ehp Environmental Health Perspectives
ehponline.org
Published by the National Institute of Environmental Health Sciences

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doi:10.1289/ehp.9592 (available at http://dx.doi.org/)
Online 6 September 2006

The National Institute of Environmental Health Sciences
National Institutes of Health
U.S. Department of Health and Human Services

The World Trade Center Disaster and the Health of Workers:
Five-Year Assessment of a Unique Medical Screening Program

Robin Herbert[1], Jacqueline Moline[1], Gwen Skloot[2], Kristina Metzger[1], Sherry Baron[3], Benjamin Luft[4], Stephen Markowitz[5], Iris Udasin[6], Denise Harrison[7], Diane Stein[1], Andrew Todd[1], Paul Enright[8], Jeanne Mager Stellman[1,9], Philip J. Landrigan[1], Stephen M. Levin[1]

[1] *Department of Community and Preventive Medicine, Mount Sinai School of Medicine, New York, NY*
[2] *Div of Pulmonary, Critical Care & Sleep Medicine, Mount Sinai School of Medicine, New York, NY*
[3] *Div of Surveillance, Hazard Evaluations, and Field Studies, National Institute for Occupational Safety and Health, CDC, Cincinnati, OH*
[4] *Department of Medicine, State University of New York at Stony Brook, Port Jefferson, NY*
[5] *Center for Biology of Natural Systems, Queens College, Flushing, NY*
[6] *Environmental and Occupational Health Sciences Institute University of Medicine & Dentistry of New Jersey, Piscataway, NJ*
[7] *Department of Environmental Medicine, Bellevue Hospital Center/ New York University School of Medicine, New York, NY*
[8] *Div of Respiratory Disease Studies, National Institute for Occupational Safety and Health, CDC, Morgantown, WV*
[9] *Mailman School of Public Health, Columbia University, New York, NY*

Corresponding Author:
Robin Herbert, M.D.
Department of Community and Preventive Medicine
Mount Sinai School of Medicine
One Gustave L. Levy Place Box 1057
New York, NY 10029

Running Title**:** The WTC Disaster & the Health of Workers: 5-Year Assessment

Article Descriptor: Occupational Medicine

Abbreviations:

AOEC	Association of Occupational and Environmental Clinics
ATS	American Thoracic Society
BD	bronchodilator
CDC	Centers for Disease Control
COEM	Irving J. Selikoff Center for Occupational and Environmental Medicine
EPA	United States Environmental Protection Agency
ESC	Executive Steering Committee
FDNY	New York City Fire Department
FEV_1	Forced Expiratory Volume
FVC	Forced Vital Capacity
GERD	Gastro-esophageal reflux disorder
HIPAA	Health Insurance Portability and Accountability Act
IRB	Institutional Review Board
L	Liters
LLN	Lower Limit of Normal
$\mu g/m^3$	Micrograms per cubic meter
MSP	World Trade Center Worker and Volunteer Medical Screening Program
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute for Occupational Safety
PAH	Polycyclic aromatic hydrocarbons
PATH	Port Authority Trans-Hudson
PFT	Pulmonary function test
pH	power of hydrogen
OCME	Office of the Chief Medical Examiner
RADS	Reactive Airway Dysfunction Syndrome
VOC	Volatile organic compound
WTC	World Trade Center

Acknowledgements: We would like to thank the following for their contributions to this paper and their involvement with the World Trade Center Worker and Volunteer Medical Screening Program: S Carroll, S Jiang, E Jurgel, H Juman-James, C Katz, K Kirkland, P Landsbergis, K Leitson, B Newman, N Nguyen, R Smith, L Stevenson, J Weiner, other staff and patients of the World Trade Center Worker and Volunteer Medical Screening Program; labor, community, and volunteer organizations. Special thanks to the American Red Cross Liberty Fund, The September 11th Recovery Program, The Bear Stearns Charitable Foundation, The September 11th Fund, The Robin Hood Foundation Relief Fund, and many others. The authors declare they have no competing financial interests.

This work was supported by the Centers for Disease Control and NIOSH, contract 200-2002-0038 and grant 5U1O 0H008232.

ABSTRACT

Background. Approximately 40,000 rescue and recovery workers were exposed to caustic dust and toxic pollutants following the September 11, 2001 attacks on the World Trade Center (WTC). These workers included traditional first responders such as firefighters and police and a diverse population of construction, utility, and public sector workers.

