

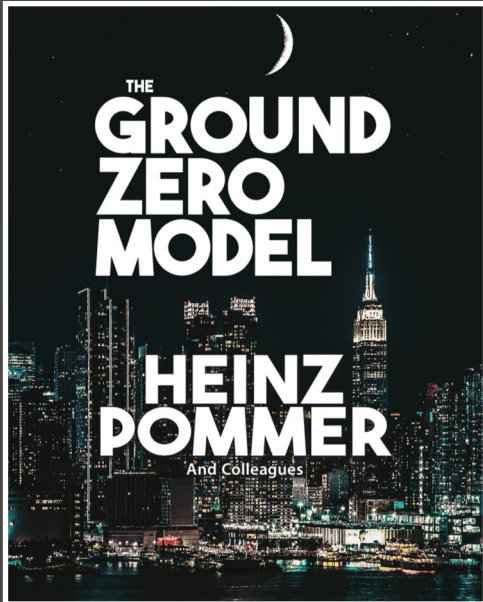
GROUND ZERO

THE 9/11 PEER REVIEW



A Jeff Prager Empathy Induced 9/11 Publication • 2020©J.Prager

For Ann, Camy, Illiana, Syrena and Kyle



The Ground Zero Model: 9/11's Nuclear Fingerprint

By physicist Heinz Pommer & Colleagues

Barnes & Noble
Soft cover: \$18.95
Hard cover \$45.95

All profits donated to charity

The unmistakable electromagnetic nuclear fingerprint revealed, as easily readable as a bar code scan if you understand the physics. The Ground Zero Model explains the physics so that anyone will fully understand the physics and chemistry.

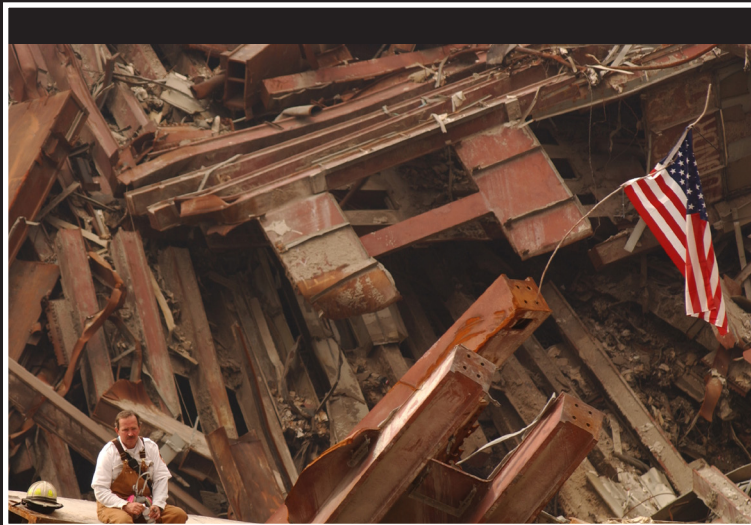




Dedicated to the 9/11 First Responders and civilians who didn't know they were giving up their lives, that they'd miss their children growing up and that they'd endure untold painful horrors from simply being in NYC on 9/11, a travesty and a human rights violation on a grand scale. Yet Christine Whitman told us the air was "safe to breath...". The consequences of her lies are painful diseases and then death.

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JEFF PRAGER



PREFACE

This book is a follow-up to **The Ground Zero Model** [1] where, in the Chapter I authored, a short chapter 2 (my chapter amounts to 10 pages in a 192-page book authored by 4 physicists), I spent a brief period discussing the Ground Zero medical peer review since my only offering for that book, not being a physicist, was that I specialize in medical peer review. I've authored over 25 books totaling, collectively, over 25,000 peer reviewed reports.

197,000+ civilians and First Responders are being followed in a medical cohort. The government spent millions of dollars locating anyone and everyone that lived in NYC, went to school in NYC, worked in NYC or was just visiting NYC on 9/11. Using kindergarten, elementary school, high school and college educational records, daycare records, Social Security records, medical records, unemployment records, drivers licenses and any other exacting method of locating people, the US government established a cohort of Americans that were in NYC on 9/11 and experienced the demolition. This cohort included ALL women in NYC on 9/11 that were pregnant, which we'll discuss in depth later and it included anyone south of State Street, the governments arbitrary and likely incorrect exposure demarcation line. Remember, Christine Todd Whitman brought us "the air is safe to breathe".

I've written this book to show that not only isn't there a shortage of peer review on Ground Zero, covering 9/11 and the health effects from psychological disturbances to cancer, but there are 100s of reports discussing every illness known to humankind.

In 2010 I wrote to the Japanese government and requested the medical peer review from Hiroshima and Nagasaki. Not the peer review from the 50s and 60s but the current peer review. The Japanese medical system with assistance from American military personnel have been following atomic bomb survivors from day one through today. Because the two nuclear weapons deployed were of entirely different types we see some differences in illnesses and long term disorders yet radiation exposure is radiation exposure in the long run.

The diseases and disorders experienced for the last 20 years by Japanese atomic bomb survivors mirror 9/11 illnesses perfectly. Exposure to radiation is odious, but most of us associate exposure with cancers which do manifest quite prolifically. Yet just as debilitating are the "other" radiation exposure induced disorders which are, literally, every disease and disorder known to humankind.

Referencing **The Ground Zero Model** there is absolutely no doubt that 9/11 was a nuclear event. Not bombs, not reactors, not weapons, but an old nuclear process developed by Edward Teller and colleagues in the 1970s that reduced above ground radiation, hopefully, ostensibly and ac-

ording to the calculations, to almost zero. Using something called “water boosting” and detonating a nuclear device underground in granite—like we see at the World Trade Center—should, and I say “should” based on the physics formulas, reduce above ground radiation to zero; under ideal conditions. During 9/11 this did not happen and radiation exposure within the Ground Zero area was extreme falling off with distance from Ground Zero. In fact, the physicists believe, with highly sophisticated and extremely expensive equipment running in the thousands of dollars, an unusually high signal can still be found today. Based on interaction with the German isotope lab, the Geiger Counter is not to be trusted under these specific circumstances.

However, it wasn't until *after* the First Responders were sent back into the Twin Towers that the nuclear devices were detonated making this without question a long-term radiological experiment on an unknowing public and the unconscionable act of nuclear blackmail.

This book contains hundreds of the most relevant peer review available on 9/11 and Ground Zero and the medical complications, the various medical protocols being experimented with to develop the most promising treatment strategies to assist radiation exposed individuals. An experiment in motion. And the victims don't know and I suspect most of the Mt. Sinai physicians are equally clueless to radiation exposure and are confident that exposure to the “toxins” in the dust caused their ailments and deaths. Little do they know.

While reading the collected peer review in this book it's important to always remember that these ailments and afflictions were caused by exposure to radioactive radiation and while the actual toxins may have exacerbated the ailment, malady or disorder, the cause was radiation exposure.

Also note that ingestion of dust differs from breathing dust as much as it differs from exposure through the skin. Ingestion leads to stomach and gastrointestinal cancers most often, breathing radioactive particles leads, most often, to lung, pulmonary and blood and heart cancers and disorder and exposure through skin can lead to cancer, psychiatric disorder, memory loss, skin cancer and 100s of other diseases and disorders. Exposure to radioactive radiation affects every human system and causes illness 1, 5, 10, 20, 30, 40 and 50 years later and can lead to disorder in children born of exposure victims through epigenetics.

Let me explain exposure to radiation and the reason, the foundation for writing and publishing this book. Exposure to radiation is repulsive, repellent, repugnant, disgusting, offensive, objectionable, vile, foul, abhorrent, loathsome, nauseating, sickening, hateful, detestable, execrable, abominable, monstrous, appalling, reprehensible, deplorable, insufferable, intolerable, despicable, contemptible, unspeakable, atrocious, awful, terrible, dreadful, frightful, nasty, ghastly, horrible, horrid, gross, godawful and beastly. I'm sure you understand my motivation.

~ Jeff Prager

INTRODUCTION

The foundation and motivation for publishing this book is to support ‘The Ground Zero Model (GZM) by Heinz Pommer & Colleagues’, a book I contributed to in a small way. The book reveals the unmistakable 9/11 nuclear fingerprint, an electromagnetic signal as easily readable as a bar code scan if you understand the physics and the GZM explains the physics such that any reader will easily understand how the buildings at Ground Zero, the Twin Towers and Building 7, were demolished; The Ground Zero Model: 9/11’s Nuclear Fingerprint, 192-pages, Barnes & Noble soft cover and hard cover with a free PDF also available [1].

Every peer reviewed report in this volume is not necessarily complete. Many are but equally many are just the abstracts. Each report has a DOI number. With that number you might find Sci-Hub. tw and learn how to download the complete report. The reports in this volume discussing Multiple Myeloma are critically important to understand. Multiple Myeloma is a disease of the elderly with 99% of those afflicted being over the age of 70. We don’t know what causes Multiple Myeloma, a complex, severe and unusual blood cancer, but we do know that internal exposure—ingestion or breathing—of even minute amounts of radioactive radiation increases the chance of Multiple Myeloma occurrence by 4% (see: US Gov’t K-25 Study). The rate or incidence of Multiple Myeloma ranges from 3 to 9 per 100,000 depending on which peer reviewed report you prefer. That’s the medically accepted range.

First Responders have a rate or incidence of Multiple Myeloma of 18 per 100,000 as of March 2011, the last time I had access to and checked the data. I’ll suggest, based on the peer review, that it may be higher now. What’s more, the First Responders with Multiple Myeloma range in age from 30 to 60 and this is unheard of. A medical first in total numbers of young people under 69 that have Multiple Myeloma is part of the peer review; a new part with researchers “reaching” for a plausible explanation and failing, of course. Yet there are researchers that mention ‘radioactivity’ and ‘radiation’ without ever actually saying or typing those words. Read between the lines.

In the peer review discussing pregnancy you’ll find an extraordinarily robust report that concludes that after following all women that lived in NYC, worked in NYC, were visiting NYC or attended an educational institution in NYC (and locating them at extraordinary expense) and that were also pregnant, they discovered a statistically significant increase in premature births, low birth weights and small head circumference, the hallmarks of fetal exposure to radiation. You’ll also find a number of additional reports that reach the same conclusions, without mentioning radiation of course. They all know.

As you read through this book you’ll find peer review that alludes to radiation, that subtly refers

to radiation exposure, all without actually using the word “radiation,” but rather, the chosen public word to describe the basis for 9/11 disorders—“toxins”. The media uses the word “toxins” because exposure to radioactivity and ionizing radiation is too horrifying to admit.

‘The Ground Zero Model by Heinz Pommer & Colleagues’ reveals the unmistakable 9/11 nuclear fingerprint readable as easily as a bar code scan and this book, “Ground Zero: The Peer Review,” supports the previous book using corporate, government and independent peer reviewed reports based on First Responder and Civilian pregnancies, cancers, and other diseases and disorders.



9/11 GROUND ZERO



THE MEDICAL PEER REVIEW



Multiple Myeloma: A Study of K-25 Workers

US CDC • June 2009

Summary

This study is the first to look at radiation exposure to see if it may be linked to multiple myeloma among K-25 workers. We found workers who had swallowed or breathed-in radioactive particles had a 4% higher chance of dying of multiple myeloma compared to workers not exposed this way. We found no increased chance of multiple myeloma among workers who were only exposed to radiation that was outside the body.

Why this study was done?

Multiple myeloma is a rare type of cancer that starts in the bone marrow. **Causes of this cancer are not known.** Studies have been done to see if radiation exposure may cause this type of cancer in certain workers, such as radiologists, veterinarians, and uranium miners. The findings from these studies were not clear. Some found radiation exposure may cause multiple myeloma, others did not.

The K-25 site (also known as the Oak Ridge Gaseous Diffusion Plant) was used to enrich uranium, a radioactive material. Workers at K-25 may have been exposed to uranium. Because of this, we felt it was important to find out if workers from K-25 have a higher chance of dying of multiple myeloma.

Who was in the study?

Those in the study worked at K-25 for at least 30 days between 1945 and 1985. The total number of workers during this time was 47,941. By looking at death certificates through 1998, we found 98 workers died of multiple myeloma. We used work records to estimate how much radiation these workers were exposed to. We wanted to see if workers exposed to radiation had a higher chance of dying of multiple myeloma compared to other workers at K-25 who were not exposed.

How radiation exposures happen

A person can be exposed externally to radiation just by standing near it. A person can be exposed internally by breathing in or swallowing radioactive particles in the air. Particles can be absorbed through cuts or sores as well. We were interested in studying all of these types of radiation exposure.

Other exposures we considered

Besides looking at exposure to radiation, we also took into account how much mercury, nickel and trichloroethylene (TCE) workers may have been exposed to. These were used in large amounts at the site and may also cause cancer.

What we found

Workers who had swallowed or breathed-in radioactive particles had a 4% higher chance of dying of multiple myeloma compared to workers not exposed this way. There was no increased chance of multiple myeloma among workers who were only exposed to radiation that was outside the body.

Important notes

At K-25, urinalysis was used to monitor internal exposure to radiation. For the workers with no urinalysis records, we used available work history records to estimate dose from internal exposures to radiation. Our study did not include workers who currently have multiple myeloma. This is because the study design we used identified multiple myeloma cases using death certificates.

Centers for Disease Control and Prevention (CDC)

CDC is the federal agency that works to promote health and quality of life by preventing and controlling disease, injury, and disability. To learn more, visit [http:// www.cdc.gov](http://www.cdc.gov) or call 1-800-CDC-INFO.

National Institute for Occupational Safety and Health (NIOSH)

NIOSH is the federal agency within CDC that is responsible for conducting research and making recommendations for the prevention of work-related injury and illness. To learn more, visit <http://www.cdc.gov/niosh>.

Study manuscript

Yiin, J H; Anderson, J L; Daniels, R D; Seel, E A; Fleming, D A; Waters, K M; and Chen, P H. A Nested Case-Control Study of Multiple Myeloma Risk and Uranium Exposure among Workers at the Oak Ridge Gaseous Diffusion Plant. *Radiation Research* 171; 637–645.

This study was done by the NIOSH Occupational Energy Research Program (OERP) and was funded by the Department of Energy (DOE). For more information about the OERP or to obtain an electronic copy of this worker notification, visit: www.cdc.gov/niosh/oerp/ or call 1-800-CDC-INFO.

References

Multiple Myeloma: A Study Of K-25 Workers:
https://www.cdc.gov/niosh/pgms/worknotify/pdfs/k25_7-06-09-508.pdf

Additional References

https://www.energy.gov/sites/prod/files/2013/10/f3/Portsmouth_Paducah_K25ProductionWorkers_NeedsAssessment.pdf

<https://www.atsdr.cdc.gov/hac/pha/oakridge/oakridgek25ands50uraniumandfluoridereleasesfinalpha9132010.pdf>



NIOSH Summary of Findings

NIOSH Assessment of Information Needed
for the Evaluation of the Health Effects Due to
Occupational Exposures for DOE Site Remediation Workers.

Investigators: Sharon R. Silver, M.A., Cynthia F. Robinson, Ph.D.,
Greg Kinnes, M.S., Tim Taulbee, M.S., Steve Ahrenholz, Ph.D.

Sites Included in the Assessment: Fernald, Mound, Rocky Flats, Savannah River Site, Hanford, Oak Ridge, and Idaho National Engineering and Environmental Laboratory.

Purpose: This report summarizes the findings of two NIOSH projects which assessed whether records currently collected by DOE sites allow accurate identification of remediation workers and their exposure, work history, and medical information. This information is needed in order to evaluate any relationships between occupational exposures and health effects workers may experience.

Information Needed to Evaluate Health Effects: To conduct studies that can adequately evaluate the health effects of occupational exposures of current and future remediation workers, the following information is required:

1. Comprehensive worker rosters (lists) identifying all remediation workers;
2. Adequate exposure, work history, and medical information for all remediation workers; and
3. Links which match individual workers with their exposure, work history and medical information.

How This NIOSH Assessment Was Done: The assessment included two recent National Institute for Occupational Safety and Health (NIOSH) projects, the Exposure Assessment Feasibility Study (EAFS) and the Integrated Health, Work

History, and Exposure Database for DOE Site Remediation Workers. These two projects assessed the availability of information about remediation workers and their activities to address the following questions:

1. Can remediation workers be identified?
2. Are adequate exposure, work history, and medical data available for remediation workers?
3. Can individual workers be linked to their exposure and medical data?
4. With current knowledge and understanding, as described in this report, can epidemiologic, exposure assessment, or hazard surveillance studies of remediation workers and the technologies they employ be conducted now or in the foreseeable future?

Report Findings

1. Some remediation workers who have worked at DOE sites cannot be identified. Complete rosters of current and former remediation workers do not exist. Reconstruction of rosters from multiple data sources at the sites is labor intensive and may exclude some groups of workers.

2. Accurate and complete exposure, work history, and medical records data are not available for this population. Although radiation exposure records appear to be complete, decentralized responsibility for chemical exposure assessment and other records has led to gaps in exposure, work history, and medical data.

3. Individual workers cannot consistently be linked to their exposure and medical data. The storage of data and records in hard copy format, on incompatible software platforms, and on media produced by now obsolete hardware has diminished the ability to identify workers and link them with their work history, exposure, and medical data. The failure to standardize data collection and archiving both within and among DOE sites will hinder linkage of individuals to their data.

4. ***At the present time the necessary information to conduct epidemiologic, exposure assessment, or hazard surveillance studies of remediation workers is not available.*** The absence of worker rosters, the difficulty of creating such rosters with currently available data, gaps in work history, exposure, and medical data, and data linkage problems limit the ability to conduct accurate and comprehensive studies of remediation workers. This report contains recommendations that address each of these findings.

<https://www.cdc.gov/niosh/oerp/pdfs/2001-133g21.pdf>

Impact of September 11 World Trade Center disaster on children and pregnant women

Philip J Landrigan, et al.

Abstract

Background: Children are uniquely sensitive to toxic exposures in the environment. This sensitivity reflects children's disproportionately heavy exposures coupled with the biologic vulnerability that is a consequence of their passage through the complex transitions of early development.

Methods and results: To assess effects on children's health associated with the attacks on the World Trade Center (WTC) of September 11, 2001, research teams at the Mount Sinai School of Medicine and other academic health centers in New York City launched a series of clinical and epidemiologic studies. Mount Sinai investigators undertook a prospective analysis of pregnancy outcomes in 182 women who were pregnant on September 11, 2001, and who had been either inside or within 0.5 miles of the WTC at the time of the attacks;

“they found a doubling in incidence of intrauterine growth retardation (IUGR) among infants born to exposed mothers as compared to infants born to unexposed women in northern Manhattan. A Columbia research team examined pregnancy outcomes in 329 women who lived, worked or gave birth in lower Manhattan in the 9 months after September 11; they found that these women gave birth to infants with significantly lower birth weight and shorter length than women living at greater distances from Ground Zero.”

NYU investigators documented increased numbers of new asthma cases and aggravations of pre-existing asthma in children living in lower Manhattan.

Mount Sinai mental health researchers documented a significant increase in mental health problems in children who directly witnessed the attacks and subsequent traumatic events; these problems were most severe in children with a past history of psychological trauma.

The New York City Department of Health and Mental Hygiene established a WTC Registry that has enrolled over 70,000 persons of all ages in lower Manhattan and will follow the health of these populations to document on a continuing basis the health consequences of September 11.

<https://pubmed.ncbi.nlm.nih.gov/18500713/>

[**Editors Note:** the current WTC Registry, as of June 30, 2020, has a total membership cohort of 105,272 First Responders and Civilians, men, women and children affected by 9/11 fallout.]

**Reproductive Outcomes
Following Maternal Exposure to the Events of September 11, 2001,
at the World Trade Center, in New York City**

By Carey B. Maslow, DrPH, MPH

Abstract

Objectives. To estimate associations between exposure to the events of September 11, 2001, (9/11) and low birth weight (LBW), preterm delivery (PD), and small size for gestational age (SGA).

Methods. We matched birth certificates filed in New York City for singleton births between 9/11 and the end of 2010 to 9/11-related exposure data provided by mothers who were World Trade Center Health Registry enrollees. Generalized estimating equations estimated associations between exposures and LBW, PD, and SGA.

Results. Among 3360 births, 5.8% were LBW, 6.5% were PD, and 9% were SGA. Having incurred at least 2 of 4 exposures, having performed rescue or recovery work, and probable 9/11-related posttraumatic stress disorder 2 to 3 years after 9/11 were associated with PD and LBW during the early study period.

Conclusions. Disasters on the magnitude of 9/11 may exert effects on reproductive outcomes for several years. Women who are pregnant during and after a disaster should be closely monitored for physical and psychological sequelae.

Public Health Implications. In utero and maternal disaster exposure may affect birth outcomes. Researchers studying effects of individual disasters should identify commonalities that may inform postdisaster responses to minimize disaster-related adverse birth outcomes.

Adverse reproductive outcomes have been linked to in utero exposure to ambient air pollution and particulate matter (PM)¹ including constituents of PM identified in samples of ambient air² and dust³ collected after the events of September 11, 2001 (9/11), at the World Trade Center (WTC) in New York City. Heavy metals including lead,⁴ polycyclic aromatic hydrocarbons (PAHs) including benzo[a]pyrene,⁵ polybrominated diphenyl ethers,⁶ and other toxic substances identified in WTC-area samples have been associated with reduced birth weight, length, and head circumference,^{7–9} and intrauterine growth retardation.¹⁰ Elevated levels of biomarkers of exposure have been documented in women who were pregnant and in the vicinity of the WTC on

and after 9/11, although associations with self-reported exposure have been inconsistent. Perera et al.¹¹ found elevated levels of PAH–DNA adducts indicating exposure-related genetic damage in maternal and umbilical cord blood from women exposed to the disaster while pregnant. Wolff et al.¹² also found elevated levels of PAH-adducts in women exposed during pregnancy. The PAH–DNA adduct levels correlated with self-reports of time in the vicinity of, and distance from, the WTC in the Perera et al. study, and with time of sample collection, but not an exposure index combining self-report and modeled emissions data in the Wolff et al. study. Biomarkers of several metals, organochlorines, and polybrominated diphenyl ethers, also associated with adverse birth outcomes,^{9,13,14} did not correlate with either measure of exposure in the Wolff et al. study. Evidence linking self-reported exposures and birth outcomes is also inconsistent. In the Perera et al. cohort, Lederman et al.¹⁵ reported decrements in birth weight and length associated with proximity of residence to the WTC, and decrements in length of gestation and head circumference associated with trimester of exposure. Comparing the Wolff et al. cohort with a presumably unexposed cohort, Berkowitz et al.¹⁶ observed associations between exposure and intrauterine growth retardation, but neither birth weight nor length of gestation. Eskenazi et al.¹⁷ reported an increase in moderately low birth weight (LBW; < 2000 g) infants in New York City, but not elsewhere in New York State during the week of 9/11, and associations between timing of exposure and very LBW (< 1500 g) in both areas. Among infants born in New York City to mothers pregnant on and shortly after 9/11, Lipkind et al.¹⁸ found no differences in birth weight or gestational age associated with exposure. Adverse reproductive outcomes have also been repeatedly linked to maternal stress during pregnancy¹⁹ and before conception,^{20,21} and to disaster-related stress, in particular. Compounding potential risks of 9/11-related physical exposures may be effects of behavioral²² and physiological^{17,23} responses to disaster-related stress on the developing fetus,²⁴ although, again, findings are inconsistent. Lipkind et al. reported higher rates of both LBW and preterm delivery (PD; < 37 weeks) in births to exposed women with probable 9/11-related posttraumatic stress disorder (PTSD), and Engel et al.²⁵ reported positive associations between scores on screens for PTSD (and depression) and gestational age, but negative correlations between these measures and head circumference at birth. Environmental exposures associated with 9/11, and 9/11-related PTSD continued long after 9/11, raising the question of whether and for how long effects on reproductive outcomes may persist.

To date, most studies have focused on pregnancies occurring on or shortly after 9/11, precluding analyses of outcomes among exposed women who became pregnant later. Furthermore, most studies have relied on cohorts created on the basis of pregnancy status, or used comparison groups for which exposure assessments were not available. As a consequence, associations between adverse outcomes and both chronic 9/11-related exposures and prolonged effects of acute exposures have not been well studied. We therefore examined rates of LBW, PD, and small-for-gestational-age (SGA; < 10% of standard, by gender) status among births occurring between 9/11 and the end of 2010 in a cohort of infants derived on the basis of detailed measures of maternal 9/11-related exposure.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5024368/>

Low birthweight in New York City and upstate New York following the events of September 11th

By Brenda Eskenazi, et al.

Abstract

Background: We examined pregnancy outcomes in New York City (NYC) and upstate New York after the September 11, 2001 World Trade Center disaster.

Methods: Using birth certificate data for NY residents (n = 1,660,401 births), we estimated risk of low birthweight (LBW: <2,500 g) and preterm birth (<37 weeks) one week after September 11th versus three weeks before, and for 10 four-week intervals post-disaster versus these intervals in the two previous years.

To corroborate regression results, we used time-series analysis.

Results: One week after September 11th in NYC, we observed an adjusted odds of 1.44 for births <1,500 g (P = 0.07) and 1.67 for births 1,500-1,999 g (P = 0.01), but a decreased odds of 2,000-2,499 g.

We found no immediate change in LBW upstate or preterm in either location. In extended analyses, we found, in both locations, increased odds of <1,500-g births around New Year and 33-36 weeks post-disaster and decreased odds of moderate preterm for several weeks post-disaster.

Time-series analyses yielded similar findings.

Conclusions: The events of September 11, 2001 in NYC were associated with immediate increases in births <2,000 g, slightly delayed decreased preterm delivery, and delayed increases in LBW among infants exposed periconception or in the first two trimesters.

Stress may contribute to observed associations.

<https://pubmed.ncbi.nlm.nih.gov/17905748/>

The Intergenerational Impact of Terror:

Did the 9/11 Tragedy Impact the Initial Human Capital of the Next Generation?

By Ryan Brown, et al.

Abstract

Given the unexpected nature of the terrorist attacks of September 11, 2001, a specific cohort of children were exogenously exposed to increased maternal psychological stress in utero.

Rich administrative data and the precise timing of the event allow this study to uniquely provide insights into the health effects of exposure to maternal psychological stress across gestation.

Results suggest that children exposed in utero were born significantly smaller and earlier than previous cohorts.

[**Editors Note:** this report as well as recent peer review indicates a statistically significant increase in small head circumference, early births and lower birth weights, all supporting 'The Ground Zero Model by Heinz Pommer & Colleagues,' 192-pages, Barnes & Noble, \$18.95 soft cover, \$45.95 hard cover, Amazon Kindle, \$2.99, free with Kindle trial, Amazon Fire Tablet, \$2.99 contains on-page audio and video; a free PDF with active internal and external hyperlinks is available at Academia.edu:

<https://prager.academia.edu/research>]

The timing of the effect provides evidence that intrauterine growth is specifically restricted by first trimester exposure to stress; reductions in gestational age and increases in the likelihood of being born at low (<2,500 grams) or very low (<1,500 grams) birth weight are induced by increased maternal psychological stress mid-pregnancy.

This study also documents a positively selected post-attack fertility response, which would bias an evaluation that includes cohorts conceived after September 11, 2001, in the control group.

<https://pubmed.ncbi.nlm.nih.gov/32514847/>

**Selected birth defects among males
following the United States terrorist attacks of 11 September 2001**

Parvati Singh, et al.

Abstract

Background: The terrorist attacks of 11 September 2001 (hereafter referred to as 9/11) preceded an increase in male fetal deaths and reduced male live births among exposed gestational cohorts across several geographic locations in the United States, including California.

We analyze whether the extreme stressor of 9/11 may have selected against frail males in utero by testing if the prevalence of male births with selected defects in California fell among cohorts exposed to the stressor during gestation.

Methods: We used data from the California Birth Defects Monitoring Program from July 1985 to January 2004 (223 conception cohorts).

We included six birth defects that as a group of phenotypes disproportionately affect males. We applied time-series methods and defined as “exposed to 9/11” the cohorts conceived in February, March, April, May, June, July, and August 2001.

Results: Three of the seven monthly conception cohorts exposed to 9/11 in utero show lower than expected odds of live born males with the studied defects: February 2001 (odds ratio [OR] = 0.39; 95% confidence interval [CI], 0.21-0.71), May 2001 (OR = 0.36; 95% CI, 0.16-0.81), and August 2001 (OR = 0.51; 95% CI, 0.28-0.93).

Conclusion: The population-wide stressor of 9/11 precedes a reduction in the risk of live born males with selected birth defects.

Our analysis contributes to the understanding of adaptation to stress among pregnant women exposed to large and unexpected ambient stressors.

Results further support the notion that the prevalence of live born defects may reflect temporal variation in cohort selection in utero against frail males.

<https://pubmed.ncbi.nlm.nih.gov/28722355/>





The 9/11 Dust Cloud and Pregnancy Outcomes: A Reconsideration

By Janet Currie and Hannes Schwandt

Abstract

The events of 9/11 released a million tons of toxic dust into lower Manhattan, an unparalleled environmental disaster. It is puzzling then that the literature has shown little effect of fetal exposure to the dust. However, inference is complicated by pre-existing differences between the affected mothers and other NYC mothers as well as heterogeneity in effects on boys and girls. Using all births in utero on 9/11 in NYC and comparing them to their siblings, we show that residence in the affected area increased prematurity and low birth weight, especially for boys.

Introduction

The collapse of the World Trade Center (WTC) in New York City following the terrorist attacks of Sept. 11, 2001 was the largest environmental disaster ever to have befallen a U.S. metropolis, releasing a million tons of toxic dust and smoke into the air of lower Manhattan (Landrigan et al. 2004; Lioy et al. 2002; Pleil et al. 2004). The levels of mutagenic and carcinogenic air pollutants measured in the aftermath of the WTC collapse are among the highest ever reported from outdoor sources (Pleil et al. 2004).

Many previous studies have found a relationship between air pollution during pregnancy and adverse birth outcomes (for example Black et al. 2013; Currie, Neidell, and Schmeider 2009; Currie and Walker 2011; Currie 2011, Graff-Zivin and Neidell 2013). It is therefore surprising that the broad 9/11 literature has so far shown little consistent evidence of effects of in utero exposure to the dust cloud on birth outcomes. Perlman et al. (2011) review the existing literature and conclude that “proximity to the WTC site on or after 9/11 does not seem to have increased the risk for low birth weight (<2500 g) or preterm deliveries.”

This study reexamines the effects of the 9/11 dust cloud on pregnancy outcomes, overcoming some of the empirical challenges that have complicated inference about its effects in previous studies. First, as we will show below, mothers living in the affected areas were different than other mothers even within lower Manhattan, and were more likely to have had positive birth outcomes other things being equal. We control for this source of possible confounding by following the same mothers over time.

Second, there are issues having to do with seasonality and low statistical power in the small

convenience samples that have typically been used to examine the effects of 9/11. By using all births in the affected area and elsewhere in Manhattan, we can control for the effects of seasonality, and we have larger samples sizes, and thus more statistical power than most previous studies.

Third, the larger sample size also allows us to estimate effects separately for boys and girls. Such subgroup analysis might reveal important gender differences as a literature on “fragile males” has found that male fetuses are more vulnerable to detrimental influences in utero than female fetuses (Kraemer 2000; Eriksson et al. 2010; Almond and Mazumder 2011; Dinkelman, 2013).

We find strong effects of residence in the area affected by the 9/11 dust cloud on gestation length, the incidence of premature birth (gestation length less than 37 weeks), birth weight, and on the incidence of low birth weight (birth weight less than 2500 grams, hereafter LBW). The effects are driven by first trimester exposure and are -- in line with the literature on “fragile males” -- much stronger for boys than for girls. The estimates are robust to choosing a variety of alternative definitions of the treatment and control groups both in terms of location and timing. Among other specification checks, we exclude births after 9/11 (so that only births to mothers pregnant before and during 9/11 are included), and instrument for potentially endogenous migration between the dust and the no-dust area of NYC.

These findings provide the first consistent evidence that the 9/11 dust cloud had detrimental impacts on pregnancy outcomes. Moreover, our analysis shows that it is the male offspring of mothers exposed to the dust cloud who bear the major burden in terms of health effects which reinforces the idea that a gender-specific analysis can be useful when assessing in utero effects of pollution and other detrimental influences.

The paper proceeds as follows: Section 2 discusses background information about previous studies of pollution from 9/11 and the greater susceptibility of males to many types of health insults. Section 3 provides an overview of our data and methods. Section 4 presents the results, and a discussion and conclusion follow in Section 5.

Background

Figure 1 shows aerial photographs of the dust cloud that resulted from the collapse of the World Trade Center towers. This dust contained a wide range of toxicants and irritants, including pulverized cement, asbestos, glass fibers, lead, dioxins and polycyclic aromatic hydrocarbons (PAHs), some of which are known to be hazardous for fetal development, while the effects of many others are unknown (Pleil et al. 2004). PAHs have been identified as contributors to adverse birth outcomes in previous research. The PAH air concentrations in the days after the disaster were among the highest outdoor PAH concentrations ever reported (1.3 to 15 ng/m³), comparable only to measurements from the Teplice coal-burning region in the Czech Republic. These initially high concentrations declined rapidly over the weeks following 9/11 (Pleil et al. 2004).

The collapse of the two towers created a zone of negative air pressure that pushed dust and smoke into the avenues surrounding the WTC site (see Figure 1). Since the area north of the WTC was less densely covered by big buildings, much of the heavy dust was pushed northwards. At the same time wind was blowing from the west from the first hours to 18 hours after the collapse (Lioy et al. 2002). When the dust particles reached the open area around Warren Street the wind started dominating the movement of the dust particles, moving them eastwards. As a result of these two effects the exposed areas include not only the area immediately adjacent to the WTC, but also the areas north and east of the WTC. High levels of WTC pollutants were found in dust samples taken from Cherry and Market Streets close to the Manhattan Bridge (Lioy et al. 2002). Figure 2 shows the Neighborhood Tabulation Areas (NTAs) 1, the smallest regional areas our data identifies, which were at least partly exposed to the 9/11 dust cloud. These include Lower Manhattan, Battery Park City, SoHo, TriBeCa, Civic Center, Little Italy, Chinatown and the Lower East Side.

Environmental exposure to the WTC dust cloud was associated with significant adverse effects on the health of adult community residents and emergency workers (Landrigan et al. 2004). The high alkalinity (pH 9.0–11.0) of WTC dust produced bronchial hyper-reactivity, persistent cough, and increased risk of asthma. These health effects are in line with experimental tests which found that mice exposed to WTC dust showed short-lived pulmonary inflammations and persistent marked bronchial hyper-reactivity

Previous Estimates of the Effects of Pollution on Newborns and of the Effects of 9/11

Many previous studies have shown that there is an association between air pollution and negative infant health outcomes (Chay and Greenstone 2003a,b; Currie and Neidell 2005; Currie et al. 2009). However most existing research has focused on pollutants which are regulated under the Clean Air Acts and there has been little research on the causal effects of many of the pollutants that appeared in the 9/11 dust cloud. One exception is Currie et al. (2015) who find that living within a mile of an industrial plant increased the incidence of low birth weight by 2 percent relative to infants born 1–2 miles away.

Existing studies of the effects of 9/11 on the health of newborns generally recruited samples of mothers either from individual hospitals in Lower Manhattan and/or via media publicity (Berkowitz et al. 2003; Lederman et al. 2004; Herbstman et al. 2010; Lipkind et al. 2010). Such recruitment processes might lead to unrepresentative samples, for example if health problems during pregnancy affect mothers' willingness to participate in such studies. A further issue is selection of mothers into neighborhoods that were differentially exposed to 9/11 dust. As we show below, the socio-economic status of mothers varies substantially across different neighborhoods of New York City (NYC).

Our sample is based on the entire population of births in NYC. In order to control for differences in the characteristics of mothers across neighborhoods, we follow the same women over time

by including mother fixed effects. These fixed effects control for all characteristics of the mother that are constant between births. Using this relatively large sample of births is advantageous in that a larger sample size implies greater statistical power than many existing studies. We also control for month of conception which is a potentially strong confounder for 9/11 effects (Currie and Schwandt; 2013).

Birth outcomes might also have been affected by 9/11 independent of the dust cloud, through maternal stress and post-traumatic stress disorder (PTSD), and many of the existing studies focus on this channel (for example Lauderdale 2006; Lederman et al. 2004; Lipkind et al. 2010). These studies suggest that maternal stress related to 9/11 may have had detrimental effects on birth outcomes, but that this effect is not restricted to mothers residing close to the WTC. In our analysis we compare mothers in the area affected by 9/11 dust to mothers in the other neighborhoods of New York City.

Fragile Males

We will show below that the 9/11 dust seems to have had much larger negative effects on male fetuses than female fetuses. This finding is in line with a broad literature about “fragile males” in epidemiology and medicine (Kraemer 2000; Eriksson et al. 2010). Fetal deaths are more common in boys (Childs 1965; Mizuno 2000), suggesting that the same environmental insults imply greater damage for male fetuses. Lower male to female sex ratios have been observed for mothers who smoke (Fukuda et al. 2002) as well as for those who experience psychological stress due to severe life events (such as severe health diagnoses of family members) or natural disasters during pregnancy (Fukuda et al. 1998; Hansen et al. 1999). Catalano et al. (2005) and Catalano et al. (2006) find that sex ratios in California and New York City respectively were slightly lower in the nine months following 9/11 than during the same season in the years before and after. They argue that maternal stress related to 9/11 might have led to more miscarriages for male than for female fetuses. Our estimates of the effects of exposure to the 9/11 dust cloud on the ratio of male to female infants born is negative but not statistically significant, suggesting that we may not have enough power to detect an effect on fetal losses though we will be able to assess markers of the health of surviving infants.²

Data and Methods

The birth data for this paper come from individual birth records covering all births in New York City (NYC) from 1994 to 2004. New York City has its own Vital Statistics Natality system for collecting and recording information from the certificate of live birth. Data for these certificates come from two worksheets. One is completed by the mother and asks information about her circumstances and behaviors (such as marital status, smoking during pregnancy, and pre-pregnancy weight). The other worksheet is completed by the medical facility where the birth takes place using medical records. This worksheet includes information about prenatal care visits, risk factors for the pregnancy, complications of labor and delivery, and newborn health. We start

with all live singleton births in New York City between 1994 and 2004, approximately 1.2 million records.

The data also includes information about the mother's neighborhood at birth (at the NTA level) and a code that allows us to match births to the same mother. This data set makes it possible to overcome many of the limitations of previous studies of the effects of 9/11 dust exposure on birth outcomes (see discussion above). Including all births in NYC circumvents sample selection due to endogenous study participation. Further, identifying births to the same mother makes it possible to eliminate time-constant differences between exposed and non-exposed mothers. Third, the large sample size enables us to control effectively for seasonality as well as to analyze heterogeneity in the effects of exposure by gender and trimester of exposure.

We identify exposure to 9/11 by individual trimester of pregnancy. Babies conceived within three months prior to 10/2001 were exposed during their first trimester (born 12/2001–7/2002, in our sample). Conceptions between three and six months prior 10/2001 imply second trimester exposure (born 9/2001–4/2002). Third trimester exposure applies to all babies conceived between six and nine months prior to 10/2001 and born in September 2001 or later (born 9/2001–12/2001).³ Babies conceived in that time period but born prematurely before September 2001 are not counted as exposed to 9/11. As explained below, this mechanical relationship of gestation length and exposure status might impart some bias. Following Currie and Rosin-Slater (2013) we therefore show robustness checks in which we instrument actual exposure with an indicator of potential exposure that is one if the baby would have been exposed had the pregnancy lasted for nine months.

Information on the mothers' neighborhood of residence is provided at the date of birth but not at the date of conception. We use the residence at birth as a proxy for the residence at conception. In order to assess the precision of this proxy we investigate migration patterns of mothers initially residing in the dust area and in a similarly sized region outside the dust area. We also test whether mothers giving birth prior to 9/11 in the dust area are less likely to be observed with an additional birth after 9/11 than mothers in the no dust area, which would indicate that women might have migrated out of NYC in response to the dust cloud exposure.

As discussed in the previous section we include in the exposure area all neighborhoods that were at least partly exposed to the 9/11 dust cloud. These are Lower Manhattan, Battery Park City, SoHo, TriBeCa, Civic Center, Little Italy, Chinatown and Lower East Side (Figure 2). Births in all the remaining neighborhoods of NYC form the control area. We explore the robustness of our results to the use of alternative areas as treatment and control groups. For example, we show regressions excluding Chinatown, a neighborhood in the dust area with specific demographics, as well as neighborhoods adjacent to the dust area. We also try restricting the control area to Manhattan instead of entire NYC.

We restrict attention to single births with non-missing information on key maternal and birth

characteristics, such as gestation length and birth weight. These restrictions yield a baseline sample of 981,462 births in all of NYC between 1994 and 2004. Table 1 column (1) shows the means of mother characteristics and birth outcomes for this sample. One third of mothers are Hispanic, white and black mothers make about a quarter of the sample each, and the remaining tenth are Asian. Average age is 28 years and almost half of the sample is unmarried; 3.7 percent of mothers smoke and 6.1 percent have a prenatal care visit during the first trimester. The rates of prematurity and low birth weight are 7.4 percent and 6.4 percent, respectively. For about half of the newborns we observe the birth of one or more siblings in our sample.

Our empirical strategy focuses on newborns in utero on 9/11, comparing those born in the dust and no dust area with their siblings born before and afterwards. In our sample a total of 87,864 births are part of sibling pairs in which one sibling was in utero on 9/11. Column (2) shows the mean characteristics of this subsample. Compared to the overall sample, mothers in the 9/11 sibling sample are more likely to be white and they are slightly younger. Rates of prematurity and low birth weight are about one percentage point lower than in the full sample.

Column (3) shows means for the “treatment” sample. These are sibling pairs in which one sibling was in utero on 9/11 and born in the dust area. A total of 1,932 births were in sibling groups where at least one infant was potentially affected. The racial composition of mothers living in the area affected by the dust is very different from the remaining sample, due to the high fraction of Asian mothers in Manhattan’s Chinatown; 54.1 percent of mothers in the affected area are Asian, compared to 11.4 percent in all NYC. Education levels are similar to those in the overall sample while mothers in the dust area are slightly older and less likely to smoke or to suffer from hypertension. Prematurity and low birth weight rates in the dust area are about 1 and 2 percentage points lower compared to overall NYC, respectively. Column (4) of Table 1 shows means for sibling pairs in Manhattan outside the 9/11 dust area. Key maternal characteristics such as the racial composition, the average age, or education levels are more distinct from the dust area characteristics than in the overall NYC sample which is why we choose the overall NYC area as the baseline sample. However, we also show regressions restricting the sample to mothers living in Manhattan only.

It is important to note that we measure the effects of potential exposure, which is a noisy indicator of actual exposures. Some pregnant women resident in lower Manhattan might have been elsewhere on the morning of 9/11, while other pregnant women resident in other parts of New York might have been affected by the dust. Hence, the estimated effects we find may well represent lower bounds on the true effects of exposure.

Methods

Table 1 shows that there are strong socioeconomic differences between mothers who give birth in different neighborhoods of NYC. One reason mothers select into different neighborhoods has to do with racial or ethnic clusters such as Chinatown in lower Manhattan. Another

driver might be differences in housing prices and skill-specific labor demand. A straightforward way to control for time-constant differences in mother characteristics across neighborhoods would be to include neighborhood fixed effects. However, the selection of mothers into different neighborhoods might change over time and in response to a disaster like 9/11. In this case, any changes in birth outcomes within neighborhoods might be entirely driven by changes in the composition of mothers over time. A way to account for time-changing regional selection is to include observable maternal characteristics in multivariate regression models. But variables such as age, race and years of education are relatively crude proxies for the socio-economic determinants of residential sorting and they are unlikely to capture the entire extent of selection. As Pischke and Schwandt (2015) show the inclusion of covariates might be of little help in reducing omitted variable bias if they are noisy or poor proxies of the true underlying confounders.

To control for both observed and unobserved mother characteristics that are constant across births (such as maternal background) we include mother fixed effects. This means we compare siblings born to the same mother at different points in time, with and without exposure to the 9/11 dust cloud. Further, we also include sibling pairs with the 9/11 sibling born in NYC outside the dust area to control for potential effects of 9/11 on birth outcomes unrelated to the 9/11 dust cloud. As discussed above, some papers have suggested that 9/11-related maternal stress and post-traumatic stress disorders lead to adverse birth outcomes, irrespective of where in NYC mothers lived (Lederman et al. 2004, Lauderdale 2006, Eskenazi et al. 2007, Lipkind et al. 2010). Including sibling pairs outside the dust area controls for 9/11 effects that are common across neighborhoods.

Hence, we compare the difference in birth outcomes between sibling pairs with one sibling in utero on 9/11 and exposed to the dust cloud to the difference between sibling pairs with one sibling in utero on 9/11 but not exposed to the dust cloud.

Discussion and Conclusions

Previous research into the health impacts of in utero exposure to the 9/11 dust cloud on birth outcomes has shown little evidence of consistent effects. This is a puzzle given that 9/11 was one of the worst environmental catastrophes to have ever befallen a U.S. metropolis, and there is a great deal of prior evidence that even low levels of pollution are associated with negative birth outcomes.

Our work suggests a simple resolution of this puzzle, which is that the women who lived in neighborhoods exposed to the 9/11 dust cloud were quite different than women in other parts of New York City. In particular, they were less likely to have poor birth outcomes, other things being equal. When we control for these pre-existing differences by following the same mothers over time, we find large effects of exposure to the dust cloud. The impacts are especially pronounced for fetuses exposed in the first trimester, and for male fetuses. We estimate that in this

group, exposure to the dust cloud more than doubled the probability of premature delivery and had similarly large effects on the probability of low birth weight. Our work also improves on past efforts by utilizing a relatively large sample of births, controlling for seasonal effects, and examining the impact of 9/11 on various observable maternal behaviors, including migration.

One might wonder whether a simple difference-in-difference estimate that does not rely on the comparison of siblings born to the same mother would deliver similar results. We report such difference-in-difference regressions for premature birth in the first two columns in Appendix Table 3. These estimates do not resemble the effects that we find when using mother fixed effects. Moreover, as the balancing regressions in columns (3) to (8) show there is evidence of selection on observable characteristics suggesting that a simple difference-in-difference design might be confounded by unobservable characteristics.

One way to assess the size of the estimated effects is to compare the effect of 9/11 exposure to the differences in health at birth between disadvantaged and advantaged mothers. The first two columns of Appendix Table 4 show mean birth outcomes for unmarried, black mothers with less than 12 years of schooling (disadvantaged) and for married, white mothers with more than 12 years of schooling (advantaged). As the comparison of columns (4) and (5) shows, the estimated effect of first trimester dust cloud exposure on boys is of similar magnitude to the difference between disadvantaged and advantaged mothers for prematurity and low birth weight. In other words, the male newborn of an advantaged mother who was exposed to the 9/11 dust cloud during the first trimester would have birth outcomes similar to the newborn of a disadvantaged mother who was not exposed. This comparison highlights the importance of controlling adequately for the baseline characteristics of the mothers, in order to uncover the detrimental effects of 9/11 on infant health at birth.

We can also place these estimates in perspective by comparing them to previous estimates of the effects of air pollution on fetal health. Many previous epidemiological studies of areas with high pollution suffer from some of the methodological weaknesses discussed above, notably, a lack of controls for possible confounders. One study of the Teplice coal mining region of northern Bohemia which had high pollution in winter due to both coal-burning and atmospheric inversions found that rates of prematurity and low birth weight were twice as high in Teplice as in a nearby district with much lower pollution levels. However, the authors note that both the ethnic makeup of the mothers and smoking behaviors differed between the two regions, which could account for some of this difference (Dejmek, Selevan, and Sram 1996).

More recent studies of low levels of pollution also find negative effects. For example, Currie and Walker (2011) found that the implementation of EZ-Pass electronic toll collections in New Jersey and Pennsylvania reduced automobile exhaust in the vicinity of high way toll plazas.

They find that these reductions in pollution resulted in a 10 percent reduction in the incidence of low birth weight and prematurity. In contrast to the relatively small though permanent

changes in pollution wrought by EZ-Pass, 9/11 was an environmental catastrophe of unparalleled magnitude. It seems reasonable then that properly measured, the effects of 9/11 are much larger.

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The data used in this article is available by application to the New York City Department of Health and Mental Hygiene. The authors of this paper are willing to advise other scholars about how to acquire and format the data. The authors would like to thank Katherine McVeigh for her assistance accessing the data and Melissa Pfeiffer, Maushumi Mavinkurve, Jisen Ho, Meredith Slopen and Slavenka Sedlar for their roles in constructing the data warehouse. Ishita Rajani provided excellent research assistance. The authors thank the Center for Health and Wellbeing at Princeton University for financial support.

