2% in year 9. Further, COPD/emphysema was only reported by 1 individual in year 8 and 1 in year 9. FDNY firefighters aged 45–65 are almost entirely WTC-exposed so we were unable to calculate analogous rates for this age group.

Cross-sectional symptom prevalence

Pre-9/11 LRS, URS and GERS were reported by between 1% and 5% of WTC-exposed firefighters. There were striking immediate post-9/11 increases in the prevalence of all symptoms. Serial cross-sectional analyses of post-9/11 years 1–4 have been reported (Webber et al., 2009). In year 5, prevalence rates ranged from a low of 9.5% for cough to

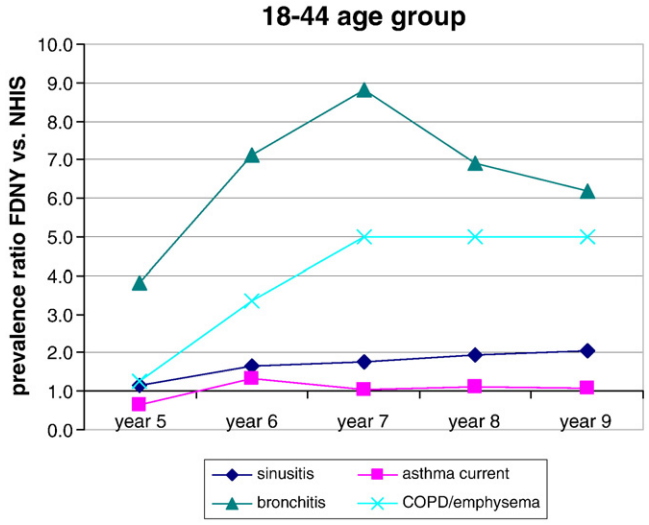

Fig. 1. Prevalence ratios of self-reported respiratory diagnoses 2005–2010: WTC-exposed FDNY vs. NHIS white male adult populations — 18–44 year age group.

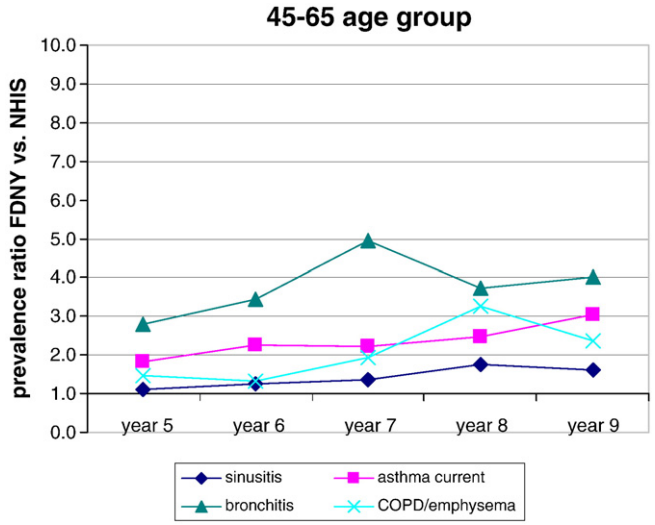

Fig. 2. Prevalence ratios of self-reported respiratory diagnoses 2005–2010: WTC-exposed FDNY vs. NHIS white male adult populations — 45–65 year age group.

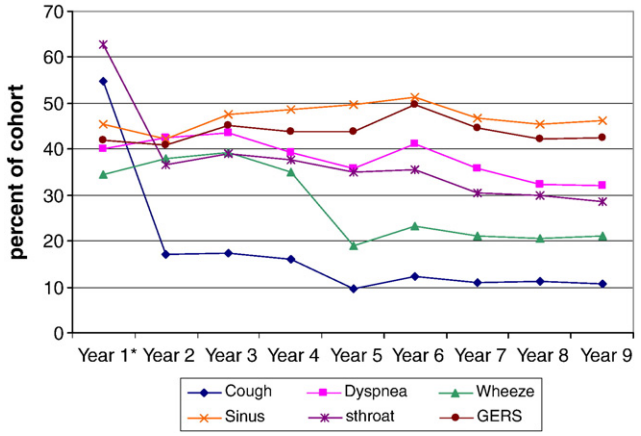

Fig. 3. Prevalence of symptoms of WTC-Exposed firefighters across 9 years since 10/02/2001. *Years refer to study years starting 10/2/2001.

49.4% for sinus. Between years 5 and 9, symptom prevalence appears to stabilize (Fig. 3). During the final study year, 25.4% of participants were co-morbid for LRS and GERS; 29.6% for URS and LRS; 30.7% for URS and GERS symptoms, with 43.7% and 21.0% co-morbid for at least one symptom in any two or in all three symptom groups, respectively.

Discussion

This study of 10,999 WTC-exposed white male firefighters demonstrates their significantly greater likelihood of reporting doctor-diagnosed respiratory conditions compared with demographically similar US males surveyed as part of NHIS during the same time period. From 2005, the first year FDNY obtained information about doctor-diagnoses to 2009, we found that the annual prevalence of diagnoses increased, especially for bronchitis (from 8.0% to 13.0% in younger and from 8.7% to 13.2% in older men) and for sinusitis/rhinitis (from 10.1% to 17.2% in younger and from 12.0% to 19.5% in older men). This contrasts with the NHIS dataset where diagnosis prevalence rates remained stable in both age groups. We also demonstrated that despite higher absolute prevalences of diagnoses in the 45–65 age group, the disparity between WTC-exposed firefighters and the reference group for bronchitis and COPD/emphysema, was greater in the younger men. This disparity