Methods. To characterize WTC-related health effects the WTC Worker and Volunteer Medical Screening Program was established. This multi-center clinical program provides free standardized examinations to responders. Examinations include medical, mental health, and exposure assessment questionnaires, physical examination, spirometry, and chest X-ray.

Results. Sixty-nine percent of 9,442 responders examined between July 2002 and April 2004 reported new or worsened respiratory symptoms while performing WTC work. Symptoms persisted to the time of examination in 59%. Among those who had been asymptomatic before 9/11, 61% developed respiratory symptoms while performing WTC work. Twenty-eight percent had abnormal spirometry. FVC was low in 21% of our population. Obstruction was present in 5%. Among non-smokers, 27% had abnormal spirometry vs. 13% in the general U.S. population. Prevalence of low FVC among non-smokers was five-fold greater than in the U.S. population (20% vs. 4%). Respiratory symptoms and spirometry abnormalities were significantly associated with early arrival at the site.

Conclusion. WTC responders had exposure-related increases in respiratory symptoms and PFT abnormalities that persisted up to 2.5 years after the attacks. Long-term medical monitoring is required to track persistence of these abnormalities and identify late effects, including possible malignancies. Lessons learned should guide future responses to civil disasters.

***Keywords*:** air pollution; disaster response; occupational lung disease; pulmonary function; September 11th; spirometry; World Trade Center.

INTRODUCTION

An estimated 40,000 men and women worked at Ground Zero, the former site of the World Trade Center (WTC) in New York City, and at the Staten Island landfill, the principal wreckage depository in the days, weeks, and months after September 11, 2001 (Levin et al. 2004). These workers and volunteers included traditional first responders such as firefighters, law enforcement officers, and paramedics as well as a diverse population of operating engineers, laborers, ironworkers, railway tunnel cleaners, telecommunications workers, sanitation workers, and staff of the Office of the Chief Medical Examiner. These men and women carried out rescue-and-recovery operations, restored essential services, cleaned up massive amounts of debris and, in a time period far shorter than anticipated, deconstructed and removed remains of buildings. Many had no training in response to civil disaster. The highly diverse nature of this workforce posed unprecedented challenges for worker protection and medical follow-up.

Workers were exposed to a complex mix of toxic chemicals and to extreme psychological trauma. These exposures varied over time and by location (Landrigan et al. 2002; Lioy et al. 2002). Combustion of 90,000 L of jet fuel immediately after the attacks created a dense plume of black smoke containing volatile organic compounds (VOCs, including benzene), metals, and polycyclic aromatic hydrocarbons (PAHs). The collapse of the "twin towers" (WTC 1 and WTC 2) and then of a third building (WTC 7) produced an enormous dust cloud containing thousands of tons of coarse and fine particulate matter (PM), cement dust, glass fibers, asbestos, lead, hydrochloric acid, polychlorinated biphenyls (PCBs), organochlorine pesticides, and polychlorinated dioxins and furans (Clark et al. 2003; Landrigan et al. 2004; Lioy et al. 2002; McGee et al. 2003). EPA estimates of airborne dust ranged from 1,000 μg/m^3 to over 100,000 μg/m^3 (U.S. EPA 2002). The high content of pulverized cement made the dust highly caustic (pH 10-11) (Lioy et al. 2002; Landrigan et al. 2004).

Dust and debris gradually settled, and rains on 9/14 further diminished the intensity of outdoor ambient dust exposure. However, rubble removal operations repeatedly re-aerosolized the dust, leading to continuing intermittent exposure for many months. Fires burned both above and under ground until December 2001 (Banauch et al. 2003; Chen and Thurston 2002; U.S. EPA 2003). Air levels of certain contaminants remained elevated well into 2002, with spikes in benzene and asbestos levels occurring as late as March and May 2002 respectively (U.S. EPA 2003).

Workers began noting symptoms soon after September 11th, most commonly involving the aero-digestive tract (upper and lower respiratory tract and esophagus) (Banauch et al. 2006; Szeinuk et al. 2003). FDNY firefighters experienced persistent cough, termed the "World Trade Center cough," accompanied by respiratory distress and bronchial hyperreactivity (Prezant et al. 2002). A sample of FDNY firefighters who had sustained extreme exposures on September 11th was nearly 8 times more likely to manifest bronchial hyperreactivity than firefighters with lower exposures when examined after six months (Banauch et al. 2003). Laborers and ironworkers manifested new-onset cough, wheeze, and sputum production (Geyh et al. 2005; Skloot et al. 2004), likely attributable to respiratory inflammation caused by the highly alkaline dust (Chen and Thurston 2002).