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Association Between World Trade Center Exposure and Excess Cancer Risk

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Abstract

Context: The terrorist attacks of September 11, 2001, resulted in the release of known and suspected carcinogens into the environment. There is public concern that exposures may have resulted in increased cancers.

Objective: To evaluate cancer incidence among persons enrolled in the World Trade Center Health Registry.

Design, Setting, and Participants: Observational study of 55 778 New York State residents enrolled in the World Trade Center Health Registry in 2003-2004, including rescue/recovery workers (n = 21 850) and those not involved in rescue/recovery (n = 33 928), who were followed up from enrollment through December 31, 2008. Within-cohort comparisons using Cox proportional hazards models assessed the relationship between intensity of World Trade Center exposure and selected cancers.

Main Outcome Measures: Cases were identified through linkage with 11 state cancer registries. Standardized incidence ratios (SIRs) adjusted for age, race/ethnicity, and sex were computed with 2003-2008 New York State rates as the reference, focusing on cancers diagnosed in 2007-2008 as being most likely to be related to exposure during September 11 and its aftermath. The total and site-specific incidence rate differences (RDs) per 100 000 person-years between the study population and the New York State population in 2007-2008 also were calculated.

Results: There were 1187 incident cancers diagnosed, with an accumulated 253 269 person-years (439 cancers among rescue/recovery workers and 748 among those not involved in rescue/recovery). The SIR for all cancer sites combined in 2007-2008 was not significantly elevated (SIR, 1.14 [95% CI, 0.99 to 1.30]; RD, 67 [95% CI, -6 to 126] per 100 000 person-years among rescue/recovery workers vs SIR, 0.92 [95% CI, 0.83 to 1.03]; RD, -45 [95% CI, -106 to

15] per 100 000 person-years among those not involved in rescue/recovery). Among rescue/recovery workers, the SIRs had significantly increased by 2007-2008 for 3 cancer sites and were 1.43 (95% CI, 1.11 to 1.82) for prostate cancer (n = 67; RD, 61 [95% CI, 20 to 91] per 100 000 person-years), 2.02 (95% CI, 1.07 to 3.45) for thyroid cancer (n = 13; RD, 16 [95% CI, 2 to 23] per 100 000 person-years), and 2.85 (95% CI, 1.15 to 5.88) for multiple myeloma (n = 7; RD, 11 [95% CI, 2 to 14] per 100 000 person-years). No increased incidence was observed in 2007-2008 among those not involved in rescue/recovery. Using within-cohort comparisons, the intensity of World Trade Center exposure was not significantly associated with cancer of the lung, prostate, thyroid, non-Hodgkin lymphoma, or hematological cancer in either group.

Conclusions: Among persons enrolled in the World Trade Center Health Registry, there was an excess risk for prostate cancer, thyroid cancer, and myeloma in 2007-2008 compared with that for New York State residents; however, these findings were based on a small number of events and multiple comparisons. No significant associations were observed with intensity of World Trade Center exposures. Longer follow-up for typically long-latency cancers and attention to specific cancer sites are needed.

The terrorist attacks on the World Trade Center (WTC) on September 11, 2001, claimed more than 2700 lives and exposed hundreds of thousands of people to dust, debris, pulverized building materials, and potentially toxic emissions, resulting in short- and medium-term health effects.¹⁻⁶ The dust, smoke, and aerosols were complex mixtures of volatile chemicals and respirable particulate matter less than 2.5 µm in diameter and contained known and suspected carcinogens including asbestos, silica, benzene, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, volatile organic compounds, and numerous metals.⁷⁻¹⁰

The presence of carcinogenic agents raises the possibility that exposure to the WTC environment could eventually lead to cancers. Thus far, the only systematic examination of cancer incidence is a study of 9853 male firefighters employed by the Fire Department of the City of New York (FDNY).¹¹ Zeig-Owens et al¹¹ reported 19% excess incidence for all cancer sites combined among WTC-exposed firefighters compared with unexposed firefighters in the 7 years following September 11. Most of the excess incidence was composed of prostate and thyroid cancers, non-Hodgkin lymphoma, and melanoma. A mortality study from the WTC Health Registry, in which 41 930 WTC-exposed New York City residents were followed up through 2009, found that the total mortality from potentially short incubation and fatal hematological malignancies did not differ significantly from expected.¹² However, the follow-up period was short relative to the onset and survival times for most cancers.

We evaluated cancer incidence to determine any excess cancer among rescue/recovery workers and volunteers and those not involved in rescue/recovery enrolled in the registry, laying the groundwork for periodic cancer surveillance.

Methods

Study Population

The World Trade Center Health Registry is a cohort study designed to monitor the health effects of the September 11 attacks among rescue/recovery workers and persons who lived, worked, or attended school in lower Manhattan. The study methods have been published elsewhere.^{2,13} Briefly, in 2003-2004 a total of 71 434 persons completed a telephone (95%) or in-person (5%) interview. Participants were either identified through lists provided by employers, government agencies, and other entities (30%; list identified) or they responded to an outreach campaign (70%; self-identified). Coverage of the eligible population was estimated as 34% for rescue/recovery workers and 23% for residents.¹⁴ Verbal informed consent was obtained from each of the participants. This analysis included registry enrollees who were New York State (NYS) residents on September 11 and at risk for a first primary invasive cancer at the time of registry enrollment, defined as never having had a primary invasive cancer documented in any of the 11 state cancer registries we used for case identification.

This study was approved by the institutional review board of the New York City Department of Health and Mental Hygiene. Each cancer registry record linkage was also approved by the respective institutional review board of 10 state departments of health listed below and the University of Medicine and Dentistry of New Jersey.

Outcome Definition

Cancers were identified through record linkage with 11 state cancer registries. Eligible study participants were matched to cancer registries that have been population based since 1976 (in NYS) and 1978 (in New Jersey). Residents of NYS on September 11 who later moved to California, Connecticut, Florida, North Carolina, Massachusetts, Ohio, Pennsylvania, Texas, or Washington were matched to the corresponding state cancer registry. The proportion of the cancer cases with a full or partial social security number was similar to that in noncancer cases (76.1% vs 76.5%, respectively; $P = .78$). An incident cancer case is defined as a first primary invasive cancer or in situ bladder cancer matched to a state cancer registry and diagnosed any time postenrollment through December 31, 2008, the last date for which complete cancer incidence records were available for observed and expected cancer computations. Cancer site was defined using the Surveillance, Epidemiology, and End Results (SEER) site recode International Classification of Diseases for Oncology, Third Edition, grouping, in which categories are based on primary site and histology.¹⁵

Exposure to WTC and Covariates

Demographic and exposure data were obtained at registry enrollment. Rescue/recovery workers were first responders, volunteers, and others who worked at the WTC site, debris-loading sites, on barges, or at the Staten Island landfill between September 11, 2001, and June 30,

2002. Participants not involved in rescue/recovery were residents, children, and staff in schools (prekindergarten-12th grade) south of Canal Street and area workers and passersby south of Chambers Street on September 11 in lower Manhattan. Persons belonging to both groups were categorized as rescue/recovery workers.

Separate qualitative descriptions of WTC exposures were used to classify exposure as high, intermediate, or low for rescue/recovery workers (excluding those who worked exclusively on Staten Island) and for participants not involved in rescue/recovery (exposure level definitions appear in the eTable 1). Highly exposed rescue/recovery workers were in the immediate area at the time of the WTC towers' collapse and worked on the dust and debris pile on September 11 or worked at the site for more than 90 days starting in the first week after September 11. Highly exposed participants not involved in rescue/recovery reported 2 or more injuries on September 11, and resided or worked in lower Manhattan and did not evacuate or were present at school on September 11.¹² Rescue/recovery workers and those not involved in rescue/recovery generally experienced qualitatively different exposures, and were therefore analyzed separately. Covariates included age at enrollment, sex, race/ethnicity, 2002 household income level, education level, smoking status, enrollment source (list identified or self-identified), and history of asthma, cardiovascular disease, stroke, emphysema, or diabetes reported at enrollment.

Data Analyses

We compared the cancer experience of each group with the NYS population using the standardized incidence ratio (SIR), computed as the ratio of observed to expected cancer cases, stratified by age (5-year age groups), race/ethnicity, sex, and calendar period (2003-2006 and 2007-2008). We used NYS cancer rates to determine expected cases because the study population was only NYS residents on September 11 and the NYS cancer registry was the source of all but 5% of study cases.

We constructed our analysis to increase the likelihood of detecting September 11 exposure-related cancer at this early stage of follow-up. A little more than 7 years elapsed between September 11 and the end of follow-up, which is less than the average latency period for most solid tumors. Nevertheless, short latency periods have been reported for cancers associated with exposure to chemicals in adults¹⁶ and exposure to radiation in children.¹⁷ We hypothesized that any exposure-related cancers would be more likely to emerge at least 5 years after September 11 and thus divided the follow-up interval into early (enrollment through 2006) and later (2007-2008) periods, and focused on cancers occurring in the later period.

We computed SIRs separately for the rescue/recovery workers and participants not involved in rescue/recovery, after excluding 1820 enrollees (61 cancers) with unknown ethnicity or unclassifiable race. Person-time of observation for each participant was calculated from the date of enrollment until the first cancer diagnosis, death, or December 31, 2008, whichever came first. The 95% confidence intervals of the SIRs were calculated using Byar approximation to the

exact Poisson distribution.¹⁸ We also computed the rate differences (RDs) and 95% confidence intervals for the later period as the difference between the actual incidence rate per 100 000 person-years of the study population and the incidence rate in the NYS general population, adjusted by age, sex, race/ethnicity, and calendar-year time to the distribution of person-years in our study population. The statistical significance and 95% confidence intervals for the RDs were computed based on the assumption of a Poisson distribution. We did not adjust the P values for multiple comparisons.

Cancer sites with significantly elevated SIRs in the later period were selected for within-cohort comparisons during the entire follow-up period and were examined by exposure category using Cox proportional hazards models separately for rescue/recovery workers and participants not involved in rescue/recovery. Hematological cancers, which include myeloma, leukemia, and lymphoma, also were examined using the Cox model because each has a potentially shorter latency period compared with solid tumors and thus might be more likely to show an early increase. Additionally, lung cancer was included because the dust and debris from the WTC site contained silica, asbestos, and other carcinogens that have been associated with lung cancer. No violation of the proportional hazards assumption was observed for any model. Hazard ratios (HRs) and 95% confidence intervals were adjusted for age at enrollment, sex, race/ethnicity, smoking status, education level, income level, and history of a serious, nonmalignant medical condition as described above. Source of enrollment (self-identified vs list identified) was included in multivariate analyses to control for potential selection bias.

To account for a 5-year lag time from first WTC exposure, we reran the Cox models under the assumption that cancers diagnosed in the early period were unlikely to be caused by WTC exposures, thereby treating all study participants in the early period as if they were not exposed while retaining the originally assigned WTC exposure category in the later period.

Because we did not have data on the cancer screening practices of the participants, we indirectly assessed potential screening bias in 2 ways. First, we compared the number of stage I cancers for selected sites as a proportion of total cancer diagnoses in the study population with the corresponding proportion in the NYS population during the same period based on the assumption that screening-detected cancers are more likely to be early-stage cancers. Second, we compared the proportions of participants who reported a routine physical checkup within the preceding 12 months between those with and without subsequent cancers among all follow-up participants. Proportions were compared using the Pearson χ^2 test.

Descriptive and multivariate analyses were performed using SAS software version 9.2 (SAS Institute Inc), and SIRs were computed using SEER*Stat MP-SIR sessions software version 7.0.5 (<http://www.seer.cancer.gov/seerstat>). Significance was set at a 2-sided P value of less than .05.

Results

This analysis was restricted to the 55 778 enrollees who were NYS residents on September 11 (78% of all registry enrollees) and at risk for a first primary invasive cancer at enrollment (Figure). We excluded enrollees with preenrollment invasive cancers (n = 1473), those with unknown age or sex (n = 141), and those who died before the start of follow-up (n = 148) or withdrew with an undocumented date (n = 212). Of the 55 778 enrollees, 90% remained in NYS throughout the follow-up period, 8% moved to states covered by the 10 state cancer registries mentioned earlier, and 2% moved elsewhere.

Through December 31, 2008, 1187 incident cancers were reported among the 55 778 eligible enrollees, with an accumulated 253 269 person-years. Of these 1187 cancers, 439 (37%) were diagnosed among rescue/recovery workers and 748 (63%) were among participants not involved in rescue/recovery. The median age at diagnosis across all cancer sites was 57 years (range, 22-103 years); none was diagnosed in persons younger than 20 years old. Characteristics of cancer cases and those without cancer are shown in Table 1 for rescue/recovery workers and in Table 2 for participants not involved in rescue/recovery. Participants diagnosed with cancer in both groups were significantly older, less likely to be Hispanic, and more likely to be ever smokers, and to have a prior history of medical conditions. The proportion who reported having a routine physical checkup within the preceding 12 months among those with subsequent cancer was not different from the proportion among those not diagnosed with cancer (72% vs 69%, respectively; P = .17).

Cancer Incidence Among Rescue/Recovery Workers

We excluded from the SIR analysis 632 rescue/recovery workers with unknown race/ethnicity, of whom 18 were cases. This left 421 cases for the SIR analysis. There were 198 cancers (47%) occurring in the early period and 223 (53%) in the later period. For all sites combined, cancer incidence was not significantly different from that in the reference population during either the early period (SIR, 0.94; 95% CI, 0.82 to 1.08) or the later period (SIR, 1.14; 95% CI, 0.99 to 1.30) (RD, 67 [95% CI, -5.5 to 126.2] per 100 000 person-years; Table 3).

Of the 23 cancer sites investigated, 3 had significantly elevated incidence during the later period: prostate (n = 67; SIR, 1.43 [95% CI, 1.11-1.82]; RD, 61 [95% CI, 20.1-91.4] per 100 000 person-years), thyroid (n = 13; SIR, 2.02 [95% CI, 1.07-3.45]; RD, 16 [95% CI, 2.1-22.6] per 100 000 person-years), and multiple myeloma (n = 7; SIR, 2.85 [95% CI, 1.15-5.88]; RD, 11.1 [95% CI, 2.2-14.2] per 100 000 person-years). Of these 3, thyroid cancer also was significantly elevated during the early period (n = 14; SIR, 2.22 [95% CI, 1.22-3.73]). Ovarian cancer was significantly elevated during the early period (n ≤ 5; SIR, 3.32 [95% CI, 1.08-7.74]) but not during the later period (no cases reported). Nonsignificant SIRs exceeding 2.0 were observed for Hodgkin lymphoma in both periods based on 5 cases or less in each period.

Firefighters enrolled in the registry may have been included in the study by Zeig-Owens et al.¹¹ We recalculated later period SIRs excluding 2965 (2888 males and 77 females) FDNY firefighters in the registry to address the possibility that annual cancer screening of firefighters might lead to earlier cancer diagnoses. After exclusion, the later period SIR for thyroid cancer decreased and became nonsignificant (n = 10; SIR, 1.76 [95% CI, 0.85-3.24]), whereas the SIRs for prostate cancer (n = 54; SIR, 1.35 [95% CI, 1.01-1.76]) and multiple myeloma (n = 6; SIR, 2.79 [95% CI, 1.02-6.06]) remained significantly elevated.

A significantly reduced SIR was observed for lung cancer during the early period based on 11 observed cases (SIR, 0.49 [95% CI, 0.24 to 0.87]). The later period SIR for lung cancer was reduced but was not statistically significant (n = 13; SIR, 0.65 [95% CI, 0.35 to 1.12]; RD, -17.2 [95% CI, -59.2 to 3.4] per 100 000 person-years). No mesothelioma cases were reported. Breast cancer among female rescue/recovery workers was significantly reduced during the early period (n = 6; SIR, 0.40 [95% CI, 0.15 to 0.87]), but not during the later period.

Cancer Incidence Among Participants Not Involved in Rescue/Recovery

We excluded from the SIR analysis 1188 participants not involved in rescue/recovery with unknown race/ethnicity, of whom 43 were cases. This left 705 cases for the SIR analysis. There were 381 cancers (54%) in the early and 324 (46%) in the later period (Table 4). For all cancer sites combined, cancer incidence was not significantly different from the reference population during either the early (SIR, 0.92 [95% CI, 0.83 to 1.02]) or later period (SIR, 0.92 [95% CI, 0.83 to 1.03]; RD, -45.0 [95% CI, -106.1 to 15.1] per 100 000 person-years). In the early period, the SIR for Hodgkin lymphoma was significantly higher than expected (n = 8; SIR, 2.60 [95% CI, 1.12 to 5.13]) and colorectal cancer was significantly lower than expected (n = 25; SIR, 0.64 [95% CI, 0.42 to 0.95]). Both cancers were nonsignificant in the later period with the SIR for Hodgkin lymphoma dropping below 1 (n ≤ 5; SIR, 0.48 [95% CI, 0.01 to 2.66]; RD, -1.7 [95% CI, -158.3 to 1.0] per 100 000 person-years). There were fewer observed lung cancer cases than expected during both periods.

Proportional Hazards Analyses

Table 5 shows the adjusted HRs (AHRs) by exposure level for selected cancers during the entire follow-up period. Multivariate analyses were not performed separately for myeloma, Hodgkin lymphoma, or leukemias due to very small numbers of cases. The exposure metric was not significantly associated with any individual cancer site for either group. For hematological cancers among rescue/recovery workers, the intermediate exposure AHR was 3.7, and the high exposure AHR was 4.5 compared with the low exposure level; however, neither the trend nor either AHR was significant (P = .20 for trend). When a 5-year lag time was introduced, the AHRs for hematological cancer were lower for both intermediate (AHR, 1.6 [95% CI, 0.8-3.0]) and high exposure (AHR, 1.5 [95% CI, 0.5-4.5]). All of the 95% confidence intervals in Table 5 included unity and were thus not statistically significant.

Comment

Dust, debris, and fumes from the WTC contained known and suspected carcinogens, including polycyclic aromatic hydrocarbons, asbestos, benzene, and dioxins.^{10,19-21} At issue is whether dosages to exposed individuals were sufficient to cause excess malignancies and, if so, whether such excesses are epidemiologically detectable at present. Also at issue is whether any specific cancer site with an observed excess might plausibly be related to September 11 exposure. In this early study with less than 8 years of follow-up, there was no statistically significant increased incidence for all cancer sites combined. Among rescue/recovery workers, however, multiple myeloma and prostate and thyroid cancers were significantly elevated in the later period. None of the cancers chosen for within-cohort comparisons (including the 3 with elevated SIRs) was associated with intensity of WTC exposure. The increase in hematological cancers with increasing exposure in rescue/recovery workers was not statistically significant.

Significant excess risks for prostate and thyroid cancers were observed. Both cancers are frequently detected during routine screening examinations,^{22,23} and are potentially subject to surveillance bias. To address this bias, we compared the proportion having a routine physical checkup within the preceding 12 months between those with and without subsequent cancer. The proportions were nearly identical. Furthermore, the respective proportions of prostate and thyroid cancer that were stage I at diagnosis (85% and 66%) were similar to those of the NYS population.²⁴ These observations suggest that cancer cases in this study may not have received more thorough cancer screening than the NYS population in general, although they do not eliminate the possible role of surveillance bias altogether. Also, our findings might be prone to type I error given the large number of comparisons.

The etiologies of thyroid and prostate cancers are quite different. Thyroid cancer can be caused by ionizing radiation,²⁵ but potentially carcinogenic levels of radiation were neither documented nor suspected at the WTC site. Many occupational and environmental causes of prostate cancer have been suggested but studies have been largely inconsistent or inconclusive.²⁶ Hematological cancers are of special interest because they are generally regarded as having shorter latency periods than solid tumors²⁷ and are associated with radiation and certain chemicals,²⁸ and therefore could be early indicators of cancer risk. We observed 7 later period cases of multiple myeloma among rescue/recovery workers, yielding a significantly elevated SIR of 2.85. The age distribution of these 7 cases was consistent with that of the general population, in contrast to the much younger age distribution in a case series report.²⁹

In the study by Zeig-Owens et al¹¹ of an FDNY cohort, the SIR was based on fewer than 5 cases of multiple myeloma and was not statistically significant. Multiple myeloma has been associated with a variety of occupations, including fire fighting,³⁰ painting, farming and other agricultural work,^{31,32} as well as with exposure to benzene.¹⁶ However, few specific environmental agents have been consistently linked to myeloma. None of the other hematological sites was associated with an elevated SIR among rescue/recovery workers. Reduced risk of later period

lung cancer in the participants not involved in rescue/recovery was observed. Lung cancer with its typically long latency period will remain a concern given WTC exposure to asbestos, silica, and other carcinogens.³³

This study has important strengths. It is the first WTC cancer incidence study that includes both sexes, all ages and races, and both rescue/recovery workers and those not involved in rescue/recovery. In addition, we constructed a multilevel metric of WTC exposure to examine dose-response relationships. The analysis considered latency to the development of cancer by dividing the follow-up into early and later periods.

There are also important limitations. First, WTC exposures were self-reported 2 to 3 years after the September 11 attacks, and thus are subject to recall error. However, numerous registry studies have established strong associations between reported levels of exposures and specific health outcomes that display a high degree of internal consistency.^{2,12} Second, the cancer cases identified through linkages with state cancer registries might be underestimated, especially among those without a social security number because about 23% of enrollees did not provide one. However, the percentage of enrollees having a full or partial social security number among cancer cases was similar to that in noncases. Third, because 70% of registry enrollees were self-identified,¹³ there may be self-selection bias.³⁴ We attempted to mitigate this bias by restricting the analyses to individuals without prior invasive cancer history documented in any of the 11 state cancer registries and focusing on cancer incidence in the later period. Fourth, multiple comparisons (23 cancers for 2 periods) could produce statistically significant findings that are in fact due to chance. Fifth, the relatively small number of persons with cancer in both the low- and high-exposure categories, and the relatively short follow-up period limited our ability to detect excess cancer risk and the association with intensity of WTC exposure, particularly for rarer cancers. Future in-depth studies of rarer cancers may benefit from combining data across the September 11 survivor and/or responder cohorts to increase sample size. In addition, we lacked information on cancer risk factors, eg, family cancer history, occupational exposures before or after September 11, history of exposure to other environmental carcinogens, and medical screening history, especially for prostate cancer.

Conclusion

In summary, this study found significantly increased prostate and thyroid cancers and multiple myeloma among rescue/recovery workers in the later period that were not significantly associated with intensity of WTC exposures. Given the relatively short follow-up time and lack of data on medical screening and other risk factors, the increase in prostate and thyroid cancers and multiple myeloma should be interpreted with caution. The etiological role of WTC exposures in these 3 cancers is unclear. Longer follow-up of rescue/recovery workers and participants not involved in rescue/recovery is needed with attention to selected cancer sites and to examine risk for cancers with typically long latency periods.

Airborne Fine and Ultrafine Particles Near the World Trade Center Disaster Site

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Documentation of the airborne fine and ultrafine particles produced by the terrorist attack on the World Trade Center (WTC), particularly while fires were burning, was essential for evaluating the risk of adverse health effects in people who live and work in this area. We collected airborne particles for 3 months at a site about 400 m east of the former WTC.

Ultrafine particles were collected by deposition onto small detector chips for morphometric analysis by atomic force microscopy. Some chips were coated with an iron nanofilm for detection of strong acids. A condensation nucleus counter and two impactors measured particle number concentrations and size distributions.

Collected particles exhibited a variety of globular forms, and most appeared to be agglomerates. No ultrafine acid particles were detected. Particle number concentrations ranged from below $1 \times 10^4 \text{ cm}^{-3}$ to about $5 \times 10^4 \text{ cm}^{-3}$. Occasional peaks reached values over $7 \times 10^4 \text{ cm}^{-3}$. The average total mass concentration was about $17 \mu\text{g}/\text{m}^3$ in mid-October, about half that value in November, and as low as $5 \mu\text{g}/\text{m}^3$ in mid-December. Particle size distributions were mostly bimodal.

The mass concentration of very fine particles (0.1 μm to 0.29 μm) ranged from 4.3 $\mu\text{g}/\text{m}^3$ to 0.7 $\mu\text{g}/\text{m}^3$, and the ultrafine ($d < 0.1 \mu\text{m}$) ranged from 1.46 $\mu\text{g}/\text{m}^3$ to nondetectable after 5 November 2001.

Some backup filters from the October sampling sessions were analyzed for organic and elemental carbon (OC/EC) and polyaromatic hydrocarbons (PAH). About 70% of the total carbon was organic. The PAH levels ranged from 10 to 1500 ng m^{-3} . Overall, our data for particle mass and number concentrations did not differ substantially from data we had collected in Manhattan the previous year. The dominant organic compounds found in these samples are those most common in urban environments.

These data do not suggest, but cannot rule out, an unusual risk of adverse health effects from the number, or mass, of the fine ambient particles.

BACKGROUND

Documentation of the airborne fine and ultrafine particles in the aerosol produced by the terrorist attack at the World Trade Center (WTC), particularly during the time that the fires were burning at the site, was essential for evaluating the potential risk of adverse health effects in people who live and work in this area. Fires erupted at the twin WTC towers after each was struck by a hijacked, fully fueled passenger jetliner on the morning of 11 September 2001. As a result of the fires and structural damage, both towers collapsed shortly afterwards, bringing down nearby buildings and releasing great clouds of debris and smoke. Thousands of people were killed. Fires continued to erupt during subsequent rescue efforts, and later as debris was cleared. New York City authorities declared the fires to be extinguished on 20 December 2001. A sampling station was set up as close to “ground zero” as possible and at the earliest possible time access to the site could be arranged. The sampling site was located at the New York University Downtown Hospital (NYUDH) about 4 blocks (400 m) east of the former WTC site. These samples were taken simultaneously with a large array of PM₁₀, PM_{2.5}, and Aethelometer samples collected by other NYU researchers. The data obtained from these samples and reported here contribute to a comprehensive picture of the airborne particles reaching this site from the WTC.

Particles derived from combustion form largely by condensation of volatile materials and grow by further coagulation of the primary particles, although some primary particles are released directly. The resultant airborne particles are thus found in the ultrafine- and fine-size modes. The particle sizes will be below about 700 nm in diameter, and most of the particles will have diameters below about 200 nm (USEPA 1996). Under normal circumstances, particles less than 200 nm represent about 90% of the number of airborne particles but, on average, only about one half of one percent of the total airborne particulate volume and mass (John 1993). **Yet there is evidence that suggests they have an important role in health decrements associated with ambient particulate matter (PM), and very recent evidence has also shown that ultrafine particles are associated with human mortality (Wichmann et al. 2000).**

Although the precise mechanism of ultrafine-particle-induced lung injury is not clear, it is known that they are biologically very reactive, and even low concentrations may elicit effects. Candidates for especially active components of the PM include the number of ultrafine particles and the concentration of H⁺. There is some toxicological evidence supporting both of their roles in health decrements, consistent with known mechanisms of toxicity. In the case of the fires that took place at the WTC, a large variety of products of incomplete combustion, some of which are likely to be harmful, would also be expected in the ultrafine fraction. Incomplete combustion was evidenced by the ongoing eruptions of fires as pockets of smoldering debris were exposed to air.

Ultrafine particles have a very high deposition efficiency in the respiratory tract, they may penetrate the epithelium more efficiently and be cleared less effectively by macrophages (Oberdo Erster et al. 1992) than larger particles, with unphagocytosed particles

penetrating to the interstitium in a few hours. Oberdo Erster et al. (2000) recently reported that nonreactive (carbon and platinum) ultrafine particles do not appear to cause inflammation in young healthy rats. Thus, it is also important to be able to distinguish the components, e.g., acidic and organic components, from the total ultrafine number concentration for appropriate exposure assessment and risk estimation, as well as for epidemiological studies. This article presents our measurements of the particle number concentration in the twelve weeks following the attack on the WTC, together with the results of our examination of particles collected on iron nanofilm and silicon detectors, the measured airborne particle size distributions, estimates of the mass concentration of ultrafine particles, and some measurements of organic and elemental carbon in the collected particles.

EXPERIMENTAL METHODS

The sampling program began on 20 September 2001 with the deployment of 4 ultrafine diffusion monitors in a meeting room on the second floor of the NYUDH with windows that faced the WTC site. The diffusion monitors were replaced on 28 September 2001 by an electrostatic aerosol sampler (EAS; Model 3100, TSI Inc., St. Paul, MN) in which airborne particles are efficiently precipitated onto the detectors. The EAS was preceded by a Mercer impactor (MI; In-Tox Products, Albuquerque, NM). A condensation Nucleus Counter (CNC; Model 3020, TSI Inc., St. Paul, MN), and a Micro-orifice uniform deposit impactor (MOUDI; MSP Technology, St. Paul, MN) were also added to the site (Figure 2). The inlets for the CNC and MI- EAS system were each 3.2 mm (0.125 inch) diameter metal tubing fitted with raincaps, extending about 0.5 m from the building wall on the second floor of the NYUDH. The inlet for the MOUDI was 7.75 mm inside diameter (0.305 inch) stainless steel tubing, fitted with a raincap, extending about 1.0 m from the building.

The ultrafine diffusion monitors (UDMs) deployed for the first week of sampling are low-flow diffusion monitors developed in our laboratory for the collection of time-integrated samples of ultrafine ambient particles. The UDM is a flat, rectangular aluminum channel, 1.0 mm high and 50 mm wide. The monitor has depressions cut to hold multiple 5 mm × 5 mm detectors flush with the inner surface. Two units are 500 mm and two are 95 mm in length. For outdoor sampling, the inlet of the UDM penetrated a slit cut through a temporary panel fitted to the window of the meeting room.

Air was drawn through each monitor by a low-flow pump at a flow rate of 200 cm³ min⁻¹. Flows were checked each day with a calibrated flow meter (triCal, BGI Inc., Waltham, MA). The particles entering the monitor deposit by diffusion onto the walls of the channel. Two iron nanofilm detectors and one nonreactive (silicon) detector are placed side by side in the cut receptacle on the lower wall. After sampling, detectors are stored under nitrogen. The iron nanofilm detectors are used to quantitate both the total number of particles and those particles that are acidic.

Six sample sets, consisting of six detectors each, were collected in the UDMs. The detector sur-

face is analyzed topographically by atomic force microscopy (AFM) to view and enumerate the particles and the acid reaction sites (Cohen et al. 2000). Briefly, the detectors are scanned using a noncontact mode in which the cantilever oscillates above the surface at a distance where Van der Waals forces interact with the surface to modify the oscillation frequency. A morphometric image of a $10\ \mu\text{m} \times 10\ \mu\text{m}$ scan results. The acid particle sites are distinguished by their signature ring around a central elevated site. An extensive field test of the detectors under ambient conditions indicated that, once formed, the acid reaction sites are stable (Cohen et al. 2003). Particles with other distinguishing morphometry can be recognized and evaluated by comparison with standard sources, e.g., The Particle Atlas (McCrone and Kelly 1973). The airborne concentration, C_a , in particles per cm^3 represented by the deposited particles is given by $C_a = N/EV$, where N is the net average number of particles counted per $100\ \mu\text{m}^2$, E is the deposition efficiency on the scan area (calculated value = 7.7×10^{-10} for $50\ \text{nm}$ diameter particles), and V is the volume of air sampled (cm^3).

The CNC operated at a flow of $300\ \text{cm}^3\ \text{min}^{-1}$. Number concentration measurements were recorded by both a chart recorder, and a data logger (Model 2101, Telog Instruments Inc., Rochester, NY). The data logger averaged concentrations over a set time interval of 1 h. The time interval was later adjusted to provide 15 min averages.

The MI and EAS formed a single sampling combination. The MI preceded the EAS to remove particles larger than $0.46\ \mu\text{m}$ in aerodynamic diameter; the remaining particles followed the airstream to the EAS. Within the MI particles were collected on 5 impaction stages. At the operating flow rate, cut-off diameters were 6.32 , 3.26 , 1.68 , 0.88 , and $0.46\ \mu\text{m}$. The glass substrates on the collection stages were weighed before and after exposure on an electrobalance (Model G-1, HAUG-BIEL, Switzerland) for the last 12 exposure periods. The net weights were used to determine the mass median aerodynamic diameter (MMAD) of the ambient particles. Fifteen sets of samples were collected. Each sample represents an integrated collection over approximately 5 days.

The EAS is a two-stage electrostatic precipitator (one charging and one collecting stage) that deposits particles in a random and uniform manner onto a $2.5\ \text{cm} \times 12.7\ \text{cm}$ collection surface for microscopic evaluation of the deposited particles. For this study, iron nanofilm detectors (described above) and glass microscope cover slips were placed over the collection area of the EAS to obtain uniform particle deposits. Counting the number of acid reaction sites, and the number of deposited particles per unit area of the surface allows determination of the number concentration of airborne acidic particles, total particles, and any specifically identifiable type of airborne particles (e.g., chain aggregates).

The MOUDI used in this study is an eight-stage cascade impactor. The nominal aerodynamic diameter cut points at a flow rate of $30\ \text{l}\ \text{min}^{-1}$ are 15 (inlet), 3.2 , 1.8 , 1.0 , 0.56 , 0.29 , 0.17 , and $0.10\ \mu\text{m}$. This impactor is equipped with a rotation mechanism that rotates alternate stages to provide a nearly uniform deposit of particles on the collection substrates. Teflon filters (Zefluor,

Pall Corp., Ann Arbor, MI), 47 mm in diameter, were used as impaction substrates. The same kind of filters were used as an afterfilter in order to collect particles with an aerodynamic diameter below 0.1 μm that penetrated the last stage of the impactor. A total of 10 sampling sessions, of 3 to 4 days each, were carried out at NYUDH from 28 September 2001 through 14 December 2001. A few prebaked quartz filters and teflon filters suitable for carbon and chemical organic analysis, and Fourier transformed infrared (FTIR) analysis, respectively, were available, so that a limited amount of analysis was possible for organic carbon (OC) and elemental carbon (EC). Some of the filters were used to collect wipe samples of the highly diffusing particles that deposited on the upper surface of the diffusion monitor channel during the first sampling week (20 September through 25 September). Some of the quartz filters were used as backup filters of the MI-EAS system during measurements in October. The samples were stored under nitrogen in the laboratory, but it took several days before they were transported to storage. The quartz filters were analyzed for organic and elemental carbon (OC/EC) by thermal-optical transmittance analysis and for polycyclic aromatic hydrocarbons (PAH) by methods detailed in Offenberg et al. (2003). The teflon filters were analyzed by FTIR. The measured OC results were corrected for adsorbed OC that was measured a year later at the same location. The average adsorbed OC was 52% of the total OC.

RESULTS

Very few particles were seen in the 10 $\mu\text{m} \times 10 \mu\text{m}$ AFM scans of detectors exposed in the UDMs. The reason was the short total exposure times that resulted from sporadic power failures and other disruptions during the sampling sessions. As a result, counting statistics were poor, and the derived concentration data have high uncertainties; they ranged roughly from 1.3×10^3 to 34×10^3 particles per cm^3 . A few scan areas had particles that could be visually compared with those observed when we sampled in Manhattan the prior year (Figure 3). There are no notable differences. The particles observed by this system are about 50–100 nm in diameter, although the scan process causes them to appear somewhat larger. The deposition efficiency for accumulation mode particles is very low in the UDMs, and we saw none on these samples. Additionally, we saw no acidic particles.

Particle number concentrations were measured with the CNC beginning 28 September 2001 (Figure 4). Hourly average number concentrations varied substantially (Figure 4a). Occasionally very high, short duration peaks are seen that reached values over $7 \times 10^4 \text{ cm}^{-3}$. The daily average number concentrations (Figure 4b) ranged from below $1 \times 10^4 \text{ cm}^{-3}$ to about $5 \times 10^4 \text{ cm}^{-3}$. There were 5 days between 28 September 2001 and 30 November 2001 when the daily average particle concentrations exceeded $3 \times 10^4 \text{ cm}^{-3}$. However, in December the concentrations increased and there were only 3 days on which the concentrations did not exceed $3 \times 10^4 \text{ cm}^{-3}$.

Deposition efficiency in the EAS is high for all particle sizes. We used the MI as a precollector to remove particles greater than about 0.46 μm , which is the cut size of the last included stage.

These detector samples show a high density of particles with a variety of globular forms. The presence of the larger ($>0.2 \mu\text{m}$) particles interferes substantially with the scanning process. Large particles cause mechanical discontinuities, because the vertical range of the AFM is quite restricted. Thus, analysis was limited to the scanning of small areas (less than $3 \mu\text{m} \times 3 \mu\text{m}$) for morphometric analysis. Figure 5 shows typical particles collected about 2 1/2 weeks (17–22 days; Figure 5a) and 8 weeks (60–66 days; Figure 5b) after the disaster. Most of the particles appear to be composed of agglomerates of smaller particles. Occasional single particles of about 30 nm are seen, and more of them, and fewer agglomerates, are seen in the later sample. These differ in character from the particles collected in prior sampling campaigns where we saw individual single unit particles almost exclusively. No fibrous particles were noted, and no acidic particles were detected.

Total ($d_a < 15 \mu\text{m}$) PM mass concentration for a sampling session was obtained by summing the concentrations measured in the individual size fractions. The average total mass concentration measured by both the MOUDI and MI was $17 \mu\text{g m}^{-3}$ in mid-October. It decreased to roughly half the value in November, and then to as low as $5 \mu\text{g m}^{-3}$ in mid-December (Figure 6). Individual MOUDI and MI samples cannot be directly compared because, although both operated over most of the 12 week sampling period, the start time and duration of the sampling sessions differed. The average total mass concentration for the different sampling sessions measured with the MOUDI ranged from $4.4 \mu\text{g m}^{-3}$ to $22.7 \mu\text{g m}^{-3}$. It did not exhibit any clear trend through time.

Partial mass concentrations were summed to compare two size fractions: (1) the very fine fraction, which includes the particles with aerodynamic diameter within the range of $0.1 \mu\text{m}$ to $0.29 \mu\text{m}$; and (2) the ultrafine size fraction of particles with aerodynamic diameter smaller than $0.1 \mu\text{m}$. Ambient mass concentration for the very fine size fraction ($0.1 \mu\text{m}$ to $0.29 \mu\text{m}$) ranged from $0.7 \mu\text{g m}^{-3}$ to $4.3 \mu\text{g m}^{-3}$. The concentration for the ultrafine size fraction ranged from nondetectable to $1.46 \mu\text{g m}^{-3}$. The ultrafine mass was not detectable in the last five samples, which were collected between 5 November 2001 and 14 December 2001.

The MMAD, calculated from the MI measurements, increased from about $1.2 \mu\text{m}$ to $1.75 \mu\text{m}$ the week of 22 October 2001 and then decreased to about $0.8 \mu\text{m}$ in November and December. The MI size distributions (Figure 7) show an ongoing reduction in the fraction of the mass collected on the upper stages, indicating that the decline in the total mass resulted from a decrease in the mass concentration of larger diameter particles.

The MOUDI size distribution results demonstrated more clearly that for most samples, the size distribution is bimodal. One mode was present at a size fraction larger than $1.0 \mu\text{m}$ in diameter and a larger mode at a size fraction smaller than $1.0 \mu\text{m}$ in diameter. The two modal peaks were found within the range of $1.0 \mu\text{m}$ to $3.2 \mu\text{m}$ for the mode larger than $1.0 \mu\text{m}$ in diameter, and $0.29 \mu\text{m}$ to $1.0 \mu\text{m}$ for the submicrometer mode. However, samples collected at the later stage of this study demonstrated that overall, the submicrometer mode became more prominent,

while the larger diameter mode diminished. The MMAD of the submicrometer mode was about 0.5 μm , which is in agreement with the MI results.

The backup filters ($d < 500 \text{ nm}$) of the MI-EAS system from the October sampling sessions were analyzed for OC, EC, and PAH. Results, presented in Table 1, show that the mean and standard deviation for the six sessions were $1.1 \pm 0.3 \mu\text{g m}^{-3}$ and $0.5 \pm 0.1 \mu\text{g m}^{-3}$ for OC and EC, respectively. The mean of the OC/EC ratio was 2.1 ± 0.5 . About 70% of the total carbon was organic. The total PAH is a sum of 37 compounds. The measured PAH levels ranged from 10 to 1500 ng m^{-3} . The concentrations of the most abundant compounds, benzo[a]anthracene, phenanthrene, fluoranthene, pyrene, and chrysene/triphenylene, comprised 55% of the total. The wipe samples of lower plates of two UDMs on prebaked quartz filters show $96 \pm 2\%$ and $96.8 \pm 0.9\%$ of organic carbon. Wipe samples on teflon filters of the UDM top plates, qualitatively analyzed by FTIR, show mainly ammonium sulfate. Some carbonyl absorbance was also found, which is consistent with ambient samples.

DISCUSSION

The number concentrations of fine particles measured with the CNC were highly variable, which is typical in an urban environment. The concentrations are affected by local combustion sources which are numerous in such a setting. This sampling site overlooked a hospital parking area and a driveway that led to a building entrance. Although traffic to the lot was highly controlled, it is likely that motor vehicles carrying patients to and from the site exhausted particles that were detected at the second floor inlet. Official government limitations on traffic in the immediate vicinity of the disaster site and in the vicinity of the NYUDH continued throughout the sampling period. Nonetheless, traffic sources were clearly significant, as indicated by generally lower concentrations on weekends.

The reason for the increase in the number concentration that we noted in December is unclear, but it likely results from resumption of more normal traffic in surrounding areas. Efforts to correlate concentrations with wind direction did not prove fruitful, probably because of the importance of local sources.

The particle number concentration measurements were compared with similar measurements made in Manhattan in the prior year. Measurements with the same instrument had been carried out in NYC in the winter of 2000 as part of an earlier research program. The NYC site was on the roof of a 14 story dormitory building at the NYU Medical School on First Avenue at 31st Street in Manhattan. The site is 3.0 miles north of the NYUDH. Figure 8 presents the particle number concentrations measured in Manhattan during a two week sampling campaign in the winter of 2000. There were high number concentrations of small particles measured after the WTC attack at NYUDH, but they are not too different from the values we previously measured in New York City.

Particle mass concentrations measured over the 12 sampling weeks ranged from about 4 to 23 $\mu\text{g}/\text{m}^3$ (averaged over 4– 6 days). None exceeded the 24 h EPA Air Quality Index (AQI) or the level of concern for susceptible subgroups of 40 $\mu\text{g}/\text{m}^3$. The size distribution showed a constant reduction in the large particle fraction of the mass, indicating that the reduction in the total mass resulted from a decrease in the mass concentration of larger diameter particles. This is consistent with data reported by others that showed very high concentrations of very coarse particles in surface-deposited dust collected soon after the destruction of the buildings (Lioy et al. 2002).

The results of the ultrafine and very fine size fractions were compared to mass concentrations we measured during an earlier study at a rural site located in Sterling Forest (SF), NY approximately 50 miles northwest of New York City. No background data was available for the WTC sampling location that could be used for comparison. During the SF study, a total of 20 samples were collected from April 1998 through September 1998 using the same MOUDI. Ambient mass concentrations at SF for the ultrafine size fraction ranged from 0.2 $\mu\text{g m}^{-3}$ to 3.2 $\mu\text{g m}^{-3}$. Ambient mass concentration for the very fine size fraction ranged from nondetectable to 3.5 $\mu\text{g m}^{-3}$. It is interesting that higher mean mass concentrations of ultrafine particles were measured at SF than at NYUDH; the mean and standard deviation of the concentrations are $1.1 \pm 0.8 \mu\text{g m}^{-3}$ and $0.3 \pm 0.4 \mu\text{g m}^{-3}$, respectively. For the very fine fraction, the mean mass concentrations measured at the two sites are very similar, $2.3 \pm 0.9 \mu\text{g m}^{-3}$ for the SF site and $2.4 \pm 1.1 \mu\text{g m}^{-3}$ for the NYUDH site.

The reason for the higher concentrations of ultrafine particles found in SF is that it is very likely that they were collected during a significantly warmer time period than the period of the NYUDH sampling. Ultrafine particles coagulate rapidly to form larger particles and move into the accumulation mode size range (Hinds 1999; Wexler et al. 1994) and are not likely to be transported long distances. Therefore, the sampled ultrafine particles are probably of local origin. Ultrafine particles at the sampling locations will either be emitted by local sources or be the product of local oxidation processes of PM precursors. Local oxidation of PM precursors, such as SO_2 , is believed to involve reaction with ozone and hydrogen peroxide (Seinfeld and Pandis 1998; Martin 1984). These oxidation processes are rapid under high relative humidity (RH) conditions (McMurry and Wilson 1983). Photochemical production of both hydrogen peroxide and ozone reaches its peak during the afternoon of summer days, and higher concentrations of both hydrogen peroxide and ozone are measured during the summer than during the winter (Sakugawa et al. 1990). The ability of the atmosphere to hold water vapor increases exponentially with temperature. Atmospheric RH is generally higher during the warmer months of the year than during the colder months of the year. Overall, the conditions for oxidation of PM precursors are more favorable during the warmer months of the year. Clement et al. (2001) have also observed several events of ultrafine particle formation at the Hyytia forest in Finland. They concluded that vapor generated by photochemical reaction products from precursors emitted by the forest, can nucleate and condense to form ultrafine particles.

Similar events were also observed at the SF site during sampling in 1999 and 2000. Therefore, it is reasonable to assume that the higher mass concentrations of ultrafine particles measured at SF are due to a higher degree of oxidation processes induced by the warmer weather conditions. The OC and EC concentrations measured in October 2001, namely $1.1 \pm 0.3 \mu\text{g m}^{-3}$ and $0.5 \pm 0.1 \mu\text{g m}^{-3}$ for OC and EC, respectively, are comparable to concentrations measured in Chicago— 1.3 to $2.5 \mu\text{g m}^{-3}$ for OC and 0.2 to $0.5 \mu\text{g m}^{-3}$ for EC (Offenberg and Baker 2000)—and in Helsinki— 2.2 to $4.2 \mu\text{g m}^{-3}$ for OC and 0.9 to $2.1 \mu\text{g m}^{-3}$ for EC with similar OC/EC ratios (Viidanoja et al. 2002).

However, these values are for PM_{2.5} while our samples consisted of particles less than 500 nm in diameter. Considerably higher concentrations have been reported in heavily polluted environments (Putaud et al. 2002; Viidanoja et al. 2002). Offenberg and Baker (2000) found the greatest proportion of carbonaceous material in the smallest particle fraction measured, $0.15 < d_{ae} < 0.45 \mu\text{m}$. They also found a high percentage of organic carbon, 84%, in their samples, similar to ours. Since no reference samples were taken during this study to correct for the artifacts arising from adsorption of organic gases or evaporation of semivolatile compounds, the measured OC values were corrected with adsorbed OC values measured a year later at the same location. The OC adsorbed onto the filter was $52\% \pm 4\%$ of the total OC.

In view of the average concentration of PAH of 5.7 ng m^{-3} , calculated from measurements made across the Hudson river at Liberty Science Center in Jersey City, NJ of 24 h TSP samples taken every 12th day between 5 July 1998 and 3 October 2001 (Gigliotti et al. 2000), all the concentrations except one measured during this study are very high.

Although this event may have generated vast amounts of organic compounds due to the fires, the values seem excessive. Some of the PAHs were also generated by the vehicles serving the hospital. High PAH concentrations have been measured in urban areas, e.g., at street level in the center of Stockholm the sum of 14 PAHs ranged from 100 to 200 ng m^{-3} , the most abundant being phenanthrene, and in Gothenburg city center up to 64 ng m^{-3} .

Benzo[a]anthracene, phenanthrene, fluoranthene, pyrene, and chrysene/ triphenylene, comprised 55% of the total PAH in the samples. The same compounds were dominant in the bulk dust samples (Offenberg et al. 2003). These are the most common PAH species found in ambient air. Phenanthrene and fluoranthene are associated with diesel-fueled heavy-duty trucks and also domestic wood and oil burning. Fluoranthene and pyrene are the most important indicators for heavy diesel vehicles. Phenanthrene, anthracene, fluoranthene, pyrene, and chrysene are representative for all mobile sources and wood burning. Benz[a]anthracene has been found from burning of biofuels and coal (Venkataraman et al. 2002; Yang et al. 2002). Swartz et al. (2002) from the USEPA have reported finding indicators of fossil fuel emissions and markers for fuel oil degradation, e.g., pristane and phytane, of emissions of burning and

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**Analysis of Aerosols from the World Trade Center
Collapse Site, New York, October 2 to October 30, 2001**

By Thomas A. Cahill, et al.