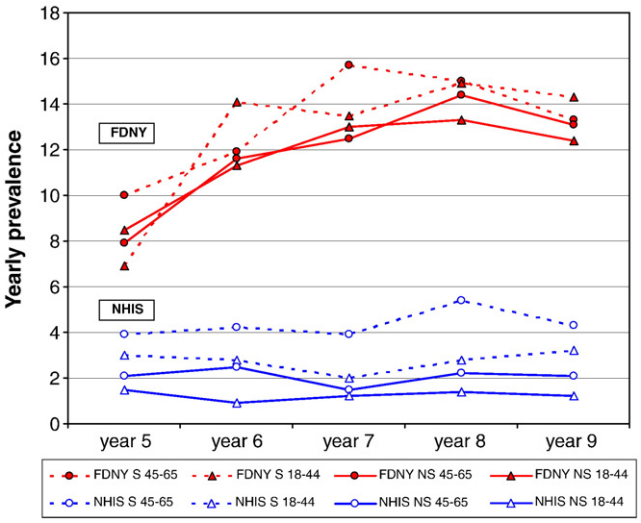

Fig. 4. Prevalence of bronchitis diagnosis in WTC-Exposed firefighter and NHIS populations stratified by smoking 2005–2010. NS = non-smokers. S = smokers.

is disturbing as pre-hire, firefighters are rigorously screened to meet high standards of respiratory health and cannot be hired if there is evidence of any condition that could interfere with the safe performance of essential job-tasks. We believe that the increase in respiratory diagnoses is not related to usual firefighting activities as since 9/11, structural fires have decreased (FDNY annual reports), personal protective equipment has improved, and smoking rates in firefighters have all declined. In fact, the current smoking rate in 18–45 year old firefighters is less than one third of the national rate (7.9% vs. 28.2% in white males). Further, the prevalence of respiratory diagnoses was low in non-WTC-exposed young firefighters, and was stable over time.

As expected, NHIS diagnosis rates were considerably higher in smokers compared with never smokers. This led to very high ORs for bronchitis and COPD/emphysema, in FDNY never-smokers. When we stratified analyses by smoking status, we found that FDNY diagnosis rates, often slightly higher in smokers, were generally similar. The only exception was COPD/emphysema, but these rates were based on few cases. Thus the effects of WTC exposure in the FDNY cohort were greater than the effects of smoking in the general population. Further follow up is needed to determine if this will persist over the next 10 to 20 years.

In the FDNY cohort, asthma diagnoses differed by age but not by smoking status. In 2005, the WTC-exposed rate was significantly lower than national rates. In the older age group, however, WTC-exposed rates climbed higher each year. In 2009, the WTC-exposed prevalence of asthma was 14.9%, with corresponding odds of an asthma diagnosis about 3.3 times the national average. Although the rate we found is similar to rates reported by other WTC rescue/recovery workers, the increase is probably greater because unlike other workers, FDNY firefighters did not have asthma pre-WTC exposure. For example, in the WTC Registry cohort, the incidence of new-onset asthma during the first 5–6 years post-9/11 was 10.2% (Brackbill et al., 2009).

Our serial cross-sectional analyses document the ongoing symptom burden of early WTC exposure, even 9 years post-WTC. Cough and sore throat symptom patterns were similar, starting with very low pre-9/11 rates, a spike in the first year following 9/11, recovery in the next year, followed by a leveling off of symptom prevalence after year 2. In contrast, GERS and sinus symptoms were commonly reported post-9/11 and remained high throughout the study period.

There are potential limitations to this work. We recognize that higher rates of self-reported doctor diagnoses in the FDNY group may partially reflect full and free access to medical care for WTC-related health conditions, which increased the proportion of FDNY participants who report having seen a physician in the last 12 months over NHIS proportions. In 2005, 74% of our cohort saw an FDNY physician compared with 72% in the NHIS population. After 2006, FDNY rates generally increased: in 2007, 2008 and 2009, FDNY rates were 75%, 79% and 82%, respectively while throughout all years, NHIS rates remained approximately 72%. We also acknowledge that FDNY rates of diagnoses are based on a repeatedly monitored cohort whereas NHIS rates come from a cross-sectionally surveyed sample. While these conditions contribute to the likelihood of some detection or surveillance bias in the FDNY cohort, we also note that the NHIS comparison population includes individuals who work and those who are too ill to work. In addition to possible detection bias, our questionnaire did not differentiate between emphysema and the more general diagnosis of COPD. The rise in COPD/emphysema prevalence, therefore, may partially reflect the use of COPD diagnosis to indicate respiratory illness when a physician has uncertainty about a specific diagnosis. There were also other small wording differences between our questions and the NHIS versions. Finally, we did not have information describing treatment, precluding examination of its influence on symptoms or diagnoses. Despite limitations, we believe there are numerous strengths to this work. This is the first study to document the full spectrum of upper and lower respiratory disease using self-reported doctor-diagnoses as compared to the general population. The sample size is

large, and less likely to self-select for participation based on symptoms because active firefighters are required to come in for monitoring exams and since 2005, retirees are strongly encouraged to do the same.

Conclusion

Firefighters exposed to the WTC continue to bear a heavy disease burden, even 9 years post-9/11. These findings reinforce and extend our earlier ones, adding the specificity of doctor diagnoses. Our recommendations remain: (1) strict enforcement of strategies to provide protection from environmental hazards, particularly during disaster recovery and clean-up phases, when such protection is feasible; and, (2) continued monitoring of the exposed and treatment of the affected.

Conflict of interest statement

Several of the authors are employed by the Fire Department of New York City. This in no way interfered with the authors' freedom to design, conduct, interpret and publish research. All authors have declared that there are no actual or potential competing financial interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.ypmed.2011.09.001.

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