Other reported pulmonary effects included cough, asthma, and RADS (Balmes et al. 2006; Banauch et al. 2006). Chronic rhinosinusitis, vocal cord inflammation, and laryngitis (de la Hoz et al. 2004) and case reports of eosinophilic pneumonia (Rom et al. 2002), granulomatous pneumonia, and bronchiolitis obliterans (Mann et al. 2005; Safirstein et al. 2003) were also reported.

Although New York has an extensive hospital network and strong public health system, no existing infrastructure was sufficient for providing unified and appropriate occupational health screening and treatment in the aftermath of 9/11. Local labor unions, who made up the majority of responders, became increasingly aware that their members were developing respiratory and psychological problems; they initiated a campaign to educate local elected officials about the importance of establishing an occupational health screening program. In early 2002, Congress directed the Centers for Disease Control (CDC) to fund most of the World Trade Center Worker and Volunteer Medical Screening Program (MSP), an action largely attributable to the collaborative efforts of organized labor and elected officials. The goals of the program were:

- To rapidly build a regional and national consortium of occupational medicine clinics to conduct geographically convenient standardized medical evaluations.
- To identify WTC responders, notify them about this program and encourage participation.
- To provide clinical examinations for eligible individuals to identify WTC-related physical and/or mental health conditions.
- To coordinate referral for follow-up clinical care for affected individuals.

- To educate workers and volunteers about exposures and associated risks to their health.
- To advise affected individuals about available benefit and entitlement programs.
- To establish "baseline" clinical status for individuals exposed at or near Ground Zero for comparison with future clinical assessments.

In April 2002, the Irving J. Selikoff Center for Occupational and Environmental Medicine (COEM) at Mount Sinai was awarded a contract by the National Institute for Occupational Safety and Health (NIOSH) to establish and coordinate the MSP. The Bellevue/New York University Occupational and Environmental Medicine Clinic, the State University of New York Stony Brook/Long Island Occupational and Environmental Health Center, the Center for the Biology of Natural Systems at Queens College in New York, and the Clinical Center of the Environmental & Occupational Health Sciences Institute at UMDNJ-Robert Wood Johnson Medical School in New Jersey were designated as the other members of the regional consortium. The Association of Occupational and Environmental Clinics (AOEC) was designated to coordinate a national examination program for responders who did not live in the New York/New Jersey area.

This paper describes design and implementation of the MSP and prevalence of selected clinical findings from screening examinations conducted between July 2002 and April 2004 in those from whom informed consent and HIPAA authorization were obtained. Mental health service provision and findings will be presented in a separate paper.

MATERIALS AND METHODS

Establishing the Cohort: Identification and Outreach

The target population was approximately 18,000 WTC responders not eligible to participate in other federally-funded programs (e.g., FDNY, Federal workers, New York State workers). Because responders came from many sectors, a high proportion as unpaid volunteers, no systematic roster of names and contact information was available. An MSP Outreach Unit was therefore established and staffed by people experienced in occupational health and familiar with key organizations, primarily labor unions representing responders.

The MSP Executive Steering Committee

To ensure key stakeholder input into all aspects of program development and oversight, an Executive Steering Committee (ESC) was established which included representatives from each of the consortium clinics, representatives from labor unions, employers, and technical experts from relevant fields.

The ESC advised the program directors on all program decisions and on basic components of the medical examination, eligibility criteria, and the outreach plan. An Advisory Council of more than 100 people was created several months after the start of the program in order to broaden stakeholder involvement and to tap into the enthusiasm and creativity of responder organizations. Generally 40-50 responder representatives attended quarterly Advisory Council meetings. The ESC and Advisory Council helped maintain open lines of communication with representatives of the program's diverse responder population.

Examination Eligibility

To be eligible to receive an examination, a responder must have been either:

A rescue, recovery, debris cleanup and related support services worker or volunteer in (a) lower Manhattan, south of Canal St, and/or (b) the Staten Island Landfill, and/or (c) barge loading piers, and have worked and/or volunteered on-site for 4 hours from September 11-14, 2001, or at least 24 hours during the month of September, or for at least 80 hours during the months of September, October, November, and December combined.

or

To have been an employee of the Office of the Chief Medical Examiner (OCME) involved in the examination and processing of human remains or other morgue worker who performed similar post-9/11 functions to OCME staff; a worker in the Port Authority Trans-Hudson Corporation (PATH) tunnel through 7/1/02 for a minimum of 24 hours; a vehicle maintenance worker with post-9/11 functions within the requisite timeframes and exposure to WTC debris while retrieving, driving, cleaning, repairing, and maintaining contaminated vehicles.