The collapse of the World Trade Center (WTC) buildings #2 (South Tower), #1 (North Tower), and #7 created an enormous collapse pile which emitted intense plumes of acrid smoke and dust until roughly mid-December, when the last spontaneous surface fire occurred. We collected particles by size (8 modes, ≈ 12 to 0.09 micrometers diameter) and time (typical resolution of 1 to 3 h) from October 2 until late December at the EML 201 Varick Street site roughly 1.8 km NNE of the collapse site and 50 m above ground level. Here we show some of the 70,000 mass and elemental data from the time period October 2 through October 30. Identification of a WTC collapse pile source for aerosols seen at the receptor site were based upon the simultaneous presence of finely powdered concrete, gypsum, and glass with intense very fine combustion mode mass episodes concurrent with winds from the southwest quadrant. The results, derived from seven independent beam-based analytical techniques, showed that while PM₁₀ and PM_{2.5} 24 h values rarely, if ever, violated federal air quality standards, WTC-derived plumes swept over lower Manhattan Island, resulting in intense aerosol impacts of duration of a few hours at any one site. The WTC plume resembled in many ways those seen from municipal waste incinerators and high temperature processes in coal-fired power plants. The size fractions above 1 micrometer contained finely powdered concrete, gypsum, and glass, with sootlike coatings and anthropogenic metals, **but little asbestos**. Composition in the very fine size range ($0.26 > D_p > 0.09 \mu\text{m}$) was dominated by sulfuric acid and organic matter, including polycyclic aromatic hydrocarbons (PAHs) and their derivatives, and glasslike silicon-containing aerosols. Many metals were seen in this mode, most, but not all, at low concentrations. The concentrations of very fine silicon, sulfur, and many metals, as well as coarse anthropogenic metals, decreased markedly during October, probably in association with the cooling of the collapse piles. Values of very fine elements seen in May, 2002 at the WTC site were only a few percent of October values.

INTRODUCTION

The collapse of the World Trade Center (WTC) buildings #2 (South Tower), #1 (North Tower), and #7 on September 11, 2001 is an unprecedented event in numerous ways. Yet the prompt and massive emissions of smoke and dust in the first days after the collapse were in accord with common understanding of such phenomena. **However, the continuing emission of these plumes, especially after the heavy rains of September 14 and the increasingly effective efforts of fire suppression in mid- and late September, are not fully understood.** Factors

which are essential for an in-depth analysis are the chemical composition of the materials that could be aerosolized and the energy sources available in the collapse piles. In this regard, the kinetic energy of the two aircraft is negligible (<1%) compared to the chemical energy in the roughly 25,000 liters of fuel in each plane (some of which was burned outside the buildings). The gravitational potential energy of the collapse was capable of raising the entire mass of debris only a few degrees K. The largest energy sources available are the combustible materials present in the buildings and furnishings and a significant body of fuel, especially under WTC #7, in the form of diesel fuel for emergency electrical generators and large quantities of oil in various forms in the Consolidated Edison substation, also under WTC #7. Very high temperatures occurred in the burning floors of the buildings prior to collapse and during the first few days of active surface fires, as shown by the melting of metals. Later, infrared surveys showed surface temperatures in the collapse pile were as high as 30 K above ambient in October, and much higher subsurface temperatures were inferred from the lower portions of removed steel beams glowing red. **The subsurface of the collapse piles remained hot for months despite use of massive amounts of water to cool them, with the last spontaneous surface fire occurring in mid-December.**

Satellite and photographic observations of the aerosol plumes are extremely useful in characterizing plume transport, especially in the early days when few other measurements were performed or are available. On the evening of September 11, the area of lower Manhattan Island was blanketed with a dark gray smoke. On September 12 at 11:30 AM, the Enhanced Thematic Mapper Plus (ETM+) aboard the Landsat 7 satellite showed a dispersed plume moving WNW to SSW in a broad plume over roughly 120° angular dispersion, while later that same day IKONOS showed a whitish coherent plume no more than about 0.3 km wide lofting above the buildings as it moved south towards open water (IKONOS 2001). Heavy rains occurred on September 14, which helped the Fire Department of New York (FDNY) extinguish surface fires while wetting the massive dust deposits. The plume detected by IKONOS on September 16 was much less intense and much darker than the plume of September 12, and the lofting is not as evident. All of these were consistent with the improved conditions on the collapse pile observed during rescue operations. In late September, rescue operations gradually ceased and recovery operations began and with them greatly increased fire suppression efforts, including wetting agents and use of heavy equipment to begin unpeeling the collapse pile.

EXPERIMENTAL TECHNIQUES

In response to the continuing emissions from the collapse site, a DELTA Group 8-DRUM sampler was prepared and air expressed to the Department of Energy's Environmental Measurement Laboratory (EML) on 201 Varick Street, New York, a 12 story building roughly 1.8 km NNE of the collapse site. The unit was sited on the roof at an elevation of roughly 50 m above the street but lower than most of the surrounding buildings. Sampling began on October 2 at 12:20 PM and continued in operation with two changes in drums until late December, when it was shipped back to Davis. Other than a few hours of uncertainty at the beginning of the study (backlash in

gears), samples were collected during over 99% of all available sampling periods in October.

SAMPLE COLLECTION

Samples were collected in a slotted rotating drum impactor (Lundgren 1967), a technique in which the UC Davis Air Quality Group and DELTA Group have specialized for the past 30 years (some examples are in Cahill et al. 1974, 1981, 1989; Flocchini et al. 1976; Feeney et al. 1975; Barone et al. 1978; Flocchini et al. 1981; Reid et al. 1994; and summarized in Cahill and Wakabayshi 1993) totaling almost 17,000 site days of sampling and analysis, most recently in international studies of aerosol transport (Reid et al. 1993; Perry et al. 1997, 1999) including the large study, ACE-Asia 2001. The present version, an 8 stage rotating drum impactor called a DRUM (Davis Rotating-drum Unit for Monitoring) was developed (Cahill et al. 1985; Raabe et al. 1988), modified (O. Raabe, private communication, 4 October 1997), and labeled the DELTA 8 DRUM. This sampler used the validated models of Raabe et al. (1989) for one of the two cases that can be derived analytically, a long slot (Marple et al. 1986). Note that in Raabe et al. (1989) a universal relationship was developed that provided the shape and cut point of all stages on a single graph, assuming that certain aerodynamic limits, such as on the Reynold's number, were respected. The behavior of the sampler was validated by comparing the predicted pressure drop on each stage to the observed pressure drop, which was on the average within 2% for Stages 2 through 7. The sampler operated at 10.0 L/min, maintained by a critical orifice on Stage 8.

The sampler was operated on a 42 day rotation schedule, delivering 8 lightly greased Mylar™ strips 168 mm long. All stages were coated with a thin (few $\mu\text{g}/\text{cm}^2$) layer of Apiezon-Ltm grease applied in a 2% toluene solution (Wesolowski et al. 1978; Cahill 1979). This has proven highly effective in preventing mis-sizing of coarse, dry particles with less than one part in 5,000 of soil mass present at 10 μm diameter appearing at 0.34 μm (Cahill et al. 1985).

The physical slot length L was 0.605 cm and the effective slot length in the deposit was 0.65 cm for all stages, but mass is seen distributed laterally, especially on Stage 1, as would be expected due to the shape of the slots which vary significantly from the theoretical "infinite slit" description. However, we measured the effective length of the slit, and the laterally distributed mass was found to come from locations close to the end of the slot. Thus, no correction must be included for this effect when converting from areal density of deposit ($\mu\text{g}/\text{cm}^2$) to concentration ($\mu\text{g}/\text{m}^3$) as long as the effective slot length is used.

The effective time resolution ' t ' is thus set by the width of the deposit and the rotation rate of the DRUM sampler. It is best for the finest stages, which for the 6 week rotation rate (4 mm per 24 hr day for this work) delivers a time resolution of about 1 h. The time resolution on the coarser stages is not as great as the physical dimension of the slot. The observed width of deposit W (d) is much smaller on the coarse stages than the slot width W (s), resulting in improved time resolution, ' t ' Time, three to four times better than would have been expected from the slot width alone. This difference decreases in the finer stages until the observed width is about 85%

of the slot width. The DRUM protocol delivered a time resolution approximating 1 to 1.5 h for the fine (PM_{2.5}) stages, although better resolution could be obtained using a deconvolution protocol.

SAMPLE ANALYSIS

Samples were received at Davis shipped on the drums used to collect the particles. Samples were dismantled according to DRUM protocols and transferred to stiff plastic frames for analysis. The frames were coded to establish the time at which the samples were taken. Due to the nature of the study, we were unable to incorporate automatic time-marking protocols on the strips during sampling thus, increasing the uncertainty with which absolute times can be determined.

Seven separate nondestructive techniques routinely used by DELTA Group collaborators were applied to the WTC samples:

- 1. Optical:** color photography (macro lens) (in air) at UCD.
- 2. Mass:** soft beta ray transmission for mass and quality assurance (Mass β) (in air), at UCD.
- 3. Mass:** scanning transmission ion microscopy (STIM) to measure high temporal resolution aerosol mass profiles (Mass STIM) (in vacuum) at Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory (LLNL).
- 4. Hydrogen:** Proton elastic scattering analysis (PESA) (in vacuum) at LLNL.
- 5. Elemental:** Na-U, synchrotron x-ray fluorescence (in vacuum) (S-XRF), digital Si (Li) analysis at Advanced Light Source, Lawrence Berkeley National Laboratory (LBNL).
- 6. Speciated organic matter:** laser desorption ionization time- of-flight mass spectrometry (LDITOF/MS) (in vacuum) at UCD.
- 7. Size and morphology:** scanning electron microscopy (SEM) with X-ray analysis (in vacuum, using small pieces of the strip) at UCD.

We will emphasize in this report mass data from scanning transmission ion microscopy (STIM), hydrogen data from proton elastic scattering analysis (PESA), and elemental data from Synchrotron-induced X-Ray Fluorescence (S-XRF), while other results will be used to help clarify and interpret these primary data.

Mass by STIM

Mass was measured in vacuum by STIM using the 3 MeV proton microprobe of the Center for Accelerator Mass Spectrometry (CAMS), Lawrence Livermore National Laboratory (LLNL). This method is described in Bench et al. (2002), which establishes the accuracy and precision of STIM on equivalent samples in some detail. Mass was measured by the energy loss of the proton as it passes through the Mylar substrate (480 $\mu\text{g}/\text{cm}^2$), the grease coating (nominally 10 $\mu\text{g}/\text{cm}^2$), and the deposit with a minimum detectable level equivalent to about 0.5 $\mu\text{g}/\text{m}^3$ in clean DRUM

samples. The STIM proton beam, which can be as narrow as 1 μm , was set at a width of 125 μm to match the width of deposit of the sampler which was equivalent to 45 min time resolution for the 4 mm/day DRUM rotation rate (Table 1). Thus, the analysis width is slightly less than the width of deposit, giving an equivalent time resolution of about 1 h taken every 45 min for the finest DRUM stages. The measurement was made in a vacuum, which removes unbound or lightly bound water and some fraction of volatile constituents, primarily organic matter and some nitrates.

While relative time accuracy is excellent (<3 h in 4 weeks), absolute times are uncertain because of the finite width of the beginning and ending deposits on the Mylar strip, backlash in the gearing, etc. Normal DELTA Group protocols call for a blank region in the middle of each strip for time and blank calibration and for a fixed ultrafine after filter, neither of which could be implemented in the short time available. Thus, absolute times are given with an estimated maximum error of 6 h.

Hydrogen by PESA

Hydrogen was measured by PESA (Cahill et al. 1989, 1990, 1996; Malm et al. 1994) at CAMS, LLNL, which is also described in Bench et al. (2002). The time and spatial resolution was identical to that of the STIM analyses, roughly 1 h resolution taken every 45 min. The strips had already been exposed to vacuum in the STIM analyses and were additionally exposed to vacuum during the PESA analyses, which removes unbound or lightly bound water and some fraction of volatile constituents, primarily organic matter and some nitrates. Thus, the remaining hydrogen is primarily found in inorganic ions and organic matter. With knowledge of the chemical state of major ions, the remaining hydrogen has been found to be closely associated with organic matter (Cahill et al. 1989, 1990, 1996). This has been independently verified in over 100,000 ambient aerosols sampled in the past 14 years as part of IMPROVE (Interagency Monitoring of Protected Visual Environments) quality assurance protocol (Malm et al. 1994; IMPROVE 1988–2002), which directly compares Organic Matter by Carbon (OMC) by combustion to organic matter via PESA (OMH). Despite the fact that these measurements for IMPROVE were made on different substrates (fired quartz for OMC, stretched Teflon for OMH) by different laboratories, with OMC in air and OMH in vacuum, the results are very well correlated, with a slope with $\pm 10\%$ of unity.

Elemental by S-XRF

The concentration of elements from sodium through molybdenum and selected heavy elements was established by synchrotron X-ray fluorescence (S-XRF) on the DELTA Group Beam Line 10.3.1. X-ray microprobe at the Advanced Light Source, Lawrence Berkeley National Laboratory (ALS, LBNL). S-XRF is X-ray fluorescence in which the primary excitation source consists of polarized X-rays from a synchrotron. We have used this technique on samples from the Kuwaiti oil fires at the Stanford Linear Accelerator (Cahill 1992; Reid 1994), and it is becoming more widely appreciated (Khodzher et al. 2000) as a tool for aerosol analysis. The advantages are

many, including removal of more than 95% of the X-ray background due to the polarization of the beam and the ability to focus the beam into small areas due to ALS's extraordinary source brightness. Through use of a "white" beam covering $4 \text{ keV} < E_x < 18 \text{ keV}$, possible because of the polarization, all elements between sodium and uranium can be simultaneously measured. However, in realistic ambient samples, the elements from molybdenum through the rare earths and some heavy elements usually have serious interferences and are not routinely quantified. The measurements are made in a vacuum, which allows elements as light as carbon to be seen, but self absorption corrections make quantification very difficult. The X-rays are detected by a digital Si(Li) detector and electronics, and calibration is accomplished through 65 thin National Institute of Standards and Technology (NIST) traceable elemental standards and 12 certified elements, Al-Pb, in NIST Standard Reference Materials (SRMs) 1832 and 1833. The results are reduced in the DELTA Group version of the International Atomic Energy Agency's preferred code, AXIL. Accuracy and precision have been verified by repeated analyses and blind intercomparisons with IMPROVE (0.99 ± 0.04) and California Air Resources Board (CARB) (1.02 ± 0.11) filters (DQAP ver. 7.02, 2002). The minimum detectable limit in a 30 s analysis is around 0.2 ng/cm^2 for most elements other than the exceptions (above), which converts to 0.004 ng/m^3 for the 6 week DRUM sampler used in this study. An example of the integration of these data with mass by STIM and hydrogen by PESA is given in Bench et al. (2002).

RESULTS

Single Particle Analysis

The impaction of particles onto the lightly greased flat Mylar substrate made single particle analysis possible for both coarse and fine particles. Samplers were analyzed on the actual substrates without attempts at removal, which necessitates removing a small portion of the DRUM strip onto a SEM stem for analysis.

Figure 1a shows an example of particles from aerodynamically defined stage, Stage #2, from 5.0 to $2.5 \text{ }\mu\text{m}$ diameter, while Figure 1b shows the same period but for particles from 0.26 to $0.09 \text{ }\mu\text{m}$ diameter. The SEM data represent the period that occurred on October 4, a period which will later be assigned to WTC plume impact, and had the highest value for very fine silicon. In Figure 1a, in addition to the large number of particles in the aerodynamically selected 5 to $2.5 \text{ }\mu\text{m}$ range, there are what appear to be large agglomerated flakes that would normally be aerodynamically sized along their thinnest aspect, as would the one fiber roughly $25 \text{ }\mu\text{m}$ long. **In all the pictures taken, only one other asbestos-like fiber was seen, $120 \text{ }\mu\text{m}$ long, collected in the coarsest size mode ≈ 12 to $5.0 \text{ }\mu\text{m}$ equivalent aerodynamic diameter.** Figure 1b shows the silicon particles are indeed very fine, $0.26 > D_p > 0.09 \text{ }\mu\text{m}$ diameter. The electron beam of the SEM system was used to detect numerous silicon-containing particles below the surface of roughly $3 \text{ }\mu\text{m}$ -thick grease antibounce coating. The silicon particles appear to have been imbedded in the grease of the surface coating because of the high (sonic) speed of impact during collection, while the sulfate particles stayed on the hydrophobic grease surface. The presence of large amounts of sulfur was confirmed in the elongated particles, which appear to be gener-

ated by postcollection aggregation. The alignment was parallel to the air flow over the sample. This is in accord with both the PESA hydrogen data.

Mass

The mass data are voluminous (over 7,000 values) and are posted on the DELTA Group web site (<http://delta.ucdavis.edu>) in the World Trade Center file. Figure 2 presents results for coarse particles, roughly PM12 (12 to 0.09 μm diameter), and fine particles, roughly PM2.5, (2.5 to 0.09 μm diameter), both lacking the ultrafine component below 0.09 μm diameter.

One of the most unusual aspects of the mass data was the high levels of very fine aerosols, $0.26 > D_p > 0.09 \mu\text{m}$, measured at this site (Figure 3). This results in an extraordinarily large number of particles that have the ability to penetrate deep into the lung. Plotted on the same graph are the results of the hydrogen measurement by PESA (over 7,000 values) taken shortly after and on the same system as used for the STIM analysis. Generally, there was an extremely high correlation between the mass and hydrogen data, which also provides an estimate of the precision of the two techniques (Bench et al. 2002). The hydrogen data have been multiplied by 10.

Elemental Analysis

Elemental analysis was performed on all DRUM samples by S-XRF, yielding low detectable limits for element sodium through zirconium and some heavy metals, with limited information of the remaining trace elements. The amount of information contained in the 55,000 values (plus an equal number of uncertainties and minimum detectable limits) prevents a full accounting in this report. Thus, we will only highlight some of the more significant findings in this publication.

COARSE PARTICLES

The mass distribution was bimodal, with peaks in the coarse mode ($5.0 > D_p > 2.5 \mu\text{m}$) and very-fine mode ($0.26 > D_p > 0.09 \mu\text{m}$). Such a distribution is not typical of ambient aerosols, which tend to have a mass minimum around 2.5 μm and very low values for very fine aerosols $< 0.26 \mu\text{m}$. We will treat each mode separately. In Figures 4 and 5 we present the plots of major crustal elements and noncrustal elements in the size fraction $5.0 > D_p > 2.5 \mu\text{m}$. Averages of crustal elements are more typical of soil except for the excesses (enrichment factor of 6) for calcium. Finely powdered concrete is a probable source for the Ca excess, based on WTC building inventories of friable materials by mass.

In Figure 6, the supermicron ($5.0 > D_p > 2.5 \mu\text{m}$) excess calcium signatures of the mineral aerosol are presented, using the Al/Ca ratio. Similar results are obtained using the Ca/Si and Ca/Fe ratio to calculate the noncrustal calcium excess. The anomalously fine mineral aerosols shown in Figure 5 have a presumed major source from cement dust, the largest friable building com-

ponent by mass. The use of both Ca/Si and Ca/Fe ratios corrects for the presence of another friable material, glass, but the results are essentially equivalent in identifying the calcium excess. Likewise, sulfur appears in the coarse mode, correlated with the excess calcium sulfate aerosols in the 5.0 to 2.5 μm size mode. The sulfur/calcium correlation is excellent, in two periods: $r^2 \approx 0.9$, Ca/S ratio of 6.1 ± 0.2 seen on October 3, and $r^2 \approx 0.8$, Ca/S = 3.5 ± 0.5 for all other periods. Gypsum, Ca_2SO_4 , used in the wallboard that was used in the core of the buildings, is a potential source for this material.

The noncrustal elements are showed in Figure 5. The large chlorine episode on October 14 begins with an oceanic sea salt signature, namely winds from the ocean (120°) and a Na/Cl molar ratio of close to 1.0. Otherwise, there is excess chlorine for all other chlorine peaks.

VERY FINE PARTICLES

Figure 8 plots the major crustal species in the very fine mode, $0.26 > D_p > 0.09 \mu\text{m}$ for comparison with Figure 4. Note that there is an enormous enhancement of silicon relative to all other crustal elements showing that the form is not soil. This is illustrated in Figure 9, in which we plot the Al/Si ratio versus time.

Figure 10 shows the same silicon, but this time plotted against sulfur, while Figure 11 shows vanadium, nickel, and chromium. Clearly, there is a relationship between the very fine silicon and sulfur, but the ratio varies widely. Note, the Si/S ratio decreases throughout October.

The vanadium and nickel retain a relatively constant ratio, $\text{V}/\text{Ni} \approx 5$, for all peaks seen in October except the last one, where it dropped to ≈ 1.2 on an east wind trajectory.

PARTICULATE SIZE

The size distribution of major elements was anomalous with almost all mass either coarse or very fine, unlike typical ambient aerosols seen in scores of studies since 1972 (Whitby 1978). This is shown in Figure 12, which gives the size profile for the particle episodes of October 3 through 5, in contrast to the typical ambient size distribution for these species show in Figure 12. In Figure 12, we also plot a non-WTC episode on October 29, which except for excess very fine sulfur, looks like a typical size distribution. ***The presence of so much mass in the very fine size fraction thus leads to a very high particulate surface area and number of particles. The coarse mode has a relatively large amount of mass in the vicinity of 3.5 μm , with high potential for deposition in the bronchial tract.***

DISCUSSION

In this section, we treat four topics: (1) which of the aerosol episodes seen in the PM₁₀, PM_{2.5}, and elemental data were most likely derived in all or part from the WTC collapse piles; (2) what

are the most likely sources within the collapse piles that generated the episodes; (3) how the WTC-derived episodes seen at Varick Street compare to similar sampling at other sites and times around the world; and (4) what supplemental measurements are being made that have or could reduce the uncertainties in the data interpretation.

Identification of Episode Origins at the WTC Collapse Site

The repeated presence of intense aerosol plumes of short duration at the Varick Street site could arise from a number of local and regional sources within and upwind of New York City. Clearly, full interpretation of this enormous data set (circa 7,000 mass, 7,000 hydrogen, over 50,000 elements) will require close analysis with local data that are only now being developed as current investigations progress. In this analysis, we will attempt to identify probable sources for the PM10 and PM2.5 concentrations presented earlier in Figure 2.

Many of the normal source identification protocols that could, in principle, be used to identify the origins of these aerosol events are not possible in this work. Only one sampler of this type was operated, and thus no direct upwind-downwind comparison is possible. No prior measurements of this type have been made in New York, but data have been recently generated (May 2002) in New York with identical instrumentation. Similar data have been generated in Baltimore as part of the Supersite program which will aid comparisons in future papers. Similar size- and time-resolved compositional data are available at Shenandoah National Park as part of the IMPROVE program (Cahill and Wakabayashi 1996) which is mostly useful in characterizing regional upwind sources that typically dominate aerosols in the eastern US each summer. In this regard, the urban IMPROVE site in Washington, DC and Shenandoah National Park are essentially identical each summer in the period July– September for PM2.5 mass and almost every measured parameter (IMPROVE 1998–2002), and we expect this to be largely true of New York City. Potentially strong local sources, thermal electric power plants, were all operating on natural gas in this period, and thus would not be a major source of sulfur, vanadium, and nickel, which they would be if operating on heavy fuel oil.

The wind rose, and direct plume transport studies lack detailed meteorology at the source and local measurements at the receptor site. Complexities include unmeasured parameters such as street canyon transport and plume loft, which are the focus of continuing studies by other groups but are unavailable at present. Standard 24 h PM2.5 data are available but are of limited use in identifying short-duration aerosol events, especially events dominated by particles below 0.26 μm diameter. Standard statistical source-receptor techniques cannot be used since the WTC aerosol source was uncharacterized. In this regard, the detailed measurements of Lioy et al. (2002) represent settled dust from the immediate collapse, which we expect would be very different from the continuing emissions from the hot collapse pile.”

In the face of these uncertainties, we have chosen to use as a basis for identification of potential WTC-derived aerosol plumes those enhanced aerosol concentrations deriving from the south-

west quadrant that have probable WTC source materials (coarse Ca, coarse S) and are divergent from standard ambient size resolved aerosol data (very fine mass) and from background values at times when persistent prevailing winds would not allow major WTC impacts.

The most extreme divergence from standard ambient aerosols is mass in the very fine mode, $0.26 > D_p > 0.09 \mu\text{m}$. In Figure 3 we present the highly time-resolved very fine mass and hydrogen. Very fine mass below $0.26 \mu\text{m}$ diameter are typically associated with high temperature and industrial sources (U.S. EPA 1996 and references therein). Further, the very high diffusion rates of these particles generally make their residence times in the atmosphere short, favoring relatively local high temperature sources.

The highest time resolution data available, the size-resolved mass data from STIM, has an effective time resolution of roughly 1 h. The very fine mode $0.26 > D_p > 0.09 \mu\text{m}$ was generally at very low levels outside of the events, giving a sharp event–nonevent signature. For background we used values during October 6 and 7 with winds from the northwest and west, which had very fine mass $0.26 > D_p > 0.09 \mu\text{m}$ averaging $0.26 \mu\text{g}/\text{m}^3$. For all nonevent periods, totaling 25 days, masses averaged $1.8 \mu\text{g}/\text{m}^3$, while in the 18 events, totaling about 96 h, masses averaged $6.9 \mu\text{g}/\text{m}^3$, or about 25 times background values. In Table 2 we have identified 18 such aerosol events based on very fine mass levels greater than $4.0 \mu\text{g}/\text{m}^3$ that persisted for at least 2 h and listed them by date, since no more than one event was present on any given day.

HYSPLIT regional backward isentropic trajectories were used to identify the quadrant from which the air mass originated (HYSPLIT 2002). One hour peak values were used for wind direction and wind velocity. HYSPLIT forward isentropic trajectories were used to show transport from the WTC down-wind. (Figure 13), while providing information on plume behavior in the vertical dimension. Note the strong subsidence of the trajectories from the WTC site as the air parcels follow the potential temperature. A similar pattern was seen on September 13, October 4, October 5, October 23, and October 24, dates when surface haze layers were seen at LaGuardia, measured at downwind air sampling sites along the trajectory, and widely perceived by residents of Manhattan. From HYSPLIT, we can then approximate 11 AM lapse rate: -- = very stable, rapidly descending isentropic trajectories; - = stable, descending isentropic trajectories; 0 = neutral; + = unstable, rising isentropic trajectories; and ++ = very unstable with rapidly rising isentropic trajectories. For Episodes 8, 10, 15, and 16, the actual peak hours were used for this calculation. We have also included the presence of ground level haze at LaGuardia (LGA) airport which lies at an angle of roughly 235° from the WTC.

Finally, in Table 2, we present the coarse calcium and coarse sulfate values. The sulfur/calcium correlation is excellent in two periods: $r^2 \approx 0.9$, Ca/S ratio of 6.1 ± 0.2 seen on October 3; and $r^2 \approx 0.8$, Ca/S = 3.5 ± 0.5 for all other periods. Three hour averaging times for species are used, but background values are a 2 day average. Mass is in $\mu\text{g}/\text{m}^3$ and other concentrations are in ng/m^3 . None of these parameters is by itself definitive proof of a WTC source. For example, WTC-enhanced cement dust was distributed widely over lower Manhattan Island, so that it

could be present on winds from other directions. However, there had been several days of rainfall since September 11, (September 14, 20, 28, and 30, as well as October 1, 6, 16, and 17) which would tend to suppress the dust. **Despite massive use of water starting later September, the WTC collapse pile itself remained hot and dusty until at least December 14, when the last spontaneous surface fire occurred.**

The presence of surface haze layers of short (typically 3 h) duration at LaGuardia Airport provides supportive evidence on WTC plumes. These hazes were observed on September 13, 22, and 24, and October 3, 4, 5, 23, and 24. The haze episodes were typically about 3 h in extent, and in all cases the surface-based hazes occurred at times of stable atmospheric conditions and descending isentropic trajectories that would hold the aerosols close to the ground. This was confirmed on September 13, when a haze event was also seen at LaGuardia Airport. Two air-monitoring sites, PS 64 in lower Manhattan and PS 199 in Queens, lie on a rough line between the WTC site and LaGuardia. Each showed one hour PM_{2.5} concentrations above 100 µg/m³ (U.S. EPA briefing paper, September 10–15, 2001). No other site in the New York area reported one hour PM_{2.5} values greater than 50 µg/m³ at any time in this 5 day period. This result is in accord with numerous photographs from ground and satellites showing a characteristically narrow aerosol plume that rose rapidly to roughly 500 m and then passed over much of the area without visual evidence of ground contact.

While the probable association of the aerosol events to the WTC source is hypothesized in these tables, the confounding presence of potential sources upwind of the WTC collapse site cannot be neglected. In Table 3 we compare the aerosol event of October 3 with concurrent 24 h sampling at two sites on Staten Island, Fresh Kills and PS 44, and in New York City at Battery Park, Manhattan Borough Community College, and PS 64 (U.S. EPA 2001). The wind direction of 225° at 0700 hours local allows for the WTC plume to impact Varick Street but the lofting of the plume from the hot collapse pile may reduce ground level concentrations in ways we cannot calculate with the available data, including lack of measurements of temperature in the plume itself as it issued from the WTC site. Nevertheless, the 24 h values measured at Varick Street in nonplume periods, 25.3 µg/m³, almost exactly matches the average upwind PM_{2.5} mass values from Staten Island, 24.9 µg/m³. Thus, all mass above about 25 µg/m³ at the local EPA sites and at Varick Street cannot be assigned to regional background, but must be a local source. Thus, there is no inconsistency between the high time resolution DRUM mass data and the 24 h EPA filter measurements.

All the EPA values were at elevations close to ground level, but our data were taken at 50 m. However, qualitative observations of WTC pollutants such as odor and smoke were widely observed in New York on these days, leading to a NYC Health Department Press release issued on October 5 reporting that **“despite the smoky conditions in areas of lower Manhattan that are close to the World Trade Center site, test results from ongoing monitoring of airborne contaminants indicates that the levels continue to be below the level of concern to public health”** despite “the presence of dust and smoke odor in the downtown area” (Mullin and Butler 2001).

The very high levels on October 3 require an explanation. Two possible explanations lie in changes of emission rate and/or changes in transport efficiency. We have no detailed information from site activities that can be used to derive changes in the emission rate. Heavy equipment was in constant use, uncovering hot subsurface zones in the collapse pile, and perhaps enhancing emissions. In terms of transport efficiency, the HYSPLIT isentropic trajectories at 200 m and 500 m were rapidly descending, reaching the ground in only a few kilometers. This was the most extreme case seen in the entire period and is most likely a major part of an explanation for the low level transport of the plume. It is also possible that the cooling of the site after 2 days of light rain and massive fire fighting efforts would reduce plume lofting, thus increasing downwind surface concentrations. Significantly, the highest 24 h PM value seen by the EPA at sites just north of the WTC (Site A) occurred on October 3, over 400 $\mu\text{g}/\text{m}^3$ (U.S. EPA 2002). It is also important to appreciate that the Varick Street values were taken at an elevation of about 50 m and thus could well be impacted directly by a slightly lofted plume from the still hot WTC collapse site.

While much of lower Manhattan south and west of the Varick Street receptor site, other than intense activities at the WTC collapse site itself, was relatively inactive in October 2001, there were a very large number of idling diesel trucks lined up almost as far north as the sampling site waiting to take debris loads to the Hudson River transport site. In addition, many diesel generators were in use on the WTC site for power water pumping, etc. Diesel exhaust tends to peak in the very fine mode, roughly the same as Stage 8 of the DRUM sampler, $0.26 > D_p > 0.09 \mu\text{m}$ (Cahill and Zielenska 2003). Information of the relative influence of the diesel source can be gained from two sources, meteorology and sulfur/mass ratios. First, since many of the trucks were much closer to the receptor site than the WTC site, truck exhaust would reach the receptor site more frequently than WTC aerosols, giving broader periods of influence than the more remote WTC aerosols, which only occur in sharp narrow peaks. This would broaden the sulfur peaks relative to other species, which is not observed. Second, recent measurements of the sulfur/mass ratio in very fine size modes from diesel exhaust using "road" (non-California) fuel (Cahill and Zielenska 2003) give a ratio of roughly 0.3% as opposed to the average value seen in the 9 highly probable WTC events, 10.3%. Thus, we conclude that diesel exhaust was at most a minor component of the observed very fine aerosol episodes at the Varick Street receptor site. We confidently propose a dominant WTC collapse pile source for 5 episodes (October 3, October 4, October 5, October 23, and October 24). Four more episodes on October 10, 11, 12, and 20 have a high probability of a WTC collapse pile source, while episodes on October 26, and 28 are likely from other sources in Manhattan and north-northwest of the city. The remaining episodes are likely to have important WTC components, but may include other sources.

Likely Sources of Aerosols from the WTC Collapse Pile Episodes

With major episodes identified as having a probable WTC sources, we can examine other components of the aerosol not used in the source identification and additional methods that clarify the nature of the WTC aerosol plumes, although in many cases the mechanisms involved in

generating the aerosols are uncertain (Table 4). As before, the events are labeled by the day on which they occurred.

There are several points to note in Table 4. The ratio very fine sulfur to very fine mass was quite stable in the 9 highly probable WTC episodes ($\pm 17\%$), despite a 20-fold decrease in concentrations, while the VF H/VF mass and VF V/VF mass were both stable to $\pm 35\%$. These data also strengthen the association with other events to a WTC source. Note that the mass (by STIM), hydrogen (by PESA), and sulfur and vanadium (by S-XRF) were all done at different times in two different laboratories and with different integration periods, all of which could increase variability in the highly time-variable episodes. The VF Si/VF mass was about 3 times more variable than hydrogen of vanadium. The meteorology, including subsiding isentropic trajectories, was almost identical during October 3 to 5 versus October 23 and 24. The coarse nonsoil calcium and sulfur were essentially the same on October 3 to 5 and October 23 and 24, and haze was seen at LaGuardia at about the same intensity, 14.1 km versus 12.3 km. The ratio of very fine mass to very fine sulfur was also constant, 9.8 versus 11.1, in this period. Thus, the conclusion is that these two periods both strongly sampled the WTC collapse pile plumes. However, other parameters, especially the very fine components normally associated with high temperature combustion sources, decreased radically in the same period, mass by a factor of 5.2, silicon by 12.9, sulfur by 5.3, vanadium by 7.2, and many other very fine aerosols had similar behavior. Coarse vanadium, largely absent in the immediate collapse dust (Liroy et al. 2001), decreased by a factor of 5.1, marking a sharp decrease in the V/Ca ratio, but lead only decreased by a factor of 2.2. The same behavior was seen in the even-longer record for lead aerosols measured by the EPA close to the source and shown in Figure 14 (U.S. EPA 2001a). We interpret these decreases as a consequence of the cooling collapse pile, which in turn strengthens the association of these species with the WTC source. In Table 4 we have also included data taken in May 2002 at 4 indoor sites in lower Manhattan Island, three of which were open to the outdoor air, and three of which were immediately adjacent to the WTC site. Very fine particles penetrate buildings easily, and these measurements should be similar to outdoor values. The very low levels of silicon and vanadium in May further strengthen the association of silicon and vanadium, and most of the sulfur, to the WTC collapse piles. Note that there was still heavy construction and diesel sources at the WTC site during these measurements.

The aerosols identified as having an origin in the WTC collapse piles are extraordinary in almost every regard, from the species mix to the concentrations in the very fine mode.

Nevertheless, there are similarities to other aerosol sources that we propose could explain some of the features observed, while the local meteorology and low temperature plume behavior could explain the variable ground level concentration values. These hypotheses will need to be evaluated by more detailed information on emission factors from the WTC collapse piles and complex meteorological analysis in the Manhattan street canyons.

The major coarse particle mass is explainable in terms of the WTC building inventories of potentially friable materials (cement floors, gypsum in the dry wall, glass windows, etc.) and is sim-

ilar to the data of Liroy et al. (2001) in many regards. Differences could well occur, however, since the coarsest particles described in detail in our report (5.0 to 2.5 μm) are still about 10 times finer than those that dominated the Liroy et al. (2001) compositional data. A major compositional difference is that our particles have more metals, consistent with the results of Natusch and Wallace (1974) and Natusch et al. (1974), which showed that condensed metal vapors from coal combustion tended to form relatively uniform layers on more refractory materials. This gives relatively higher metal to refractory ratios as particles become smaller, which is consistent with our results.

These ratios indicate a different source than merely finely ground crustal materials. SiO_2 can potentially change to either vapor SiO , as in coal fired power plant plumes, or SiCl_4 , to be reoxidized to SiO_2 to form the very fine glassy particles seen in the optical and elemental data. The boiling point of pure SiO_2 is 1725 $^\circ\text{C}$, but that of SiCl_4 is 12 $^\circ\text{C}$. It is also clear that by October 24 these very fine silica particles have been greatly diminished despite evidence of direct plume impact via coarse particles and meteorology.

We propose the unusual ratios of fine metals seen in the WTC plumes may reflect a phenomenon well known in waste incinerators. The volatility temperature that dominates emission of metals is generally far lower than the boiling point of the pure metals due to formation of molecular species (Barton et al. 1990; Seeker and Koshland 1990). Further, the presence of chlorine in the waste greatly depresses the volatility temperature of some metals, but not others. For example, Seeker (1990) showed that many federally regulated metals are affected by 10% chlorine in the waste (Table 5). In addition, vanadium, normally very refractory but not a Federal Register 1986 EPA-regulated metal, converts to vapor VCl_4 with a boiling point of 147 $^\circ\text{C}$. Some of the metals are naturally volatile at temperatures below 315 $^\circ\text{C}$ (especially Se, Cd, As, and Hg) even without the presence of chlorine. Thus, these metals and metal compounds can leave the WTC collapse pile as gasses and vapors, providing both very fine (and presumably ultrafine) metals directly and coating larger and more refractory particles. Both effects would decrease in time as the collapse piles cooled, as both we and the EPA observed. In this regard, the relatively large chlorine inventory in the WTC buildings from plastics, including the ubiquitous PVC, and chlorine-bleached paper and our observation of persistent high levels of nonseal salt chlorine aerosols (Figure 5) including, some in the submicron modes, lends support to this hypothesis.

Comparison of WTC-Derived Episodes with Prior Data at Other Sites

With these assignments, we can compare the 3 h average data for very fine particles with those measured at other sites and times using equivalent sampling and analysis protocols in Table 6. In all cases, each comparative value represents the highest 3 h average concentration in a field exercise of at least 3 weeks duration. **Mass, hydrogen (in organic matter and sulfuric acid), Si, S, V, Ni, Cu, As, and Se occurred at unprecedented levels in the very fine size range from WTC-derived aerosol episodes.** Working with the American Lung Association of New York City we performed an indoor air study at one site in mid- town Manhattan and three sites

directly adjacent to the WTC. The 55 Liberty Street site has excellent contact with outdoor air, but **very fine particles penetrate buildings very much like a gas**. The peak 3 h values are similar to non-WTC data from October, 2001, and are generally only a few percent of peak WTC episodes, except for Sulfur. Midtown sulfur values were only 1/6 to the WTC site values. There was still heavy use of diesel equipment in the WTC pit in May, which may be the source.

Information from Supplemental Analyses

The analyses begun in this report are being continued in several areas. There are archived but unanalyzed DRUM strips for the period October 31 through mid-December 2001 which, when analyzed, will help clarify the effects of cooling the WTC collapse pile and excavating into deeper debris horizons. Although we present here some of the data from the finest DRUM stage from May 2002, there are additional DRUM strip sites both remote and adjacent to the WTC site awaiting further analysis. But the major continuing effort is analysis of the existing DRUM strips of October 2 through October 30 using the compositionally sensitive laser desorption ionization time of flight mass spectrometry (LDI TOF/MS). While all results must be considered preliminary at this time, we present LDI TOF/MS results for aerosols on October 4. All of these values greatly exceed background values taken on October 6 and 7. The analysis of the samples by laser desorption ionization time-of-flight mass spectrometry (LDITOF/MS) focuses primarily on the PAHs and their derivatives. The samples are analyzed with both positive and negative polarity, and the spectra are complex. In this report, we can only report on preliminary results of these analyses. Figures 15a and b show the negative ion spectra from the WTC October 3 to 5, 2001.

The positive ions detected correspond to Na^+ , K^+ , and very large mass ions which have the similar masses as Polycyclic Aromatic Hydrocarbons (PAH) compounds found in diesel soot. A small amount of the PAH compounds observed may contain heteroatom functional groups. The negative ions detected correspond to small carbon clusters (up to C_{10}), chloride, hydroxide, nitrite, nitrate, CO_2H^- , CN^- , CNO^- , SO_2^- , SO_3^- , and HSO_4^- . The presence of CN^- and CNO^- indicate there are some nitrogen-containing organic compounds, not necessarily that cyanide is present in the samples themselves. In many cases, the nitrite and nitrate ion signals are of comparable size, indicating the source is most likely a mixture of nitrous and nitric acids formed when NO_2 created in the fire dissolved in water. In a few of the samples from October 3–5 the signal from the nitrate ion is much larger than the signal from nitrite; this indicates there are nitrated organic compounds in the sample.

The sulfur oxides appear to originate from sulfuric acid; the ratio of the intensities of $\text{HSO}_4^- / \text{SO}_3^-$ remains relatively constant. This conclusion is supported by data on hydrogen content by PESA and the sulfur content by S-XRF, both measured in a vacuum, which leads to an attribution by mass balance of most of the very fine sulfur to the form sulfuric acid. The constant ratio of mass to sulfur, 10.4 ± 1.9 for the 9 highly probable WTC episodes (Table 5), and the establishment of a dominant form of sulfuric acid by the H/S ratio and TOF/MS data, shows that $29\% \pm$

5% of the very fine mass was sulfuric acid throughout the month of October. This information, together with some measure of nitrates and nitrites, allows a calculation of total organic matter (Cahill et al. 1989; Cahill et al. 1990), which has been validated by comparisons with organic matter via combustion as part of the IMPROVE program (Malm et al. 1994). The result shows that in the very fine mode, $0.26 > D_p > 0.09 \mu\text{m}$, organic matter makes up about 1/3 ($30\% \pm 6\%$) of the measured mass in the WTC-attributed peaks, with concentrations ranging from 1.0 to $9.3 \mu\text{g}/\text{m}^3$. In the clean period of October 6 and 7, the value was $0.04 \mu\text{g}/\text{m}^3$.

There also appears to be some organic acid present in the samples; this is indicated by the signal at 45 amu in the TOF/MS spectra which corresponds to CO_2H^- fragment. The presence of hydrocarbons functionalized by heteroatoms is worrisome. The toxicity of these compounds is higher than the toxicity of the PAH compounds themselves. It should be noted, without observing the parent peak ions, this method is unable to determine how these hydrocarbons are functionalized.

CONCLUSIONS

In this work, we have isolated and characterized the nature of the aerosol plumes coming from the WTC collapse site in the period between October 2 and October 30, 2001. The key finding is the plumes were generally both coherent and elevated, thus not generally impacting ground-based sites in New York City away from the WTC collapse pile. However, under certain meteorological conditions, the plumes could ventilate to the ground, leading to periods of sharply elevated coarse, fine, and very fine particulate mass over periods of a few hours 1.8 km from the WTC collapse site and beyond. The WTC plume data were in semiquantitative accord with EPA 24 h $\text{PM}_{2.5}$ measurements, confirming that the 24 h PM_{10} and $\text{PM}_{2.5}$ mass standards were not violated even during periods of plume impact. However, plume impacts delivered a very different type of the aerosol exposure, which is thus dependent on the fraction of time a plume is present at a given site.

The coarse particulate mass, finer than typical soils, appeared to be derived from hot portions of the collapse pile itself as it persisted even after periods of rain and despite increasingly effective efforts to wet and cool the pile. The particles were primarily finely powdered concrete, gypsum from dry wall, and rounded glass shards, with a mass peak in the 2.5 to $5 \mu\text{m}$ diameter range, as well as above $12 \mu\text{m}$ which we did not measure. They had components including sulfates, soot, and metals consistent with anthropogenic coatings derived from the hot collapse piles. This conclusion is supported by the rapid decrease in lead versus distance in the EPA data, indicative of lead in or on a coarse particle. The noncrustal metals associated with coarse particles declined steadily during October and were largely gone late in the month, unlike the more volatile lead which continued to show elevated levels that, however, never approached 24 h EPA standards. The measured mass of very fine particles peaked in the very finest range measured 0.26 to $0.09 \mu\text{m}$ aerodynamic diameter. Based on the size distribution, it is likely that there were components in the ultrafine mode $<0.09 \mu\text{m}$ diameter, but these particles

were not collected. **The levels of mass and several of the very fine components were the highest we have recorded in a variety of studies, including on the ground in the oil fields of Kuwait, June 1991 (Reid et al. 1994).** Note that a study in May 2002 at the 55 Liberty Street near the WTC site showed very low concentrations of essentially all very fine species except sulfur, possibly reflecting heavy use of diesels in the WTC pit at that time. Midtown Manhattan values of sulfur never exceeded 110 ng/m³. The particulate mass of WTC events was dominated by organic matter (30% ± 6%) and sulfuric acid (29% ± 5%), but included metals consistent with chlorine depression of volatility temperatures, as shown by highly correlated V/Ni values. A variety of organics were observed, including many derivatives of PAHs.

Very fine silicon particles, similar to those recently seen near coal-fired power plants, were a major component, about 10%, and may be derived either from similar high temperature processes or the formation of volatile halosilanes such as SiCl₄. Due to the combination of relatively high mass and smaller-than-usual size, the number and surface concentration are unusually high both absolutely and on a per µg of mass basis. Since these particles are poorly soluble in lung fluids, they will likely have long retention times in the lung and most likely be cleared through macrophage ingestion and transport through the blood stream, although the data are available only for the even smaller ultrafine particles (U.S. EPA 1996). Very fine particle silicon concentrations dropped sharply during October, far faster than the sulfates. **Very fine metals were routinely seen, but while most were at low concentrations, some metals (V, Ni, Cu, As, Se, Br, and Hg) occurred at unprecedented levels in the very fine size range.**

This study shows the value of highly time-resolved, size-resolved, and compositionally resolved aerosol data in aerosol emission events do not match the typical ambient aerosol patterns. In such situations, it may not be appropriate to base the estimated impact on health derived from the results of epidemiological studies based on 24 hour averages.

A model based on acute industrial exposures may be more appropriate if extended to susceptible populations, i.e., young, old, and sick people. A person could, in a few hours, be subject to materials in amounts and composition that they would not have had to endure in years of typical ambient conditions.

While the impacts of the plumes at sites away from the WTC collapse pile were episodic, that is not true for workers at the site itself, for which our data, when scaled to on-site conditions, could be relevant to health impact investigations.

Finally, while the WTC event is hopefully unique, there have been in the past 30 years many similar types of events that deviate strongly from typical ambient conditions, including industrial accidents, major fires, dust storms, and the Mt St. Helens eruption, that would have benefited from increased information on particle size and composition as a function of time.

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**Chemical characterization of volatile organic compounds
near the World Trade Center: Ambient concentrations and source apportionment**

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Abstract

Concentrations of 53 volatile organic compounds (VOCs) are reported from four locations near the World Trade Center (WTC) (New York, USA) complex for canister samples collected from September 2001 through January 2002.

Across the four sampling sites, mean concentrations ranged from 94.5 to 219 mg m⁻³ for total VOCs. The highest mean concentrations for individual VOCs at any site were for ethane 18:7 mgm⁻³, isopentane 17:1 mgm⁻³, and m;p-xylenes 17:0 mgm⁻³. VOC concentrations were generally highest for samples collected north and west of the WTC complex. Concentrations of total VOCs (and most individual VOCs) decreased from the period when fires were present at the WTC complex (before 19 December 2001) to the period after fires.

The EPA Unmix Version 5.0 receptor model was used to assess the impact of WTC fires and recovery efforts on ambient VOC concentrations. Four factors were identified: burning of building debris, a mixed recovery/heating source, motor vehicle exhaust, and a mixed gasoline source.

Introduction

The collapse of the World Trade Center (WTC) stemming from the terrorist attacks on 11 September 2001 (9/11) led to a cloud of dust and debris that dispersed over lower Manhattan. In addition to the release of air pollutants from the initial collapse, fires at the WTC complex persisted for approximately three months after 9/11. Although air pollutants released to the atmosphere were expected to be similar in nature to previous building collapses and fires, the scale and duration of the WTC collapse and aftermath were without parallel.