Development of the examination protocol

The clinical consortium partners, supplemented by experts in psychiatry, pulmonary medicine, otolaryngology, industrial hygiene, and epidemiology, collaborated in protocol development to provide high quality standardized occupational health screening examinations and gather information for a research database to enable scientific assessment of the full health impact of the disaster. A decision was made early in protocol planning that direct clinical services had priority where clinical protocols conflicted with collection of research data.

Standardized Medical Examination

Responders received a clinical screening evaluation consisting of medical, mental health and exposure-assessment questionnaires, a standardized physical examination, pre- and post-bronchodilator (BD) spirometry, complete blood count, blood chemistries, urinalysis, and chest radiograph. Participants received both immediate and final letters with examination results and a face-to-face physician consultation at the end of the examination day. Participants were provided referrals for evaluation and treatment for physical or mental health conditions identified in the screening examination.

A trained healthcare practitioner administered a medical questionnaire on selected diagnoses and on prior upper and lower respiratory conditions (e.g., chronic sinusitis and asthma); occurrence of symptoms in the year before 9/11/01, while working at the WTC site, for the month before the screening examination and whether pre-existing symptoms and diagnoses worsened during their WTC work; and smoking history. Where possible, questions were adapted from standardized instruments (e.g., Burney et al. 1989; ECRHS 1994; Miller et al. 2005; NCHS 1996; NIOSH 2006; Piccirillo et al. 2002).

We used an interviewer-administered survey instrument to obtain pre- and post-9/11 occupational and environmental exposure histories, including dates that responders reported for first working or volunteering for 9/11-related duties and, for those present on

9/11, whether they were exposed to the cloud of dust from the building collapses. We constructed the ordinal date-related categories shown in the tables as a rough measure of relative dust exposures, and also categorized workers by location where they spent the majority of their time when first working at Ground Zero. We also obtained data on respirator type and use during the first week of the WTC recovery and will report those data in subsequent analyses.

Eligible responders were invited for clinical examinations irrespective of their willingness to provide consent to have data aggregated. Only data from responders providing IRB consent and HIPAA authorization (on or after April 14, 2003) are included in data analyses.

Spirometry

Spirometric examination employed the EasyOne spirometer (ndd Medical Technologies, Chelmsford, MA) using standard techniques (Miller et al. 2005). We compared spirometry results to age-, gender-, and ethnic-specific reference values derived from the NHANES III national population survey (Hankinson et al. 1999). Interpretation followed the recently combined American Thoracic Society and European Respiratory Society guidelines (Pellegrino et al. 2005). Only spirometry of acceptable quality as defined by international guidelines (Miller et al. 2005) was included in the analysis (n=8,384). Airway obstruction was defined as FEV_1/FVC below the lower limit of normal (LLN) with a normal FVC. Spirometry with FVC < LLN but FEV_1/FVC ≥ LLN was categorized as "low FVC." Obstruction and low FVC was defined as FEV_1/FVC and FVC below the LLN. A significant bronchodilator response was defined as an increase in FEV_1 or FVC of greater than 12% and 200 ml. Comprehensive spirometry quality assurance was an integral aspect of this program.

Data analysis

We used SAS 9.1 (SAS Institute, Inc., Cary, NC) for all analyses. Categorization of occupational sector was based on the union and/or organization to which the responder reported belonging during work on the WTC effort. We categorized prevalence of specific health outcomes by date of arrival and exposure to the dust cloud and used the Cochrane-Armitage trend test to assess significance of trends in prevalence across exposure categories.

RESULTS

The MSP began examining responders in July 2002, three months after receipt of federal funding. Of the 16,528 responders meeting eligibility criteria, we examined 11,095 responders in the New York / New Jersey regional clinical consortium , and 645 elsewhere between July 16, 2002 and April 16, 2004. In the NY/NJ Consortium, 9,442 responders who were examined between July 2002 and April 2004 provided appropriate consent to be included in this report.

Demographics: The responders screened in this program were predominantly male (87%) and white (66%), with a median age of 42 years (range: 18-82 years) (Table 1), with more than 92% living in the tristate (New York, New Jersey, Connecticut) area: 54% from New York City and 15% on Long Island. Eighty-six percent were union members.