Studies have reported health effects from populations exposed to contaminants released from the WTC collapse. Medical evaluations of firefighters were completed for a period of 6 months following 9/11 (Prezant et al., 2002). Of the 10,116 firefighters evaluated, 332 were diagnosed with persistent cough and other respiratory symptoms referred to as "World Trade Center

cough" (Chen and Thurston, 2002; Scanlon, 2002). In a study of community residents, medical questionnaires were completed by 2166 residents of lower Manhattan, and lung function was evaluated for a subset of that study population (Landrigan et al., 2004). For both asthmatic and non-asthmatic residents, increased respiratory symptoms were reported after 9/11 (Landrigan et al., 2004). More recently, Herbert et al. (2006) reported results from a medical screening program for rescue and recovery workers. Of the 9442 participants, 69% of workers reported new or worsening respiratory problems (Herbert et al., 2006). A more extensive discussion of possible health outcomes stemming from environmental and occupational exposures after 9/11 is provided elsewhere (Claudio, 2001; Berkowitz et al., 2003; Landrigan et al., 2004).

Research related to quantifying pollutant levels after the WTC collapse has focused on dust samples and ambient air samples (especially particulate matter). Preliminary sampling at the WTC complex focused on assessing occupational exposure, especially quantification of asbestos levels (Landrigan, 2001). A National Institute for Occupational Safety and Health (NIOSH) report (summarized in McKinney et al., 2002) describes general area and breathing zone samples collected from September to October 2001.

Recent studies (Lioy et al., 2002; Offenberg et al., 2003) have examined bulk dust samples collected within one week of 9/11, where the sum of 37 PAHs comprised as much as 0.4% by mass of the dust samples (Lioy et al., 2002). Researchers have also reported concentrations of particulate matter less than 2.5 mm $\text{PM}_{2.5}$ and its constituents (Swartz et al., 2003; Olson et al., 2004; Pleil et al., 2004). Olson et al. (2004) reported concentrations of elemental carbon (EC), organic carbon matter (OM), $\text{PM}_{2.5}$, and reconstructed soil, trace element oxides, and sulfate from four locations near the WTC complex. Swartz et al. (2003) reported over 60 non-polar analytes, including numerous combustion markers (e.g., 30 PAHs, pristane, and phytane). Pleil et al. (2004) analyzed archived $\text{PM}_{2.5}$ filters for levels of stable PAHs (4–6 rings) and found the fires contributed a substantial portion of PAHs to the air in lower Manhattan during the first 100 days following 9/11. Cohen et al. (2004) reported PM measurements collected for 3 months from a site approximately 400 m from the WTC site, where the sum of 37 PAHs ranged from 0.01 to 1.5 mg m^{-3} for October samples. Cahill et al. (2004) reported PM measurements from October 2001 from a site approximately 1.8 km from the WTC site and approximately 50 m above ground. Size fractions greater than 1 mm were comprised of concrete, gypsum, glass, soot-like materials, and metals.

Although several studies have reported concentrations of air pollutants after the WTC collapse, none have focused on volatile organic compounds (VOCs). In addition to the importance of VOCs on ozone production and secondary organic aerosol formation, numerous individual VOCs have known or suspected health effects, e.g., benzene (IARC, 1987) and 1,3-butadiene (Jackson et al., 2000). Furthermore, published data are available for the days and weeks following 9/11 for some air pollutants (especially PM), but no information is currently available on VOC levels over longer time intervals. The objective of this research component is to better characterize temporal and spatial trends in ambient VOCs near the WTC complex. To this end, ambient concentrations of 53 VOCs are reported from four locations where canister samples were collected from September

2001 through January 2002. The Unmix receptor model was also used to assess the impact of WTC fires and recovery efforts on ambient VOC concentrations.

VOC measurements were collected from three stationary outdoor locations surrounding the WTC complex and one additional location (see Fig. 1 in Olson et al., 2004); these sampling locations were also used to collect PM_{2.5} measurements as described elsewhere (Olson et al., 2004). Gaseous grab samples were collected from September 2001 until January 2002. The north site was located at the intersection of West Broadway and Park Place (40° 42:830 N; 74° 00:630 W; hereafter referred to as site N), the east site was located at the intersection of Broadway and Cedar Street (40° 42:590 N; 74° 00:600 W; hereafter referred to as site E), and the west site was located at the intersection of West Street and Albany Street (40° 42:590 N; 74° 00:900 W; hereafter referred to as site W). In addition to the sites surrounding Ground Zero, samples were also collected at the US EPA Region 2 building located at 290 Broadway (40° 42:910 N; 74° 00:370 W; hereafter referred to as site NE).

These samples were collected from the edge of the 16th floor offset on the southwest corner (of the 32-floor building), approximately 50 m above ground and 3 m from the building face.

The intent of this sampling strategy was to surround the WTC complex so that at least one downwind (i.e., source-impacted) sample was collected each sampling day. Also noteworthy is that sites N, E, and W were located near the boundaries of the WTC complex and subsequent debris pile. Site NE (Broadway site) was located near the approximate dividing line where the general public was not allowed access until October 2001.

Sample collection

A total of 85 samples were collected as grab samples in 6-L, evacuated, internal surface treated (Summa electropolished), stainless steel canisters; all grab samples were collected at approximately 10:00 AM. Sampling strategies immediately after 9/11 focused on emergency response and multiple site coverage; for these reasons, and due to the lack of secure sampling locations, only grab samples were collected for this study. Canister cleaning and sample preparation were performed using US EPA compendium method TO-14A (U.S. EPA, 1999).

Analytical methods

Canister samples were analyzed for C₂-C₁₄ VOCs using a gas chromatograph (GC, Hewlett-Packard 5890 Series) equipped with flame ionization detector (FID) with cryogenic preconcentration. Because of the need for timely analysis of canister samples, a GC-FID instrument was selected due to instrument availability. Analytical procedures were completed using US EPA compendium method TO-14A (U.S. Environmental Protection Agency, 1999). A 60-m, 0.32-mm i.d., fused silica capillary column with 1.0 mm film thickness (DB-1, J & W Scientific, Rancho Cordova, CA) was used for separation of target analytes. Additional details describing cryogenic

concentration of samples, peak identification and quantitation are provided elsewhere (U.S. Environmental Protection Agency, 1999; Seila et al., 2001).

A compound list consisting of 53 VOCs was used for all samples described in this study, based on a hydrocarbon target list used at the US EPA Photochemical Assessment Monitoring Station (PAMS) network sites (U.S. Environmental Protection Agency, 2003). Similar target lists have been used in previous source apportionment studies involving VOCs (e.g., Fujita, 2001; Watson et al., 2001; Mukerjee et al., 2004).

Data analysis

Data processing and descriptive statistics were performed using SAS v.8.02 (SAS Institute, Cary, NC). A level of significance of a 1/4 0:05 was used for all statistical procedures. The multivariate receptor model Unmix (Henry et al., 1994; Lewis et al., 2003; Mukerjee et al., 2004) was used to assess source contributions from VOC samples using EPA Unmix Version 5.0 (U.S. Environmental Protection Agency, 2006).

A value equal to one half the method detection limit was used in source apportionment modeling for species concentrations below the method detection limit.

For source apportionment results using Unmix, the following compounds were used as fitting species: acetylene, ethane, propane, propylene, isobutane, n-butane, 1,3-butadiene, isopentane, n-heptane, benzene, cyclohexane, isopropylbenzene, m; p-xylenes, o-xylenes, styrene, and toluene. These fitting species were chosen using the select initial species function and the suggest more species function. The source contributions using these fitting species in Unmix resulted in a four-factor solution.

Results and discussion

Statistical summary and temporal patterns

Table 1 gives a statistical summary of ambient concentrations of 53 VOCs. Concentrations of n-hexane and methylcyclopentane are not included in Table 1 because these two chemicals were identified as possible artifacts associated with collocated PM sampling. A preliminary factor analysis with varimax rotation included a factor with only n-hexane and methylcyclopentane. These same two chemicals were also detected from a headspace analysis of the oil used for the impactor inlet used for PM sampling. Results of PM sampling are reported elsewhere (Olson et al., 2004). Concentrations of all 53 VOCs for all samples analyzed in this study are included in Tables S1–S4 (Supporting Information). A preliminary evaluation of background effects was assessed using the AIRS database (U.S. Environmental Protection Agency, 2004) for the New Brunswick, NJ site (40° 25:820 N; 74° 24:990 W). For 34 of the compounds in Table 1, mean concentrations from the WTC sites were at least three times those from the New Brunswick, NJ site. Concentrations for select VOC compounds from the New Brunswick site (mean concentra-

tion during 2001) include acetylene 80:9 mg m⁻³ p, benzene 80:9 mg m⁻³ p, toluene 86:0 mg m⁻³ p, and the sum of all PAMS compounds 852:8 mg m⁻³ p. Thus, it is likely that samples collected near the WTC complex were influenced by local sources and were not simply reflective of regional background influences. Across the four sampling sites, mean concentrations ranged from 94.5 to 219 mg m⁻³ for total VOCs. The highest mean concentrations for individual VOCs at any site were for ethane (18:7 mg m⁻³ at site N), isopentane (17:1 mg m⁻³ at site N), and m; p-xylenes (17:0 mg m⁻³ at site E).

The highest mean concentrations of VOCs were generally measured at site N, suggesting that this site was most influenced by local sources. Conversely, the lowest mean concentrations of VOCs were generally measured at site NE. This result was expected because site NE was located the farthest from the WTC complex and samples were collected at a higher elevation at site NE. These patterns of highest VOC concentrations at site N and lowest concentrations at site NE were similar to those for PM species as discussed by Olson et al. (2004). In addition, the higher VOC concentrations typically measured at site N may have been caused by flow channeling near the WTC complex; wind effects are discussed in more detail elsewhere (Olson et al., 2004). At each site, lighter n-alkanes (e.g., C₂ C₅ p) tended to have higher mean concentrations compared with heavier n-alkanes. Similarly, lighter aromatic compounds (especially BTEX compounds) tended to have higher mean concentrations compared with heavier aromatic compounds.

Several statistical tests (Wilcoxon scores, Kolmogorov–Smirnov test, Bonferroni comparisons) were used to determine if differences between sites in any VOC species were statistically significant. Statistical tests were completed using log-transformed data and the residuals from the tests were normally distributed. Only site NE was significantly different than the other sampling sites for most VOC species (and typically between site N and NE); differences between the other sampling sites were generally not statistically significant. Patterns were similar for the transformed (natural logarithm) data.

Fig. 1 shows a plot of concentrations of select VOC species (acetylene, benzene, isopropylbenzene, and styrene) as a function of sampling day. These compounds were selected as representative of temporal variability in VOC concentrations and are potentially indicative of motor vehicle emissions (acetylene and benzene) and building fire emissions (benzene, isopropylbenzene, and styrene). As shown in Fig. 1, species potentially associated with building fire emissions clearly decrease over time, whereas no clear pattern is evident with acetylene concentrations.

Description of sources

The Unmix receptor model was used to assess the effect of sources on ambient concentrations. Ambient concentrations from sites N, E, and W were used to generate all model results. Concentrations from site NE were not used in this analysis because these samples were collected at a higher elevation than the other sites. Initial attempts to apportion ambient data using each

site separately generally did not result in a feasible model solution, which was expected given the comparatively small number of data points per site. For this reason, source apportionment results were generated using a combined data set that included all samples from sites N, E, and W. Model results for each of the sources did not show a pattern with respect to site location. In addition, residuals of modeled source concentrations showed no statistical differences between sampling sites, indicating that it was a reasonable assumption to use the combined data set for source apportionment purposes.

Numerous attempts were made to resolve the number of sources using various sets of fitting species. In general, model inputs of more than four sources did not result in feasible solutions for any set of fitting species. Conversely, model inputs of three sources or less typically resulted in some blending of sources (e.g., motor vehicles and building fires).

For these reasons, a four-source solution was selected and this solution will be discussed for this study. The four-source solution resulted in reasonable separation of expected VOC sources as well as the highest correlation between predicted and measured concentrations.

Profiles of VOC species are shown in Fig. 2 for a four-factor solution generated using Unmix. Error bars of two standard deviations shown in Fig. 2 were estimated using a bootstrapping routine. The first source has the highest amounts of benzene, isopropylbenzene, styrene, and toluene, as well as elevated levels of propane, propylene, xylenes, 1-butene, and ethylbenzene. Few studies have reported concentrations of VOCs from building fires due to difficulties in sampling and analysis (Austin et al., 2001). However, Austin et al. (2001) reported concentrations of 144 VOCs from a series of experimental fires. An average of 65% of the VOC mass was comprised of 14 VOCs (propylene, benzene, xylenes, 1-butene/2-methylpropene, toluene, propane, 1,2-butadiene, isopentane, ethylbenzene, naphthalene, styrene, cyclopentene, 1-methylcyclopentene, and isopropylbenzene). Using VOC species that were measured in both the present study and in Austin et al. (2001), the highest emitting compounds from building fires (propylene, benzene, xylenes, 1-butene, toluene, propane, isopentane, ethylbenzene, naphthalene, styrene, cyclopentene, and isopropylbenzene) were also identified in the first factor in Fig. 2. For this reason, the first source is identified as burning of building debris.

The second source in Fig. 2 has the highest levels of acetylene, as well as elevated levels of toluene, other aromatics, MTBE, and lower molecular weight alkanes. This source is identified as motor vehicle emissions, and is consistent with numerous other studies (e.g., Fujita, 2001; Mukerjee et al., 2004) attributing these compounds to motor vehicle emissions.

The third source in Fig. 2 is characterized by the highest levels of xylenes, n-pentane, and isopentane. This source was dominated by one sample (collected on 26 December 2001) where higher concentrations of xylenes and pentanes were measured. A repeat analysis of the same sample confirmed the higher concentrations of xylenes and pentanes that were measured. This source is identified as a mixed gasoline source and is consistent with existing profiles on evap-

orated gasoline emissions (e.g., Fujita, 2001). In general, this source was not present during the remainder of the sampling period.

The last source in Fig. 2 has elevated levels of lower molecular weight alkanes, isobutane, isopentane, and aromatics. This source is identified as a mixed recovery source associated with debris removal and residential heating because it contains chemicals associated with power and heating generators that used propane and liquid gasoline. This source profile is consistent with previous studies (e.g., Mukerjee et al., 2004) that have identified liquid gasoline as consisting of elevated Mukerjee et al., 2004). However, 11 of the compounds listed in Table 1 (benzene, 1,3-butadiene, ethylbenzene, MTBE, naphthalene, styrene, toluene, 1,2,4-trichlorobenzene, and xylenes) are also classified as hazardous air pollutants (HAPs), which are chosen because of known or suspected health effects. Fig. 3 shows a plot of these HAPs for each of the four identified sources.

For several of the compounds shown in Fig. 3 (e.g., benzene, toluene, ethylbenzene, and styrene), the combined concentrations from the burning and recovery sources constituted a majority of emissions for that compound. The burning source had the highest percentages of benzene, ethylbenzene, and styrene, while the recovery source had the highest percentages of 1,2,4-trichlorobenzene and MTBE. The highest concentrations of 1,3-butadiene, toluene, and naphthalene were from the motor vehicle source.

Temporal patterns in source apportionment results

Modeled concentrations of the burning, motor vehicle, and mixed recovery sources (predicted using Unmix) are shown in Fig. 4 as a function of sample date. Also shown in Fig. 4 is a comparison of predicted total VOC concentrations and measured concentrations as a function of sample date. The modeled total VOC concentration was obtained using Unmix where total VOC was treated as a separate (unweighted) input variable.

As expected, predicted concentrations of the burning source were highest in the weeks immediately after the collapse and decreased during the sampling period. This pattern is also consistent with reported accounts of the end of fires at the WTC complex, which occurred on 19 December 2001 (www.cnn.com, 2001). For samples where modeled concentrations of the burning source were above 100 mg m⁻³, approximately half of those samples were collected at site N. Thus, the highest mean concentrations for numerous burning markers (e.g., propylene, benzene, toluene, propane, isopentane, ethylbenzene, naphthalene, styrene, cyclopentene, and isopropylbenzene) are from site N.

The mixed recovery/heating source does not show a strong temporal pattern, although several high concentrations are evident earlier in the sampling period. The motor vehicle source was also present throughout the entire sampling period. In fact, the highest motor vehicle concentration occurred relatively early in the sampling period (on 9 October 2001). One possible

complication to the motor vehicle profile was the presence of acetylene torches during the recovery period at the WTC complex. The highest motor vehicle concentration (on 9 October 2001) also corresponded to the highest acetylene concentration, an expected result given the predicted motor vehicle profile (Fig. 2). It is possible that the motor vehicle source represented a mix of motor vehicles and recovery operations (especially early in the sampling period), although attempts to further separate this source did not yield feasible solutions using Unmix. Reported operations of recovery efforts noted the presence of both acetylene tanks and torches at the WTC complex (U.S. Department of Labor, 2006).

A trajectory analysis was completed using the HYSPLIT trajectory model to further examine the effect of sources on ambient concentrations. All sample days characterized by higher burning concentrations occurred on sampling days where the prevailing wind directly impacted the sampling site from the debris pile.

Previous researchers (Olson et al., 2004) have attempted to characterize temporal changes in source concentrations from wind effects, and no conclusion results were found using either wind speed or wind direction. This conclusion is likely the result of complex building topography surrounding the sampling sites and the lack of site-specific meteorological data with hourly time resolution. Wind effects are described in more detail elsewhere (Olson et al., 2004).

The temporal pattern in HAP concentrations was also examined in Fig. S1 (see Supporting Information1), where the sum of 11 HAPs are shown as a function of sample date for each of the four identified sources. As shown in Fig. S1, the burning factor was the dominant source of HAPs early in the sampling period, often comprising as much 75% of the total HAPs. The motor vehicle and mixed recovery/heating sources were present throughout the sampling period, where the recovery/heating source often constituted at least 25% of the total HAPs.

Conclusions

Although several studies have reported concentrations of air pollutants near the WTC (especially related to PM and PM constituents), none have focused on VOCs. The findings described herein represent the largest study to date reporting concentrations of VOCs near the WTC complex. One major finding is that source apportionment modeling results clearly indicates a source of burning building debris and that this source is confirmed by previous source profiles on building fires. For several of the HAPs measured during this study (especially benzene and styrene), the burning factor comprised a large percentage of emissions for that compound.

Also noteworthy is that sources attributable to urban background (especially motor vehicles) were present throughout the entire sampling period.

<https://www.sciencedirect.com/science/article/abs/pii/S1352231007001938>

The Physical and Mental Health Challenges Experienced by 9/11 First Responders and Recovery Workers: A Review of the Literature

By Erin C Smith, Lisa Holmes and Frederick M Burkle

Abstract

Introduction: In the years following the September 11, 2001 terrorist attacks in New York (USA), otherwise known as 9/11, first responders and recovery workers began experiencing a range of physical and mental health challenges. Publications documenting these provide an important evidence-base identifying exposure-related health challenges associated with environmental exposures from the World Trade Center (WTC) site and describe the key lessons learned regarding both physical and mental health challenges (including symptoms and defined conditions) from the 9/11 disaster response.

Methods: A systematic literature review was conducted using the MEDLINE, PubMed, CINAHL, and PsychInfo databases (September 11, 2001 to September 11, 2018) using relevant search terms, truncation symbols, and Boolean combination functions. Publications were limited to journal articles that documented the physical or mental health challenges of 9/11 on first responders or recovery workers.

Results: A total of 156 publications were retrieved by the search strategy. The majority (55%) reported a quantitative methodology, while only seven percent reported the use of a qualitative research methodology. Firefighters were the group of responders most frequently reported in the literature (35%), while 37% of publications reported on research that included a mix of first responders and recovery workers. Physical health was the focus of the majority of publications (57%). Among the challenges, respiratory issues were the physical health condition most frequently reported in publications, while posttraumatic stress disorder (PTSD) was the most frequent mental health condition reported on. Publications were published in a broad range of multi-disciplinary journals (n = 75).

Discussion: These findings will go some way to filling the current gap in the 9/11 evidence-base regarding the understanding of the long-term health challenges for first responders and recovery workers.

Keywords: 9/11; first responder; health; mental health; recovery worker.

<https://pubmed.ncbi.nlm.nih.gov/31625489/>

Paramedic and Emergency Medical Technician Reflections on the Ongoing Impact of the 9/11 Terrorist Attacks

By Erin C Smith and Frederick M Burkle

Abstract

INTRODUCTION: In the years following the September 11, 2001 terrorist attacks in New York City (New York USA), otherwise known as 9/11, first responders began experiencing a range of health and psychosocial impacts. Publications documenting these largely focus on firefighters.

This research explores paramedic and emergency medical technician (EMT) reflections on the long-term impact of responding to the 9/11 terrorist attacks.

METHODS: Qualitative methods were used to conduct interviews with 54 paramedics and EMTs on the 15-year anniversary of 9/11.

RESULTS: Research participants reported a range of long-term psychosocial issues including posttraumatic stress disorder (PTSD), anxiety, depression, insomnia, relationship breakdowns and impact on family support systems, and addictive and risk-taking behaviors.

Ongoing physical health issues included respiratory disorders, eye problems, and cancers.

DISCUSSION: These findings will go some way to filling the current gap in the 9/11 evidence-base regarding the understanding of the long-term impact on paramedics and EMTs.

The testimony of this qualitative research is to ensure that an important voice is not lost, and that the deeply personal and richly descriptive experiences of the 9/11 paramedics and EMTs are not forgotten.

Keywords

ALS Advanced Life Support; BLS Basic Life Support; CDC Centers for Disease Control and Prevention; EMS Emergency Medical Services; EMT emergency medical technician; FDNY Fire Department of New York; PTSD posttraumatic stress disorder; WTC World Trade Center; 9/11; EMT; September 11 terrorist attack; emergency medical technician; paramedic.

<https://pubmed.ncbi.nlm.nih.gov/30761979/>

**The Forgotten Responders:
The Ongoing Impact of 9/11
on the Ground Zero Recovery Workers**

By Erin C Smith and Frederick M Burkle

Abstract

In the years following the September 11, 2001 terrorist attacks (9/11; New York USA), emergency first responders began experiencing a range of physical health and psychosocial impacts.

Publications documenting these tended to focus on firefighters, while emerging reports are starting to focus on other first responders, including paramedics, emergency medical technicians (EMTs), and police.

The objective of this research was to explore the long-term impact on another important group of 9/11 responders, the non-emergency recovery workers who responded to the World Trade Center (WTC) site of the 9/11 terrorist attacks.

In the 16 years following 9/11, Ground Zero recovery workers have been plagued by a range of long-term physical impacts, including musculoskeletal injuries, repetitive motion injuries, gait deterioration, and respiratory disorders.

Psychosocial issues include posttraumatic stress disorder, anxiety, depression, insomnia, support system fatigue, and addictive and risk-taking behaviors.

These findings go some way to filling the current gap in the understanding on the long-term impact of 9/11 and to provide an important testimony of the "**Forgotten Responders**" - the Ground Zero recovery workers.

Keywords

2001 terrorist attacks; 9/11 September 11; EMT emergency medical technician; FDNY Fire Department New York; GERD gastro-esophageal reflux disease; NYPD New York Police Department; WTC World Trade Center; 9/11; ground zero; long-term impact; recovery worker; terrorism.

<https://pubmed.ncbi.nlm.nih.gov/30129910/>

**Injuries and illnesses among
New York City Fire Department Rescue Workers
after responding to the World Trade Center attacks**

Centers for Disease Control and Prevention (CDC)

Abstract

Within minutes of the terrorist attacks on September 11, 2001, the Fire Department of New York City (FDNY) operated a continuous rescue/recovery effort at the World Trade Center (WTC) site.

Medical officers of FDNY Bureau of Health Services (FDNY-BHS) responded to provide emergency medical services.

The collapse of the WTC towers and several adjacent structures resulted in a vast, physically dangerous disaster zone. The height of the WTC towers produced extraordinary forces during their collapse, pulverizing considerable portions of the buildings' structural components and exposing first responders and civilians to substantial amounts of airborne particulate matter.

Fires burned continuously under the debris until mid-December 2001.

Because of ongoing fire activity and the large numbers of civilians and rescue workers who were killed during the attacks, approximately 11,000 FDNY firefighters and many emergency medical service (EMS) personnel worked on or directly adjacent to the rubble and incurred substantial exposures (Figure).

This report describes morbidity and mortality in FDNY rescue workers during the 11-month period after the WTC attacks and documents a substantial increase in respiratory and stress-related illness compared with the time period before the WTC attacks.

These findings demonstrate the need to provide acute and long-term medical monitoring, treatment, and counseling to FDNY rescue workers exposed to this disaster and to solve supply, compliance, and supervision problems so that respiratory protection can be rapidly provided at future disasters.

<https://pubmed.ncbi.nlm.nih.gov/12238534/>

Epidemiology of respiratory health outcomes among World Trade Center disaster workers: review of the literature 10 years after the September 11, 2001 terrorist attacks

Christine C Ekenga ¹, George Friedman-Jiménez

Abstract

Tens of thousands of workers participated in rescue, recovery, and cleanup activities at the World Trade Center (WTC) site in lower Manhattan after the terrorist attacks on September 11, 2001 (9/11).

The collapse of the WTC resulted in the release of a variety of airborne toxicants.

To date, respiratory symptoms and diseases have been among the most examined health outcomes in studies of WTC disaster workers.

A systematic review of the literature on respiratory health outcomes was undertaken to describe the available information on new onset of respiratory symptoms and diseases among WTC disaster workers after September 11, 2001.

Independent risk factors for respiratory health outcomes included being caught in the dust and debris cloud, early arrival at the WTC site, longer duration of work, and delaying mask and respirator use.

Methodological challenges in epidemiologic studies of WTC disaster workers involved study design, exposure misclassification, and limited information on potential confounders and effect modifiers. In the 10 years after 9/11, epidemiologic studies of WTC disaster workers have been essential in investigating the respiratory health consequences of WTC exposure.

Longitudinal studies along with continued medical surveillance will be vital in understanding the long-term respiratory burden associated with occupational WTC exposure.

<https://pubmed.ncbi.nlm.nih.gov/21908698/>

**FDNY and 9/11:
Clinical services and health outcomes
in World Trade Center-exposed firefighters
and EMS workers from 2001 to 2016**

By Jennifer Yip, Mayris P Webber,
Rachel Zeig-Owens, Madeline Vossbrinck,
Ankura Singh, Kerry Kelly and David J Prezant

Abstract

Background: After the World Trade Center (WTC) attacks on September 11, 2001, the Fire Department of the City of New York (FDNY) instituted a WTC medical monitoring and treatment program and established a data center to document health outcomes in the WTC-exposed workforce of <16,000 firefighters and EMS workers.

Methods: FDNY schedules routine monitoring exams every 12-18 months and physical and mental health treatment appointments, as required.

Results: FDNY research studies have consistently found that early arrival to work and/or prolonged work at the WTC-site increased the risks for adverse physical and mental health outcomes.

To date, a substantial proportion has been diagnosed with obstructive airways disease, chronic rhinosinusitis, and gastroesophageal reflux disease; a quarter has two or more of these conditions.

Conclusions: While much has been learned, the entire spectrum and trajectory of WTC-related disorders and their mechanisms of onset and persistence remain to be fully described.

Keywords:

September 11 terrorist attacks; ems workers;
firefighters; occupational health; world trade center.

<https://pubmed.ncbi.nlm.nih.gov/27427498/>

The T. Mort. Chaplaincy at ground zero: presence and privilege on holy ground Storm Swain

Abstract

Drawing on interviews with the chaplains and archival material from Disaster Chaplaincy Services--NY, this article discusses the formation of the chaplaincy at the Temporary Mortuary at Ground Zero after the terrorist attacks on September 11, 2001. It describes the initial chaplaincy response in New York by local clergy and the SAIR team of the American Red Cross. The first 6 weeks of chaplaincy at Ground Zero are explored highlighting the significant contributions of the Archdiocese of New York and Episcopal Diocese of New York out of St. Paul's Chapel. The mission and impact of the Temporary Mortuary chaplains' ministry of presence and blessing is discussed with some final reflections for the future of Disaster Chaplaincy.

<https://pubmed.ncbi.nlm.nih.gov/21850560/>

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Correlates of compassion fatigue and burnout in chaplains and other clergy who responded to the September 11th attacks in New York City

Kevin J Flannelly¹, Stephen B Roberts, Andrew J Weaver

Abstract

Participants at a June 2002 conference about the September 11th attacks were tested for compassion fatigue, compassion satisfaction, and burnout. The sample consisted of 343 clergy, including 97 chaplains. A total of 149 (43.4%) of the participants had responded as disaster-relief workers following the September 11th attacks. The number of hours clergy worked with trauma victims each week was directly related to compassion fatigue among responders and non-responders. Compassion fatigue also was positively related to the number of days that responders worked at Ground Zero, while disaster-relief work with the American Red Cross reduced compassion fatigue and burnout. Clinical Pastoral Education tended to decrease compassion fatigue and burnout and increase compassion satisfaction in both responders and non-responders. Burnout was inversely related to age in both groups.

<https://pubmed.ncbi.nlm.nih.gov/16281795/>

Clinical deterioration in pediatric asthmatic patients after September 11, 2001

By Anthony M Szema, Meera Khedkar, Patrick F Maloney,
Patricia A Takach, Michael S Nickels, Harshit Patel,
Francesmary Modugno, Alan Y Tso and Deborah H Lin

Abstract

Background: New York City residents were exposed to a variety of inhaled substances after the collapse of the World Trade Center.

Exposure to these substances might lead to an increase in asthma severity, with residential distance from Ground Zero predictive of the degree of change.

Objective: We sought to assess the effect of the World Trade Center collapse on local pediatric asthmatic patients.

Methods: We retrospectively reviewed the charts of 205 pediatric patients with established asthma from a clinic in lower Manhattan's Chinatown.

Clinical data were obtained for the year before and the year after September 11, 2001. Measurements included numbers of visits, asthma medication prescriptions, oral corticosteroid prescriptions, weekly doses of rescue inhaler, and peak expiratory flow rates. Residential zip codes were used to compare the asthma severity of patients living within and beyond a 5-mile radius of Ground Zero.

Results: After September 11, 2001, these children had more asthma-related clinic visits ($P = .002$) and received more prescriptions for asthma medications ($P = .018$). No significant differences in oral steroid or rescue inhaler use were noted.

Those living within 5 miles had more clinic visits after September 11, 2001 ($P = .013$); the increase in clinic visits for patients living more than 5 miles from Ground Zero was not significant. Mean percent predicted peak expiratory flow rates decreased solely for those patients living within 5 miles of Ground Zero during the 3 months after September 11, 2001.

Conclusions: Asthma severity worsened after September 11, 2001, in pediatric asthmatic patients living near Ground Zero. Residential proximity to Ground Zero was predictive of the degree of decrease in asthma health.

<https://pubmed.ncbi.nlm.nih.gov/15007340/>

**Accelerated spirometric decline
in New York City firefighters with α_1 -antitrypsin deficiency**

By Gisela I Banauch, Mark Brantly, Gabriel Izbicki,
Charles Hall, Alan Shanske, Robert Chavko, Ganesha Santhyadka,
Vasilios Christodoulou, Michael D Weiden and David J Prezant

Abstract

Background: On September 11, 2001, the World Trade Center (WTC) collapse caused massive air pollution, producing variable amounts of lung function reduction in the New York City Fire Department (FDNY) rescue workforce. α_1 -Antitrypsin (AAT) deficiency is a risk factor for obstructive airway disease.

Methods: This prospective, longitudinal cohort study of the first 4 years post-September 11, 2001, investigated the influence of AAT deficiency on adjusted longitudinal spirometric change (FEV₁) in 90 FDNY rescue workers with WTC exposure. Workers with protease inhibitor (Pi) Z heterozygosity were considered moderately AAT deficient. PiS homozygosity or PiS heterozygosity without concomitant PiZ heterozygosity was considered mild deficiency, and PiM homozygosity was considered normal.

Alternately, workers had low AAT levels if serum AAT was ≤ 20 μ mol/L.

Results: In addition to normal aging-related decline (37 mL/y), significant FEV₁ decline accelerations developed with increasing AAT deficiency severity (110 mL/y for moderate and 32 mL/y for mild) or with low AAT serum levels (49 mL/y). Spirometric rates pre-September 11, 2001, did not show accelerations with AAT deficiency.

Among workers with low AAT levels, cough persisted in a significant number of participants at 4 years post-September 11, 2001.

Conclusions: FDNY rescue workers with AAT deficiency had significant spirometric decline accelerations and persistent airway symptoms during the first 4 years after WTC exposure, representing a novel gene-by-environment interaction.

Clinically meaningful decline acceleration occurred even with the mild serum AAT level reductions associated with PiS heterozygosity (without concomitant PiZ heterozygosity).

<https://pubmed.ncbi.nlm.nih.gov/20634282/>

**Obstructive airways disease with air trapping
among firefighters exposed to World Trade Center dust**

Michael D Weiden, et al.

Abstract

Background: The World Trade Center (WTC) collapse produced a massive exposure to respirable particulates in New York City Fire Department (FDNY) rescue workers.

This group had spirometry examinations pre-September 11, 2001, and post-September 11, 2001, demonstrating declines in lung function with parallel declines in FEV(1) and FVC. To date, the underlying pathophysiologic cause for this has been open to question.

Methods: Of 13,234 participants in the FDNY-WTC Monitoring Program, 1,720 (13%) were referred for pulmonary subspecialty evaluation at a single institution. Evaluation included 919 full pulmonary function tests, 1,219 methacholine challenge tests, and 982 high-resolution chest CT scans.

Results: At pulmonary evaluation (median 34 months post-September 11, 2001), median values were FEV(1) 93% predicted (interquartile range [IQR], 83%-101%), FVC 98% predicted (IQR, 89%-106%), and FEV(1)/FVC 0.78 (IQR, 0.72-0.82). The residual volume (RV) was 123% predicted (IQR, 106%-147%) with nearly all participants having normal total lung capacity, functional residual capacity, and diffusing capacity of carbon monoxide. Also, 1,051/1,720 (59%) had obstructive airways disease based on at least one of the following: FEV(1)/FVC, bronchodilator responsiveness, hyperreactivity, or elevated RV.

After adjusting for age, gender, race, height and weight, and tobacco use, the decline in FEV(1) post-September 11, 2001, was significantly correlated with increased RV percent predicted ($P < .0001$), increased bronchodilator responsiveness ($P < .0001$), and increased hyperreactivity ($P = .0056$). CT scans demonstrated bronchial wall thickening that was significantly associated with the decline in FEV(1) post-September 11, 2001 ($P = .024$), increases in hyperreactivity ($P < .0001$), and increases in RV ($P < .0001$). Few had evidence for interstitial disease.

Conclusions: Airways obstruction was the predominant physiologic finding underlying the reduction in lung function post-September 11, 2001, in FDNY WTC rescue workers presenting for pulmonary evaluation.

<https://pubmed.ncbi.nlm.nih.gov/19820077/>

Lung function in rescue workers at the World Trade Center after 7 years

By Thomas K Aldrich, et al.

Abstract

Background: The terrorist attacks on the World Trade Center on September 11, 2001, exposed thousands of Fire Department of New York City (FDNY) rescue workers to dust, leading to substantial declines in lung function in the first year. We sought to determine the longer-term effects of exposure.

Methods: Using linear mixed models, we analyzed the forced expiratory volume in 1 second (FEV(1)) of both active and retired FDNY rescue workers on the basis of spirometry routinely performed at intervals of 12 to 18 months from March 12, 2000, to September 11, 2008.

Results: Of the 13,954 FDNY workers who were present at the World Trade Center between September 11, 2001, and September 24, 2001, a total of 12,781 (91.6%) participated in this study, contributing 61,746 quality-screened spirometric measurements.

The median follow-up was 6.1 years for firefighters and 6.4 years for emergency-medical-services (EMS) workers. In the first year, the mean FEV(1) decreased significantly for all workers, more for firefighters who had never smoked (a reduction of 439 ml; 95% confidence interval [CI], 408 to 471) than for EMS workers who had never smoked (a reduction of 267 ml; 95% CI, 263 to 271) ($P < 0.001$ for both comparisons).

There was little or no recovery in FEV(1) during the subsequent 6 years, with a mean annualized reduction in FEV(1) of 25 ml per year for firefighters and 40 ml per year for EMS workers.

The proportion of workers who had never smoked and who had an FEV(1) below the lower limit of the normal range increased during the first year, from 3% to 18% for firefighters and from 12% to 22% for EMS workers, stabilizing at about 13% for firefighters and 22% for EMS workers during the subsequent 6 years.

Conclusions: Exposure to World Trade Center dust led to large declines in FEV(1) for FDNY rescue workers during the first year.

Overall, these declines were persistent, without recovery over the next 6 years, leaving a substantial proportion of workers with abnormal lung function.

<https://pubmed.ncbi.nlm.nih.gov/20375403/>

**Pulmonary function after exposure to the World Trade Center collapse
in the New York City Fire Department**

Gisela I Banauch, et al.

Abstract

Rationale: On September 11, 2001, the World Trade Center collapse created an enormous urban disaster site with high levels of airborne pollutants.

First responders, rescue and recovery workers, and residents have since reported respiratory symptoms and developed pulmonary function abnormalities.

Objectives: To quantify respiratory health effects of World Trade Center exposure in the New York City Fire Department.

Measurements: Longitudinal study of pulmonary function in 12,079 New York City Fire Department rescue workers employed on or before 09/11/2001.

Between 1.1.1997 and 9.11.2002, 31,994 spirometries were obtained and the FEV(1) and FVC were analyzed for differences according to estimated World Trade Center exposure intensity.

Adjusted average FEV(1) during the first year after 09/11/2001 was compared with the 5 yr before 09/11/2001. Median time between 09/11/2001 and a worker's first spirometry afterwards was 3 mo; 90% were assessed within 5 mo.

Main results: World Trade Center-exposed workers experienced a substantial reduction in adjusted average FEV(1) during the year after 09/11/2001 (372 ml; 95% confidence interval, 364-381 ml; $p < 0.001$) This exposure-related FEV(1) decrement equaled 12 yr of aging-related FEV(1) decline.

Moreover, exposure intensity assessed by initial arrival time at the World Trade Center site correlated linearly with FEV(1) reduction in an exposure intensity-response gradient ($p = 0.048$). Respiratory symptoms also predicted a further FEV(1) decrease ($p < 0.001$). Similar findings were observed for adjusted average FVC.

Conclusions: World Trade Center exposure produced a substantial reduction in pulmonary function in New York City Fire Department rescue workers during the first year after 09/11/2001.

<https://pubmed.ncbi.nlm.nih.gov/16645172/>

**Biomarkers of World Trade Center Particulate Matter Exposure:
Physiology of Distal Airway and Blood Biomarkers that Predict FEV₁ Decline**

Michael D Weiden, et al.

Abstract

Biomarkers can be important predictors of disease severity and progression. The intense exposure to particulates and other toxins from the destruction of the World Trade Center (WTC) overwhelmed the lung's normal protective barriers.

The Fire Department of New York (FDNY) cohort not only had baseline pre-exposure lung function measures but also had serum samples banked soon after their WTC exposure.

This well-phenotyped group of highly exposed first responders is an ideal cohort for biomarker discovery and eventual validation. Disease progression was heterogeneous in this group in that some individuals subsequently developed abnormal lung function while others recovered.

Airflow obstruction predominated in WTC-exposed patients who were symptomatic. Multiple independent disease pathways may cause this abnormal FEV₁ after irritant exposure. WTC exposure activates one or more of these pathways causing abnormal FEV₁ in an individual.

Our hypothesis was that serum biomarkers expressed within 6 months after WTC exposure reflect active disease pathways and predict subsequent development or protection from abnormal FEV₁ below the lower limit of normal known as WTC-Lung Injury (WTC-LI). We utilized a nested case-cohort control design of previously healthy never smokers who sought subspecialty pulmonary evaluation to explore predictive biomarkers of WTC-LI.

We have identified biomarkers of inflammation, metabolic derangement, protease/antiprotease balance, and vascular injury expressed in serum within 6 months of WTC exposure that were predictive of their FEV₁ up to 7 years after their WTC exposure.

Predicting future risk of airway injury after particulate exposures can focus monitoring and early treatment on a subset of patients in greatest need of these services.

<https://pubmed.ncbi.nlm.nih.gov/26024341/>

Review • Am J Ind Med

doi: 10.1002/ajim.22631 • July 2016

**FDNY and 9/11:
Clinical services and health outcomes
in World Trade Center-exposed firefighters and EMS workers from 2001 to 2016**

Jennifer Yip, et al.

Abstract

Background: After the World Trade Center (WTC) attacks on September 11, 2001, the Fire Department of the City of New York (FDNY) instituted a WTC medical monitoring and treatment program and established a data center to document health outcomes in the WTC-exposed workforce of <16,000 firefighters and EMS workers.

Methods: FDNY schedules routine monitoring exams every 12-18 months and physical and mental health treatment appointments, as required.

Results: FDNY research studies have consistently found that early arrival to work and/or prolonged work at the WTC-site increased the risks for adverse physical and mental health outcomes. To date, a substantial proportion has been diagnosed with obstructive airways disease, chronic rhinosinusitis, and gastroesophageal reflux disease; a quarter has two or more of these conditions.

Conclusions: While much has been learned, the entire spectrum and trajectory of WTC-related disorders and their mechanisms of onset and persistence remain to be fully described.

Keywords: September 11 terrorist attacks; ems workers; firefighters; occupational health; world trade center.

<https://pubmed.ncbi.nlm.nih.gov/27427498/>

Review • Curr Probl Surg

doi: 10.1067/j.cpsurg.2007.06.001.

Terror in the 21st century: milestones and prospects—part II

Gidon Almogy and Avraham I Rivkind

Document Link: <https://sci-hub.tw/10.1067/j.cpsurg.2007.06.001>

By Debora S Chan, PharmD FASHP CDM, Charles W Callahan and Jeanne S Hoffman

September 11th anniversary: revisiting the damage beyond Ground Zero

TO THE EDITOR: A pediatric patient with asthma taught us that we are only beginning to recognize the impact of September 11, 2001.

Case Report

A 10-year-old white boy with moderate persistent asthma previously well controlled with fluticasone and montelukast was seen regularly as part of a telemedicine asthma research project. Since the attack on September 11, he had a history of 5 days of chest tightness at school. The episodes were attributed to his asthma, even though his daily peak-flow measurements had not changed from baseline and he had no other symptoms. He was started on oral prednisolone according to the asthma action plan. The chest tightness persisted for 4 more days, then abated on the weekend, and his mother discontinued the prednisolone. On the next Monday, he again complained of chest tightness as he was walking to school with his mother and was given 2 puffs of albuterol. He was seen by the school nurse 3 or 4 times for additional doses of albuterol throughout the day.

We saw the boy 2 days later. He seemed distracted and looked tired, but had no other symptoms, and his examination was normal. His peak flow was at baseline. He complained of chest tightness, but had no abnormal physical findings. After the examination, we asked some questions about his upcoming move from Hawaii to the mainland.

"I'm not flying on a plane! I'm afraid to fly after what happened." Although his mother had tried not to expose him to the images repeatedly shown on television, he had seen them at school. We asked about school and why he seemed to be having chest tightness during school. He took a deep breath, stared off, and said slowly, "Osama bin Laden said that he would target places where there are Christians and Jews. My school has Christians and Jews." We talked about his school for awhile, but he was not comforted despite our very best efforts to assure him that his school would not be a likely target for terrorists. He crossed his arms and said, "There shouldn't have to be a war." This comment prompted us to ask about what this military family member might really be worried about.

"Are you afraid that your father will have to go and fight this war?" He nodded his head vigorously, then broke down in tears and ran to his mother's lap, where he wept for several minutes. We all cried together and assured him that even grown-ups get scared when events like this happen. Eventually, he quieted down. On the ride home, he took a deep breath and sighed. When his mother asked why he sighed, he said, "I feel much better now." His chest tightness resolved completely. He had no further symptoms and has continued to do well.

Discussion

Posttraumatic stress disorder (PTSD) is an anxiety disorder resulting from exposure to events that involve the threat of death or serious injury to self or others.^{1,2} Symptoms of PTSD include reexperiencing, hypervigilance, and avoidance of the feared stimuli over a 6-month period.² These events can be experienced directly or indirectly via media exposure. Although this patient did not meet full criteria for PTSD, he experienced symptoms of hypervigilance and avoidance accompanied by anxiety. He had been exposed through the media to violence; his father, by the nature of his job, could be in harm's way. He had learned that terrorists threatened Americans, especially Christians and Jews, and he attended a school with Christians and Jews.

His hypervigilant logic resulted in him concluding that school might be a dangerous place. His chest tightness appeared to be a physiologic result of his psychological arousal. Although this phenomenon has not been well studied in children, it has been demonstrated in adults.^{2,3}

On September 11, 2001, we were caught between wanting to go on with our lives and dealing with the greatest tragedy of our lives. But at the same time, there was a great deal of processing that needed to take place about what we experienced. For children, the processing was more difficult; for some, it may be incomplete.

On the anniversary of the 9-11 attacks, pharmacists and pediatricians should be aware of the manifestations of PTSD in children who were exposed to the extreme media coverage of this disaster or the direct experience of the loss of loved ones that day. We should take the lead in educating parents and schools regarding the potential impact that seeing these images again might have on our patients and families. The trauma of that day has not ended for any of us.

The views and opinions expressed in this letter are those of the authors and do not reflect the official policy or position of the Department of the Army, the Department of Defense, or the United States Government.

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<https://pubmed.ncbi.nlm.nih.gov/15479771/>

**Indirect exposure to the September 11 terrorist attacks:
does symptom structure resemble PTSD?**

Michael Suvak, et al.

Abstract

The authors conducted confirmatory factor analyses of reports of posttraumatic stress reactions using a national probability sample of individuals indirectly exposed to the terrorist attacks of September 11, 2001 (n = 675). Reactions at three time points in the year after the attacks were best accounted for by a lower-order, 4-factor solution (Reexperiencing, Strategic Avoidance, Emotional Numbing, and Hyperarousal Symptoms). Indirect exposure to a traumatic event appears to induce a response with a similar symptom structure as responses to direct exposure.

<https://pubmed.ncbi.nlm.nih.gov/18302169/>

Psychiatry

**Predictors of peritraumatic reactions and PTSD
following the September 11th terrorist attacks**

Steven R Lawyer, et al.

Abstract

In this study the authors characterize peritraumatic reactions of residents of New York City during and immediately following the September 11th terrorist attacks; and current (past month) PTSD symptoms. Factor analyses of peritraumatic reactions yielded three related, but distinct, peritraumatic response patterns—dissociation, emotional reactions, and panic/physiological arousal. Several demographic, historical, and exposure-related variables predicted one or more peritraumatic reaction patterns. After controlling for demographic, historical, and exposure factors, each of the peritraumatic reactions factors, one historical factor and one event-related exposure factor remained as significant predictors of PTSD. These results support a growing literature concerning the predictive value of peritraumatic reactions in relation to PTSD. Implications for preventive efforts and suggestions for future research are discussed.

<https://pubmed.ncbi.nlm.nih.gov/16822192/>

The impact of the September 11th terrorist attacks on psychiatric patients: a review

Victoria A Franz, et al.

Abstract

Studies of the general population have shown that the terrorist attacks of September 11, 2001 had a well-documented psychological effect, regardless of whether or not individuals were directly exposed to the events. In light of findings that pre-existing mental illness and prior exposure to trauma are associated with vulnerability to PTSD following a subsequent traumatic event, this article reviews research on the impact of the September 11th terrorist attacks on psychiatric patients. Findings suggest that, in general, psychiatric patients experienced immediate and long-term posttraumatic symptoms at levels greater than normal controls, although there were differential effects by diagnostic group and symptoms as observed did not always match complaints of subjective impairment. Studies sampling inpatients and outpatients, as well as research regarding service utilization, are evaluated. Assessment and treatment implications for clinicians responsible for the care of psychiatric patients following a national trauma are discussed, and recommendations for future research are presented.

<https://pubmed.ncbi.nlm.nih.gov/19321246/>

Suicide Life Threat Behav

doi: 10.1521/suli.34.4.439.53744 • Winter 2004

The effect of the September 11 terrorist attacks on suicide and deliberate self-harm: a time trend study

Aart W De Lange and Jan Neeleman

Abstract

Suicide rates may be affected by world news. Our objective was to investigate the possible impact of the terrorist attacks of September 11, 2001, on suicidal behavior in the Netherlands. There was evidence of an increase in rates of suicide and deliberate self-harm in the weeks immediately following the attacks. These findings contrast with Durkheim's (1897) original suggestion that suicide rates decline in times of war and outside threat but are in line with findings of increases in suicidal behavior after media coverage of lethal violence.