Thirty-four percent were construction workers and 29% law enforcement. We conducted more than 14% of the examinations in languages other than English.

Time of arrival and location: Of the more than 40% of the responders who first arrived for work at the site on September 11th, 49% reported having been engulfed in the building-collapse dust cloud (Table 1). Another 30% percent first arrived on 9/12 or 9/13. Irrespective of date of arrival, 35% of responders began working on the pile or in the pit at Ground Zero. Another 55% worked adjacent to the pile. The remaining 10% worked at other sites. The reported average duration of exposure (the time between the first and last days of work on the WTC effort) was 171 days (range, 1 day to ≥2.5 yrs). The average time between first work day and the MSP examination was 20 months.

Symptoms: Most of the 9,442 responders examined reported being asymptomatic in the year prior to 9/11 for lower respiratory tract symptoms (85%), and a large majority (66%) were asymptomatic for upper respiratory tract symptoms (Table 2). In the previously asymptomatic group, 44% reported developing lower respiratory symptoms and 55% developed upper respiratory symptoms while engaged in WTC-related work. These new symptoms were persistent in many; at the time of exam, 32% reported current lower respiratory symptoms and 44% reported current upper respiratory symptoms (Table 2). Fully 69% of all responders reported having had at least one WTC-worsened or newly incident respiratory symptom while performing WTC response work (63%, upper airway and 47% lower airway symptoms, with overlap between the groups) (Table 3). Respiratory symptoms persisted to the time of examination in 59% of the population.

Early arrival at the WTC site was significantly associated with an increased reported prevalence of both newly incident and worsened respiratory symptoms (Table 3). We observed the highest prevalence among those who arrived on September 11th and were exposed to the dust cloud (54% lower and 66% upper respiratory symptoms). Those who began work on September 11th but who were not directly exposed to the dust cloud had the next highest prevalence (47% lower and 62% upper respiratory symptoms). We found a continuing statistically significant downward trend (although the prevalence remained high) in the incidence of reported symptoms for later arrival dates. Even those responders who arrived at the site on or after October 1st had a 41% prevalence of lower respiratory and a 59% prevalence of upper respiratory symptoms, nearly three times the percentage who had reported lower respiratory symptoms in the year prior to 9/11 and nearly twice of the percentage who reported prior upper respiratory symptoms.

Twenty-eight percent of the 8,384 participants with acceptable quality pulmonary function exams had abnormal pre-bronchodilator spirometry results (Table 4). A low FVC was the most common abnormality (21%), while obstruction occurred in 5% and a mixed pattern (obstruction and low FVC) in 2%. We also documented a significant response to bronchodilator in 910 (11%) of participants including 33% of those with obstruction, 56% with a mixed pattern, and 18% of those with a low FVC.

Compared with a US general population sample of employed, adult, white males (Mannino et al. 2003), the 4,641 participants who had never smoked had a higher prevalence of abnormalities on spirometry (27% vs. 13%). The difference was mainly attributable to a higher prevalence of tests with a low FVC (20% vs. 4%).

A statistically significant association was observed between time of arrival and low FVC, with a higher prevalence of abnormality in those who arrived earlier (Table 5). There was no significant difference in the prevalence of obstruction based on onset of exposure.

Thirty-one percent of the sample reported having received medical care for WTC-related respiratory conditions. A total of 17 % of examinees reported missing work because of WTC-related health problems. Of the 1,973 workers with a self-reported diagnosis of sinusitis, 40% were seen by a doctor for this condition during the six months after 9/11, compared to only 13% in the six months prior to 9/11. Similar increases were reported in the numbers of responders who sought medical help for acute bronchitis (45% vs. 18%) and pneumonia (10% vs. 1%).

DISCUSSION

Two principal lessons emerge from our experiences with the World Trade Center Worker and Volunteer Medical Screening Program. First, the prevalence rates of respiratory and other symptoms, and the prevalence of pulmonary function abnormalities in the nearly 10,000 WTC workers and volunteers whom we examined clinically between 2002 and 2004 were very high and they are persistent. Health effects were most frequent in responders who sustained the most intense exposures. In the aftermath of future civil disasters, hospitals and health care providers will need to anticipate and prepare for the severe health consequences that inevitably result from the extreme exposures sustained by workers in these situations.

Second, in the event of future disasters, it is likely that existing health care facilities and public health programs will not be sufficiently robust or flexible to deal with the special needs and complex health problems sustained by responders and victims. It will likely be necessary to establish large, multi-center medical follow-up programs such as were needed in New York. The more rapidly such programs can be established and funded, the more quickly essential services will be provided (Rosner and Markowitz 2006).

Abnormal spirometry was still evident in almost one third of all WTC workers and volunteers 1 to 2.5 years after September 11, 2001. The most common spirometric abnormality seen was a low FVC, a finding that had also been found in the first 1,138 participants from this group (Levin et al. 2004). Low FVC was about 5 times more prevalent among non-smokers than expected in the general US population, based on NHANES III data (Mannino et al. 2003). Prevalence of low FVC was higher in responders who arrived at the disaster site closer to the time of the collapse of the twin towers than in those who arrived on or after October 1st.

There are several possible explanations for the high rates of low FVC observed in this group. They include: 1) true restriction due to parenchymal lung disease (e.g., interstitial lung diseases such as sarcoidosis, idiopathic pulmonary fibrosis, pneumoconiosis, etc); 2) true restriction due to physical factors such as obesity or chest wall abnormalities; 3) “pseudorestriction” due to air trapping (e.g., airways obstruction) or due to submaximal inspiratory and/or expiratory effort (typically the result of chest pain/tightness or in an attempt to reduce coughing during the test); or 4) our selection of the reference value used to define the lower limit of the normal range for FVC.

It is likely that, in some responders, the observed increase in low FVC is due to air trapping in the lungs, possibly due to inhalation of caustic dust and airborne pollutants in the course of their WTC work. A finding that supports this explanation is our observation of an increase in FVC following administration of a bronchodilator, seen in 18% of WTC workers and volunteers with this pattern.

Another possible explanation for our observed abnormalities in pulmonary function is our choice for the lower reference limit of the normal range for FVC. In our analysis we chose to use the Hankinson pulmonary reference values derived from the NHANES III, because we considered them to be most appropriate for an ethnically diverse population such as this workforce (Hankinson et al. 1999). In previous studies of workers, several spirometry reference equations other than those from NHANES III have been used (Crapo et al. 1981; Knudson et al. 1983; Miller et al. 1983; Morris et al. 1973). While the mean predicted values calculated from these five studies are very similar for whites, differences in the lower limits of the normal range provide large differences in spirometry abnormality rates when testing large, ethnically diverse groups of workers. For example, when using the Crapo equations, substantially higher rates of obstruction but lower rates of spirometric restriction (low FVC) are found in whites in our cohort. It is also possible that some responders have developed true restrictive lung disease due to their WTC-related exposures. We anticipate that these issues will become clearer with continuing prospective follow-up of this cohort.

The MSP faced many challenges, and similar challenges are likely to arise in future major civil disasters. We faced organizational challenges in coordinating work at five clinical sites in the New York New Jersey metropolitan area, as well as in the national program. There was no systematic roster of responders. We found that a broad and vigorous outreach program to systematically identify responders and persuade them of the importance of undergoing examination was essential. Most of these workers, many of whom had volunteered their services after September 11th, were unable to take paid time off to be screened, and many were not in the position to forfeit a day's wages. We needed to schedule the examinations at times and in locations that respected those difficulties. The examination content needed to be relevant and acceptable to the responders and at the same time sufficiently standardized to permit interpretation of aggregated clinical data. Translation was one of the more challenging aspects of program coordination. More than 14% of responders required non-English examinations and written materials.

The need for follow-up medical treatment and for provision of social benefits in the event of future civil disasters must be anticipated and federal funds must be provided early on to support such programs. There was substantial social and economic disruption to the lives of many of the responders, and benefits counseling became an urgent need and an integrated component of the MSP. Many responders needed follow-up treatment for physical or mental health illnesses, and many lacked health insurance. We were obliged to secure private funding from philanthropic organizations to develop and implement treatment programs for responders. Federal funding for treatment of these workers is anticipated to begin in Fall 2006.

Several limitations in these data should be noted. We do not have pre-9/11 clinical information on our cohort. It may be that those responders who were sicker were more likely to participate, leading to an overestimation of risk. Conversely, we may be underestimating risk because most responders were likely to have been fit workers (healthy worker effect). This paper does not consider the psychological consequences, which we already know to be serious (Smith et al. 2004). Subsequent papers will address responder mental health.

CONCLUSIONS

The workers and volunteers who served New York City and the nation through their heroic service in the aftermath of September 11, 2001 need continuing medical surveillance and follow-up, especially since some diseases, like cancer, are of long latency. Malignant mesothelioma resulting from exposure to asbestos, for example, may not become evident for 30 to 50 years. These biological facts plus the magnitude and complexity of the exposures indicate that WTC responders should be monitored for at least twenty to thirty years, so that long-term effects are detected early, when treatment would be most beneficial.