<https://pubmed.ncbi.nlm.nih.gov/15585465/>

New onset delusions in the aftermath of the September 11th terrorist attacks

By Elizabeth L H Hegarty, et al.

The attacks on the World Trade Center on September 11, 2001 represented the most deadly act of terrorism on U.S. soil in the nation's history. These attacks have had numerous social, political, economic, and psychological effects on individuals across the nation. Given the startling and gruesome nature of the attacks, it is not surprising that posttraumatic stress disorder (PTSD) has been one of the primary psychological sequelae of the events of September 11.

Galea et al. used a random-digit dialing telephone survey to assess the prevalence of acute PTSD in adults living in Manhattan south of 110th street 5 to 8 weeks after the attacks.¹ They found that 8.8% of the sampled population reported symptoms consistent with current PTSD. In addition, 57.8% of respondents reported experiencing at least one PTSD symptom in the past month, the most frequent being intrusive memories and insomnia. The likelihood of PTSD was found to be greatest among those who were more directly affected by the attacks—e.g., those who lost possessions, lived close to the World Trade Center, or were involved in the rescue efforts. In a separate publication, Galea et al. reported that adults living south of 110th street in Manhattan had a prevalence approximately twice that of previously reported estimates^{2,3} for both current PTSD (7.5%) and depression (9.7%) 5 to 8 weeks after the attacks.⁴ Respondents who lived south of Canal Street and were thus in closer geographical proximity to the World Trade Center showed an even higher prevalence of PTSD (20%).⁴ These studies suggest that the burden of PTSD is heaviest among individuals who were directly affected by the attacks.

However, evidence exists that those who were less immediately affected may also have experienced PTSD symptoms. A random-digit dialing telephone survey of adults in the New York City metropolitan area conducted by Galea et al. found that only two thirds of those who met criteria for probable PTSD 6 months after the attacks on September 11 had been directly affected by the attacks, while one third had not been directly affected.⁵ A web-based epidemiological survey by Schlenger et al. done 1 to 2 months after September 11, 2001 found an increased prevalence of PTSD in New York City (11.2%) compared to Washington, DC (2.7%), other major metropolitan areas (3.6%), and the rest of the country (4.0%).⁶ The authors suggested that the lower prevalence of PTSD in Washington, DC compared to New York City may have been due to a number of different factors, including the fact that the Pentagon is more geographically distant from the city than the World Trade Center, that it is a military instead of a civilian target, and that the level of devastation at the Pentagon was much less than that at the twin towers. It has also been reported that the level of PTSD symptoms was associated both with the level of direct exposure to the attacks as well as indirect exposure via time spent viewing television coverage of the event on September 11 and several days afterwards. Thus, the incidence of PTSD symptoms in response to a large-scale frightening event may extend beyond those who were directly affected to the general population as a whole.

Although PTSD is the psychiatric disorder that is classically most often associated with major traumatic events such as the attacks on September 11, other significant psychological sequelae of these attacks have also been described.

For example, Vlahov et al. performed a random-digit dialing telephone survey of Manhattan residents to estimate the prevalence of increased cigarette smoking, alcohol consumption, and marijuana use after the attacks⁷ and found that more than one quarter of respondents (29%) reported an increase in use of at least one of these three substances. Specifically, 9.7% of all respondents had increased cigarette smoking, 24.6% had increased alcohol consumption, and 3.2% reported increased marijuana use. A higher prevalence of current PTSD and major depression was also found among those who reported.

This study was supported with resources and the use of facilities at the James A. Haley Veterans' Hospital, Tampa, FL.

<https://pubmed.ncbi.nlm.nih.gov/18032987/>

J Pers Soc Psychol

doi: 10.1037/0022-3514.88.6.984 • June 2005

**Self-enhancement
among high-exposure survivors of the September 11th terrorist attack:
resilience or social maladjustment?**

By George A Bonanno, et al.

Abstract

The authors examined self-enhancing bias as a predictor of adjustment among individuals in or near the World Trade Center during the September 11, 2001, terrorist attacks.

Resilience was defined from categorical and continuous analyses of both participant self-report and friend and relative ratings of adjustment. Self-enhancement was associated with a resilient outcome, ratings of better adjustment prior to September 11th, greater positive affect, and reduced perceptions of social constraints.

Additional analyses indicated that self-enhancers' reduced symptom levels were fully mediated by their low perceived social constraints. However, consistent with previous evidence suggesting a social cost to self-enhancement, at 18 months post-September 11th, self-enhancers' friends and relatives also rated them as decreasing in social adjustment and as being less honest.

<https://pubmed.ncbi.nlm.nih.gov/15982117/>

Am J Orthopsychiatry

doi: 10.1037/0002-9432.75.2.190 • April 2005

**Behavior problems in New York City's children
after the September 11, 2001, terrorist attacks**

By Jennifer Stuber, et al.

Abstract

Children's behavior was assessed with 3 cross-sectional random-digit-dial telephone surveys conducted 11 months before, 4 months after, and 6 months after September 11, 2001. Parents reported fewer behavior problems in children 4 months after the attacks compared with the pre-September 11 baseline. However, 6 months after the attacks, parents' reporting of behavior problems was comparable to pre-September 11 levels. In the 1st few months after a disaster, the identification of children who need mental health treatment may be complicated by a dampened behavioral response or by a decreased sensitivity of parental assessment to behavioral problems.

<https://pubmed.ncbi.nlm.nih.gov/15839756/>

Review • Crit Care

doi: 10.1186/cc1059 • December 2001

**The World Trade Center attack:
Helping the helpers: the role of critical incident stress management**

By J Hammond and J Brooks

Abstract

Healthcare and prehospital workers involved in disaster response are susceptible to a variety of stress-related psychological and physical sequelae. Critical incident stress management, of which critical incident stress debriefing is a component, can mitigate the response to these stressors. Critical incident stress debriefing is a peer-driven, therapist-guided, structured, group intervention designed to accelerate the recovery of personnel. The attack on the World Trade Center, and the impact it may have on rescue, prehospital, and healthcare workers, should urge us to incorporate critical incident stress management into disaster management plans.

<https://pubmed.ncbi.nlm.nih.gov/11737916/>

**The impact of the September 11th terrorist attacks on psychiatric patients:
a review**

By Victoria A Franz, et al.

Abstract

Studies of the general population have shown that the terrorist attacks of September 11, 2001 had a well-documented psychological effect, regardless of whether or not individuals were directly exposed to the events.

In light of findings that pre-existing mental illness and prior exposure to trauma are associated with vulnerability to PTSD following a subsequent traumatic event, this article reviews research on the impact of the September 11th terrorist attacks on psychiatric patients. Findings suggest that, in general, psychiatric patients experienced immediate and long-term posttraumatic symptoms at levels greater than normal controls, although there were differential effects by diagnostic group and symptoms as observed did not always match complaints of subjective impairment. Studies sampling inpatients and outpatients, as well as research regarding service utilization, are evaluated. Assessment and treatment implications for clinicians responsible for the care of psychiatric patients following a national trauma are discussed, and recommendations for future research are presented.

<https://pubmed.ncbi.nlm.nih.gov/19321246/>

Int J Emerg Ment Health • Fall 2001

Observations from Ground Zero at the World Trade Center in New York City, Part I

By R L Levenson Jr and J K Acosta

Abstract

The authors are mental health clinicians with the Police Organization Providing Peer Assistance (POPPA), an affiliate organization of the Patrolman's Benevolent Association of the New York Police Department (NYPD). Beginning on September 11, 2001 we were at Ground Zero of the World Trade Center (WTC) to assist in the all phases of crisis intervention and Critical Incident Stress Management (CISM), as indicated. Our observations and anecdotal reports, as we worked on teams with NYPD Peer Support Officers (PSOs), are the subject of this paper.

<https://pubmed.ncbi.nlm.nih.gov/12025483/>

**Observations from Ground Zero at the World Trade Center in New York City, Part II:
Theoretical and clinical considerations**

By Judith K Acosta and Richard L Levenson Jr

Abstract

Part I of this series discussed our observations of Ground Zero of the World Trade Center (WTC) immediately after the attack on September 11, 2001, as well as the stress-response of police officers on site. This paper offers a variety of clinical techniques for emergency mental health practitioners and first responders for use with victims of critical incidents. The suggested interventions are based on the theory and clinical practice of Emergency Medical Hypnosis, Neuro-Linguistic Programming, and Ericksonian Psychotherapy. Specific examples of how they were applied with police personnel following the World Trade Center attack are provided along with specific clinical guidelines. These interventions are designed to augment and enhance standard CISM, mental health, and medical practice in the field.

<https://pubmed.ncbi.nlm.nih.gov/12166017/>

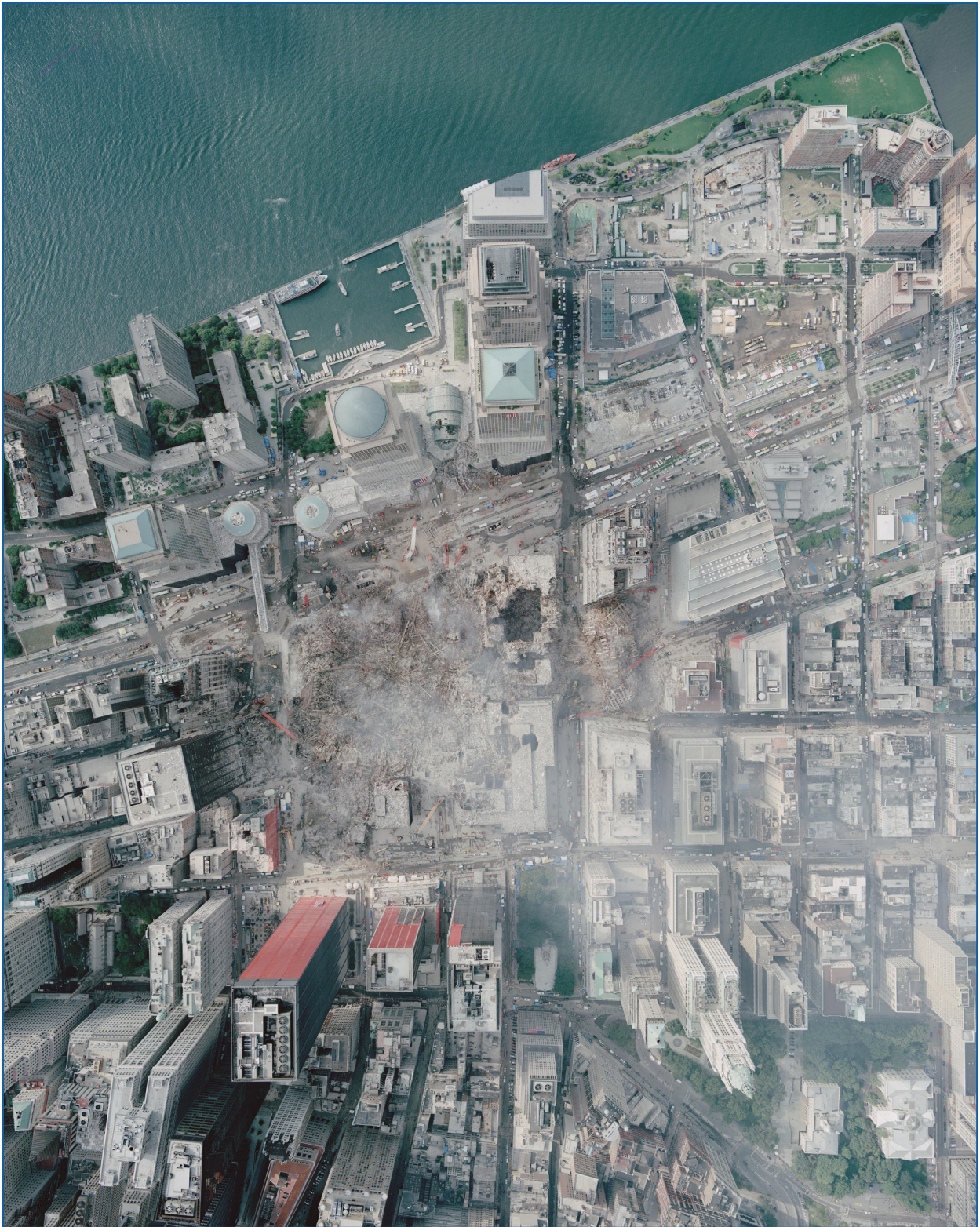
**Large group crisis intervention for law enforcement
in response to the September 11 World Trade Center mass disaster**

By Cherie Castellano

Abstract

University Behavioral HealthCare, University of Medicine and Dentistry of New Jersey in partnership with the New Jersey Department of Personnel established a program entitled "Cop 2 Cop" in 1999 to assist law enforcement personnel within the state. The events of September 11, 2001, demanded an unprecedented response to address the behavioral health care needs of those individuals in New Jersey and New York. Although the Cop 2 Cop program was initiated as a crisis intervention hotline, the legislature which established the program also identified facilitating Critical Incident Stress Management services for New Jersey law enforcement and their families as needed to be within the scope of function. This paper describes the Cop 2 Cop program interventions with the Port Authority Police Department (PAPD) which involved service provision to over 1,200 PAPD officers and an intensified process entitled an "Acute Stress Management Reentry Program" created for over 200 officers with unprecedented exposure to traumatic events.

<https://pubmed.ncbi.nlm.nih.gov/14730762/>



This high resolution image can be zoomed several times

Review • Radiology

doi: 10.1148/radiol.2371040585 • August 2005

**Facing the new threats of terrorism:
radiologists' perspectives based on experience in Israel**

Jacob Sosna, et al.

Abstract

On September 11, 2001, the world changed. The vicious giant of terrorism that was dormant until that date had arisen. After the horrific mass-casualty terror attack on the United States, any and all forms of assault seem possible. Owing to the complexity of injuries encountered in terror attack victims, fast and accurate imaging plays an essential role in triage and identification of abnormalities associated with injuries. The radiologist becomes a crucial part of the first-line team of doctors treating these patients. Knowledge that the best available treatment is given to terror attack victims can enhance the strength and endurance of society against terror. On the basis of the authors' experience with terror events in Israel, the steps involved in imaging of terror attack patients include conventional radiography, focused abdominal sonography in trauma, computed tomography, and angiography, with the judicious use of supplemental imaging.

<https://pubmed.ncbi.nlm.nih.gov/16100082/>

Review • J Nerv Ment Dis

doi: 10.1097/NMD.0b013e318225ee90 • August 2011

Psychiatry and terrorism

Frederick J Stoddard Jr., et al.

Abstract

Terrorism has dominated the domestic and international landscape since 9/11. Like other fields, psychiatry was not well prepared. With the 10th anniversary of the 9/11 attack approaching, it is timely to consider what can be done to prepare before the next event. Much has been learned to provide knowledge and resources. The roles of psychiatrists are challenged by what is known of the causes of, consequences of, and responses to terrorism. Reflecting on knowledge from before and since 9/11 introduces concepts, how individuals become terrorists, how to evaluate the psychiatric and behavioral effects of terrorism, and how to expand treatments, behavioral health interventions, public policy initiatives, and other responses for its victims. New research, clinical approaches, and policy perspectives inform strategies to reduce fear and cope with the aftermath. This article identifies the psychiatric training, skills and services, and ethical considerations necessary to prevent or reduce terrorism and its tragic consequences and to enhance resilience.

<https://pubmed.ncbi.nlm.nih.gov/21814075/>

**Terror-related injuries:
a comparison of gunshot wounds
versus secondary-fragments-induced injuries
from explosives**

Nadav Sheffy, et al.

Abstract

Background: Terror-related injuries caused by secondary fragments (SF) from explosive devices show a distinctive pattern in severity, distribution, outcomes of assault, and health-system resource use as compared with terror-related penetrating injuries caused by gunshot wounds.

Study design: A case-comparison study conducted in a tertiary university hospital and the only Level I trauma center in the Jerusalem vicinity. During a period of 4 years, over 1,500 casualties of terror-related injuries were treated in one Level I trauma center.

The study included 533 patients who were admitted for hospitalization.

Excluded from the study were victims who were dead on arrival or who succumbed to their injuries within 30 minutes of arrival at the emergency department.

Data were collected from trauma registry records.

Results: Gunshot-wound victims were mostly men, aged 19 to 30, and SF victims were more evenly distributed between the genders and across the age spectrum. Injury Severity Score (ISS) was considerably higher in SF victims, although critical mortality rates were higher in gunshot-wound victims.

More than 40% of SF victims were injured in three or more body regions, as opposed to < 10% in gunshot-wound victims. Use of imaging modalities and ICUs was considerably higher for SF victims.

Conclusions: Terror victims suffering from SF wounds have more complex, widespread, and severe injuries than victims suffering from gunshot wounds.

They tend to involve multiple body regions and use more in-hospital resources.

Attenuation of bus seats and protective vests can lead to a reduction in severity of these injuries.

<https://pubmed.ncbi.nlm.nih.gov/16931301/>

The role of radiology in terror injuries

Dorith Shaham, et al.

Abstract

Although one might think that nothing could be further apart than “terror” and “medicine,” in reality, medicine is intimately involved in the rescuing of those who are injured in terrorist attacks and in identifying and determining the cause of death in those who do not survive. Radiology has an important role in the workup of trauma patients in general, and in patients injured during the course of a terrorist attack in particular. Radiologic examinations determine the location and severity of injuries and are used to follow injured patients, particularly when complications occur. Conventional X-rays and CT scans are useful to detect the presence of foreign bodies, such as bullets, shrapnel and nails, which are often combined with the explosive charge in suicide bombings. Both can also be used for postmortem examinations. Although biologic, chemical and radiologic warfare constitute a real threat for the future, it is essential that we be familiar with the more “conventional” forms of terror that we face today.

<https://pubmed.ncbi.nlm.nih.gov/12120475/>

Crisis

doi: 10.1027/0227-5910.25.1.27 • 2004

Grace and Compassion at “Ground Zero,” New York City

By James R Rogers and Karen M Soyka

Abstract

Responding to the request to write about our work at “ground zero” the site of the former World Trade Center in New York City following the September 11, 2001, terrorist attack has proved to be a challenging task. Challenging in that we have found it difficult to discuss and honor our experiences with mere words alone. Thus, this work has been “in progress” for a long period of time. Part of the challenge is reflected for us in the title of the article by the choice of the word “grace.” That is, writing about grace at ground zero does not fit comfortably with our scientist-practitioner training. In searching for words to describe our experiences, however, we tried out a number of alternatives to “grace” including luck, chance, coincidence, and serendipity. None of these alternatives quite captured our experiences and our sense that certain events may best be conceptualized as unsolicited “gifts” that facilitated our work at the WTC site. So while the term “grace” may seem out of place in the scientific and professional literature, it fits well as a descriptor of some of our experiences as we continue our struggle to understand.

<https://pubmed.ncbi.nlm.nih.gov/15384654/>

**The radiological management
of bomb blast injury**

S S Hare, et al.

Abstract

A need to understand the nature and patterns of bomb blast injury, particularly in confined spaces, has come to the fore with the current worldwide threat from terrorism.

The purpose of this review article is to familiarize the radiologist with the imaging they might expect to see in a mass casualty terrorist event, illustrated by examples from two of the main institutions receiving patients from the London Underground tube blasts of 7 July 2005.

We present examples of injuries that are typical in blast victims, as well as highlighting some blast sequelae that might also be found in other causes of multiple trauma.

This should enable the radiologist to seek out typical injuries, including those that may not be initially clinically apparent.

Terror-related injuries are often more severe than those seen in other trauma cases, and multi-system trauma at distant anatomical sites should be anticipated.

We highlight the value of using a standardized imaging protocol to find clinically undetected traumatic effects and include a discussion on management of multiple human and non-human flying fragments.

This review also discusses the role of radiology in the management and planning for a mass casualty terrorist incident and the optimal deployment of radiographic services during such an event.

<https://pubmed.ncbi.nlm.nih.gov/17145257/>

Assessment of acute injuries, exposure to environmental toxins, and five-year health surveillance of New York Police Department working dogs following the September 11, 2001, World Trade Center terrorist attack

By Philip R Fox, Birgit Puschner and Joseph G Ebel

Abstract

Objective: To determine deployment logistics of New York Police Department (NYPD) working dogs that assisted in relief efforts at the World Trade Center (WTC) site following the September 11, 2001, terrorist attack; establish types and rates of related acute injuries and illnesses; identify environmental toxin exposures; and determine long-term (ie, 5-year) health effects of deployment.

Design: Prospective cohort study.

Animals: 27 working dogs.

Procedures: Deployment logistics for the period from September 11, 2001, through May 30, 2002, were determined, and acute health disorders were identified by means of physical examination; a questionnaire; interviews with dog handlers; and toxicologic (blood and hair samples), clinicopathologic, microbiologic (nasal swab specimens submitted for *Bacillus anthracis* culture), and radiographic methods. Long-term health surveillance ended September 21, 2006.

Results: Dogs worked a total of 1,428 days (15,148 hours) at the site. Seventeen of the 27 (62.9%) dogs had health disorders during the first week. Specific conditions included fatigue (incidence rate [events/1,000 active deployment hours], 13.1), conjunctival irritation (13.1), respiratory tract problems (12.4), decreased appetite (10.8), dehydration (10), and cuts (9.3). Only minor hematologic and serum biochemical abnormalities were identified. Bacterial culture of nasal swab specimens did not yield *B anthracis*. Only mild and infrequent health conditions were identified during the 5-year follow-up period. None of the dogs were identified as having chronic respiratory tract disease. Six dogs died of various causes.

Conclusions and clinical relevance: Results suggested that acute injuries and illnesses were common among NYPD working dogs deployed to the WTC disaster site, but that longterm health complications were minimal.

<https://pubmed.ncbi.nlm.nih.gov/18593312/>

J Pastoral Care Counsel

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**Correlates of compassion fatigue and burnout
in chaplains and other clergy
who responded to the September 11th attacks
in New York City**

By Kevin J Flannelly,
Stephen B Roberts and Andrew J Weaver

Abstract

Participants at a June 2002 conference about the September 11th attacks were tested for compassion fatigue, compassion satisfaction, and burnout.

The sample consisted of 343 clergy, including 97 chaplains. A total of 149 (43.4%) of the participants had responded as disaster-relief workers following the September 11th attacks.

The number of hours clergy worked with trauma victims each week was directly related to compassion fatigue among responders and non-responders.

Compassion fatigue also was positively related to the number of days that responders worked at Ground Zero, while disaster-relief work with the American Red Cross reduced compassion fatigue and burnout.

Clinical Pastoral Education tended to decrease compassion fatigue and burnout and increase compassion satisfaction in both responders and non-responders.

Burnout was inversely related to age in both groups.

<https://pubmed.ncbi.nlm.nih.gov/16281795/>

**Compassion fatigue and burnout
among Rabbis working as chaplains**

By Bonita E Taylor, Kevin J Flannelly,
Andrew J Weaver and David J Zucker

Abstract

Compassion Fatigue, Compassion Satisfaction, and Burnout were studied in a convenience sample of 66 male and female Rabbis who work as chaplains and attended the annual conference of the National Association of Jewish Chaplains (NAJC) in 2002.

Although Compassion Fatigue and Burnout were low among the survey participants, both measures were significantly higher among the women in the sample.

Compassion Fatigue was also higher among chaplains who were divorced, and it increased with the number of hours per week the chaplains spent working with trauma victims or their families ($r = .25, p < .05$).

Hierarchical multiple regression was performed to determine the influence of six professional and five personal variables on each of the three dependent variables.

Four professional variables accounted for 19.5% of the variation and three personal variables accounted for 20.3% of the variation in Compassion Fatigue.

Attempts to predict Burnout and Compassion Satisfaction were far less successful. Burnout was predicted by only two variables (i.e. age and years as a Rabbi), which accounted for just 18.4% of the variance in Burnout scores.

Age was the only variable found to have a significant effect on Compassion Satisfaction, and its effect was positive. The implications of the findings are discussed.

<https://pubmed.ncbi.nlm.nih.gov/16733948/>

Factors that influence the development of compassion fatigue, burnout, and compassion satisfaction in emergency department nurses

Stacie Hunsaker, Hsiu-Chin Chen, Dale Maughan and Sondra Heaston

Abstract

Purpose: The purpose of this study was twofold: (a) to determine the prevalence of compassion satisfaction, compassion fatigue, and burnout in emergency department nurses throughout the United States and (b) to examine which demographic and work-related components affect the development of compassion satisfaction, compassion fatigue, and burnout in this nursing specialty.

Design and methods: This was a nonexperimental, descriptive, and predictive study using a self-administered survey. Survey packets including a demographic questionnaire and the Professional Quality of Life Scale version 5 (ProQOL 5) were mailed to 1,000 selected emergency nurses throughout the United States. The ProQOL 5 scale was used to measure the prevalence of compassion satisfaction, compassion fatigue, and burnout among emergency department nurses. Multiple regression using stepwise solution was employed to determine which variables of demographics and work-related characteristics predicted the prevalence of compassion satisfaction, compassion fatigue, and burnout. The α level was set at .05 for statistical significance. Findings:

The results revealed overall low to average levels of compassion fatigue and burnout and generally average to high levels of compassion satisfaction among this group of emergency department nurses. The low level of manager support was a significant predictor of higher levels of burnout and compassion fatigue among emergency department nurses, while a high level of manager support contributed to a higher level of compassion satisfaction.

Conclusions: The results may serve to help distinguish elements in emergency department nurses' work and life that are related to compassion satisfaction and may identify factors associated with higher levels of compassion fatigue and burnout.

Clinical relevance: Improving recognition and awareness of compassion satisfaction, compassion fatigue, and burnout among emergency department nurses may prevent emotional exhaustion and help identify interventions that will help nurses remain empathetic and compassionate professionals.

<https://pubmed.ncbi.nlm.nih.gov/25644276/>

**Helping at Ground Zero:
the experience of four Canadian emergency medicine residents
and an emergency department nurse**

By Anna-Maria Carvalho, Marie-Elaine Delvin, Carolyn Rosenczweig,
Sujit Sivarman and Raghu Venugopal

Abstract

On September 11th, 2001, the world witnessed one of the worst, and unprecedented, terrorist attacks in human history on the World Trade Center's twin towers in New York City and on the Pentagon in Washington, DC. As an unofficial contingent of 4 Canadian emergency medicine (EM) residents and an emergency department (ED) nurse, we joined US medical personnel to offer assistance during the rescue phase of the disaster in New York City.

What follows is a summary of our experiences and a discussion of some of the lessons we learned.

On September 11th we were performing our respective clinical duties at the various institutions of the McGill University Health Centre (MUHC) in Montreal, Que. Each of us learned almost immediately of the tragedies occurring in Pennsylvania, Washington, DC, and New York City. Initially, no contact was made with each other yet it was clear to all that this was definitely a "disaster" — a natural or human-caused event causing intense negative impacts on people, goods, services and/or the environment, exceeding the affected community's capability to respond.

All MUHC-affiliated institutions were placed on Level II Code Orange (external disaster) alert. Wards and EDs in Montreal were cleared of all but the most urgent cases. In addition to being active in these operations, from 1000 to 1700 (local time) our group attempted to seek clarification from our clinical service chiefs and residency director about the possibility of taking part in any emergency medical response efforts in the United States.

By 2200 on September 11th, after telephone consultations with emergency physicians from across the country, it was becoming evident that few, if any, patients would be transferred to Canada. telephone consultations with physicians in Baltimore and New York could not provide further clarification regarding the need for additional medical assistance in the US. Television news from New York City repeatedly requested medical aid of any level, though the contact numbers given were unavailable throughout the course of the evening. Given the relative paucity of information, after a brief group meeting, we decided to assemble whatever medical supplies we could, and begin traveling toward New York City to assess the situation further.

<https://pubmed.ncbi.nlm.nih.gov/17612432/>

Walking humbly. Minnesota's DMORT team members remember 9-11

Daniel E Rose and John M Williams

No Abstract Available, No Article Available

(WBIR - KNOXVILLE) Two major national disasters are marked within a few weeks of each other: Hurricane Katrina and the Sept. 11 terror attacks.

It's been 10 years since the massive storm ripped through the Gulf Coast, and almost 14 years since the terrorist attacks on the World Trade Center and Pentagon and the hijacking and crash of a fourth U.S. passenger airliner. For two East Tennessee men who worked as Disaster Mortuary Operational Response Team (DMORT) members, memories of each tragedy are still extremely vivid.

"Some things you can't overcome," Steve Tinder said. "It doesn't matter how strong you are, and I don't think you're expected to. You deal with it the best you can, and you pray that the Lord will get you through this." Tinder met Art Bohanan in 1975. They've acted as a team ever since.

"I think to most of us it's a special calling, and that's what we're there for," Bohanan said. "To help in the worst situation ever possible." Together, the two have served a total of more than 80 years in law enforcement. Bohanan's long law enforcement career included 26 years with the Knoxville Police Department, and Tinder for 33 years. Bohanan is most known for his invention of a technique to lift fingerprints using Super Glue. His technique is used to solve crimes around the world. They've been deployed to more than a dozen disaster zones together, including responding to Hurricane Katrina and the Sept. 11 attacks.

"The first three weeks we processed bodies that had drowned and then the second three weeks, we processed caskets that had floated out, over a thousand caskets that had floated out," Bohanan said. "We opened those caskets to look for identifications so their families can get the bodies back." Tinder said it's impossible to forget those who were affected by each disaster.

"You think, Well, seeing the remains of what we do in forensics... we've done it for so many years, it's natural," Tinder said. "But when it comes to the families ... That got me emotionally." Both of them had a loss for words when it came to 9/11.

"To this day, I can't explain what I felt," Tinder said. "It was unbelievable. We just saw it two days ago on TV and didn't believe it. Now we're here. We're looking at it. We're seeing this firsthand, and we really can't believe it now. You almost had to touch the ground to realize you were there."

"My first time was at night, walking around in the rubble, and I (saw) a huge red crane slowly

going over the rubble trying to find anyone that was living," Bohanan said. "It was just – I can't explain what I seen and felt at that time because we knew thousands were dead there." They said their DMORT team is the best way to cope with each following year.

"Stay focused, lean on each other," Bohanan said. "We're there to help the living not the dead."

<https://pubmed.ncbi.nlm.nih.gov/12418169/>

Article Link:

<https://www.freep.com/story/news/2015/09/02/disaster-responders-remember-hurricane-katrina-9-11/71624804/>

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**Air levels of carcinogenic polycyclic aromatic hydrocarbons
after the World Trade Center disaster**

Joachim D Pleil, et al.

Abstract

The catastrophic collapse of the World Trade Center (WTC) on September 11, 2001, created an immense dust cloud followed by fires that emitted soot into the air of New York City (NYC) well into December. The subsequent cleanup used diesel equipment that further polluted the air until the following June. The particulate air pollutants contained mutagenic and carcinogenic polycyclic aromatic hydrocarbons (PAHs). By using an assay developed for archived samples of fine particles, we measured nine PAHs in 243 samples collected at or near Ground Zero from September 23, 2001, to March 27, 2002. Based on temporal trends of individual PAH levels, we differentiated between fire and diesel sources and predicted PAH levels between 3 and 200 d after the disaster. Predicted PAH air concentrations on September 14, 2001, ranged from 1.3 to 15 ng/m³; these values are among the highest reported from outdoor sources. We infer that these high initial air concentrations resulted from fires that rapidly diminished over 100 d. Diesel sources predominated for the next 100 d, during which time PAH levels declined slowly to background values. Because elevated PAH levels were transient, any elevation in cancer risk from PAH exposure should be very small among nonoccupationally exposed residents of NYC. However, the high initial levels of PAHs may be associated with reproductive effects observed in the offspring of women who were (or became) pregnant shortly after September 11, 2001. Because no PAH-specific air sampling was conducted, this work provides the only systematic measurements, to our knowledge, of ambient PAHs after the WTC disaster.

<https://pubmed.ncbi.nlm.nih.gov/15280534/>

**Summary of Evidence For Establishing Dates
on which Cleanup of the Pentagon and Shanksville, Pennsylvania Sites
of the Terrorist-Related Aircraft Crashes of September 11, 2001 Concluded**

Prepared for the Administrator, World Trade Center Health Program by:
Robert E. McCleery, MSPH, CIH

Executive Summary

Section 3311(C)(i)(I) and (II) of the James Zadroga 9/11 Health and Compensation Act of 2010 (Zadroga Act) requires the Administrator of the World Trade Center Health Program (WTCHP) to determine dates of eligibility for enrollment in the World Trade Center Health Program for individuals who were members of a fire or police department (whether fire or emergency personnel, active or retired), worked for a recovery or cleanup contractor, or were a volunteer; and performed rescue, recovery, demolition, debris cleanup, or other related services at the Pentagon in Arlington, Virginia or the Shanksville, Pennsylvania, sites of the terrorist-related aircraft crashes of September 11, 2001. Specifically, the Zadroga Act requires the Administrator to determine the dates on which cleanup of the Pentagon and Shanksville sites of the terrorist-related aircraft crashes of September 11, 2001, concluded.

To develop information and evidence of the concluding dates for cleanup activities at these two sites, an extensive literature search was conducted, requests for information were sent and conference calls were held with response participants (e.g., fire departments; Somerset County; Pennsylvania coroner; Pentagon Renovation Program; U.S. National Park Service; United Airlines; and others), and a face-to-face meeting was held with local volunteer fire departments in and around Shanksville. In addition, available informational documents (e.g., Arlington County after-action report, Department of Defense [DOD] Historical Office book, journal articles, and individual accounts of events) were reviewed.

Pentagon Site

Beginning on September 11, 2001 the Arlington County Fire Department (ACFD) led the fire and rescue phase of the Pentagon response. On September 21, 2001, the ACFD relinquished control of the site to the Federal Bureau of Investigation (FBI), and the site was officially designated a crime scene. At that time, one fire fighter company, a technical rescue team, and paramedics remained at the site until the site was turned over to DOD. The FBI continued their crime scene investigation until transferring control of the site to Washington Headquarters Services (a DOD Field Activity). Differing accounts of the date of the transfer place it on either September 26, 2001, or September 28, 2001.

On October 2, the Pentagon Renovation Program (a Washington Headquarters Services office) controlled the site and began preparations for demolition and cleanup of the impact area. However, these activities were delayed until after October 11, 2001, when the first memorial service

for the victims of the attack was held. The demolition/cleanup phase of the project began on October 18, 2001, and was completed on November 19, 2001. Cleanup activities began on September 12, 2001 with a contractor cleaning soot, smoke, and water-soaked materials from inhabitable areas of the Pentagon in preparation for returning employees. Numerous law enforcement agencies responded to the Pentagon in support of the Arlington County Police Department, the Pentagon Defense Protective Service (federal law enforcement personnel whose jurisdiction includes the Pentagon), and the FBI. Response activities included rescue efforts, site security, traffic control, and evidence collection. The contribution of volunteers to the Pentagon response cannot be captured in its entirety, as thorough records are not available. The American Red Cross was a major contributor and many other volunteers played a role throughout the response.

A number of different groups conducted pre- and post-cleanup environmental sampling. Employees began to return to work on September 12, 2001; therefore, the sampling focused on their work areas. Most of the samples collected were area samples; however, some personal sampling was conducted. Much of the data from these sampling efforts are documented in a report from the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). This report's conclusions suggest that contamination was concentrated at the incident site and most of the environmental samples collected, especially post-cleanup, were below occupational health or environmental standards.

Most of the fire department personnel left the site after it was turned over to the FBI on September 21, 2001, except for the one fire fighter company, a technical rescue team, and paramedics. Fire department presence continued at the Pentagon until the site was turned over to DOD on September 26, 2001, or September 28, 2001. The available information does not indicate what period of time fire department personnel were onsite from the end of September until the completion of demolition and cleanup activities on November 19, 2001.

The available literature indicates that police departments had a presence at the Pentagon until the site was turned over to DOD on September 26, 2001, or September 28, 2001. The literature suggests that after the site was turned over to DOD, many of the services typically provided by police departments were handled onsite by military police or by Defense Protective Service personnel. However, the available information does not indicate whether police department personnel were onsite from the end of September until the completion of demolition and cleanup activities on November 19, 2001.

Recovery or cleanup contractors were onsite at the Pentagon until November 19, 2001, which is the date demolition activities concluded. This information is referenced in numerous documents and the Pentagon Renovation Program.

The available information does not provide a complete listing of all volunteers onsite, or the timeframes of their participation. It is reasonable to conclude that at least some volunteers were onsite through the crime scene phase of the response, ending on September 26, 2001, or 28, 2001. However, the available information does not indicate whether volunteers were onsite during the demolition and cleanup phase of the response.

The available information has substantial uncertainties that limit the ability to determine with absolute precision specific end times for each group's activities at the site. To ensure that those who did respond are provided adequate opportunity for medical monitoring and treatment benefits, WTCHP eligibility is recommended for the period covering September 11, 2001 through November 19, 2001 for individuals who worked for a fire department, a police department, or a recovery or cleanup contractor, or were a volunteer, and performed rescue, recovery, demolition, debris cleanup, or other related services at the Pentagon site of the terrorist-related aircraft crash of September 11, 2001. Pentagon Site Concluding Date: November 19, 2001.

Shanksville Site

Beginning on September 11, 2001, the FBI controlled the site and declared it a crime scene. After 13 days of work on-site, the FBI relinquished control of the site to the Somerset County Coroner on September 24, 2001.

The nature of the site did not require a fire and rescue response phase although fire and police departments were among the first to respond by extinguishing localized hot spots and brush fires while Pennsylvania State Troopers provided security.

During the last weekend of September 2001, the Somerset County coroner enlisted the assistance of approximately 300 personnel (volunteers, fire fighters, police, and the Pennsylvania Region 13 Counter-terrorism Task Force [task force of 13 counties in western Pennsylvania]), the State Funeral Directors Association, and other volunteers to conduct "Operation Clean Sweep," which involved scouring the area to pick up remaining aircraft parts and flagging any objects resembling human remains. The contribution of volunteers to the Shanksville response cannot be captured in its entirety, as thorough records are not available. The American Red Cross was a contributor, and many other volunteers played a role throughout the response.

After the response to the crash was completed, United Airlines contracted Environmental Resources Management, Inc. (ERM) to reclaim the site. Site characterization for potential aircraft-related contaminants was conducted according to Pennsylvania environmental law. ERM concluded that surface soils, subsurface soils, and ground water beneath the site did not exceed any state health standards and did not require any remediation. Additionally, none of the surface water results indicated any contamination that could be attributed to the Flight 93 v | Evidence of Dates Cleanup Concluded at the Pentagon and Shanksville, Pennsylvania

crash. ERM backfilled the crater between October 1, 2001, and October 3, 2001. The site was restored as close as possible to its original appearance; 4–6 inches of topsoil was added on top of the crater and through the forest area, and the area was seeded with flowers and grasses. ERM continued monitoring ground water until mid-2002.

The Somerset County coroner indicated that in the years following the response, the Pennsylvania National Guard and Camp Cadet (camp for youth operated by the Pennsylvania State Police) had been out to the site to collect aircraft parts.

Most of the fire and police department personnel and volunteers left the site after the FBI turned the site over to the Somerset County coroner on September 24, 2001. However, fire and police department and volunteer presence was limited at the Shanksville site until the conclusion of the final sweep of the crash site for aircraft parts and potential human remains on September 29–30, 2001. Available information suggests that law enforcement personnel remained at the site to provide security for a number of years. The available information does not indicate whether fire department personnel or volunteers were onsite during the site restoration activities from October 1–3, 2001.

Available information indicates that environmental restoration contractors restored the site close to its original appearance from October 1–3, 2001, signaling the conclusion of the response.

The available information has substantial uncertainties that limit the ability to determine with absolute precision specific end times for each group's activities at the site. To ensure that those who did respond are provided adequate opportunity for medical monitoring and treatment benefits, WTCHP eligibility is recommended for the period covering September 11, 2001 to October 3, 2001 for individuals who worked for a fire department, police department, or a recovery or cleanup contractor, or were a volunteer, and performed rescue, recovery, demolition, debris cleanup, or other related services at the Shanksville site of the terrorist-related aircraft crash of September 11, 2001. Shanksville, Pennsylvania Site Concluding Date: October 3, 2001

Link to CDC PDF:

<https://www.cdc.gov/niosh/docket/archive/pdfs/NIOSH-248/0248-041312-ShanksvilleResponse.pdf>

Review • Crit Care

doi: 10.1186/cc1056 • December 2001

**The World Trade Center attack.
Observations from New York's Bellevue Hospital.**

By J D Roccaforte

Abstract

This report describes selected aspects of the response by Bellevue Hospital Center to the World Trade Center attack of 11 September 2001. The hospital is 2.5 miles (4 km) from the site of the attack. These first-hand observations and this analysis may aid in future preparations. Key issues described relate to communication, organization, injuries treated, staffing, and logistics.

<https://pubmed.ncbi.nlm.nih.gov/11737913/>

Newsweek • October 14, 2001

Dedicated to Bill Biggart
who was killed taking photographs on September 11th, 2001
and whose last photos survived

**After the attack: horror and heroes.
Ground Zero: Shooting To The End**

By J Adler

Bill Biggart walked two miles from his apartment near Union Square to reach Ground Zero on the morning of the attack, taking pictures along the way, and he went about 100 feet too far.

Other photographers were almost as close to the Twin Towers that morning, but Biggart--who disdained the telephoto lens as a device best suited to taking pictures of Jennifer Lopez sunbathing--felt the need to get closer than any of them. As a photojournalist Biggart was drawn to conflict, but the best pictures he brought back were of faces--grinning Israeli soldiers and exuberant Palestinian youths, shot from so close that his wife, Wendy Doremus, didn't dare ask for details of his trips until he was safely back in New York. And from the site of the most recent horror, which struck almost with-in sight of his windows, he would have brought back faces, too, if he had returned himself. Instead, the 300-odd photographs he took that morning with his three cameras--two film, one digital--were buried along with him in the rubble of the second tower's collapse, and dug out four days later, along with his body. He was the only professional photographer who died covering the disaster.

This time, Doremus knew where he was, because he'd said goodbye and headed out the door soon after the first plane hit. Judging from what he shot along the way, he must have walked down Fifth Avenue, through Greenwich Village and then to West Street, along the river, where the fire trucks were. Most of the other photographers appear to have come down Broadway and approached the Twin Towers from the east. A few minutes after he left, Doremus, with a mixture of curiosity and anxiety, grabbed her Instamatic and headed downtown herself through a sea of pedestrians streaming in the other direction. She was within a few blocks of Ground Zero when the first tower collapsed. She called him on his cell phone.

"Bill," she said, "this is an attack. One of the towers collapsed and the Pentagon's been hit." He told her he would meet her in 20 minutes at his studio, a safe distance away. "I'm OK," he reassured her. "I'm with the firemen."

Of course, everyone knows what happened to the firemen. Doremus was heading back uptown toward the studio when she heard a boom; she turned around just in time to make a snapshot of the second tower as its million tons of concrete and steel collapsed above her husband's head. No one who knew Biggart was surprised that he stayed to make a few more shots. "My dad was always saying he'd be home in 20 minutes," says his oldest child, Bill Jr., 31. Still, in the weeks since, the family couldn't help thinking about how things would have been different if Biggart

had kept his word and left when he'd promised to. It's an easy question, says Bill Jr. "For the rest of his life, he would have been bitching about how we made him miss the photo of the second tower falling."

Biggart had attitude, but it served him well enough in life. "We got all these cards," says Bill Jr.'s wife, Veronica, "and the ones that talked about what a sweet, lovable guy he was were all from people who didn't know him very well." He was a cocksure, streetwise Irish-Catholic kid in a family of 12 kids, at ease among cops and firemen and soldiers and the boyos of the Belfast slums. His strength was in loyalty to his family and his convictions. He'd raised Billy himself from infancy after his first wife, a model, went out for a pack of cigarettes and forgot to come home--even though for years, until he met Doremus, it locked him into the predictable routine of commercial studio work, taking pictures of pouting women in fur coats while, in the world outside, men heroically fought and died. It would be 1985 before he earned a working-press card, allowing him to follow in the footsteps of his hero, Mathew Brady, whose press card was signed by Abraham Lincoln. War held for him the allure of the horrible; Biggart was the despair of his father, a conservative Army officer and businessman who had come to the agonizing conclusion that his peace-loving son was a commie. His passion was for gardening; he planted trees on the grubby street outside his studio for the edification of the transvestite hookers who inhabited this gentrification-proof neighborhood.

For almost his whole life, Biggart had been afraid of fire, ever since his house burned down when he was 3, killing a younger brother and sister. But he was drawn to fires, too, to burning tanks in the Middle East, bonfires in Northern Ireland, kitchen fires in the tenements of New York City. For more than a decade he was a mainstay of Impact Visuals, an independent agency that (until it folded earlier this year) provided photos to New York's alternative weekly papers.

Many people died painfully in the flames of the burning towers that morning, but on the street, where Biggart was, death came with a swift and mercifully obliterating blow to the head. After waiting for him a few hours at the studio, unable to raise him on his cell phone, Doremus had returned home to be with their 16-year-old daughter, Kate, who was preparing to leave for a year-abroad program in Spain. Their son, Peter, 14, was in his first day of eighth grade and returned later that day. The next morning, Bill's friend Chip East arose early and went down to the west bank of the Hudson River to take a picture of the sun rising over the new skyline of lower Manhattan. Then he headed for a trauma center where the families of the missing were gathering, and he heard someone call his name. It was Doremus.

"Have you heard from Bill?" she asked breathlessly. Like every photojournalist, East has been to disasters of every kind and scale, from motorcycle accidents to plane crashes, but he had never been touched by one directly before.

"My God," he thought, "how will I take a picture now?" Then a woman saw his camera and came toward him, holding a photograph of her missing son. She was crying. Reflexively, he brought his camera up and began snapping pictures through his own tears.

Like thousands of others, Doremus made the grim rounds of trauma centers and hospitals for

the next four days, until with mingled dread and relief she got the call on Saturday to come to the medical examiner's office. Biggart's death, she thinks, has been hardest on Peter, who shared with his father a passion for the Yankees. The team is in the playoffs again this year, and for the first time Bill won't be there to listen to the games with his son. Kate and Doremus have made a small game out of imagining where Bill really has been the last three weeks. On an aircraft carrier. No, in Pakistan. Maybe Afghanistan, even--the only American photographer to get a picture of Osama bin Laden. No wonder he hasn't called.

After four days, Biggart's body was pulled from the rubble, and identified by his fingerprints. The medical examiner told Doremus it was not suitable for viewing. But his clothes were all recovered, and all his belongings, down to the \$26 in his wallet; the only sign that he'd been at the scene of one of the world's great conflagrations was a burned edge on his press card. As for his equipment, the three camera bodies were mostly intact, although the lenses had been smashed or sheared off, and the backs had blown off the two film cameras, destroying whatever images might have been in them at the end. But seven rolls of exposed film had been recovered, and the microdisk was still in the back of his digital camera.

Doremus left it all untouched until East returned from his own postdisaster assignment, shooting American soldiers preparing for battle at Fort Bragg. Not knowing what to expect, East popped the disk from Biggart's camera into his computer and on the second try got an image, then more--154 in all, perfectly preserved, in sequence from the moment he glimpsed the towers in the distance until... well, the last of them was time-stamped 9:28 a.m., but Biggart had evidently neglected to correct the camera's clock for daylight saving time, so it was actually an hour later, more or less the precise time of the second collapse. Looking at the hellish landscape, the stump of the South Tower barely emerging from its shroud of smoke and dust, East realized he was seeing what his friend had seen in his last moments on earth.

As always, Biggart had concentrated on faces; his gift was for street portraiture, even at disasters. In the tens of thousands of photographs he left behind in his studio there are no moody landscapes, cute babies or scowling celebrities pretending to hate having their picture taken. (Almost none: he once came upon New York's accidental vigilante Bernhard Goetz reading a newspaper in the subway and started clicking away; when a bystander urged him to leave he growled back, "When you shoot four kids on the subway you give up your right to privacy.")

Biggart would go into battle with a 35mm lens, ideal for close-ups, while everyone around him was shooting with telephotos. "One thing he always taught me," says Tom McKitterick, a colleague from Impact Visuals, "was that sometimes the picture is behind you, in the faces of the people watching." As disaster unfolded all around him, Biggart pointed his camera at a lone fireman, his yellow stripes bright against a background of opaque ash, kicking up dust as he trudged closer; he saw a man in what was left of a business suit, holding his necktie in one hand, his shirt unaccountably unbuttoned, filthy on one side but clean where it had lain against his skin; another man covered in gray soot except for two circles around his eyes--he looks down at the ground as if searching for his vanished eyeglasses.

And what can you learn from these pictures? About Biggart, that up until the end he was doing

his job: "He was on his game, he was following the picture, he was framing his shots," says East. About the unfolding catastrophe itself, that in the last minutes there was no panic, no chaos, no fear of imminent death. "The faces of the firemen were serene--exhausted, but serene and focused," says McKitterick. A great deal of honor has been heaped, deservedly, on the heroes who rushed to the World Trade Center that morning to rescue lives. In his own way--a way any journalist can understand--Biggart was a hero as well. He rescued faces.

<https://www.newsweek.com/shooting-end-154369>

Am J Psychiatry

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**A peer-based assistance program
for officers with the New York City Police Department:
report of the effects of Sept. 11, 2001**

By Frank G Dowling, Gene Moynihan, Bill Genet and Jonathan Lewis

Abstract

Few data on stress symptoms related to the World Trade Center disaster in law enforcement personnel have been reported. Most New York City Police Department (NYPD) officers had significant exposure to the events of Sept. 11, 2001.

Approximately 5,000 officers responded within the first 2 days, and more than 25,000 officers worked at ground zero, the morgues, or the Staten Island landfill.

Because the police are the first line of defense against terrorist attacks, it is imperative that they maintain optimal health and functioning. Concern for the long-term effects from traumatic exposure is warranted. In partnership with Project Liberty, peer officers and clinicians from the Police Organization Providing Peer Assistance performed outreach, support work, and screening for stress symptoms related to the disaster in the NYPD from December 2002 until December 2003.

Psychological issues in law enforcement personnel, a description of the outreach program, and data from these screenings are presented.

<https://pubmed.ncbi.nlm.nih.gov/16390904/>

Eight Blocks Away: Memoirs of September 11, 2001

By the New York Law School Community

Reflections — Then and Now

Excerpt

By Richard A. Matasar

Rereading the reflections in *Eight Blocks Away* has brought back many memories — bad and good. There was confusion, deep depression, worry, fear, anger, and uncertainty. There was also love, dedication, perseverance, sharing, and optimism in the face of challenges. For many, 9/11 was the worst day of their lives, indelibly tattooed as a marker of the loss of innocence.

For others it marked a day to plot retaliation, hope for revenge, and strike out at enemies within and without. For most, it brought them to colleagues and friends to share mutual support. It allowed healing of fractured parts of our lives, giving back, reaching out to others, and moving forward with renewed purpose.

Looking back at my own words, I cannot remember writing, but I can remember feeling — sometimes alone, always challenged to act stronger than I felt and more cheerful than I wanted to be — conscious that in bad times, the Dean must be CEO, comforting parent, counselor, strategist, and even clergyman. Before 9/11, I worked at New York Law School. After 9/11, I embraced New York Law School as my home and saw our community as my family. These events remade me and our School.

In the fall of 2001, I met frequently with students who wanted to drop out of law school — some to go home to be with their families, some who wanted to be anywhere but in our neighborhood (or war zone as they called it), some who were fearful, some who saw it as a chance to leverage their way into higher ranked schools, and some who simply could not cope. But when the dust settled, when faculty began teaching again, when “normalcy” returned — so too did our students. Why?

Perhaps it was because this tragedy brought out the best in all of us. It turned our commuter school into a community. It took us away from our selfish pursuits and led us to focus on the needs of others — the legal needs of our neighbors who lost so much, the spiritual needs of those far from home, the intellectual needs of students seeking to understand how to deal with lawlessness, and the simple need to be close to those who comfort us and to provide comfort to those who need us.

My father died of a stroke in October of 2001. I felt I failed to grieve his loss properly because I needed to be at the law school and to be strong for others. Now, some ten years later, I under-

stood that I poured all of my grief into work — redoubling my efforts to make others feel better, making sure that their needs were met, assuring our students, faculty, staff, and graduates that everything would be ok. I realize now that those were qualities I did not know I had — qualities my father gave to me by being the wonderful man he was and the silent and strong leader of his organization. Through our city's tragedy, I implicitly tried to emulate my dad. Perhaps his death passed to me his strength.

Now, ten years later, what of the fears we had? Our country blindly went to multiple wars that continue to this day. Governmental lawyers ran roughshod over the Constitution and liberties built over centuries. But they were rebuked by a Supreme Court made up of strong believers in Executive power, who simply could not condone usurpation of our traditions. We returned to a system of laws. We somehow held off further attacks. Wow!

Ten years later, we have learned that the anthrax attacks were the work of a home grown kook, that terrorist devastation could lead our neighborhood into being the most progressive and economically vibrant place in New York City, that students would return to New York in droves, that the country could elect an African-American as President, and that we could manage to screw up our economy all on our own!

What of New York Law School ten years later? After the disaster, we grew stronger, more confident, more active, more committed. We took advantage of the rebounding and resilience of TriBeCa to make a record sale of some of our property, used the proceeds to secure the financing that built a wonderful new building that will keep us as a downtown institution in perpetuity (see next page), enrolled the best students ever to attend the law school, expanded our programs in ways we could not have imagined before 9/11, grew our resources beyond our fondest dreams, and established a remarkably student-centric program. Was all this also an effect of 9/11?

I think so. The larger meaning of 9/11 for all of us here on that day was a reminder that some things are beyond our control, that evil exists in the world, and that blindly striking out rarely is a satisfactory answer to a problem. 9/11 also taught us that we must control what we can control — our programs, our treatment of each other, our talent put to use to add value, our outreach to those in need, and our mutual respect. It taught us to make the best of those things, to learn from the past, and then to look forward.

The chronicle contained in Eight Blocks Away decodes the DNA of New York Law School and all of us who work and study here. Though the events of 9/11 are now a decade behind us, their impact and the lessons that they have taught us will forever remain indelible.

Link to PDF:

https://digitalcommons.nyls.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1002&context=tribeca_square_press

The World Trade Center attack. The paramedic response: an insider's view

By L. Cook

FDNY EMS Division Two, Bronx, New York, USA

Abstract

The World Trade Center attack and collapse is the first time an aircraft has been used as a weapon of mass effect. The scale and magnitude of this manmade disaster can only be compared with a natural catastrophe such as the Armenian earthquake of December 1988. The importance of an incident command system and the Simple Triage and Rapid Treatment, and the need for fixed Casualty Collection Points, is explained.

Keywords: casualty collection, incident command, World Trade Center

Introduction

A mass casualty incident in New York City is defined as any incident that produces five or more patients with the potential need for extraordinary resources [1]. Managing a mass casualty incident begins with notifying local emergency response agencies. Whichever agency arrives first sizes up the situation and provides a preliminary situation report. This forms the basis of an Incident Command System (ICS). The accuracy of the ICS plan is crucial to the successful command and control of an incident. This discussion will outline the mass casualty incident response and the ICS plan of the World Trade Center attack through the personal experiences of the author. This article is purely from the perspective of a paramedic 'on the ground' and should not be construed as official views or policy of the City of New York Fire Department.

Incident management system and START triage

All incidents have an Incident Commander. The World Trade Center attack was primarily an aircraft crash, so the Incident Commander came from the Fire Department of New York (FDNY). As part of the ICS plan, the Incident Commander breaks down the operation into task-specific branches. The tasks include communications, logistics, setting up a morgue, safety, transportation, triage, and treatment. The idea is that each branch operates dynamically and can expand or contract as the situation escalates or de-escalates. In New York City, mass casualty triage is accomplished through the START system — Simple Triage and Rapid Treatment [2]. This method is designed to allow advanced Life Support Paramedics and Basic Life Support Emergency Medical Technicians to triage patients in 60 s or less using three observations: respiration, circulation and mental status. The goal is to identify the most life threatening problem, to correct it, to assign the patient a priority, and to move on. The patients' priority is indicated by a color-coded triage card that is tagged to them and holds the most basic information. New York City uses the MET-

TAG© triage card [3], which uses color to identify patient status: black for deceased, red for when immediate attention is needed, yellow for when attention can be delayed, and green for minor injuries. After triage, those with green tags are encouraged to assist the more severely injured (called 'buddy aid'), which helps to maximize the amount of care one paramedic can provide.

11 September 2001

When the FDNY heard an aircraft had struck the World Trade Center, my Chief and I assumed it was a small observation plane or a light aircraft that had left its authorized air corridor. That was until we turned on the local 24 hour television news station. It took less than 30 min to travel from the Bronx to lower Manhattan, despite it being the morning rush hour. The New York Police Department had done a magnificent job of clearing major roads and thoroughfares. On arrival we received orders from the Emergency Medical Services (EMS) Major Response Duty Chief to take over medical operations inside 1 World Trade Center. Inside 1 World Trade Center, the tower that had just been hit, a command station had already been set up and was staffed by the FDNY, the New York Police Department, and the Port Authority Police Department of New York and New Jersey. My Chief and myself were asked to organize a safe and, if possible, covered way out for self-evacuating civilians and to create a triage area on a floor in 1 World Trade Center below the fire. Before much could be achieved, however, the second aircraft hit Tower 2 and, as we all know, Tower 2 soon collapsed. The collapse of Tower 2 caused havoc for the command and control structure, overloaded the operations' radio frequencies, and resulted in immense loss of life among the emergency teams. It was difficult to adapt operations to the new demands; a difficulty that increased exponentially when Tower 1 collapsed. However, we rapidly re-established a temporary medical command post at one of the adjacent undamaged hotels and the operation was once again broken down into task-specific branches. This was a monumental task given the psychological impact of the event, the damage to local telephone services, and what can only be described as the 'fog of war' view at the site.

After the collapses

The EMS operations resumed literally before the dust settled. Triage and treatment teams entered the collapse zone to begin what would be a Herculean effort. To relieve the downtown hospitals from the influx of patients, two Casualty Collection Points were created to treat the throngs of self-evacuating civilians from Lower Manhattan: to the north, Chelsea Recreational Piers; and to the east, Staten Island Ferry terminal. These two Casualty Collection Points also enabled better command and control, better patient tracking, and provided improved safety for EMS responders and civilians. Within the collapse zone, patients were being transported across long and rough distances because of the dust and debris. To assist the on-scene personnel, the EMS deployed its fleet of all-terrain vehicles, which became the workhorse of the operation, running 24 hours a day. By this time we were receiving assistance from EMS units in the surrounding New York counties and New Jersey. At first, we had problems communicating with one another and tracking patients, but this was quickly overcome once we acquired compatible radio equipment and standardized our tracking mechanisms. My Chief and myself were given the task of setting up the Staten Island Ferry Casualty Collection Point. While working around the tip of lower Manhattan, we saw a flotilla of every conceivable craft rushing into port, standing against

any sea wall space they could find, in an attempt to help civilians (injured to varying degrees) get away from the dust and debris covering Manhattan. We set up an aide station inside the ferry terminal capable of treating upwards of 100 casualties up to the level of advanced life support. We were joined by Emergency Medical Technicians and reinforced by off-duty paramedics, all prepared to receive and treat the crush injuries, dust impacted airways, and burns. However, the volume of casualties was unexpectedly light. After the first 24 hours of the operation, no further survivors were recovered from the collapse zone or void spaces.

Problems created by good intentions

Early on in the incident, we saw many well-intentioned medical professionals involving themselves in situations for which they were unprepared, untrained, and unequipped. Several lone physicians, dressed in scrubs and running shoes, were found in the collapse zone providing medical intervention to potentially trapped victims. In some cases, impromptu medical clinics had been established. Once identified, these physicians were politely but firmly escorted out of the area because they created problems, such as medical oversight and accountability, liability, patient tracking, and safety to name but a few. Part of the FDNY EMS response is to call up 'Response Physicians', medical practitioners trained and authorized to work in such conditions. As if the traveling medical shows were not enough, in the collapse zone, in heavily damaged buildings and covered in dust, well-intentioned people offered food to the rescuers. However, given the disruption to water and gas, the lack of hand-washing, unrefrigerated food, poorly cooked food, and dust-contaminated food all presented the potential to cause illness among the already worn-down rescuers. Public health officials and the police eventually eliminated these 'chow lines', and a more organized system of mass feeding was organized.

Conclusion

Clearly the World Trade Center attack opens a new and frightening chapter in history. The unprecedented use of commercial airliners as weapons of mass effect outlines the need for all public safety response agencies to seriously review and perhaps even modify their response and operational doctrine in dealing with terrorist attacks. LC is the Advanced Life Support Coordinator and a hazardous materials technician of the EMS Division Two of the FDNY. He has 15 years' experience of the New York City EMS system. EMS Division Two is located at Jacobi Hospital in North Bronx, New York. The opinions expressed here are those of LC and do not necessarily reflect those of the FDNY EMS.

The Emergency Medical Service Command Memorial Foundation accepts donations to benefit the widows and children of the members of the FDNY EMS Command who made the supreme sacrifice in the line of duty. Donations can be sent to: The EMS Memorial Foundation, P.O. Box 2650, New York, NY 10108, USA.

Competing interests: None declared.

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**“We are all public health”:
September 11 and its aftermath
through the eyes of public health educators at Ground Zero**

By Carol F Azar and Yumary Ruiz

Abstract

No one could have predicted the events of September 11. The days following this tragic event put public health educators' skills to the test as they transferred theory to practice to assist rescue workers, victims, and community residents to cope and rebuild their lives. As health educators working in New York City at that time, the authors were quickly thrust into experiences, roles, and responsibilities for which they thought they had little preparation. But as they worked at Ground Zero in the days immediately after the attack and later in the neighborhoods of lower Manhattan, they realized their health promotion practice and research training provided them with what they needed to play their part. This article briefly illustrates their experiences and describes the skills and knowledge they tapped into to assist the community.

<https://pubmed.ncbi.nlm.nih.gov/14611020/>

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Observations from Ground Zero at the World Trade Center in New York City, Part I

By R L Levenson Jr and J K Acosta

Abstract

The authors are mental health clinicians with the Police Organization Providing Peer Assistance (POPPA), an affiliate organization of the Patrolman's Benevolent Association of the New York Police Department (NYPD). Beginning on September 11, 2001 we were at Ground Zero of the World Trade Center (WTC) to assist in the all phases of crisis intervention and Critical Incident Stress Management (CISM), as indicated. Our observations and anecdotal reports, as we worked on teams with NYPD Peer Support Officers (PSOs), are the subject of this paper.

<https://pubmed.ncbi.nlm.nih.gov/12025483/>

**Residual indoor contamination from World Trade Center rubble fires
as indicated by polycyclic aromatic hydrocarbon profiles**

Joachim D Pleil, et al.

Abstract

The catastrophic destruction of the World Trade Center (WTC) on Sept. 11, 2001 (9/11) created an immense dust cloud followed by fires that emitted smoke and soot into the air of New York City (NYC) well into December.

Outdoor pollutant levels in lower Manhattan returned to urban background levels after about 200 days as the fires were put out and the debris cleanup was completed. However, particulate matter (PM) from the original collapse and fires also penetrated into commercial and residential buildings. This has created public concern because WTC dust is thought to cause adverse pulmonary symptoms including “WTC cough” and reduced lung capacity. Additionally, some recent studies have suggested a possible link between exposure to WTC contamination and other adverse health effects.

Distinguishing between normal urban pollutant infiltration and residual WTC dust remaining in interior spaces is difficult; efforts are underway to develop such discriminator methods. Some progress has been made in identifying WTC dust by the content of fibers believed to be associated with the initial building collapse. There are also contaminants created by the fires that burned for 100 days in the debris piles of the building rubble. Using WTC ambient air samples, we have developed indicators for fire related PM based on the relative amounts of specific particle bound polycyclic aromatic hydrocarbons (PAHs) and the mass fraction of PAHs per mass of PM. These two parameters are combined, and we show a graphical method for discriminating between fire sources and urban particulate sources as applied to samples of settled dusts. We found that our PAHs based discriminator method can distinguish fire source contributions to WTC related particulate matter and dusts. Other major building fires or large open burn events could have similar PAHs characteristics.

We found that random samples collected approximately 3.5 years after the WTC event from occupied indoor spaces (primarily residential) in the New York area are not statistically distinguishable from contemporary city samples.

<https://pubmed.ncbi.nlm.nih.gov/16572771/>

Health and environmental consequences of the World Trade Center disaster

Philip J Landrigan, Paul J Liroy, George Thurston, Gertrud Berkowitz, L C Chen, Steven N Chillrud, Stephen H Gavett, Panos G Georgopoulos, Alison S Geyh, Stephen Levin, Frederica Perera, Stephen M Rappaport, Christopher Small and the NIEHS World Trade Center Working Group

Abstract

The attack on the World Trade Center (WTC) created an acute environmental disaster of enormous magnitude. This study characterizes the environmental exposures resulting from destruction of the WTC and assesses their effects on health.

Methods include ambient air sampling; analyses of outdoor and indoor settled dust; high-altitude imaging and modeling of the atmospheric plume; inhalation studies of WTC dust in mice; and clinical examinations, community surveys, and prospective epidemiologic studies of exposed populations. WTC dust was found to consist predominantly (95%) of coarse particles and contained pulverized cement, glass fibers, asbestos, lead, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and polychlorinated furans and dioxins. Airborne particulate levels were highest immediately after the attack and declined thereafter. Particulate levels decreased sharply with distance from the WTC. Dust pH was highly alkaline (pH 9.0-11.0). Mice exposed to WTC dust showed only moderate pulmonary inflammation but marked bronchial hyperreactivity. Evaluation of 10,116 firefighters showed exposure-related increases in cough and bronchial hyperreactivity. Evaluation of 183 cleanup workers showed new-onset cough (33%), wheeze (18%), and phlegm production (24%). Increased frequency of new-onset cough, wheeze, and shortness of breath were also observed in community residents. Follow-up of 182 pregnant women who were either inside or near the WTC on 11 September showed a 2-fold increase in small-for-gestational-age (SGA) infants. In summary, environmental exposures after the WTC disaster were associated with significant adverse effects on health. The high alkalinity of WTC dust produced bronchial hyperreactivity, persistent cough, and increased risk of asthma. Plausible causes of the observed increase in SGA infants include maternal exposures to PAH and particulates.

Future risk of mesothelioma may be increased, particularly among workers and volunteers exposed occupationally to asbestos. Continuing follow-up of all exposed populations is required to document the long-term consequences of the disaster.

<https://pubmed.ncbi.nlm.nih.gov/15121517/>

**Persistent organic pollutants in dusts
that settled indoors in lower Manhattan after September 11, 2001**

John H Offenberg, Steven J Eisenreich, Cari L Gigliotti,
Lung Chi Chen, Judy Q Xiong, Chunli Quan, Xiaopeng Lou,
Mianhua Zhong, John Gorczynski, Lih-Ming Yiin, Vito Illacqua, Paul J Liroy

Abstract

The explosion and collapse of the World Trade Center (WTC) was a catastrophic event that produced an aerosol impacting many residents, workers, and commuters after September 11, 2001. In all, 12 bulk samples of the settled dust were collected at indoor locations surrounding the epicenter of the disaster, including one sample from a residence that had been cleansed and was once again occupied.

Additionally, one sample was collected from just outside a fifth story window on the sill. These samples were analyzed for many components, including inorganic and organic constituents as well as morphology of the various particles.

The results of the analyses for persistent organic pollutants on dusts that settled at indoor locations are described herein, including polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and select organo-chlorine pesticides. The Sigma(86)-PCB concentrations, comprising less than one part per million by mass of the bulk in the two samples analyzed, indicated that PCBs were of limited significance in the dust that settled at indoor locations across lower Manhattan. Likewise, organo-chlorine pesticides, Hexachlorobenzene, Heptachlor, 4,4'-DDE, 2,4'-DDT, 4,4'-DDT and Mirex were found at even lower concentrations in the bulk samples. Conversely, Sigma(37)-PAHs comprised up to 0.04% (<0.005-0.036%) by mass of the bulk indoor dust in the 11 WTC impacted bulk indoor samples.

Analysis of one sample of indoor dusts collected from a vacuum cleaner of a rehabilitated home shows markedly lower PAH concentrations (<0.0005 mass%), as well as differing relative contributions for individual compounds. In addition to similar concentrations, comparison of PAH concentration patterns (i.e. chemical fingerprints) shows that dusts that settled indoors are chemically similar to previously measured WTC dusts found at outdoor locations and that these PAH analyses may be used in identifying dusts of WTC origin at indoor locations, along with ascertaining further needs for cleaning.

<https://pubmed.ncbi.nlm.nih.gov/15014547/>

Destruction of the World Trade Center and PCBs, PBDEs, PCDD/Fs, PBDD/Fs, and chlorinated biphenylenes in water, sediment, and sewage sludge

By Simon Litten, et al.

Abstract

Ash-laden runoff samples collected near Ground Zero soon after the September 11, 2001 attack on the World Trade Center (WTC) and subsequent fire demonstrate the release of polychlorinated biphenyls (PCBs), polybrominated dipheyl ethers (PBDEs), polybrominated dibenzo-p-dioxins and polybrominated dibenzofurans (PBDD/Fs), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs), and tetra- and pentachlorinated biphenylenes (PCBPs) from the incident.

Relative abundances of PCDD/F congeners in the runoff water and post-disaster lower Manhattan dust samples were different from those seen in pre-disaster NYC combined sewer outfall (CSO) samples.

The WTC-related samples showed a greater relative abundance of 2,3,4,7,8-PeCDF than usually seen in CSOs, sludges, and treated wastewaters. This congener may be associated with certain types of incineration.

Comparison of sediment and water samples collected in the lower Hudson River before and shortly after September 11, 2001 (9/11) showed no changes in PCB or PCDD/F concentrations or homologue profiles determined down to the parts per quadrillion range.

Comparisons of ambient water samples collected post-9/11 with archived samples suggest that the WTC disaster did not significantly impact ambient concentrations of the target chemicals.

Ambient concentrations of PBDD/Fs in New York Harbor are similar to those of PCDD/Fs, suggesting that these contaminants deserve increased scrutiny with respect to toxicity, sources, and fate in the environment.

<https://pubmed.ncbi.nlm.nih.gov/14717157/>

**Complementary biobank of rodent tissue samples
to study the effect of World Trade Center exposure on cancer development**

Wil Lieberman-Cribbin, et al.

Abstract

World Trade Center (WTC) responders were exposed to mixture of dust, smoke, chemicals and carcinogens.

New York University (NYU) and Mount Sinai have recreated WTC exposure in rodents to observe the resulting systemic and local biological responses.

These experiments aid in the interpretation of epidemiological observations and are useful for understanding the carcinogenesis process in the exposed human WTC cohort.

Here we describe the implementation of a tissue bank system for the rodents experimentally exposed to WTC dust. NYU samples were experimentally exposed to WTC dust via intratracheal inhalation that mimicked conditions in the immediate aftermath of the disaster.

Tissue from Mount Sinai was derived from genetically modified mice exposed to WTC dust via nasal instillation. All processed tissues include annotations of the experimental design, WTC dust concentration/dose, exposure route and duration, genetic background of the rodent, and method of tissue isolation/storage.

A biobank of tissue from rodents exposed to WTC dust has been compiled representing an important resource for the scientific community. The biobank remains available as a scientific resource for future research through established mechanisms for samples request and utilization. Studies using the WTC tissue bank would benefit from confirming their findings in corresponding tissues from organs of animals experimentally exposed to WTC dust.

Studies on rodent tissues will advance the understanding of the biology of the tumors developed by WTC responders and ultimately impact the modalities of treatment, and the probability of success and survival of WTC cancer patients.

<https://pubmed.ncbi.nlm.nih.gov/31601237/>

The development of a Biobank of cancer tissue samples from World Trade Center responders

By Wil Lieberman-Cribbin, et al.

Abstract

Background: World Trade Center (WTC) responders were exposed to mixture of dust, smoke, chemicals and carcinogens. Studies of cancer incidence in this population have reported elevated risks of cancer compared to the general population. There is a need to supplement current epidemiologic cancer follow-up with a cancer tissue bank in order to better elucidate a possible connection between each cancer and past WTC exposure. This work describes the implementation of a tissue bank system for the WTC newly diagnosed cancers, focused on advancing the understanding of the biology of these tumors. This will ultimately impact the modalities of treatment, and the probability of success and survival of these patients.

Methods: WTC Responders who participated (as employees or volunteers) in the rescue, recovery and cleanup efforts at the WTC sites have been enrolled at Mount Sinai in the World Trade Center Health Program. Responders with cancer identified and validated through linkages with New York, New Jersey, Pennsylvania, and Connecticut cancer registries were eligible to participate in this biobank. Potential participants were contacted through letters, phone calls, and emails to explain the research study, consent process, and to obtain the location where their cancer procedure was performed. Pathology departments were contacted to identify and request tissue samples.

Results: All the 866 solid cancer cases confirmed by the Data Center at Mount Sinai have been contacted and consent was requested for retrieval and storage of the tissue samples from their cancer. Hospitals and doctors' offices were then contacted to locate and identify the correct tissue block for each patient. The majority of these cases consist of archival paraffin blocks from surgical patients treated from 2002 to 2015. At the time of manuscript writing, this resulted in 280 cancer samples stored in the biobank.

Conclusions: A biobank of cancer tissue from WTC responders has been compiled with 280 specimens in storage to date.

This tissue bank represents an important resource for the scientific community allowing for high impact studies on environmental exposures and cancer etiology, cancer outcome, and gene-environment interaction in the unique population of WTC responders.

<https://pubmed.ncbi.nlm.nih.gov/30309352/>

**Enhanced exposure assessment and genome-wide DNA methylation
in World Trade Center disaster responders**

Pei-Fen Kuan, et al.

Abstract

DNA methylation has emerged as a promising target linking environmental exposures and cancer. The World Trade Center (WTC) responders sustained exposures to potential carcinogens, resulting in an increased risk of cancer.

Previous studies of cancer risk in WTC-exposed responders were limited by the deficiency in quantitative and individual information on exposure to carcinogens. The current study introduces a new exposure-ranking index (ERI) for estimating cancer-related acute and chronic exposures, which aimed to improve the ability of future analyses to estimate cancer risk. An epigenome-wide association study based on DNA methylation and a weighted gene co-expression network analysis were carried out to identify cytosine-phosphate-guanosine (CpG) sites, modules of correlated CpG sites, and biological pathways associated with the new ERI. Methylation was profiled on blood samples using Illumina 450K Beadchip. No significant epigenome-wide association was found for ERI at a false discovery rate of 0.05. Several cancer-related pathways emerged in pathway analyses for the top ranking genes from epigenome-wide association study as well as enriched module from the weighted gene co-expression network analysis.

The current study was the first DNA methylation study that aimed to identify methylation signature for cancer-related exposure in the WTC population. No CpG sites survived multiple testings adjustment. However, enriched gene sets involved in cancer, were identified in both acute and chronic ERIs, supporting the view that multiple genes play a role in this complex exposure.

Conflict of interest statement

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The authors reported no biomedical financial interests or other potential conflicts of interest.

<https://pubmed.ncbi.nlm.nih.gov/30001286/>

**Adolescents exposed to the World Trade Center collapse
have elevated serum dioxin and furan concentrations more than 12 years later**

Linda G Kahn, et al.

Abstract

Background: The collapse of the World Trade Center (WTC) on September 11, 2001 released a dust cloud containing numerous environmental contaminants, including polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans (PCDD/Fs). PCDD/Fs are toxic and are associated with numerous adverse health outcomes including cancer, diabetes, and impaired reproductive and immunologic function. Prior studies have found adults exposed to the WTC disaster to have elevated levels of PCDD/Fs. This is the first study to assess PCDD/F levels in WTC-exposed children.

Methods: This analysis includes 110 participants, a subset of the 2014-2016 WTC Adolescent Health Study, a group of both exposed youths who lived, attended school, or were present in lower Manhattan on 9/11 recruited from the WTC Health Registry (WTCHR) and unexposed youths frequency matched on age, sex, race, ethnicity, and income. Our sample was selected to maximize the contrast in their exposure to dust from the WTC collapse. Questionnaire data, including items about chronic home dust and acute dust cloud exposure, anthropometric measures, and biologic specimens were collected during a clinic visit. Serum PCDD/F concentrations were measured according to a standardized procedure at the New York State Department of Health Organic Analytical Laboratory. We used multivariable linear regression to assess differences in PCDD/Fs between WTCHR and non-WTCHR participants. We also compared mean and median PCDD/F and toxic equivalency (TEQ) concentrations in our cohort to 2003-4 National Health and Nutrition Examination Survey (NHANES) levels for youths age 12-19.

Results: Median PCDD/F levels were statistically significantly higher among WTCHR participants compared to non-WTCHR participants for 16 out of 17 congeners. Mean and median TEQ concentrations in WTCHR participants were >7 times those in non-WTCHR participants (72.5 vs. 10.1 and 25.3 vs. 3.39pg/g lipid, respectively). Among WTCHR participants, median concentrations of several PCDD/Fs were higher than the NHANES 95th percentiles. After controlling for dust cloud exposure, home dust exposure was significantly associated with higher PCDD/F level.

Conclusions: Adolescents in lower Manhattan on the day of the WTC attack and exposed to particulate contamination from the WTC collapse had significantly elevated PCDD/F levels

>12years later compared to a matched comparison group, driven by chronic home dust exposure rather than acute dust cloud exposure. PCDD/F and TEQ levels substantially exceeded those in similar-aged NHANES participants. Future studies are warranted to explore associations of PCDD/Fs with health and developmental outcomes among individuals exposed to the WTC disaster as children.

Trial registration: ClinicalTrials.gov NCT02068181.

Keywords: Adolescents; Children; Dioxins; Endocrine disruptors;
Environmental exposures; World Trade Center.

<https://pubmed.ncbi.nlm.nih.gov/29246432/>

Review • Int J Emerg Ment Health

PMID: 18546757 • Winter 2008

Police peer support programs: current knowledge and practice

By Peggy Grauwiler, Briana Barocas and Linda G Mills

Abstract

This review examines the current empirical research and literature on peer assistance programs, peer support, and peer-facilitated interventions for police officers.

A literature search was conducted to identify studies on police, peer support, and peer assistance programs. Studies were examined in terms of the following criteria: description of data collection methods, findings, study limitations, implications for police, workplace assistance, and peer support. Articles on peer support in the aftermath of the September 11, 2001, World Trade Center rescue and recovery efforts were also reviewed. The research studies reviewed in this article do not evaluate peer program effectiveness from the perspective of those officers receiving peer services.

To better serve this invaluable population, efforts must be made to incorporate their views. Information is also needed on the effectiveness of peer assistance programs and peer-driven crisis intervention models. Finally, research is needed that specifically examines the effectiveness of programs that utilize trained peers in partnership with professional mental health practitioners.

<https://pubmed.ncbi.nlm.nih.gov/18546757/>

Serum perfluoroalkyl substances and cardiometabolic consequences in adolescents exposed to the World Trade Center disaster and a matched comparison group

By Tony T Koshy, et al.

Abstract

Background: Large amounts of various chemical contaminants, including perfluoroalkyl substances (PFASs), were released at the time of the World Trade Center (WTC) disaster. Thousands of children who lived and/or attended school near the disaster site were exposed to these substances but few studies have examined the possible consequences related to these exposures. Objectives: To examine the relationship of PFASs serum levels with cardiometabolic profile in children and adolescents enrolled in the World Trade Center Health Registry (WTCHR) and a matched comparison group.

Methods: We evaluated WTCHR enrollees who resided in New York City and were born between September 11, 1993 and September 10, 2001, and a matched comparison group consisting of individuals who were ineligible for WTCHR participation upon distance of their home, school or work from the WTC and lack of participation in rescue and recovery activities. Matching was based on date of birth, sex, race, ethnicity, and income. We assessed exposure to PFASs, as measured by serum levels and association with cardiometabolic profile as measured by arterial wall stiffness, body mass index, insulin resistance, fasting total cholesterol, HDL, LDL and triglycerides.

Results: A total of 402 participants completed the study and serum samples were analyzed from 308 participants, 123 in the WTCHR group and 185 in the comparison group. In multivariable regression analysis, after adjusting for relevant confounders, we observed a significant, positive association of perfluorooctanoic acid (PFOA) with triglycerides (beta coefficient=0.14, 95% CI: 0.02, 0.27, 15.1% change), total cholesterol (beta coefficient=0.09, 95% CI: 0.04, 0.14, 9.2% change), and LDL cholesterol (beta coefficient=0.11, 95% CI: 0.03, 0.19, 11.5% change). Perfluorohexanesulfonic acid levels were associated with decreased insulin resistance (beta coefficient=-0.09, 95% CI: -0.18, -0.003, -8.6% change); PFOA and perfluorononanoic acid were associated with increased brachial artery distensibility.

Conclusions: This research adds to our knowledge of the physical health impacts in a large group of children exposed to the WTC disaster. Abnormal lipid levels in young adults might be an early marker of atherosclerosis and cardiovascular diseases and our findings highlight the importance of conducting longitudinal studies in this population.

<https://pubmed.ncbi.nlm.nih.gov/28890218/>

Comparative Study

doi: 10.1016/j.envres.2017.01.008 • April 2017

Serum perfluoroalkyl substances in children exposed to the world trade center disaster

Leonardo Trasande, et al.

Abstract

The World Trade Center (WTC) disaster released large amounts of various chemical substances into the environment, including perfluoroalkyl substances (PFASs). Yet, no studies have examined exposures in children living or attending schools near the disaster site.

We measured serum PFASs in WTC Health Registry (WTCHR) respondents who were ≤ 8 years of age on September 11, 2001 and a sociodemographically-matched comparison group. We also examined the relationship of PFASs levels with dust cloud exposure; home dust exposure, and with traumatic exposure, the latter to take into account differences related to possible mental health consequences and associated behavioral problems. Serum samples, collected between 2014 and 2016, were analyzed from 123 WTCHR participants and from 185 participants in the comparison group. In the WTCHR group, median perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) levels were 1.81ng/mL and 3.72ng/mL, respectively. Controlling for sex, caloric intake, race/ethnicity, and date of birth, significant increases among WTCHR participants compared with the matched comparison group were detected for perfluorohexanesulfonate (0.23ng/mL increase or 0.24log unit increase, $p=0.006$); PFOS (0.86ng/mL increase or 0.16log unit increase, $p=0.011$); PFOA (0.35ng/mL increase or 0.18log unit increase, $p<0.001$); perfluorononanoic acid (0.12ng/mL increase or 0.17log unit increase, $p=0.003$); perfluorodecanoic acid (0.06ng/mL increase or 0.42log unit increase, $p<0.001$); and perfluoroundecanoic acid (0.03ng/mL increase or 0.32log unit increase, $p=0.019$).

Stronger associations were identified for home dust exposures and traumatic exposures than dust cloud.

These findings highlight the importance of conducting longitudinal studies in this population to assess possible cardiometabolic and renal consequences related to these exposures.

Keywords: Children; Dust cloud; Home dust exposure;
Perfluoroalkyl substances; World Trade Center disaster.

<https://pubmed.ncbi.nlm.nih.gov/28104511/>

**Cardiometabolic profiles of adolescents and young adults
exposed to the World Trade Center Disaster**

Leonardo Trasande, et al.

Abstract

Background and objective: Few studies have examined the possible cardiometabolic consequences of World Trade Center-related exposures on children who lived and/or attended school near the disaster site. Our objective was to compare cardiometabolic profiles of participants in the World Trade Center Health Registry (WTCHR) with a matched comparison group.

Methods: We evaluated WTCHR enrollees who resided in New York City and were born between September 11, 1993 and September 10, 2001, and a matched comparison group. We assessed exposure to dust cloud, home dust, as well as traumatic exposure, and associations with blood pressure, arterial wall stiffness, body mass index (BMI), total cholesterol, triglycerides, HDL, and LDL.

Results: A total of 402 participants completed the study, 222 in the comparison group and 180 in the WTCHR group. In multivariable regression analysis, after adjusting for relevant confounders we detected a weak association between participation in the WTCHR group and lower BMI (-1.12kg/m^2 , 95% CI $-2.11, -0.12$; $p = 0.03$), which became non-significant after adjusting for multiple comparisons. With respect to traumatic and psychosocial exposures, the only association that persisted in our multivariable model, below our predefined level of significance, was between post-traumatic stress disorder and higher BMI (2.06kg/m^2 , 95% CI $0.37, 3.74$; $p = 0.02$).

Conclusions: Our findings do not support an association between self-reported exposures to the WTC disaster and adverse cardiometabolic profile. However, further longitudinal studies may better inform the full extent of WTC-related conditions associated with exposure to the disaster.

Trial registration: ClinicalTrials.gov NCT02068183.

Keywords: Cardiometabolic effects; Dust exposure;
Traumatic exposure; World Trade Center Disaster.

Potential Conflicts of Interest:

The authors have no conflicts of interest relevant to this article to disclose

<https://pubmed.ncbi.nlm.nih.gov/28972913/>

**Serum perfluoroalkyl substances and lung function
in adolescents exposed to the World Trade Center disaster**

Abigail Gaylord, et al.

Abstract

The effects of childhood exposure to perfluoroalkyl substances (PFASs) on lung function remain mostly unknown.

Previous research indicates that children living or going to school near the World Trade Center (WTC) disaster were exposed to high levels of PFASs, among other toxic chemicals. To explore the effects of PFAS exposure on lung function, we measured serum PFASs in a cohort of children from the WTC Health Registry and a matched control group.

Perfluorooctanesulfonate had the highest median concentrations in both groups (WTCHR = 3.72 ng/mL, Comparison = 2.75 ng/mL), while the lowest median concentrations were seen for perfluoroundecanoic acid (WTCHR = 0.12 ng/mL, Comparison = 0.01 ng/mL). Lung function outcomes were measured by spirometry, plethysmography, and oscillometry. Asthma diagnosis and serum eosinophil count were also recorded. We examined the relationships of each PFAS with lung function parameters and eosinophil count using linear regressions. Odds ratios for asthma were obtained for each PFAS using logistic regression. The effect of total PFASs on these outcomes was also assessed. All regression models were adjusted for sex, race/ethnicity, age, body mass index (BMI) and tobacco smoke exposure.

We found that serum PFASs were not statistically associated with the measured lung function parameters, asthma diagnosis, or eosinophil count in this cohort ($p < 0.05$). These findings highlight the need for more longitudinal studies to explore the long-term effects of childhood PFAS exposure on lung function past adolescence and early adulthood.

Trial registration:
ClinicalTrials.gov NCT02068183.

Keywords:
Asthma; Children; Lung function;
Perfluoroalkyl substances (PFASs); World Trade Center disaster.

<https://pubmed.ncbi.nlm.nih.gov/30822559/>

**Epidemiology of respiratory health outcomes
among World Trade Center disaster workers:
review of the literature 10 years after
the September 11, 2001 terrorist attacks**

By Christine C Ekenge and George Friedman-Jiménez

Abstract

Tens of thousands of workers participated in rescue, recovery, and cleanup activities at the World Trade Center (WTC) site in lower Manhattan after the terrorist attacks on September 11, 2001 (9/11). The collapse of the WTC resulted in the release of a variety of airborne toxicants.

To date, respiratory symptoms and diseases have been among the most examined health outcomes in studies of WTC disaster workers.

A systematic review of the literature on respiratory health outcomes was undertaken to describe the available information on new onset of respiratory symptoms and diseases among WTC disaster workers after September 11, 2001.

Independent risk factors for respiratory health outcomes included being caught in the dust and debris cloud, early arrival at the WTC site, longer duration of work, and delaying mask and respirator use.

Methodological challenges in epidemiologic studies of WTC disaster workers involved study design, exposure misclassification, and limited information on potential confounders and effect modifiers.

In the 10 years after 9/11, epidemiologic studies of WTC disaster workers have been essential in investigating the respiratory health consequences of WTC exposure.

Longitudinal studies along with continued medical surveillance will be vital in understanding the long-term respiratory burden associated with occupational WTC exposure.

<https://pubmed.ncbi.nlm.nih.gov/21908698/>

**Pulmonary disease in rescue workers
at the World Trade Center site**

By G I Banauch, A Dhala and D J Prezant

Abstract

Purpose of review: The catastrophic collapse of the World Trade Center (WTC) towers on September 11, 2001 created a large-scale disaster site in a densely populated urban environment.

Over the ensuing months, tens of thousands of rescue, recovery and cleanup workers, volunteers, and residents of the adjacent community were exposed to a complex mixture of airborne pollutants.

This review focuses on currently described respiratory syndromes, symptoms, and physiologic derangements in WTC rescue, recovery, and cleanup workers, discusses potential long-term effects on respiratory health, and draws parallels to community findings.

Recent findings: Detailed qualitative and quantitative analyses of airborne pollutants with their changing composition during initial rescue/recovery and subsequent cleanup have been published. Major concerns include persistent aerodigestive tract inflammatory syndromes, such as reactive airways dysfunction syndrome (RADS), reactive upper airways dysfunction syndrome (RUDS), gastroesophageal reflux disease (GERD), and inflammatory pulmonary parenchymal syndromes, as well as respiratory tract and nonrespiratory malignancies.

Aerodigestive tract inflammatory syndromes have now been documented in WTC exposed occupational groups, and syndrome incidence has been linked to WTC airborne pollutant exposure intensity. Community based investigations have yielded similar findings.

Summary: While it is too early to ascertain long-term effects of WTC dust exposure, current studies already demonstrate a definite link between exposure to WTC-derived airborne pollutants and respiratory disease, both in the occupational and the community setting.

A better understanding of causes and effects of this exposure will help in developing appropriate preventative tools for rescue workers in future disasters.

<https://pubmed.ncbi.nlm.nih.gov/15699790/>

**Persistence of multiple illnesses
in World Trade Center rescue and recovery workers: a cohort study**

Juan P Wisnivesky, et al.

Abstract

Background: More than 50,000 people participated in the rescue and recovery work that followed the Sept 11, 2001 (9/11) attacks on the World Trade Center (WTC). Multiple health problems in these workers were reported in the early years after the disaster. We report incidence and prevalence rates of physical and mental health disorders during the 9 years since the attacks, examine their associations with occupational exposures, and quantify physical and mental health comorbidities.

Methods: In this longitudinal study of a large cohort of WTC rescue and recovery workers, we gathered data from 27,449 participants in the WTC Screening, Monitoring, and Treatment Program. The study population included police officers, firefighters, construction workers, and municipal workers. We used the Kaplan-Meier procedure to estimate cumulative and annual incidence of physical disorders (asthma, sinusitis, and gastro-oesophageal reflux disease), mental health disorders (depression, post-traumatic stress disorder [PTSD], and panic disorder), and spirometric abnormalities. Incidence rates were assessed also by level of exposure (days worked at the WTC site and exposure to the dust cloud).

Findings: 9-year cumulative incidence of asthma was 27.6% (number at risk: 7027), sinusitis 42.3% (5870), and gastro-oesophageal reflux disease 39.3% (5650). In police officers, cumulative incidence of depression was 7.0% (number at risk: 3648), PTSD 9.3% (3761), and panic disorder 8.4% (3780). In other rescue and recovery workers, cumulative incidence of depression was 27.5% (number at risk: 4200), PTSD 31.9% (4342), and panic disorder 21.2% (4953). 9-year cumulative incidence for spirometric abnormalities was 41.8% (number at risk: 5769); three-quarters of these abnormalities were low forced vital capacity. Incidence of most disorders was highest in workers with greatest WTC exposure. Extensive comorbidity was reported within and between physical and mental health disorders.

Interpretation: 9 years after the 9/11 WTC attacks, rescue and recovery workers continue to have a substantial burden of physical and mental health problems. These findings emphasise the need for continued monitoring and treatment of the WTC rescue and recovery population.

Funding: Centers for Disease Control and Prevention
and National Institute for Occupational Safety and Health.

<https://pubmed.ncbi.nlm.nih.gov/21890053/>

**Exposure, probable PTSD and lower respiratory illness
among World Trade Center rescue, recovery and clean-up workers**

B J Luft, et al.

Abstract

Background: Thousands of rescue and recovery workers descended on the World Trade Center (WTC) in the wake of the terrorist attack of September 11, 2001 (9/11).

Recent studies show that respiratory illness and post-traumatic stress disorder (PTSD) are the hallmark health problems, but relationships between them are poorly understood. The current study examined this link and evaluated contributions of WTC exposures.

Method: Participants were 8508 police and 12 333 non-traditional responders examined at the WTC Medical Monitoring and Treatment Program (WTC-MMTP), a clinic network in the New York area established by the National Institute for Occupational Safety and Health (NIOSH).

We used structural equation modeling (SEM) to explore patterns of association among exposures, other risk factors, probable WTC-related PTSD [based on the PTSD Checklist (PCL)], physician-assessed respiratory symptoms arising after 9/11 and present at examination, and abnormal pulmonary functioning defined by low forced vital capacity (FVC).

Results: Fewer police than non-traditional responders had probable PTSD (5.9% v. 23.0%) and respiratory symptoms (22.5% v. 28.4%), whereas pulmonary function was similar. PTSD and respiratory symptoms were moderately correlated ($r=0.28$ for police and 0.27 for non-traditional responders). Exposure was more strongly associated with respiratory symptoms than with PTSD or lung function. The SEM model that best fit the data in both groups suggested that PTSD statistically mediated the association of exposure with respiratory symptoms.

Conclusions: Although longitudinal data are needed to confirm the mediation hypothesis, the link between PTSD and respiratory symptoms is noteworthy and calls for further investigation.

The findings also support the value of integrated medical and psychiatric treatment for disaster responders.

<https://pubmed.ncbi.nlm.nih.gov/22459506/>

Review Crit Care

doi: 10.1186/cc1055 • December2001

The World Trade Center attack. Doctors in the fire and police services

By C Martinez and D Gonzalez

Abstract

The World Trade Center attack cast some physicians in roles outside their usual hospital practice. The incident required several physicians to function in the dangerous environment of the disaster. Priorities and triage strategies established by the police, emergency medical service and fire departments, while adhered to, required instantaneous modification and upgrading given the vast loss of civilian and rescue personnel lives. Many civilian medical staff presented themselves with good intentions but needed to be placed out of the collapse zone for fear of incurring additional casualties. In addition, problems with re-establishment of command and control, communications, personnel and equipment replacement all impacted on the rescue effort.

This article recounts the roles played by the two coauthors during the World Trade Center attack.

<https://pubmed.ncbi.nlm.nih.gov/11737912/>

Review Crit Care

doi: 10.1186/cc1056 • December 2001

The World Trade Center attack. Observations from New York's Bellevue Hospital

By J D Roccaforte

Abstract

This report describes selected aspects of the response by Bellevue Hospital Center to the World Trade Center attack of 11 September 2001. The hospital is 2.5 miles (4 km) from the site of the attack. These first-hand observations and this analysis may aid in future preparations. Key issues described relate to communication, organization, injuries treated, staffing, and logistics.

<https://pubmed.ncbi.nlm.nih.gov/11737913/>

Injuries and illnesses among New York City Fire Department rescue workers after responding to the World Trade Center attacks

Centers for Disease Control and Prevention (CDC)

Abstract

Within minutes of the terrorist attacks on September 11, 2001, the Fire Department of New York City (FDNY) operated a continuous rescue/recovery effort at the World Trade Center (WTC) site.

Medical officers of FDNY Bureau of Health Services (FDNY-BHS) responded to provide emergency medical services (see box). The collapse of the WTC towers and several adjacent structures resulted in a vast, physically dangerous disaster zone.

The height of the WTC towers produced extraordinary forces during their collapse, pulverizing considerable portions of the buildings' structural components and exposing first responders and civilians to substantial amounts of airborne particulate matter.

Fires burned continuously under the debris until mid-December 2001. Because of ongoing fire activity and the large numbers of civilians and rescue workers who were killed during the attacks, approximately 11,000 FDNY firefighters and many emergency medical service (EMS) personnel worked on or directly adjacent to the rubble and incurred substantial exposures.

This report describes morbidity and mortality in FDNY rescue workers during the 11-month period after the WTC attacks and documents a substantial increase in respiratory and stress-related illness compared with the time period before the WTC attacks.

These findings demonstrate the need to provide acute and long-term medical monitoring, treatment, and counseling to FDNY rescue workers exposed to this disaster and to solve supply, compliance, and supervision problems so that respiratory protection can be rapidly provided at future disasters.

<https://pubmed.ncbi.nlm.nih.gov/12238534/>

CDC MMWR Morb Mortal Wkly Rep

PMID: 12238539 • September 2002

**Use of respiratory protection
among Responders
at the World Trade Center site
New York City, September 2001**

Centers for Disease Control and Prevention (CDC)

Abstract

The terrorist attacks on the World Trade Center (WTC) on September 11, 2001, created an occupational health and safety challenge for New York City (NYC) firefighters and rescue workers responding to the disaster. Immediate respiratory hazards included explosions, fire, falling debris, and dust clouds containing particulate matter comprised of pulverized building materials.

Ongoing risks included lingering particulate matter in the air and intermittent combustion products from initial and persistent fires beneath the rubble pile.