Federal leadership is needed to bring together a wide range of civilian and military experts to prepare for the complex physical and mental health issues and the environmental issues certain to arise in future disasters. Future disaster response must incorporate rapid establishment of both diagnostic and treatment programs, and they must make a firm commitment for the long-term follow up of exposed workers. Finally, there is a need to ensure strong and active participation by worker representatives and local citizens. Their local knowledge is unique, and it will not become available to state and federal planners unless these vital stakeholders are invited to take an active role in the planning and implementation of responses to future disasters.

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Table 1. Demographic and exposure characteristics of the WTC Medical Screening Program study population (n=9442)

	N	%
Gender		
Male	8186	86.7
Female	1256	13.3
Race		
White	6203	65.7
Black	1060	11.2
Asian	121	1.3
Other	253	2.7
Unknown	1805	19.1
Hispanic Ethnicity		
Yes	2249	23.8
Language of exam		
English	8114	85.9
Spanish	984	10.4
Polish	311	3.3
Other	33	0.3
Union member		
Yes	8075	86.0
Union/organization affiliation		
Construction	3209	34.0
Law Enforcement	2776	29.4
Public Sector -- Blue Collar	739	7.8
Technical and Utilities	683	7.2
Transportation	516	5.5
Cleaning/Maintenance	258	2.7
Volunteers	245	2.6
Firefighters*	138	1.5
Health Care	83	0.9
News Agencies	81	0.9
Office/Administration/Professional	50	0.5
Other	664	7.0
Time first began WTC-related work		
On 9/11	3812	40.5
On 9/11 and in dust cloud	1878	20.0
On 9/11 and not in dust cloud	1934	20.5
9/12-9/13	2801	29.8
9/14-9/30	2133	22.7
On or after 10/1	666	7.1
Location of majority of work		
On the pile/in the pit	3215	34.8
Adjacent to pile/pit	5074	54.8
Landfill	313	3.4
Barges/loading pier	106	1.1
OCME	77	0.8
Elsewhere south of Canal St.	466	5.0

*Does not include active-duty New York City firefighters

Table 2. Prevalence of lower and upper respiratory symptoms among the WTC Medical Screening Program study population (n=9442)

	Responders who reported symptoms in year prior to 9/11		Responders who did not report symptoms in year prior to 9/11			
			New symptoms while working at WTC site		Symptoms still present in month prior to exam	
	N	%	N	%	N	%
Lower Respiratory Symptoms						
Dry cough	362	3.9	2541	28.3	1534	17.1
Cough with phlegm	325	3.5	1183	13.1	742	8.2
Shortness of breath	344	3.7	1477	16.5	1266	14.1
Wheeze	557	6.0	1232	14.1	749	8.6
Chest tightness	464	5.1	1258	14.6	933	10.8
Any lower respiratory symptom	1451	15.4	3486	43.8	2535	31.9
Upper Respiratory Symptoms						
Sinus-related[a]	2169	23.1	2219	30.7	1863	25.8
Nasal-related[b]	1967	20.9	3254	43.8	2536	34.1
Throat-related[c]	887	9.4	3579	42.0	2450	28.8
Any upper respiratory symptom	3148	33.5	3453	55.2	2772	44.3
Any respiratory symptom	3767	40.0	3443	61.0	2846	50.4

[a] Facial pain or pressure, head of sinus congestion, or post-nasal discharge
[b] Blowing your nose more than usual, stuffy nose, sneezing, runny nose, or irritation in nose
[c] Throat irritation, hoarseness, sore throat, or losing your voice (laryngitis).

Table 3. Prevalence of new or worsened respiratory symptoms among WTC workers by date of arrival for work at WTC site and by exposure to the dust cloud (n=9442)