Because the nature and extent of exposures in disaster situations are complex and difficult to characterize, the use of adequate personal protective equipment (PPE), including respiratory protection, is essential in protecting the health of firefighters and other rescue workers.

During the weeks after September 11, the NYC Fire Department's Bureau of Health Services (FD-NY-BHS) and CDC's National Institute for Occupational Safety and Health (NIOSH) organized a collaborative study to evaluate occupational hazards and exposures for these workers, including their use of respiratory protection.

This report summarizes the results of that study, which indicate that the majority of firefighters did not use adequate respiratory protection during the first week of the rescue/recovery operation.

<https://pubmed.ncbi.nlm.nih.gov/12238539/>

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Quality of Life of Persons Injured on 9/11: Qualitative Analysis from the World Trade Center Health Registry

By Lisa M. Gargano, Robyn R. Gershon and Robert M. Brackbill

Abstract

Introduction: A number of studies published by the World Trade Center Health Registry (Registry) document the prevalence of injuries sustained by victims of the World Trade Center Disaster (WTCD) on 9/11. Injury occurrence during or in the immediate aftermath of this event has been shown to be a risk factor for long-term adverse physical and mental health status. More recent reports of ongoing physical health and mental health problems and overall poor quality of life among survivors led us to undertake this qualitative study to explore the long-term impact of having both disaster-related injuries and peri-event traumatic exposure on quality of life in disaster survivors.

Methods: Semi-structured, in-depth individual telephone interviews were conducted with 33 Registry enrollees who reported being injured on 9/11/01. Topics included: extent and circumstance of the injury(ies), description of medical treatment for injury, current health and functional status, and lifestyle changes resulting from the WTCD. The interviews were recorded, transcribed, and inductively open-coded for thematic analysis.

Results: Six themes emerged with respect to long term recovery and quality of life: concurrent experience of injury with exposure to peri-event traumatic exposure (e.g., witnessing death or destruction, perceived life threat, etc.); sub-optimal quality and timeliness of short- and long-term medical care for the injury reported and mental health care; poor ongoing health status, functional limitations, and disabilities; adverse impact on lifestyle; lack of social support; and adverse economic impact. Many study participants, especially those reporting more serious injuries, also reported self-imposed social isolation, an inability to participate in or take enjoyment from previously enjoyable leisure and social activities and greatly diminished overall quality of life.

Discussion: This study provided unique insight into the long-term impact of disasters on survivors. Long after physical injuries have healed, some injured disaster survivors report having serious health and mental health problems, economic problems due to loss of livelihood, limited sources of social support, and profound social isolation. Strategies for addressing the long-term health problems of disaster survivors are needed in order to support recovery.

Introduction

A large number of studies have shown that victims of natural and human-made disasters experience both adverse physical and mental health effects, with survivors especially at risk of post-traumatic stress disorder (PTSD) and depression.^{1, 2, 3, 4, 5} The World Trade Center Health Registry (Registry) was developed to understand the short, medium, and long-term public health impacts of the attacks on people exposed to the World Trade Center (WTC) disaster on September 11, 2001 (9/11). The Registry enrolled more than 70,000 people who were members of populations at risk, including: those in the vicinity of the attacks in lower Manhattan on 9/11/01 either in buildings (including the WTC Towers) or passing through the area; residents who lived in the immediate area surrounding the WTC site; rescue, recovery and ancillary workers working at the site on 9/11 or on later clean-up and recovery operations; and children who were enrolled in schools in the vicinity of the WTC.^{1, 6}

A study published by the Registry found that over 9,000 (13%) enrollees reported being injured on 9/11.⁶ The most common injury reported was a sprain or strain.⁶ Some groups were more likely to be more seriously injured; for instance, while 3,672 (44%) of Registry enrollee survivors were injured, 474 (13%) reported an injury involving a fracture or dislocation, burn, or head injury.⁷ These and other Registry studies have also found injury to be a significant risk factor for mental health disorders, including a two-fold higher likelihood of PTSD, after controlling for other risk factors.^{7, 8} The occurrence of any injury was also found to be independently associated with new onset heart disease post-9/11.⁸ In addition to well-documented on-going health and mental health problems noted by Registry enrollees who were injured, there have also been numerous anecdotal reports of poor quality of life reported by survivors. Whether this is related to injuries sustained on 9/11 or to peri-traumatic exposure to the disaster, or both, is an open question, as it is hard to disentangle the long-term effects of injuries from long-term effects of the traumatic exposure.

After the attacks, the New York State Office of Mental Health collaborated with New York City and county mental health departments to address mental health needs using two related but distinct response strategies.⁹ The first, named Project Liberty, aimed at the general population consisted of public education concerning traumatic stress reactions and appropriate coping strategies, outreach to all affected communities, and short-term supportive counseling for anyone affected by September 11th. The second response strategy was aimed at a subset of the affected population: individuals whose traumatic symptoms persisted and were of sufficient severity to meet diagnostic criteria for PTSD and/or other mental disorder. From mid-October 2001 through March 2002, Project Liberty staff provided over 42,000 service encounters, representing service to over 91,000 unique individuals. An evaluation of Project Liberty showed that counselors were able to identify which individuals might require more intensive mental health treatment. Overall, about 9% of individuals encountered through Project Liberty were referred for mental health treatment. These individuals experienced about twice as many traumatic symptoms as those not referred, and rates of referral were higher for highly traumatized groups such as families of the deceased

and WTC evacuees.⁹ Information on disaster-related factors that may influence long-term quality of life of survivors can inform the development of strategies to ensure the best possible outcome and recovery for seriously injured disaster survivors. The goals of this qualitative study were to 1) fill in the gaps in knowledge concerning the circumstances surrounding the injuries, 2) determine the short and long term mental and physical health effects of being injured, and 3) assess the social and economic impacts of being injured.

Methods

A semi-structured interview script, which was informed by a conceptual model of long-term health impacts in disaster survivors, was used to conduct the interviews. Telephone interviews were conducted on 33 eligible Registry enrollees between March and June 2015 (83% of those contacted by phone agreed to be interviewed). Up to 50 interviews were planned, but saturation¹⁰ was reached with 33 interviews and therefore, in order to minimize respondent burden, no further recruitment was conducted. These interviewees met the study criteria eligibility: a) completion of registry survey waves 1, 2, and 3; b) report of sustaining any one or more of five types of injuries on 9/11 (sprain/strain, cut/laceration, burn, fracture, or head injury) on the Registry's Wave 1 (2002-2003) interview; c) report of being present south of Chambers Street on the morning of 9/11; d) aged 17 years or older on 9/11; e) English language preference; f) and current address in U.S. We maximized representation of persons who either reported multiple types of injuries or more severe types of injuries by including those with head/concussion, burns, or bone fractures or dislocation injuries, while also including persons with less severe types of injuries, such as sprain/strain or lacerations. For the first 10 interviews, we did not recruit persons with a history of probable PTSD, which is defined as attaining a score of 44 or greater on the PCL-171 , 11 in order to assess the degree of distress during the interview that might occur. In subsequent batches we recruited persons with probable PTSD at Waves 1 or 2 and then Wave 3. Recruiters and the interviewer were blinded to the PTSD scores of all participants in order to minimize the risk of interviewer bias.

Potential study participants were first sent an invitation letter with a description of the study, its purpose and the benefits and risks of participation. Registry recruitment staff called all potential participants to schedule an interview and to obtain verbal consent prior to conducting the interview. Participants were sent a \$50 gift card as compensation for their time.

Each interview lasted approximately one hour. The interviewer's guide was developed by all authors with input from other Registry staff. Table 1 displays topics and sample questions from the guide. All interviews were recorded with enrollee permission and transcribed verbatim by a professional transcriptionist. This study was approved by the institutional review board of the NYC Department of Health and Mental Hygiene.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5140849/>

Surveillance for World Trade Center disaster health effects among survivors of collapsed and damaged buildings

Robert M Brackbill, et al.

Abstract

Problem/condition: Survivors of collapsed or damaged buildings from the attack on the World Trade Center (WTC) were among those most exposed to injury hazards, air pollution, and traumatic events.

Reporting period: This report summarizes data from health outcomes collected during interviews conducted from September 5, 2003, to the close of the World Trade Center Health Registry (WTCHR) enrollment on November 20, 2004.

Description of system: WTCHR will be used to monitor periodically the mental and physical health of 71,437 enrollees for 20 years. The analysis is limited to 8,418 adult survivors of collapsed buildings (n = 5,095) and buildings with major or moderate damage (n = 3,323), excluding those who were involved in rescue and recovery.

Results: A total of 62.4% of survivors of collapsed or damaged buildings were caught in the dust and debris cloud that resulted from the collapse of the WTC towers, and 63.8% experienced three or more potentially psychologically traumatizing events. Injuries were common (43.6%), but few survivors reported injuries that would have required extensive treatment. More than half (56.6%) of survivors reported experiencing new or worsening respiratory symptoms after the attacks, 23.9% had heartburn/reflux, and 21.0% had severe headaches. At the time of the interview, 10.7% of building survivors screened positive for serious psychological distress (SPD) using the K6 instrument. After multiple adjustments, data indicated that survivors caught in the dust and debris cloud were more likely to report any injuries (adjusted odds ratio [AOR] = 3.9; p < or = 0.05); any respiratory symptom (AOR = 2.7; p < or = 0.05); severe headaches (AOR = 2.0; p < or = 0.05); skin rash/irritation (AOR = 1.7; p < or = 0.05); hearing problems or loss (AOR = 1.7; p < or = 0.05); heartburn (AOR = 1.7; p < or = 0.05); diagnosed stroke (AOR = 5.6; p < or = 0.05); self-reported depression, anxiety, or other emotional problem (AOR = 1.4; p < or = 0.05); and current SPD (AOR = 2.2; p < or = 0.05). Adjustment for SPD did not diminish the observed associations between dust cloud exposure and physical health outcomes. Building type and time of evacuation were associated with injuries on September 11, 2001 and reported symptoms; building type (collapsed versus damaged) also was associated with mental distress.

Interpretation: Two to three years after September 11, survivors of buildings that collapsed or that were damaged as a result of the WTC attack reported substantial physical and mental health

problems. The long-term ramifications of these effects are unknown. Many survivors were caught directly in the dust and debris of collapsing towers, a dense cloud of particulate matter that might have produced or exacerbated these health effects.

Public Health Action Recommended: Long-term follow-up of building survivors and all other persons enrolled in WTCHR should be maintained, with particular attention to those persons exposed to the dust cloud. Some of these findings might lead to building designs that can minimize injury hazards.

CDC MMWR Morb Mortal Wkly Rep

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**Rapid assessment of injuries among survivors
of the terrorist attack on the World Trade Center--New York City, September 2001**

Centers for Disease Control and Prevention (CDC)

Abstract

On September 11, 2001, a jet aircraft crashed into the north tower of the World Trade Center (WTC) in lower Manhattan. Minutes later, a second aircraft crashed into the south tower. The impact, fires, and subsequent collapse of the buildings resulted in the deaths of thousands of persons. The precise number and causes of deaths could not be assessed in the immediate aftermath of the attack; however, data were available on the frequency and type of injuries among survivors

In previous disasters, such information assisted in characterizing type and severity of injuries and the health-care services needed by survivors. To assess injuries and use of health-care services by survivors, the New York City Department of Health (NYCDOH) conducted a field investigation to review emergency department (ED) and inpatient medical records at the four hospitals closest to the crash site and a fifth hospital that served as a burn referral center. This report summarizes findings of that assessment, which indicated that the arrival of injured persons to this sample of hospitals began within minutes of the attack and peaked 2 to 3 hours later.

Among 790 injured survivors treated within 48 hours, approximately 50% received care within 7 hours of the attack, most for inhalation or ocular injuries; 18% were hospitalized. Comprehensive surveillance of disaster-related health effects is an integral part of effective disaster planning and response.

<https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5101a1.htm>

**Mental health service use 1-year after the World Trade Center disaster:
implications for mental health care**

By Joseph A Boscarino , Richard E Adams and Charles R Figley

Abstract

The objective of this study was to assess prevalence and predictors of mental health service use in New York City (NYC) after the World Trade Center disaster (WTCD).

One year after the attacks, we conducted a community survey by telephone of 2368 adults living in NYC on September 11, 2001.

In the past year, 19.99% (95% confidence interval [CI]=18.2-21.77) of New Yorkers had mental health visits and 8.1% (95% CI=7.04-9.16) used psychotropic medications. In addition, 12.88% (95% CI=11.51-14.25) reported one or more visits were related to the WTCD. Compared to the year before, 8.57% (95% CI=7.36-9.79) had increased post-disaster visits and 5.28% (95% CI=4.32-6.25) had new post-disaster treatment episodes. Psychotropic medication use related to the WTCD was 4.51% (95% CI=3.75-5.26). Increased post-disaster medication use, compared to the year before, was 4.11% (95% CI=3.35-4.86) and new medication episodes occurred among 3.01% (95% CI=2.34-3.69). In multivariate logistic analyses, mental health visits were associated with younger age, peri-event panic attack, posttraumatic stress disorder (PTSD) and depression. In addition, WTCD-related visits had a positive "dose-response" association with WTCD event exposures ($P<0.0001$). WTCD-related visits also were positively associated with peri-event panic, anxiety, lower self-esteem, PTSD, and depression. All three medication measures were positively related to PTSD and depression, and negatively associated with African American status. WTCD-related medication use also was positively related to younger age, female gender, WTCD event exposures, negative life events, anxiety and lower self-esteem. Finally, while the percentage of New Yorkers seeking post-disaster treatment did not increase substantially, the volume of visits among patients apparently increased.

We conclude that exposure to WTCD events was related to post-disaster PTSD and depression, as well as WTCD-related mental health service use. African Americans were consistently less likely to use post-disaster medications. Although the WTCD did have an impact on treatment-seeking among current patients, it did not substantially increase mental health treatment among the general population.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2746086/>

**Injury Severity and Psychological Distress
Sustained in the Aftermath of the Attacks of 11 September 2001
Predict Somatic Symptoms in World Trade Center Health Registry Enrollees
Sixteen Years Later**

Howard E. Alper, et al.

Abstract

The World Trade Center attacks of 11 September 2001 (9/11) have been associated with the subsequent development of chronic diseases. Few studies have investigated the burden of somatic symptoms on attack victims, or the association of such symptoms with exposure to the 9/11 attacks. World Trade Center Health Registry (Registry) enrollees who were present south of Chambers Street during or immediately after the 9/11 attacks and who provided consistent answers regarding injury sustained on 9/11 were followed prospectively for up to 16 years post-9/11/01. We employed linear regression to evaluate the associations between injury severity, psychological distress and somatic symptoms in 2322 persons who completed all four Registry surveys and a subsequent Health and Quality of Life survey. Twenty-one percent of subjects had a “very high” burden of somatic symptoms, greater than in populations not exposed to a disaster. Somatic symptoms exhibited a dose-response association separately with injury severity and psychological distress trajectories. Victims of the 9/11 attacks suffer from a substantial burden of somatic symptoms which are associated with physical and psychological consequences of exposure to the attacks. Physical and mental health professionals need to work together when treating those exposed to complex disasters such as 9/11.

Introduction

The terrorist attacks on the World Trade Center (WTC) on 11 September 2001 resulted in over 2800 deaths, and many thousands more injured. The dust/debris cloud generated by the collapse of the WTC towers enveloped many survivors and responders, who also may have been injured or witnessed horrific events such as seeing airplanes strike the towers. These exposures led to the development of a variety of physical and mental conditions, such as asthma [1,2,3,4,5], post-traumatic stress disorder (PTSD) [6,7,8,9], heart disease [6,10], stroke [8], and cancer [11,12].

Literature has shown that, among the general population with experience of serious injuries, anxiety, depression, or posttraumatic stress disorder (PTSD) can persist for years after the injury [13]. Being injured during the 9/11 attacks significantly increased the likelihood of PTSD years later [3]. Brackbill et al. [14] found that the likelihood of being diagnosed with respiratory or circulatory dis-

eases 10–11 years after the disaster exhibited a dose-response relation with the number of types of injuries they sustained on 9/11. A recent study showed that heart disease (e.g., heart attack, angina) in particular exhibited a strong dose-response relationship with the number of injuries sustained on 9/11 10–11 years after the disaster [6].

A recent qualitative study by the WTCHR of persons who sustained an injury on 9/11 reported various decrements in quality of life [15]. Subjects reported pain, gastrointestinal problems, functional limitations and disabilities, and limitations on social activities. This qualitative study informed a subsequent investigation of physical and mental functioning in Registry enrollees injured on 9/11, which demonstrated that poor physical functioning 16 years after the 11 September 2001 attacks, as measured by the SF-12 scale, exhibited a dose-response relationship with increasing severity of injury on 9/11 [16].

Somatic symptoms constitute the experience of various bodily symptoms whose causes can be difficult to determine. Severe somatic symptoms are described as somatoform disorders and consist of symptoms such as loss of vision or hearing. Less severe, but more prevalent, are symptoms such as gastrointestinal complaints, bodily pain (e.g., arms back, headache), cardiopulmonary effects (e.g., chest pain, dizziness), and fatigue (e.g., sleeping troubles, low energy). Somatic symptoms accompany many physical [17,18] and mental disorders [19] and contribute substantially to the cost of health care [20].

Somatic symptoms are a class of outcomes that have not been evaluated in reference to 9/11 but have been the subject of studies for other disasters. For example, a study of 162 persons exposed to the Great Midwestern Flood of 1993 found that 25% of subjects experienced new somatic symptoms after the flood [21]. A review of 57 studies of somatic symptoms after disasters worldwide from 1983 to 2003, reported that prevalence of Medically Unexplained Physical Symptoms (MUPS) varied by which were dominant symptoms and latency after the disaster [22]. For example, symptom prevalence three months post disaster ranged from 10% to 65%, while some symptoms (fatigue, poor digestion, trouble breathing, skin problems, or cough) persisted at least six years post disaster with prevalence ranging from 10% to 50%. Predictors of MUPS include disaster-related consequences such as injury, and post-disaster variables such as coping style. The latter may be affected by mental health conditions that develop post-disaster, such as PTSD or psychological distress. While research has investigated the association of PTSD with somatic symptoms [23], no studies to our knowledge have looked at the relation between psychological distress and somatic symptoms. Furthermore, there has been little research on the association of injury number, type, or severity with somatic symptoms [24]. Moreover, we know of no research exploring the association between both psychological distress and injury with somatic symptoms. Finally, the association between psychological distress and injury with somatic symptoms in those exposed to the 9/11 attacks has not been investigated.

The goals of this study were to: (1) evaluate the prevalence of somatic symptoms among those exposed to the 11 September 2001 attacks, with comparison to other groups not exposed to a

disaster, (2) estimate the association between the severity of injuries sustained on 9/11, and (3) history of non-specific psychological distress, with somatic symptoms after controlling for pre-9/11 history of physical and mental health diseases, demographics, and other risk factors.

Materials and Methods

Data Source and Study Design

The World Trade Center Health Registry (The Registry) was created in 2002 to monitor the physical and mental health consequences of those exposed to the terrorist attacks of 11 September 2001. Enrollees included rescue/recovery workers, residents, area workers, passersby, and students/staff of local schools. The initial Registry survey was conducted in 2003–2004 (wave 1), and subsequently in 2006–2007 (wave 2), 2011–2012 (wave 3), and 2015–2016 (wave 4). The methods used by the Registry have been described in detail in previous publications [3,25]. The Registry was approved by the institutional review boards of the Centers for Disease Control and Prevention and the New York City Department of Health and Mental Hygiene.

The data source for this study was derived from a Registry sub-study, “The Health and Quality of Life 15 Years After 9/11 Survey” (HQoL survey) [26]. The HQoL study was approved by the institutional review board of the New York City Department of Health and Mental Hygiene. The HQoL study was completed after the wave 4 survey. Inclusion criteria for this study included: (a) completing all four WTCHR survey waves, (b) being at least 18 years of age on 9/11, and (c) speaking English. This sample consisted of two groups. The injured group included persons who reported on Wave 1 that they sustained one or more of five types of injuries on 9/11: cut, abrasion or puncture wound; sprain or strain; burn; broken bone or dislocation; and concussion or head injury. Those who reported “other injury” or an “eye injury” only were not included. The second group consisted of a non-injured comparison group of randomly selected persons who did not report any type of injury including “other” or “eye injury”.

Analytic Sample

The sample for this study was derived from the HQoL study data source by applying the following additional inclusion/exclusion criteria: (1) the enrollee was south of Chambers Street on 9/11, (2) the enrollee reported being injured on both the wave 1 and HQoL surveys, and (3) the enrollee had non-missing values of the Kessler 6 psychological distress sum score (see below) at waves 1, 2, and 4.

Study Variables

Outcome Measure

The severity of somatic symptoms was assessed using the Somatic Symptom Scale-8 scale (SSS-8) [27]. The SSS-8 consists of eight questions, each measured on a Likert scale from 0 (“not at all”) to 4 (“very much”). The item scores are summed to create the scale, which can range in value from 0

to 32. The scale has excellent psychometric properties and good reliability (Cronbach's $\alpha = 0.81$) [27]. The SSS-8 scale possesses good construct validity, as it correlates with depression ($r = 0.57$), anxiety ($r = 0.55$), and general health status ($r = -0.24$) [27]. Somatic symptoms severity categories were taken from Gierk et al.: no to minimal (0–3), low (4–7), medium (8–11), high (12–15), and very high (16–32) somatic symptom burden [27]. The factor structure obtained from the SSS-8 scale reflects gastrointestinal (stomach or bowel), pain (arms, legs, joints, or headache), fatigue (tiredness, trouble sleeping), and cardiopulmonary (chest pain, shortness of breath, dizziness) components of general somatic symptom burden [27]. We chose the SSS-8 scale because it is well-validated and is briefer than scales such as the PHQ-15 [28,29]

2.3.2. Exposure Variables

Level of injury severity. This was categorized as none, low, medium, or high. None was defined as having reported no injury at 9/11 on the HQoL survey. Low injury severity was defined as having reported being injured at 9/11 on the HQoL survey, but answering no to all the following injury severity questions: (a) Spent the day in a bed, chair, or couch any time during the week after your injury, (b) Used a cane or crutch to help you walk any time during the week after your injury, (c) Spent time in a wheelchair any time during the week after your injury, (d) Where did you receive treatment for the most serious of your injuries (hospital/ER, doctor's office, other, not applicable), (e) Have you ever received physical therapy, and (f) Did you have surgery for your injury. Medium injury severity was defined as having reported being injured at 9/11 on the HQoL survey, answering yes to all questions a–c above and no to all questions d–f. High injury severity was defined as having reported being injured at 9/11 on the HQoL survey and answering yes to any of the questions d–f above. This is summarized in Brackbill et al. [16].

Mental health status. This was represented for the post-9/11 period by the trajectories (see below) of non-specific psychological distress, as measured by the Kessler (K6) instrument [30], a shortened form of the Kessler K10 scale. The K6 asks respondents to report how often they experienced six emotional states related to psychological distress in the past 4 weeks. The responses range from "All of the time", "Most of the time", "Some of the time", "A little of the time", and "None of the time". The total score was obtained by the summation of each of the six emotional states related to psychological distress where "All of the time" = 4, and "None of the time" = 0. Total scores ranged from 0 to 24, where 0 indicated the lowest degree of psychological distress, and 24 indicated the highest. Individuals with a score greater than 13 were considered to have severe psychological distress (Kessler et al., 2002, [30]). The K6 has high internal consistency and reliability (Cronbach's $\alpha = 0.89$), and has minimal bias with regards to demographic features such as sex and education (Kessler et al., 2002, [30]). The K6 was administered at Waves 1, 2, and 4. We could not use the K6 data from Wave 3 because of an inadvertent measurement error, but the data from Waves 1, 2, and 4 were enough to form K6 trajectories.

The K6 trajectories cover the period wave 1 to wave 4. Injury severity includes events that occurred in the first weeks after the 9/11 attacks, and other events (e.g., surgery, hospitalization for other reasons) that could have occurred up to wave 4.

Covariates

Mental health status pre-9/11 was treated as a dichotomous variable, such that if the enrollee self-reported PTSD, anxiety, or depression the mental health variable was set to 1, whereas if the enrollee reported none of these conditions, it was set to 0.

Physical health status. This was represented by a single variable, covering both pre-9/11 and post-9/11 periods, corresponding to the number of chronic diseases self-reported by the enrollee, including high cholesterol, hypertension, gastro-esophageal reflux disease (GERD), asthma, or sleep apnea. The physical health variable consisted of the count of positive responses to having any of the above diseases either before or after the 9/11 attacks. This was categorized as 0, 1, or 2 or more diseases.

Covariates included the following sociodemographic characteristics: gender (male, female), age at 9/11, race (white non-Hispanic, black non-Hispanic, Hispanic, Asian non-Hispanic, other), education (less than high school, high school/GED, some college/college grad/post-grad), income ($0 \leq \text{USD } 25 \text{ K}$, $\text{USD } 25 \leq \text{USD } 50 \text{ K}$, $\text{USD } 50 \leq \text{USD } 75 \text{ K}$, $\text{USD } 75 \leq \text{USD } 150 \text{ K}$, $\geq \text{USD } 150 \text{ K}$), eligibility group (rescue/recovery, resident, area worker, passerby, student/staff), and marital status (married/living together vs. divorced/separated/widowed).

Risk or protective factors were social support at wave 4 and stressful events before wave 3. Low social support is associated with increased severity of mental conditions such as PTSD and depression, and potentially with somatic symptom severity [31]. Social support was defined by the sum of the answers to five questions, each of which can range from 0 (“none of the time”) to 4 (“all of the time”): “How often is someone available to take you to the doctor if you need to go?”, “To have a good time with you?”, “To hug you?”, “To prepare your meals if you are unable to do it yourself?”, and “To understand your problems?”. The total score can range from 0 to 20, and low social support was defined as a total score below 15.

Stressful events can exacerbate mental health conditions that may contribute to somatic symptoms [32]. Having stressful events was based on a sum of endorsement of up to six events (such as unable to pay bills, lost a job, family problems), expressed categorically as none (0 events), low/medium (1 or 2 events), and high (greater than 2 events) [33].

Statistical Analysis

The frequency distributions for the exposure variables (injury severity, psychological distress trajectories), the sociodemographic variables, and risk factors were calculated. The mean SSS-8 score and its standard deviation were also computed for each category of the above variables.

The frequency distribution over the five somatic symptoms categories (none/minimal, low, me-

dium, high, very high) derived from the SSS-8, was obtained for the following: (1) the full analytic sample of the present study, and (2) a nationally representative German sample [27].

The trajectories for psychological distress were obtained using the free program PROC TRAJ. This groups enrollees with similar patterns of K6 over time into mutually exclusive trajectories, with input from the investigator. In particular, the user can choose the number of trajectory groups, and the mathematical form of the trajectory (linear, quadratic, cubic). By varying these parameters and using both statistical (e.g., BIC or Bayesian Information Criterion) and subject matter criteria to evaluate a series of potential models, the user can arrive at a final model. This process is described in detail in a previous Registry publication [34].

We conducted unadjusted and adjusted trajectory analyses of psychological distress over time. The unadjusted models only included the K6 scores, whereas the adjusted models incorporated time-varying and time-invariant covariates. Trajectory analysis enabled (1) prediction of membership in trajectory groups, (2) prediction of trajectory shapes, and (3) direct comparison of two trajectories. Time invariant covariates predict group membership, while time variant covariates predict trajectory shape.

The user defines the number of trajectories. Additionally, the user selects the order (linear, quadratic, cubic) of the regression equation for each trajectory group. The optimal number of groups and equation order are determined by incremental decreases in Bayesian information criteria (BIC) from the test model to the previous model. PROC TRAJ can accommodate a variety of distributions; the present study selected a censored normal distribution as K6 is a psychometric scale. For each enrollee, PROC TRAJ outputs the probability for likelihood of assignment to each group; each enrollee is assigned to the group with the highest probability. PROC TRAJ operates on complete-case analysis for covariates: enrollees missing any time variant or time invariant covariates were excluded from the analysis.

Model selection was conducted iteratively, starting with the number of groups set to one, and the order set to quadratic. The number of groups was increased in each iteration of the model; the BIC was monitored for substantial changes. We did not consider model orders greater than quadratic since we only had three data points for the K6. Once the optimal model was selected, posterior probabilities and group size estimates were obtained from the PROC TRAJ output. Next, the time varying and time invariant covariates were included in the above optimal model. This final model produced the K6 trajectories employed in all analyses. PROC TRAJ model selection was also informed by previous trajectory analyses on other psychological variables, particularly PTSD. For this, the following trajectory types are often observed: resilient, low stable, moderate increasing, high decreasing, and chronic. We hypothesized similar results for psychological distress. After using PROC TRAJ on the K6 data as described above, we observed the first four of the above five trajectory types: resilient, low stable, moderate increasing, and high decreasing.

Linear regressions were performed to determine the associations of the continuous SSS-8 scale

score with injury severity, psychological distress trajectories, sociodemographic variables, and risk factors. Regression coefficients and their 95% confidence intervals were taken as the measure of association and its statistical significance. We examined the injury severity-psychological distress trajectory interaction by including their product term in a version of the main regression. If the associated p-values < 0.05 an interaction was assumed to exist. We also tested for linear dose-response relationships of SSS-8 scores with injury severity and psychological distress trajectories by treating these exposures as continuous (not categorical) and calculating the p-value of the regression coefficient. If this was <0.05, we concluded a linear dose-response relationship. All calculations were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

The mean SSS-8 scores are shown in Table 1. Somatic symptoms increase substantially with both injury severity (none: 7.7, low: 11.0, medium: 13.7, high: 14.3) and psychological distress trajectory (resilient: 5.0, low stable: 9.8, moderate increasing: 16.2, high decreasing: 15.2). Somatic symptoms decline with education (less than high school: 12.4, high school: 11.6, college: 8.5), as it does with income. Somatic symptoms scores are higher among those having more stressful events (three or more: 14.6, one or two: 11.5, none: 8.5).

The characteristics of the study sample (n = 2322) are also shown in Table 1. No, low, medium, or high injury severity were experienced by 67%, 4%, 16%, and 13% of study enrollees, respectively. The PROC TRAJ procedure identified four K6 trajectories: Resilient, low-stable, moderate increasing, and high decreasing. The resilient group was characterized by mean K6 scores below two through waves 1–4. The low-stable exhibited average K6 scores between 3–5 over waves 1–4. The moderate-increasing trajectory had an initial mean K6 value of 8 but increased to 13 by wave 4. Finally, the high-decreasing group had a wave 1 K6 mean value of 11, which decreased to below 7 by wave 4. These trajectory groups characterized 24%, 58%, 10%, and 8% of the study sample, respectively. There were 57% male, 51% aged 25–44 at 9/11, 77% white non-Hispanic, 66% college-educated, 58% earned above USD 75 K, 58% area workers, and 69% were married/living together. A total of 56% reported low social support. The overwhelming majority (95%) of enrollees did not report stressful events, and 62% reported at least one chronic disease pre- or post-9/11.

The somatic symptoms category distributions are presented in Figure 1 for the following: (1) present study, full analytic sample (orange) and (2) nationally representative German sample (blue) [27]. Several features are notable. First, 21% of the present study sample were in the “very high” somatic symptom severity category, while only 47% were in the “none” or “low” categories. For the nationally representative German sample, only 2–3% were in the “very high” category, while 88% were in the “none” or “low” categories.

Distribution of Somatic Symptoms by Category

Results for the linear regressions are presented in Table 2. Somatic symptoms exhibited a modest

dose-response relationship with injury severity (for low injury severity $\beta = 1.5$, 95% confidence interval (CI) 0.3–2.7; for medium injury severity $\beta = 3.1$, 95% CI 2.4–3.8; for high injury severity $\beta = 3.7$, 95% CI 2.9–4.5; dose-response test $p < 0.001$) and a strong dose-response relationship with the psychological distress trajectories (Low stable $\beta = 3.3$, 95% CI 2.7–3.9; moderate increasing $\beta = 8.2$, 95% CI 7.2–9.2; high decreasing $\beta = 6.4$, 95% CI 5.4–7.4; dose-response test $p < 0.001$). The interaction between injury severity and psychological distress trajectories was not significant ($p = 0.39$).

Discussion

To our knowledge, the present study is one of the first to investigate the prevalence and predictors of somatic symptoms among those present at the attacks of 11 September 2001. We found a prevalence of “very high” somatic symptom levels of 21%, significantly higher than in a nationally representative German sample (2–3%). Though the SSS-8 scale has not, to our knowledge, been applied to a representative sample of the United States population, it is likely the prevalence of “very high” somatic symptom levels would approximate the above German sample.

We showed that somatic symptoms exhibited a substantial and statistically significant dose-response relationship with both the severity of injury sustained on 9/11 and trajectories of psychological distress, two factors that encompass a 15-year period. This is consistent with the hypothesis that both physical and mental health conditions contribute over time to the development of somatic symptoms.

The mechanism leading from injury to somatic symptoms is unclear. Nader [35] proposed that traumatic injury can lead to peripheral inflammation, which can produce or exacerbate somatic symptoms. Irwin [36] summarized evidence that activation of the pro-inflammatory cytokine network in response to tissue injury can underlie the pathophysiology of somatic symptoms. These findings are also consistent with an effect of injury on somatic symptoms. Another theory [37] proposes that somatic symptoms develop as a response to mental health conditions that are not recognized by the person or remain untreated for other reasons. This is consistent with the finding of the present study of an independent (from the effect of injury severity) association between K6 psychological distress trajectories and somatic symptoms. Additionally, recent research [38] has shown that anxiety sensitivity might explain the co-morbidity between PTSD and somatic symptoms, consistent with both direct and mediated effects of injury.

The present study extends previous Registry research into the effects of the 9/11 attacks by investigating somatic symptoms. Specifically, while previous Registry studies showed an association between injury, PTSD, and heart disease [6,14] out to 10–11 years post-disaster, the present study demonstrated that injury severity and psychological distress trajectories are also associated with somatic symptoms measured 16 years after the 9/11 attacks.

The present study contributes to the literature on the prevalence and predictors of somatic symp-

toms. While several studies have investigated the association of PTSD with somatic symptoms [23], few if any have looked at the relation between psychological distress, arguably a more accurate description of one's general psychological state, and somatic symptoms. Nevertheless, our study agrees with previous research in that increased severity of mental health disease was associated with increased severity of somatic symptoms. Furthermore, the association of injury characteristic with somatic symptoms has been little studied [24], but the present study agrees with previous research in that increased number or severity of injury was associated with increased severity of somatic symptoms.

The importance of somatic symptoms extends beyond the suffering of individuals. Somatic symptoms also contribute substantially to health care costs. They are estimated to account for 10–20% of total annual medical costs in the US [20], and for 10% of health care costs among working age people in the UK [39]. In the US, patients with somatic symptoms have twice as many primary care visits, specialty visits, emergency department visits, and hospital visits compared to patients without somatic symptoms [20]. The same study found that health costs for patients with somatic symptoms were also 2–3 times that of patients without such symptoms. The individual and societal costs associated with somatic symptom remain an important public health concern.

A major strength of the present study is the use of a prospective cohort, which allows us to investigate the association of exposures to, and sequelae of exposure to, the 9/11 attacks with later emerging conditions. Further, the sample was composed of injured and non-injured enrollees, which allowed determination of the association between injury severity and somatic symptoms. The present investigation also used well-validated measures of psychological distress, the K6 scale, and of somatic symptoms, the SSS-8 scale [27]. Finally, the longitudinal nature of the Registry cohort made it possible to measure both K6 trajectories and injury severity over a 15-year period.

A limitation of our study is that the list of injuries reported in Wave 1 might seem mild to moderate only. However, in the HQoL survey injured enrollees reported the circumstances of their injury [26]. In total, 9.8% of reported being hit by a falling object, and 8.3% reported hitting their head on an object. Further, in their answers to an open-ended question on how injury occurred enrollees provided details such as “a building fell on me” and “consumed in fire”. Since such injuries were likely to be more than moderate, we believe that this study includes enrollees with mild, moderate, and severe injuries.

A second limitation is that this study included only enrollees whose spoken language was English. While 95% of Wave 1 enrollees spoke English, excluding non-English speakers introduced a bias in our ability to generalize our results to the entire affected population.

Another limitation of our study was our inability to compare our somatic symptoms results to subjects representative of either New York City/State or the US, because the SSS-8 has not, to our knowledge, been used in such a survey. However, a recent study using data from the National

Latino and Asian American Study (NLAAS) [40], a nationally representative survey of White, Latino, and Asian Americans adults, found that subjects on average endorsed only 0.5–1 somatic symptoms of fourteen possible symptoms. The NLAAS results could be consistent with those for the nationally representative German sample [27] described above, but there may be differences in ethnic and cultural endorsement of specific somatic symptoms, so caution in the above comparison is warranted.

Another limitation of our study was that data for exposures, outcomes, and covariates were self-reported. However, there has been good agreement between Registry findings based on self-report and those based on hospitalization data [11].

A further limitation is that the injury severity exposure variable was constructed using data from the HQoL survey, sixteen years after 9/11. It is possible enrollees provided inaccurate answers to the injury severity questions, such as receiving treatment or having surgery. However, we excluded all enrollees who provided inconsistent answers, between the wave 1 and HQoL surveys concerning being injured on 9/11.

An additional limitation was that the pre-9/11 mental health status variable encompassed only self-reported diagnoses of depression, anxiety, and PTSD. The definition excluded externalizing conditions such as substance use disorders, ADHD, and conduct and antisocial personality disorders. These conditions, encompassing impulsivity, aggression, and rule breaking manifestations, are associated with risks of exposure to trauma. Externalizing pathology, particularly of the antisocial variety, is associated with both diagnosed chronic disease and medically unexplained symptoms.

Another limitation is that our analytic sample included enrollees (70%) with at least one of the five most prevalent chronic diseases at wave 4. These could affect the associations between somatization and injury severity and/or psychological distress trajectories. We tested this hypothesis by creating a sub-sample of ~700 enrollees with none of the five chronic diseases. The associations between somatization and the two above exposures for this sub-sample were similar in size to associations obtained using the complete analytic sample.

Finally, the attrition observed in the Registry cohort could bias the associations we observed, though a recent study [41] found such bias to be small.

Conclusions

The present study shows that exposure to the events of 11 September 2001 was associated with experiencing somatic symptoms 16 years after the attacks. Specifically, the severity of injury and the psychological distress trajectories were associated with the degree of subsequent experience of somatic symptoms. Given the large fraction of enrollees who experienced “very high” levels of somatic symptoms, the present study implies that a substantial number of people present for the

9/11 attacks could currently be experiencing somatic symptoms, adding to an already significant burden of disease. Physical and mental health professionals need to work together when treating those exposed to complex disasters such as 9/11. In particular, Roennenberg et al. [42] suggest active therapeutic interventions to promote self-efficacy, through education, relaxation and mindfulness, self-help, and physical activation rather than passive organ-related measures. Multimodal treatment is reserved for more severe cases. They suggest that research is needed into prevention, psychophysiology, and differential treatment for patients with different symptoms.

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**Chronic physical health consequences of being injured
during the terrorist attacks on World Trade Center on September 11, 2001**

By Robert M Brackbill, James E Cone, Mark R Farfel and Steven D Stellman

Abstract

Few studies have focused on injuries from the World Trade Center disaster on September 11, 2001. Severe injury has health consequences, including an increased mortality risk 10 years after injury and the risk of mental health problems, such as posttraumatic stress disorder (PTSD). The World Trade Center Health Registry identified 14,087 persons with none of a selected group of preexisting chronic conditions before 2002 who were present during and soon after the World Trade Center attacks, 1,980 of whom reported sustaining 1 or more types of injury (e.g., a broken bone or burn). Survey data obtained during 2003-2004 and 2006-2007 were used to assess the odds of reporting a diagnosis of chronic conditions (heart disease, respiratory disease, diabetes, cancer) up to 5-6 years after the attacks. Number of injury types and probable PTSD were significantly associated with having any chronic conditions diagnosed in 2002-2007. Persons with multiple injuries and PTSD had a 3-fold higher risk of heart disease than did those with no injury and no PTSD, and persons with multiple injuries and with no PTSD had a 2-fold higher risk of respiratory diseases. The present study shows that injured persons with or without comorbid PTSD have a higher risk of developing chronic diseases. Clinicians should be aware of the heightened risk of chronic heart and respiratory conditions among injured persons.

Keywords:

9/11 World Trade Center attacks; chronic conditions;
disasters; injury; posttraumatic stress disorder.

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Conducting a study to assess the long-term impacts of injury after 9/11: participation, recall, and description

By Robert M. Brackbill, Patricia Frazier and Lisa M. Gargano

Background

The World Trade Center (WTC) attacks on September 11, 2001 (9/11) resulted in over 2700 fatalities and thousands injured. Injury on 9/11 has been identified as a risk factor for physical and mental health conditions, but the reasons for this are not well understood.

In a population exposed to 9/11 and since followed, an in-depth study on the impacts of injury on 9/11 was conducted to identify factors that contribute to long-term functional issues. This report sought to examine factors influencing participation, participant recall of injury status over time, and determinants of injury severity.

Methods

Enrollees from the World Trade Center Health Registry who completed all surveys between 2003 and 2016 and initially reported being injured (N=2699) as well as a sample of non-injured (N=2598) were considered to be eligible for the Health and Quality of Life 15 Years after 9/11 (HQoL) Study. Predictors of study non-participation and inconsistent recall of injury over time (i.e., discrepant reports) were identified through fitting log binomial models.

Results

Participation rates were high overall (76.1%) and did not vary by initially reported injury status, although younger (vs. older), non-White (vs. White), and less educated (vs. more educated) enrollees were less likely to participate in the HQoL Study. Discrepant reporting of 9/11 injury status was much more common among enrollees who initially reported being injured on 9/11 (49.6%) compared with those who did not (7.3%). However, those who incurred more severe injuries on 9/11 were less likely to have discrepant reporting over time compared with those with more minor injuries (broken bone vs. sprain: risk ratio=0.33, 95% Confidence Interval: 0.19, 0.57).

Among those who consistently reported that they were injured on 9/11, most injuries occurred as a result of descending down stairs (31.5%) or by tripping and falling (19.9%); although being hit by a falling object was most often associated with high severity injuries (63.2%) compared with other modes of injury.

Conclusions

These findings highlight the methodological issues involved in conducting a study on the long-term impact of injury more than a decade after the initial incident and may be relevant to future investigators. Factors affecting participation rates, such as demographic characteristics, and those related to discrepant reporting over time, such as injury severity, may affect both the internal and external validity of studies examining the long-term impact of injury.

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An Assessment of Long-Term Physical and Emotional Quality of Life of Persons Injured on 9/11/2001

Robert M. Brackbill, et al.

Abstract

Fifteen years after the disaster, the World Trade Center Health Registry (Registry) conducted The Health and Quality of Life Survey (HQoL) assessing physical and mental health status among those who reported sustaining an injury on 11 September 2001 compared with non-injured persons. Summary scores derived from the Short Form-12 served as study outcomes. United States (US) population estimates on the Physical Component Score (PCS-12) and Mental Component Score (MCS-12) were compared with scores from the HQoL and were stratified by Post-traumatic Stress Disorder (PTSD) and injury status. Linear regression models were used to estimate the association between both injury severity and PTSD and PCS-12 and MCS-12 scores. Level of injury severity and PTSD history significantly predicted poorer physical health (mean PCS-12). There was no significant difference between injury severity level and mental health (mean MCS-12). Controlling for other factors, having PTSD symptoms after 9/11 predicted a nearly 10-point difference in mean MCS-12 compared with never having PTSD. Injury severity and PTSD showed additive effects on physical and mental health status. Injury on 9/11 and a PTSD history were each associated with long-term decrements in physical health status. Injury did not predict long-term decrements in one's mental health status. Although it is unknown whether physical wounds of the injury healed, our results suggest that traumatic injuries appear to have a lasting negative effect on perceived physical functioning.

Introduction

The World Trade Center (WTC) disaster on 11 September 2001 exposed thousands of persons to both environmental pollutants and psychological trauma, which have had long-term physical and psychological ramifications. Having been injured on 9/11 has emerged as a common risk factor for both physical and mental health conditions [1,2,3]. For example, one study found that, among those injured on the day of the 9/11 disaster, the likelihood of having been diagnosed with a physical health condition, including respiratory disease problems (i.e., asthma, chronic bronchitis, emphysema) and/or circulatory disease (i.e., heart attack, angina, stroke) increased with the number of types of injuries they sustained (e.g., burn, head injury, and musculoskeletal) [4]. Injury on 9/11 also increased the likelihood of posttraumatic stress disorder (PTSD) 2-fold to 3-fold, which was measured by a post-traumatic stress checklist (PCL) screening instrument after adjusting for demographic factors and other WTC-related exposures [2,3]. In addition, physical injury has been reported as a risk factor for psychological sequelae among persons directly affected by other disasters, such as Hurricane Ike [5] and the 2004 Southeast Asia tsunami [6].

In general, among those who experience serious injuries, psychological distress related to anxiety, depression, or post-traumatic stress disorder (PTSD) can persist for years after the injury [6]. For instance, in a meta-analysis of the long-term impacts of injuries incurred in motor vehicle crashes, ranging from serious spinal cord injuries to less life-threatening musculoskeletal injuries, showed that the injuries had large impacts on psychological distress that, in some cases, increased in magnitude over time [7]. Serious injuries can also result in increased vulnerability to physical health conditions in the absence of psychological pathology [8]. This suggests that an injury, in addition to its immediate physical damage, can have long-term effects on physical health without an intervening psychological factor.

Given that mortality from injury has declined substantially because of treatment advances, the primary focus for non-fatal injuries currently is the impact of injuries on functionality and quality of life. For instance, Danish patients injured between 1995 and 2005 were more likely than a non-injured group of people to experience poor/very poor health [9]. In the Netherlands, from 1999 to 2000, limitations in mobility, self-care, and the ability to conduct daily activities were self-reported by severely injured adult patients followed up between 12 and 18 months post-injury [10]. Long-term declines in overall physical and mental health status following trauma were found in studies in Oslo, Australia, and the United States (US) using standard instruments (e.g., Short Form 36, Brief Pain Inventory, and Short Form 12) [11,12,13]). In the Danish study, Toft observed the effects on overall health up to 10 years after the injury [9] and for at least 2 years for both physical and mental health when compared with national norms [12,14]. In most cases, a greater relative decline in physical health compared with mental health was observed. However, researchers typically do not include in their assessment the relationship between PTSD and functional health status, especially physical health, nor do they employ a non-injury comparison group. A prior qualitative inquiry of persons who sustained an injury on 9/11 found injured persons reported that their injuries were debilitating and limited daily activities, especially musculoskeletal injuries

that required multiple surgeries with physical therapy [15]. In addition, quality of life and social integration problems emerged among participants in the study regardless of whether they had a history of PTSD [15].

This study examines the long-term effects of injury sustained on 9/11, including functional effects and a comparison group without injury. Based on the findings from the qualitative study, we hypothesized that the severity of the 9/11 injury would predict deficits in health status for both physical and mental health domains. We also hypothesized that PTSD history would be sufficient—but not a necessary factor—in observed long-term detriments in physical and mental health, as measured by the Short Form-12 (SF-12). In addition, it was hypothesized that the presence of other factors, such as social support and self-efficacy, would ameliorate the impact of injury and PTSD on physical and mental health status.

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CDC MMWR Morb Mortal Wkly Rep • September 2002

Injuries and illnesses among New York City Fire Department rescue workers after responding to the World Trade Center attacks.

Abstract

Within minutes of the terrorist attacks on September 11, 2001, the Fire Department of New York City (FDNY) operated a continuous rescue/recovery effort at the World Trade Center (WTC) site. Medical officers of FDNY Bureau of Health Services (FDNY-BHS) responded to provide emergency medical services (see box). The collapse of the WTC towers and several adjacent structures resulted in a vast, physically dangerous disaster zone. The height of the WTC towers produced extraordinary forces during their collapse, pulverizing considerable portions of the buildings' structural components and exposing first responders and civilians to substantial amounts of airborne particulate matter. Fires burned continuously under the debris until mid-December 2001. Because of ongoing fire activity and the large numbers of civilians and rescue workers who were killed during the attacks, approximately 11,000 FDNY firefighters and many emergency medical service (EMS) personnel worked on or directly adjacent to the rubble and incurred substantial exposures (Figure). This report describes morbidity and mortality in FDNY rescue workers during the 11-month period after the WTC attacks and documents a substantial increase in respiratory and stress-related illness compared with the time period before the WTC attacks. These findings demonstrate the need to provide acute and long-term medical monitoring, treatment, and counseling to FDNY rescue workers exposed to this disaster and to solve supply, compliance, and supervision problems so that respiratory protection can be rapidly provided at future disasters.