	All responders (N=9442)		Arrived on 9/11 and in dust cloud (N=1878)		Arrived on 9/11 and not in dust cloud (N=1934)		Arrived 9/12-9/13 (N=2801)		Arrived 9/14-9/30 (N=2133)		Arrived on or after 10/1 (N=666)		Trend Test p-value[a]
	N	%	N	%	N	%	N	%	N	%	N	%	
Lower Respiratory Symptoms													
Dry cough	2688	28.7	640	34.2	587	30.6	777	28.0	538	25.5	140	21.3	<0.001
Cough with phlegm	1320	14.1	328	17.6	256	13.4	373	13.5	275	13.0	84	12.7	<0.001
Shortness of breath	1613	17.3	390	20.9	298	15.6	471	17.1	339	16.1	109	16.6	0.001
Wheeze	1408	15.1	339	18.3	296	15.5	403	14.6	281	13.4	85	13.0	<0.001
Chest tightness	1393	15.4	334	18.5	268	14.4	384	14.3	311	15.2	91	14.1	0.003
Any lower respiratory symptom	4371	46.5	1017	54.2	912	47.2	1232	44.2	930	43.8	271	40.8	<0.001
Upper Respiratory Symptoms													
Sinus-related[b]	510	37.3	785	41.9	712	36.9	1020	36.6	783	37.0	200	30.1	<0.001
Nasal-related[c]	4552	48.4	982	52.4	939	48.6	1334	47.9	981	46.3	300	45.1	<0.001
Throat-related[d]	4128	43.9	885	47.2	847	43.9	1199	43.1	923	43.6	264	39.7	0.001
Any upper respiratory symptom	5883	62.5	1233	65.8	1205	62.4	1719	61.7	1316	62.1	394	59.2	0.001
Any respiratory symptom	6479	68.8	1376	73.4	1345	69.7	1878	67.3	1435	67.7	429	64.5	<0.001

[a] One sided p-values using the Cochran-Armitage trend test

[b] Facial pain or pressure, head of sinus congestion, or post-nasal discharge

[c] Blowing your nose more than usual, stuffy nose, sneezing, runny nose, or irritation in nose

[d] Throat irritation, hoarseness, sore throat, or losing your voice (laryngitis).

Table 4. Spirometry results (pre-bronchodilator) among the WTC Medical Screening Program study population (n=8384)[a]

	National Population[b]	WTC Medical Screening Program Population							
	Never smoker	Never smoker		Former smoker		Current smoker		All	
	%	N	%	N	%	N	%	N	%
Normal	87.1	3396	73.2	1541	72.8	1047	67.1	6031	71.9
Obstruction[c]	8.0	237	5.1	97	4.6	114	7.3	451	5.4
Low FVC[d]	4.4	940	20.3	431	20.3	336	21.5	1721	20.5
Obstruction and low FVC[e]	0.6	68	1.5	49	2.3	63	4.0	181	2.2
Total	--	4641	55.8	2118	25.5	1560	18.8	8384	100.0

[a] Only acceptable quality spirometric examinations are included in this table (Miller et al 2005).

[b] General U.S. population sample of employed, adult, white males ages 17-69 who never smoked from the National Health and Nutrition Examination Surveys (NHANES III)

[c] Obstruction was defined as having FEV_1/FVC ratio less than 5th percentile of predicted value and normal FVC

[d] Low FVC was defined as having FVC less than 5th percentile of predicted value and a normal FEV_1/FVC ratio

[e] Obstruction and low FVC was defined as having FEV_1/FVC ratio less than 5th percentile of predicted value and having FVC less than 5th percentile of predicted value

Table 5. Spirometry results (pre-bronchodilator) by date of arrival for work at WTC site and exposure to the dust cloud among the WTC Medical Screening Program study population (n=8384)[a]

	Arrived on 9/11 and in dust cloud		Arrived on 9/11 and not in dust cloud		Arrived 9/12-9/13		Arrived 9/14-9/30		Arrived on or after 10/1		Trend Test p-value[b]
	N	%	N	%	N	%	N	%	N	%	
Normal	1160	68.5	1222	69.9	1781	71.6	1397	75.3	453	78.6	--
Obstructive[c]	81	4.8	96	5.5	140	5.6	104	5.6	28	4.9	0.418
Low FVC[d]	408	24.1	400	22.9	506	20.3	318	17.1	84	14.6	<0.001
Obstruction and low FVC[e]	44	2.6	29	1.7	61	2.5	36	1.9	11	1.9	0.095

[a] Only acceptable quality spirometric examinations are included in this table (Miller et al 2005).

[b] One sided p-values using the Cochran-Armitage trend test

[c] Obstruction was defined as having FEV_1/FVC ratio less than 5th percentile of predicted value and normal FVC

[d] Low FVC was defined as having FVC less than 5th percentile of predicted value and a normal FEV_1/FVC ratio

[e] Obstruction and low FVC was defined as having FEV_1/FVC ratio less than 5th percentile of predicted value and having FVC less than 5th percentile of predicted value