<https://www.cdc.gov/mmwr/preview/mmwrhtml/mm51SPa1.htm>

**Impact of September 11 attacks
on workers in the vicinity of the World Trade Center--New York City.**

Abstract

In January 2002, CDC's National Institute for Occupational Safety and Health received requests for Health Hazard Evaluations from labor unions representing workers employed in buildings in the vicinity of the World Trade Center (WTC). Workers reported persistent physical and mental health symptoms that they associated with exposures from the WTC collapse and ensuing fires. To address these concerns, CDC conducted surveys of workers at four workplaces in New York City (NYC), a high school (high school A) and college (college A) near the WTC site, and a high school (comparison high school B) and college (comparison college B) > or = 5 miles from the WTC site to determine rates of physical and mental health symptoms. This report summarizes the preliminary results of the employee surveys, which indicated that workers employed near the WTC site had significantly higher rates of physical and mental health symptoms than workers employed > or = 5 miles from the site. Intervention programs should be tailored to address the needs of these workers, and the effectiveness of these programs should be evaluated. Further assessment is warranted to describe the nature and extent of illness in specific working groups and individual medical follow-up in those with persistent.

https://www.unboundmedicine.com/medline/citation/12238540/Impact_of_September_11_attacks_on_workers_in_the_vicinity_of_the_World_Trade_Center_New_York_City

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**The enduring mental health impact of the September 11th terrorist attacks:
challenges and lessons learned**

Fatih Ozbay, et all

The authors review the existing literature on the mental health impact of the September 11th attacks and the implications for disaster mental health clinicians and policy makers. The authors discuss the demographic characteristics of those affected and the state of mental health needs and existing mental health delivery services; the nature of the disaster and primary impacts on lives, infrastructure, and socioeconomic factors; the acute aftermath in the days and weeks after the attacks; the persistent mental health impact and evolution of services of the postacute aftermath; and the implications for future disaster mental health practitioners and policy makers.

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**Occupational exposures to air contaminants
at the World Trade Center disaster site—New York, September-October, 2001.**

Abstract

Amid concerns about the fires and suspected presence of toxic materials in the rubble pile following the collapse of the World Trade Center (WTC) buildings on September 11, 2001, the New York City Department of Health (NYCDOH) asked CDC for assistance in evaluating occupational exposures at the site. CDC's National Institute for Occupational Safety and Health (NIOSH) collected general area (GA) and personal breathing zone (PBZ) air samples for numerous potential air contaminants.

This report summarizes the results of the assessment, which indicate that most exposures, including asbestos, did not exceed NIOSH recommended exposure limits (RELs) or Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) (1,2). One torch cutter was overexposed to cadmium; another worker was overexposed to carbon monoxide (CO) while cutting metal beams with an oxyacetylene torch or a gasoline-powered saw, and two more were possibly overexposed to CO. NIOSH recommended that workers ensure adequate on-site ventilation when using gas-powered equipment and use rechargeable, battery-powered equipment when possible.

Toxic substances of concern included asbestos (from insulation and fireproofing materials), concrete (made from Portland cement and used in the buildings' construction) and the crystalline silica it contained, CO (from fires and engine exhaust), diesel exhaust (from vehicles and equipment), mercury (from fluorescent lights), chlorodifluoromethane (Freon™-22, from air conditioning systems), heavy metals (from building materials), hydrogen sulfide (from sewers, anaerobically decomposing bodies, and spoiled food), inorganic acids, volatile organic compounds (VOCs), and polynuclear aromatic hydrocarbons (PAHs) (from fires and engine exhaust). Environmental sampling during September 18--October 4 focused on search-and-rescue personnel, heavy equipment operators, and workers cutting metal beams (Figure 1) but also included various other occupations.

A total of 1,174 air samples was collected, including 804 for asbestos. NYCDOH contractors collected most of the asbestos samples; NIOSH personnel collected all other samples. In addition, NIOSH collected 33 bulk samples of dust, debris, and other materials. All samples were collected and analyzed according to the NIOSH Manual of Analytic Methods (3) with some modifications.

A total of 29 bulk samples of undisturbed settled material from various locations was analyzed for asbestos; 27 of these also were analyzed for crystalline silica and metals. Of the 29 samples, 26 (90%) had <1% asbestos (by mass); the three others had 1%--3%. All but one of 27 samples

had crystalline silica; concentrations (by mass) ranged from 0--18%, with a median (for all 27 samples) of 3.2%. The most abundant metals in the samples were calcium, magnesium, aluminum, iron, and zinc. Lead, arsenic, cadmium, and beryllium concentrations (by mass) were <0.1%. Three bulk samples of fireproofing material on I-beams from the main debris pile were analyzed for asbestos; one was negative, and two had <1% asbestos. A sample of paint from a metal beam had 0.3% lead.

Phase contrast microscopy (PCM) revealed fibers in 358 (45%) of the 804 asbestos air samples. Excluding 30-minute samples, 25 samples had fiber concentrations that, if the fibers had been asbestos, would have exceeded the REL of 0.1 fibers per cubic centimeter of air (f/cc) (1). None of the 30-minute sample concentrations exceeded the OSHA short-term excursion limit of 1.0 f/cc (2). Of the 25 samples with fiber concentrations >0.1 f/cc (range: 0.1--0.5 f/cc) by PCM, 18 were analyzed by transmission electron microscopy (TEM), which can distinguish between asbestos and nonasbestos fibers. All had asbestos concentrations <0.1 f/cc. The seven samples not analyzed by TEM had fiber concentrations ranging from 0.1--0.2 f/cc.

Differential analysis by polarized light microscopy of these same 25 air samples revealed most nonasbestos fibers to be fibrous glass, gypsum, and cellulose.

Air concentrations of total (36 samples) and respirable (18 samples) particulate ranged up to 2.3 milligrams per cubic meter (mg/m³) and 0.3 mg/m³, respectively, which are below the corresponding RELs of 10.0 mg/m³ and 5.0 mg/m³ for Portland cement (1). Respirable crystalline silica was not detected in any of 18 air samples. Of 45 air samples analyzed for various metals, one from a 6½-hour PBZ sample from a torch cutter had a cadmium concentration (8.6 microgram per cubic meter [µg/m³]) that would have exceeded the PEL (8-hour time-weighted average [TWA]) of 5.0 µg/m³ even without further exposure during the remainder of the 8-hour shift.

None of the samples had concentrations of lead, arsenic, beryllium, or other metals that exceeded NIOSH or OSHA exposure limits.

Two instantaneous peak CO measurements (1,239 and 1,368 parts per million [ppm]) exceeded 1,200 ppm, the level NIOSH considers an immediate danger to life and health (1). One was from a torch cutter and the other from a gasoline-powered saw operator. In 99 air samples, concentrations of CO ranged from 0.2 to 242.0 ppm; the highest finding (in a 32½-minute PBZ sample from a saw operator) exceeded the NIOSH limit of 200 ppm and would have exceeded the PEL of 50 ppm (8-hour TWA) had it been sustained for 2 hours (1,2). CO concentrations of 41 ppm and 45 ppm in PBZ samples from torch cutters and 40 ppm in a GA sample near a saw operator, with sampling durations of ½, 5, and 2½ hours, respectively, would have exceeded the REL of 35 ppm had they represented full-shift exposures (1,2).

Hydrogen sulfide was present in seven of 10 samples, one or more inorganic acids in all 27 samples, mercury in five of 16 samples, and one or more VOCs in 14 of 76 samples; all con-

centrations were below applicable NIOSH and OSHA exposure limits except for two benzene concentrations (0.4 mg/m³ and 0.5 mg/m³) that exceeded the REL of 0.3 mg/m³ (1). Both were in GA samples from a smoke plume and did not represent any specific worker's exposure. The highest concentration of elemental carbon (an indicator of diesel exhaust) was 0.023 mg/m³. Neither NIOSH nor OSHA has a numerical exposure limit for diesel exhaust, but the American Conference of Governmental Hygienists has proposed a limit of 0.2 mg/m³ (measured as elemental carbon) (4). No Freon™-22 was detected in any of five samples.

Small amounts of various PAHs were present in all 12 samples, but not at concentrations that exceeded individually or collectively any applicable NIOSH or OSHA exposure limit.

Reported By

K McKinney, MPA, New York City Dept of Health; S Benson, New York City Office of Emergency Management; A Lempert, New York City School Construction Authority. M Singal, MD, Cincinnati, Ohio. K Wallingford, MS, E Snyder, MS, Div of Surveillance, Hazard Evaluations and Field Studies, National Institute for Occupational Safety and Health, CDC.

Editorial Note:

In addition to the physical hazards associated with work at the WTC site, hazardous exposures to toxic dusts and gases were suspected initially. Asbestos exposure, in particular, was an occupational and community health concern. The findings of this survey documented no occupational exposure to asbestos, at least after September 18, in excess of NIOSH or OSHA occupational exposure limits. The seven air samples that had fiber concentrations (determined by PCM) higher than the REL for asbestos probably would have had asbestos concentrations <0.1 f/cc if analyzed by TEM.

In many other samples, asbestos concentrations determined by TEM tended to be lower than those determined by PCM. The NIOSH asbestos sampling did not provide data about occupational exposures before September 18 and was designed to assess occupational exposures, not community exposures, which probably were lower.

The absence of exposure to respirable crystalline silica, despite its presence in the bulk samples, indicates either that the crystalline silica in the dust at the site consisted of larger, nonrespirable particles or that work activities were not causing the dust to become airborne. In the absence of effective dust-control measures, the former explanation seems more likely. Although the air sampling indicated the presence of respirable airborne particulate, this material was apparently not crystalline silica. One torch cutter had cadmium overexposure, and excess CO was associated with workers using oxyacetylene torches and gasoline-powered saws. To reduce CO exposure, NIOSH recommended replacing gasoline-powered saws with rechargeable, battery-powered saws.

At the time of the NIOSH sampling, the ambient air did not appear to be contaminated with toxic substances from the buildings or their contents or with combustion products to an extent that posed an occupational health hazard. However, the presence of hazards related to specific work activities at the WTC disaster site underscores the importance of assessing suspected occupational exposures. In response to the WTC disaster, NIOSH has issued guidelines for addressing a variety of occupational safety and health hazards at disaster sites (5).

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**Potential exposures to airborne and settled surface dust
in residential areas of lower Manhattan following the collapse
of the World Trade Center--New York City, November 4-December 11, 2001.**

Abstract

Following the terrorist attacks of September 11, 2001, which destroyed the World Trade Center (WTC) in lower Manhattan, the New York City (NYC) Department of Health and Mental Hygiene (DOHMH) and the Agency for Toxic Substances and Disease Registry (ATSDR), with assistance from the U.S. Public Health Service (PHS) Commissioned Corps Readiness Force* and the WTC Environmental Assessment Working Group†, assessed the composition of outdoor and indoor settled surface and airborne dust in residential areas around the WTC and in comparison areas. This report summarizes the results of the investigation, which found 1) similar levels of airborne total fibers in lower and in upper Manhattan, 2) greater percentage levels of synthetic vitreous fibers (SVF) and mineral components of concrete and building wallboard in settled dust of residential areas in lower Manhattan than in upper Manhattan, and 3) low levels of asbestos in some settled surface dust in lower Manhattan residential areas (1). Based in part on the results of this investigation, the U.S. Environmental Protection Agency (EPA) is cleaning and sampling residential areas as requested by lower Manhattan residents. In addition, to assess any short- or long-term health effects of smoke, dust, and airborne substances around the WTC site, DOHMH and ATSDR are developing a registry that will track the health of persons who were most highly exposed to these materials.

During November 4--December 11, 2001, air and settled surface dust samples were collected in and around 30 residential buildings within three concentric circles surrounding the WTC site in lower Manhattan, including 59 residential units (2). In addition, five residential units in four buildings located north of 59th Street (approximately 5 miles northeast of the WTC site) were sampled for purposes of comparison. Attention was focused on building material constituents 1) that have irritant properties (e.g., SVF, including fiberglass and gypsum) or might have negative long-term health effects (e.g., crystalline silica and asbestos) and 2) that were reasonably presumed to be either in the initial WTC collapse dust cloud or in dust generated by subsequent rescue and recovery activities at the WTC site. All samples collected during the investigation were analyzed for the presence of asbestos, SVF, crystalline mineral components of concrete (e.g., silica, calcite, and portlandite), and crystalline mineral components of building wallboard (e.g., gypsum, mica, and halite).

At each sampling location, time-weighted air sampling was conducted for three or four particulate matter (PM) fractions (i.e., PM 100 microns, 10 microns, 4 microns, and 2.5 microns) (3--5). Each PM fraction was analyzed for crystalline minerals by using X-ray diffraction (XRD) analysis (6). The XRD analysis for crystalline minerals was semiquantitative (i.e., estimated). Air samples

for fibers were analyzed first by phase contrast microscopy (PCM) (5). If the concentration of total fibers was higher than the maximum concentration of fibers found in the comparison homes (0.003 fibers per cubic centimeter of air [f/cc]), the sample was re-analyzed for asbestos fibers by using transmission electron microscopy (TEM) (5). In addition, scanning electron microscopy (SEM) to look for SVF was used for PCM fiber counts >0.003 f/cc if the settled surface dust sample from that area contained SVF.

Settled surface dust samples also were taken at each sampling location and analyzed for crystalline minerals and fibers (Figure). Fiber analysis of settled dust samples for asbestos and SVF was conducted by using polarized light microscopy (PLM) (7). If asbestos levels were below the detection limit (i.e., <1%), samples were re-analyzed by using TEM (7). The dust samples also were analyzed for crystalline mineral content by using XRD.

Air Sampling Results

For 111 (94.9%) of the 117 air samples, the concentrations of fibers found in lower Manhattan residential areas were similar to the concentration of fibers found in comparison areas (<0.003 f/cc). The six lower Manhattan areas that had elevated total fiber counts were re-examined by TEM and SEM to determine the types of fibers; the results indicated that neither asbestos nor SVF (e.g., fiberglass) contributed to the elevated total fiber counts.

Air sampling results for minerals detected quartz and other building material constituents in lower Manhattan. No other forms of crystalline silica were detected in any air samples except for a one-time detection of cristobalite (15 micrograms per cubic meter [$\mu\text{g}/\text{m}^3$]). The estimated concentrations of these minerals in air were low. In some locations, mineral components of concrete (quartz [not detected (ND)--19 $\mu\text{g}/\text{m}^3$], calcite [ND--14 $\mu\text{g}/\text{m}^3$], and portlandite [ND--95 $\mu\text{g}/\text{m}^3$]) and mineral components of building wallboard (gypsum [ND--15 $\mu\text{g}/\text{m}^3$], mica [ND--43 $\mu\text{g}/\text{m}^3$], and halite [ND--19 $\mu\text{g}/\text{m}^3$]) were detected at higher estimated levels in air samples in lower Manhattan than in samples collected in comparison areas. Gypsum was the only mineral detected in the comparison building air samples (ND--5 $\mu\text{g}/\text{m}^3$). No other minerals tested (i.e., quartz, calcite, portlandite, mica, and halite) were detected in comparison building air samples.

Settled Surface Dust Results

In lower Manhattan, asbestos and SVF were found in some indoor settled dust samples from residential units and common areas (Table 1). No asbestos or SVF was detected in the comparison area dust samples. Quartz, calcite, portlandite, and gypsum comprised a higher percentage of the dust in 29 samples from buildings in lower Manhattan compared with eight samples from comparison area buildings (Table 2). Only two (2.1%) of the 97 dust samples collected provided enough bulk material for pH analysis. The samples, which were collected from two outdoor locations in lower Manhattan, had pH values of 8.6 and 9.8, respectively.

Reported by: NL Jeffery, MPH, C D'Andrea, MS, J Leighton, PhD, New York City Dept of Health and Mental Hygiene, New York. SE Rodenbeck, ScD, L Wilder, CIH, D DeVoney, PhD, S Neurath, PhD, CV Lee, MD, RC Williams, MS, Div of Health Assessment and Consultation, Agency for Toxic Substances and Diseases Registry.

Editorial Note:

Exposure to substantial amounts of SVF, mineral components of concrete, and mineral components of building wallboard might cause skin rashes, eye irritation, and upper respiratory irritation, all of which were reported more frequently than expected seasonal rates by community members and first responders after the collapse of the WTC towers (8--10). If the reported irritant effects were associated with WTC-related materials, these effects would subside once exposure to SVF, mineral components of concrete, and mineral components of building wallboard ceased. Persons with pre-existing heart or lung diseases (e.g., asthma) or a previous history of occupational exposure to these materials might be more sensitive to their irritant effects.

Settled surface dust might become airborne if disturbed, potentially causing exposures to occur through inhalation. Several worst-case assumptions were made to assess the potential long-term public health risks for inhaling airborne asbestos and quartz. These assumptions included 1) that no cleaning of indoor spaces had occurred or would occur, 2) that all airborne fibers were asbestos, and 3) that the highest levels detected during sampling represented long-term air levels. Under these worst-case conditions, prolonged exposure (i.e., decades) to airborne asbestos and quartz might increase the long-term risk for persons developing lung cancer and other adverse lung health effects (approximately one additional case per 10,000 persons exposed). However, persons who clean their residences frequently as recommended (1) or who participate in the EPA cleaning and sampling program are unlikely to be exposed to worst-case conditions.

The findings of this investigation are subject to at least two limitations. First, the results do not necessarily reflect conditions found in other buildings, the time period immediately after the collapse, or the time period after December 12, when the sampling was completed. Second, a limited number of samples were obtained from comparison areas to determine NYC background levels of asbestos, SVF, mineral components of concrete, and mineral components of building wallboard. The comparison area results might not reflect NYC background levels.

Following the investigation, DOHMH and ATSDR made three recommendations (1). First, because more asbestos, SVF, mineral components of concrete and building wallboard were found in settled surface dust in lower Manhattan residential areas than in comparison residential areas, residents of lower Manhattan were advised to continue cleaning frequently with high-efficiency particulate air (HEPA) filter vacuums and damp cloths/mops to reduce the potential for exposure. Second, to ensure the effectiveness of the recommended cleaning, DOHMH and

ATSDR recommended additional monitoring of residential areas in lower Manhattan and an investigation to define background levels specific to NYC for asbestos, SVF, mineral components of concrete, and mineral components of building wallboard. EPA is implementing this recommendation and conducting this investigation. Finally, lower Manhattan residents concerned about possible WTC-related dust in their residential areas were advised to request cleaning and testing from EPA no later than December 31, 2002. EPA is conducting the requested cleaning and testing of lower Manhattan residential areas.

DOHMH and ATSDR are developing a registry of those persons who were most highly exposed, including persons living, working, or attending school in lower Manhattan; persons who responded to the emergency; persons working at the WTC site or the Staten Island landfill following the attacks; and persons working in buildings that were damaged or destroyed in the attacks. The registry will track the health of participants to determine whether their exposures to smoke, dust, and airborne substances around the WTC site might have any short- or long-term impacts on their physical health. Additionally, the registry is intended to track the mental health of the approximately 100,000--200,000 persons who might enroll.

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New York City Department of Health response to terrorist attack, September 11, 2001.

Abstract

In response to two jet aircraft crashing into and causing the collapse of the 110-storied World Trade Center (WTC) towers and the subsequent destruction of nearby portions of lower Manhattan, the New York City Department of Health (NYCDOH) immediately activated its emergency response protocol, including the mobilization of an Emergency Operations Center.

Surveillance, clinical, environmental, sheltering, laboratory, management information systems, and operations were among the preestablished emergency committees. Because of its proximity to the WTC site, an emergency clinic was established at NYCDOH for triage and treatment of injured persons. NYCDOH focused its initial efforts on assessing the public health and medical impact of the attack and the resources needed to respond to it such as the care and management of large numbers of persons injured or killed by the crash; subsequent fire and building collapse; the health and safety of rescue workers; the environmental health risks (e.g., asbestos, smoke, dust, or chemical inhalation); other illnesses related to the disruption of the physical infrastructure (e.g., waterborne and foodborne diseases); and mental health concerns.

Despite the evacuation and relocation of NYCDOH's headquarters, the department continued essential public health services, including death registration.

A rapid assessment conducted by NYCDOH during the first 24 hours after the incident indicated that most emergency department (ED) visits were for minor injuries; approximately 10%--15% of ED patients were admitted and few deaths occurred. Hospital bed and staff capacity was adequate. Following the incident, NYCDOH prioritized four surveillance activities: 1) in collaboration with the Greater New York Hospital Association, an ongoing assessment of hospital staffing and equipment needs, and cumulative numbers of incident-related ED visits and hospital admissions; 2) an epidemiologic assessment of the types of injuries seen during the first 48 hours after the attack at one tertiary referral hospital and the four EDs closest to the crash site where the largest number of incident-related cases presented; 3) prospective surveillance of illnesses and injuries among rescue workers evaluated at the four hospitals and Disaster Medical Assistance Team triage units located at the crash site; and 4) active surveillance in EDs for specified clinical syndromes to identify unusual disease manifestations or clusters associated with these incidents, including those syndromes that could result from the release of a biologic agent.

To assist NYCDOH with syndromic surveillance, CDC Epidemic Intelligence Service officers have been stationed at EDs in 15 sentinel hospitals distributed throughout the five New York City boroughs. Other NYCDOH activities included an already existing syndromic surveillance sys-

tem to monitor 911 emergency calls. No unusual patterns of illness have been identified. NYCDOH also conducted laboratory testing of environmental samples and did not find evidence of a biologic agent release.

Air quality, safety of the municipal water supply, restaurant safety and rodent control, and other environmental conditions in the area continue to be monitored by NYCDOH, in collaboration with local, state, and federal agencies, to ensure the health and safety of workers at the site and residents in the immediate vicinity.

Frequent alerts are sent by broadcast facsimile and electronic mail to advise metropolitan New York health-care providers of ongoing public health concerns related to the aftermath of the attack. Advisories have been developed to address the public's concerns about such issues as asbestos exposure in collapsed buildings, decomposing bodies, and managing emotional trauma.

Working with the American Red Cross, NYCDOH school health program has provided nursing services and physician consultations to Red Cross shelters. The shelters serve families and persons displaced by the incident and provide respite to rescue workers. NYCDOH nurses provide nursing assessments, first-aid services, and medical referrals when needed.

In response to events in lower Manhattan and the related attack on the Pentagon in Washington, DC, the Federal Response Plan was activated.

The U.S. Department of Health and Human Services (DHHS) deployed federal resources under Emergency Support Function #8 (Health and Medical) to augment the state and local medical response.

A shipment of intravenous supplies, airway supplies, emergency medication, bandages and dressings, and other materials arrived in New York City the night of September 11; this was the first emergency mobilization of the National Pharmaceutical Stockpile. NYCDOH and the health department in Washington, DC, also obtained adequate supplies of tetanus vaccine from vaccine manufacturers.

CDC has sent epidemiologists, occupational health specialists, industrial hygienists, and other public health professionals to supplement local efforts. Information about federal support of the local public health response is available from DHHS at:

<http://www.hhs.gov>

https://www.unboundmedicine.com/medline/citation/11594721/New_York_City_Department_of_Health_response_to_terrorist_attack_September_11_2001

**Persistent mental and physical health impact
of exposure to the September 11, 2001 World Trade Center terrorist attacks**

Hannah T Jordan, et al.

Abstract

Background: Asthma, gastroesophageal reflux disease (GERD), posttraumatic stress disorder (PTSD) and depression have each been linked to exposure to the September 11, 2001 World Trade Center (WTC) terrorist attacks (9/11). We described the prevalence and patterns of these conditions and associated health-related quality of life (HRQOL) fifteen years after the attacks.

Methods: We studied 36,897 participants in the WTC Health Registry, a cohort of exposed rescue/recovery workers and community members, who completed baseline (2003-2004) and follow-up (2015-16) questionnaires. Lower respiratory symptoms (LRS; cough, dyspnea, or wheeze), gastroesophageal reflux symptoms (GERS) and self-reported clinician-diagnosed asthma and GERD history were obtained from surveys. PTSD was defined as a score > 44 on the PTSD checklist, and depression as a score > 10 on the Patient Health Questionnaire (PHQ). Poor HRQOL was defined as reporting limited usual daily activities for > 14 days during the month preceding the survey.

Results: In 2015-16, 47.8% of participants had ≥ 1 of the conditions studied. Among participants without pre-existing asthma, 15.4% reported asthma diagnosed after 9/11; of these, 76.5% had LRS at follow up. Among those without pre-9/11 GERD, 22.3% reported being diagnosed with GERD after 9/11; 72.2% had GERS at follow-up. The prevalence of PTSD was 14.2%, and of depression was 15.3%. HRQOL declined as the number of comorbidities increased, and was particularly low among participants with mental health conditions. Over one quarter of participants with PTSD or depression reported unmet need for mental health care in the preceding year.

Conclusions: Nearly half of participants reported having developed at least one of the physical or mental health conditions studied by 2015-2016; comorbidity among conditions was common. Poor HRQOL and unmet need for health were frequently reported, particularly among those with post-9/11 PTSD or depression. Comprehensive physical and mental health care are essential for survivors of complex environmental disasters, and continued efforts to connect 9/11-exposed persons to needed resources are critical.

Keywords:

Asthma; Depression; Epidemiology; Gastroesophageal reflux;
Health services; Health surveys; Quality of life; Registries;
September 11 terrorist attacks; Stress disorders, post-traumatic.

Conflict of interest statement

The US Centers for Disease Control and Prevention and New York City Department of Health and Mental Hygiene institutional review boards approved the Wave 1 and Wave 4 protocols. Verbal informed consent was obtained from each Registry participant at enrollment.

Competing interests: The authors declare that they have no competing interests.

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Alcohol use, mental health status and psychological well-being 2 years after the World Trade Center attacks in New York City

By Richard E Adams, Joseph A Boscarino and Sandro Galea

Abstract

Over the past 30 years, studies have shown that survivors of community-wide disasters suffer from a variety of physical and mental health problems. Researchers also have documented increased substance use in the aftermath of these disasters. In the present study, we examined the relationship between alcohol use and mental health status within the context of the terrorist attacks on the World Trade Center in New York City (NYC). The data for the present report come from a 2-wave panel study of adults living in NYC on the day of the attacks. Wave 1 (W1) and Wave 2 (W2) interviews occurred one year and two years after the attacks, respectively. Overall, 2,368 individuals completed the W1 survey (cooperation rate, 63%) and 1,681 completed the W2 survey (re-interview rate, 71%). The alcohol use variables examined were binge drinking, alcohol dependence, increased days drinking, and increased drinks per day. The outcomes examined included measures of posttraumatic stress disorder (PTSD), major depression, BSI-18-Global Severity and measures of SF12-mental and physical health status. After controlling for demographic, stress, and resource factors, multivariate logistic regressions indicated that all alcohol measures were related to one or more of these outcomes. In particular, binge drinking was related to partial PTSD, while alcohol dependence was associated with subsyndromal PTSD, severity of PTSD, depression, BSI-18 global severity, and SF-12 poor mental health status. Increased post-disaster drinking was positively associated with subsyndromal PTSD and negatively associated with SF-12 physical health. We discuss reasons for these results and the negative consequences that heavy alcohol use may have on the postdisaster recovery process.

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Community Needs Assessment of Lower Manhattan Residents Following the World Trade Center Attacks - Manhattan, New York City, 2001

On September 11, 2001, terrorists attacked and destroyed the World Trade Center (WTC) in New York City (NYC). An estimated 2,819 persons were reported killed in the attacks; many others were injured (Office of the Chief Medical Examiner, New York City Department of Health and Mental Hygiene [NYCDOHMH], unpublished data, 2002). An estimated 25,000 persons living nearby in lower Manhattan were affected both physically and emotionally. Many persons witnessed the attacks; lost family and friends; were exposed to smoke, dust, and debris; and evacuated their homes. To identify the health-related needs and concerns of persons residing near the attack site, NYCDOHMH, in collaboration with CDC, surveyed persons residing in areas immediately surrounding the WTC site. The primary purpose of the survey was to gather information to set priorities and direct public health interventions. This report summarizes findings from the assessment, which indicate that a large proportion of respondents had physical and psychological symptoms potentially associated with the exposure and needed information to address their health and safety concerns. On the basis of the results of the survey, NYCDOHMH responded to resident concerns, helped reduce exposure to dust and debris, and provided information about mental health resources.

The survey was conducted door-to-door in three residential areas in lower Manhattan: Battery Park City, Southbridge Towers, and Independence Plaza (populations: approximately 8,000, 2,000, and 2,300, respectively) (Figure). These areas represented compact, well-defined neighborhoods comprising approximately 50% of the residential population of lower Manhattan. On the basis of data from the NYC Department of City Planning and on information provided by building managers, a representative random sample of households were selected, yielding a final sample size of >100 households per area. Survey teams composed of NYCDOHMH and CDC staff interviewed one adult (i.e., person aged >18 years) in each household selected.

A standardized questionnaire was developed to obtain information about household demographics, exposure to the WTC attack, physical and mental health status, access to services, and urgent needs and concerns. The questionnaire included the Post-Traumatic Stress Disorder (PTSD) checklist, a validated 17-item screening instrument for symptoms of PTSD based closely on DSM-IV criteria (1). Data were analyzed using Epi-Info 6.04 and SAS 8.2. Data from the three surveyed areas were combined and weighted on the basis of the total number of occupied households in each neighborhood.

With the assistance of building managers and staff, tenant associations, and other community organizations, survey teams succeeded in contacting 485 of 990 households that had been selected randomly. Uncontacted households included those that were not yet reoccupied and those whose residents were unavailable when visited. A total of 71 persons declined to partici-

pate; the overall participation rate was 85.4%. During October 25--November 2, 2001, a total of 414 surveys were completed, including 145 in Battery Park City, 157 at Southbridge Towers, and 112 at Independence Plaza. Overall, an estimated 75.1% (95% confidence interval [CI]=71.8%--78.4%) of households were evacuated after the attacks. Respondents had a median age of 45 years (range: 18--92 years), and 16.4% (95% CI=12.7%--20.1%) had children aged <18 years. An estimated 55.2% (95% CI=50.1%--60.4%) of the population witnessed the collapse of the WTC towers, 29.0% (95% CI=24.2%--33.7%) witnessed persons being injured or killed, and 48.1% (95% CI=42.9%--53.2%) knew someone who died as a result of the attacks.

Although many households lost utility services (i.e., water, electricity, and gas) after September 11, almost all had functional services at the time of interview; however, some households still did not have telephone service (15.5%; 95% CI=12.1%--18.8%). Approximately half of the population reported feeling safe in their homes; those not feeling safe were most concerned about air quality and surface dust. Information about proper cleaning procedures was received by 61.2% (95% CI=56.3%--66.2%), and 45.2% (95% CI=39.9%--50.6%) reported that their apartments had been cleaned according to recommended methods of wet mopping hard surfaces and using high-efficiency particulate air (HEPA) filter vacuums on carpeting. Residents also indicated a need for further information regarding exposure to dust and debris from the WTC and its effect on health, recommendations for proper clean up, and availability of both mental health and relief services.

Symptoms reported most frequently that developed or increased after September 11 were nose or throat irritations (65.8%; 95% CI=60.9%--70.7), eye irritation or infection (49.7%; 95% CI=44.6%--54.9%), and coughing (46.5%; 95% CI=41.3%--51.6%). At the time of the interviews, these symptoms continued to be a problem among approximately 82% of the adult population. Few respondents reported lack of access to medical care (6.6%; 95% CI=4.1%--9.2%), yet 13.6% (95% CI=9.6%--17.5%) reported problems filling prescriptions, primarily because of problems with phones and transportation.

When asked about symptoms of PTSD, an estimated 38.9% (95% CI=33.9%--44.0%) of the adult population scored above the screening cutoff of 43, indicating a need for further mental health evaluation and a potential for PTSD. An estimated 36.8% (95% CI=28.9%--44.7%) of this population had received some type of supportive counseling, compared with 22.7% (95% CI=16.9%--28.4%) of the population with scores below the cutoff. Overall, an estimated 28.1% (95% CI=23.4%--32.8%) of the adult population had received some type of supportive counseling. A total of 38.7% (95% CI=33.6%--43.9%) thought they would benefit from any or additional supportive counseling; of these, 34.0% (95% CI=25.8%--42.3%) reported not having adequate access to this kind of support. When asked about alcohol use, 14.0% (95% CI=10.2%--17.7%) reported having used alcohol more than they meant to since the attack, and 6.5% (95% CI=3.7%--9.2%) felt that they needed to decrease their drinking since the attack.

On the basis of the survey results, NYCDOHMH initiated focused outreach in lower Manhat-

tan neighborhoods through presentations with tenant associations and community groups to share information and provide a forum for questions and concerns. Materials were developed and disseminated regarding environmental issues and related health problems, current air and dust testing results and their implications, recommendations for cleaning up and reducing further exposures, psychological effects, and availability of relief services. Materials were distributed to residential buildings and community organizations, and were made available at public places (e.g., libraries, stores, and restaurants) and on NYCDOHMH's website (<http://www.nyc.gov/html/doh/pdf/chw/needs1.pdf>). NYCDOHMH monitored efforts to maintain dust suppression in the areas close to the WTC site and communicated closely with other agencies overseeing the cleanup process around the site. The assessment findings also were shared with Project Liberty, a disaster recovery program funded by the Federal Emergency Management Agency that provides outreach, crisis counseling, and public education services to persons affected by the WTC disaster.

Reported by: R Kramer, ScD, R Hayes, MA, V Nolan, MPH, S Cotenoff, JD, A Goodman, MD, New York City Dept of Health and Mental Health. WR Daley, DVM, C Rubin, DVM, A Henderson, PhD, WD Flanders, MD. National Center for Environmental Health; N Smith, PhD, EIS Officer, CDC.

Editorial Note:

This community assessment documented the public health impact of the WTC attacks on persons living nearby in lower Manhattan. Although basic community services were available 6 weeks after the attacks, persistent physical and psychological symptoms were reported among local residents. Residents also expressed concern about air quality and potential short- and long-term health effects, especially after Environmental Protection Agency reports of the presence of asbestos, particulate matter, and volatile organic compounds at the WTC site. The high proportion of the local population that reported experiencing health problems potentially related to respiratory irritants supported this concern. As with other needs assessments conducted soon after a disaster (2,3), this survey provided systematically collected information that could be used to respond to public concerns and to address the health and mental health needs of this population.

Although the air quality in lower Manhattan improved with time, resulting in a reduction of some of the immediate physical impact from the attacks, the psychological impact remained. The estimated proportion of residents with increased potential for PTSD is consistent with estimates of PTSD following other disasters (4,5). These estimates suggest that thousands of persons residing in lower Manhattan might have been at risk for PTSD and could potentially benefit from receiving supportive mental health services. A central component to outreach in this community involved education about the benefits and availability of supportive counseling services available through Project Liberty.

The findings in this report are subject to at least four limitations. First, the survey did not in-

clude persons who had not yet returned to their homes. Those who delayed returning might have had more serious psychological or physical symptoms. Second, because the survey did not include this population, the estimates for the mean time of evacuation also are underestimated. Third, no background or comparison data were available to validate the self-reported assessment of health effects, and these assessments were not verified by health-care providers. Finally, the indicator of potential for PTSD was not diagnostic.

In response to the assessment, NYCDOHMH conducted extensive outreach, developed and disseminated informational materials, and provided referral services to meet community needs. This assessment and its follow-up activities also provided an opportunity for persons living near the WTC site to voice their concerns to government agencies in the aftermath of the disaster. NYCDOHMH was able to provide an important service for this community by giving local residents timely and comprehensive information. Feedback received from residents highlights the need to conduct a community assessment as soon as possible after a disaster.

Because the needs and health effects following a disaster often vary over time, multiple community assessments might be necessary to monitor these changes and to reach different populations if evacuations have occurred.

The availability of standardized assessment tools and local health professionals trained in rapid needs assessment procedures could facilitate understanding a community's post-disaster needs.

Acknowledgments

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<https://www.cdc.gov/mmwr/preview/mmwrhtml/mm51SPa4.htm>

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**Gastroesophageal reflux symptoms and comorbid asthma
and posttraumatic stress disorder following the 9/11 terrorist attacks
on World Trade Center in New York City**

Jiehui Li, et al.

Abstract

Objectives: Excess gastroesophageal reflux disease (GERD) was reported in several populations exposed to the September 11 2001 (9/11) terrorist attacks on the World Trade Center (WTC).

We examined new onset gastroesophageal reflux symptoms (GERS) since 9/11 and persisting up to 5-6 years in relation to 9/11-related exposures among the WTC Health Registry enrollees, and potential associations with comorbid asthma and posttraumatic stress disorder (PTSD).

Methods: This is a retrospective analysis of 37,118 adult enrollees (i.e., rescue/recovery workers, local residents, area workers, and passersby in lower Manhattan on 9/11) who reported no pre-9/11 GERS and who participated in two Registry surveys 2-3 and 5-6 years after 9/11.

Post-9/11 GERS (new onset since 9/11) reported at first survey, and persistent GERS (post-9/11 GERS reported at both surveys) were analyzed using log-binomial regression.

Results: Cumulative incidence was 20% for post-9/11 GERS and 13% for persistent GERS. Persistent GERS occurred more often among those with comorbid PTSD (24%), asthma (13%), or both (36%) compared with neither of the comorbid conditions (8%). Among enrollees with neither asthma nor PTSD, the adjusted risk ratio (aRR) for persistent GERS was elevated among:

workers arriving at the WTC pile on 9/11 (aRR=1.6; 95% confidence interval (CI) 1.3-2.1) or working at the WTC site > 90 days (aRR=1.6; 1.4-2.0); residents exposed to the intense dust cloud on 9/11 (aRR=1.5; 1.0-2.3), or who did not evacuate their homes (aRR=1.7; 1.2-2.3); and area workers exposed to the intense dust cloud (aRR=1.5; 1.2-1.8).

Conclusions: Disaster-related environmental exposures may contribute to the development of GERS. GERS may be accentuated in the presence of asthma or PTSD.

<https://pubmed.ncbi.nlm.nih.gov/21894225/>

**Effect of asthma and PTSD
on persistence and onset of gastroesophageal reflux symptoms
among adults exposed to the September 11, 2001, terrorist attacks**

Jiehui Li, et al.

Abstract

Background: Little is known about the direction of causality among asthma, posttraumatic stress disorder (PTSD), and onset of gastroesophageal reflux symptoms (GERS) after exposure to the 9/11/2001 World Trade Center (WTC) disaster.

Methods: Using data from the WTC Health Registry, we investigated the effects of early diagnosed post-9/11 asthma and PTSD on the late onset and persistence of GERS using log-binomial regression, and examined whether PTSD mediated the asthma-GERS association using structural equation modeling.

Results: Of 29,406 enrollees, 23% reported GERS at follow-up in 2011-2012. Early post-9/11 asthma and PTSD were each independently associated with both the persistence of GERS that was present at baseline and the development of GERS in persons without a prior history.

PTSD mediated the association between early post-9/11 asthma and late-onset GERS.

Conclusions: Clinicians should assess patients with post-9/11 GERS for comorbid asthma and PTSD, and plan medical care for these conditions in an integrated fashion.

Am. J. Ind. Med. 59:805-814, 2016

Keywords:

PTSD; World Trade Center; asthma; gastroesophageal reflux; terrorist attacks.

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Pulmonary disease in rescue workers at the World Trade Center site

By G I Banauch, A Dhala and D J Prezant

Abstract

Purpose of review: The catastrophic collapse of the World Trade Center (WTC) towers on September 11, 2001 created a large-scale disaster site in a densely populated urban environment.

Over the ensuing months, tens of thousands of rescue, recovery and cleanup workers, volunteers, and residents of the adjacent community were exposed to a complex mixture of airborne pollutants.

This review focuses on currently described respiratory syndromes, symptoms, and physiologic derangements in WTC rescue, recovery, and cleanup workers, discusses potential long-term effects on respiratory health, and draws parallels to community findings.

Recent findings: Detailed qualitative and quantitative analyses of airborne pollutants with their changing composition during initial rescue/recovery and subsequent cleanup have been published.

Major concerns include persistent aerodigestive tract inflammatory syndromes, such as reactive airways dysfunction syndrome (RADS), reactive upper airways dysfunction syndrome (RUDS), gastroesophageal reflux disease (GERD), and inflammatory pulmonary parenchymal syndromes, as well as respiratory tract and nonrespiratory malignancies.

Aerodigestive tract inflammatory syndromes have now been documented in WTC exposed occupational groups, and syndrome incidence has been linked to WTC airborne pollutant exposure intensity. Community based investigations have yielded similar findings.

Summary: While it is too early to ascertain long-term effects of WTC dust exposure, current studies already demonstrate a definite link between exposure to WTC-derived airborne pollutants and respiratory disease, both in the occupational and the community setting.

A better understanding of causes and effects of this exposure will help in developing appropriate preventative tools for rescue workers in future disasters.

<https://pubmed.ncbi.nlm.nih.gov/15699790/>

**Bronchial hyperreactivity and other inhalation lung injuries
in rescue/recovery workers after the World Trade Center collapse**

Gisela I Banauch, et al.

Abstract

Background: The collapse of the World Trade Center (WTC) on September 11, 2001 created a large-scale disaster site in a dense urban environment.

In the days and months thereafter, thousands of rescue/recovery workers, volunteers, and residents were exposed to a complex mixture of airborne pollutants.

Methods: We review current knowledge of aerodigestive inhalation lung injuries resulting from this complex exposure and present new data on the persistence of nonspecific bronchial hyperreactivity (methacholine PC20 \leq 8 mg/mL) in a representative sample of 179 Fire Department of the City of New York (FDNY) rescue workers stratified by exposure intensity (according to arrival time) who underwent challenge testing at 1, 3, 6, and 12 months post-collapse.

Results: Aerodigestive tract inflammatory injuries, such as declines in pulmonary function, reactive airways dysfunction syndrome (RADS), asthma, reactive upper airways dysfunction syndrome (RUDS), gastroesophageal reflux disease (GERD), and rare cases of inflammatory pulmonary parenchymal diseases, have been documented in WTC rescue/recovery workers and volunteers.

In FDNY rescue workers, we found persistent hyperreactivity associated with exposure intensity, independent of airflow obstruction.

One year post-collapse, 23% of highly exposed subjects were hyperreactive as compared with only 11% of moderately exposed and 4% of controls. At 1 yr, 16% met the criteria for RADS.

Conclusions: While it is too early to ascertain all of the long-term effects of WTC exposures, continued medical monitoring and treatment is needed to help those exposed and to improve our prevention, diagnosis, and treatment protocols for future disasters.

<https://pubmed.ncbi.nlm.nih.gov/15640671/>

**Biomonitoring of perfluorochemicals in plasma
of New York State personnel responding to the World Trade Center disaster**

Lin Tao, et al.

Abstract

The collapse of the World Trade Center (WTC) on September 11, 2001 resulted in the release of several airborne pollutants in and around the site. Perfluorochemicals including perfluorooctanesulfonate (PFOS) and perfluorooctanoic acid (PFOA), which are used in soil- and stain-resistant coatings on upholstery, carpets, leather, floor waxes, polishes, and in fire-fighting foams were potentially released during the collapse of the WTC. In this pilot study, we analyzed 458 plasma samples of New York State (NYS) employees and National Guard personnel assigned to work in the vicinity of the WTC between September 11 and December 23, 2001, to assess exposure to perfluorochemicals released in dust and smoke. The plasma samples collected from NYS WTC responders were grouped based on estimated levels of exposure to dust and smoke, as follows: more dust exposure (MDE), less dust exposure (LDE), more smoke exposure (MSE), and less smoke exposure (LSE). Furthermore, samples were grouped, based on self-reported symptoms at the time of sampling, as symptomatic and asymptomatic. Eight perfluorochemicals were measured in 458 plasma samples. PFOS, PFOA, perfluorohexanesulfonate (PFHxS), and perfluorononanoic acid (PFNA), were consistently detected in almost all samples. PFOA and PFHxS concentrations were approximately 2-fold higher in WTC responders than the concentrations reported for the U.S. general population. No significant difference was observed in the concentrations of perfluorochemicals between symptomatic and asymptomatic groups. Concentrations of PFHxS were significantly ($p < \text{or} = 0.05$) higher in the MDE group than in the LDE group. Concentrations of PFNA were significantly higher in the MSE group than in the LSE group. Significantly higher concentrations of PFOA and PFHxS were found in individuals exposed to smoke than in individuals exposed to dust. A significant negative correlation existed between plasma lipid content and concentrations of certain perfluorochemicals.

Our initial findings suggest that WTC responders were exposed to perfluorochemicals, especially PFOA, PFNA, and PFHxS, through inhalation of dust and smoke released during and after the collapse of the WTC. The potential health implications of these results are unknown at this time. Expansion of testing to include all archived samples will be critical to help confirm these findings. In doing so, it may be possible to identify biological markers of WTC exposure and to improve our understanding of the health impacts of these compounds.

<https://pubmed.ncbi.nlm.nih.gov/18522136/>

**Persistence of multiple illnesses in World Trade Center rescue and recovery workers:
a cohort study**

Juan P Wisnivesky, et al.

Abstract

Background: More than 50,000 people participated in the rescue and recovery work that followed the Sept 11, 2001 (9/11) attacks on the World Trade Center (WTC). Multiple health problems in these workers were reported in the early years after the disaster. We report incidence and prevalence rates of physical and mental health disorders during the 9 years since the attacks, examine their associations with occupational exposures, and quantify physical and mental health comorbidities.

Methods: In this longitudinal study of a large cohort of WTC rescue and recovery workers, we gathered data from 27,449 participants in the WTC Screening, Monitoring, and Treatment Program. The study population included police officers, firefighters, construction workers, and municipal workers. We used the Kaplan-Meier procedure to estimate cumulative and annual incidence of physical disorders (asthma, sinusitis, and gastro-oesophageal reflux disease), mental health disorders (depression, post-traumatic stress disorder [PTSD], and panic disorder), and spirometric abnormalities. Incidence rates were assessed also by level of exposure (days worked at the WTC site and exposure to the dust cloud).

Findings: 9-year cumulative incidence of asthma was 27.6% (number at risk: 7027), sinusitis 42.3% (5870), and gastro-oesophageal reflux disease 39.3% (5650). In police officers, cumulative incidence of depression was 7.0% (number at risk: 3648), PTSD 9.3% (3761), and panic disorder 8.4% (3780). In other rescue and recovery workers, cumulative incidence of depression was 27.5% (number at risk: 4200), PTSD 31.9% (4342), and panic disorder 21.2% (4953). 9-year cumulative incidence for spirometric abnormalities was 41.8% (number at risk: 5769); three-quarters of these abnormalities were low forced vital capacity. Incidence of most disorders was highest in workers with greatest WTC exposure. Extensive comorbidity was reported within and between physical and mental health disorders.

Interpretation: 9 years after the 9/11 WTC attacks, rescue and recovery workers continue to have a substantial burden of physical and mental health problems. These findings emphasise the need for continued monitoring and treatment of the WTC rescue and recovery population.

Funding: Centers for Disease Control and Prevention and National Institute for Occupational Safety and Health.

[https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(11\)61180-X/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(11)61180-X/fulltext)

**Potential for diffuse parenchymal lung disease
after exposures at World Trade Center Disaster site**

By Jaime Szeinuk, María Padilla and Rafael E de la Hoz

Abstract

Objective: The diffuse parenchymal lung diseases (DPLDs) are a heterogeneous group of disorders that result from damage to the lung parenchyma. While the cause of most DPLDs remains unknown, extensive epidemiological and experimental evidence has linked exposure to environmental toxins to the pathogenesis of some of those diseases. The purpose of this review is to examine the potential relation between exposure to toxins released from the World Trade Center (WTC) collapse on September 11th, 2001 and the development of DPLD based on published evidence up to date.

Methods: We examine such evidence from two points of view, (1) exposure, and (2) histopathogenesis.

Exposure: Analyses of WTC-dust and particle size demonstrate that some portion of the dust was composed of particles small enough to penetrate deep into the lungs, reaching distal airways and alveoli. The presence of such particles has been confirmed in studies of induced sputum and bronchoalveolar lavage in WTC-exposed firefighters. **Histopathogenesis:** In vitro and animal experiments and patient evidence suggest that WTC dust is capable of inducing a pulmonary interstitial inflammatory response.

Results: To date, there have been limited clinical reports documenting the development of diffuse parenchymal responses following exposure to WTC dust. No single common pathologic response has been described. The one common denominator in the reports is that the individuals who developed disease were heavily exposed either during the disaster or during the initial 2-to-3 days following the disaster.

Conclusion: DLPDs are probably associated with heavy or extended exposure to the toxins released at the WTC disaster site.

Coupled with the historical experience with exposures to occupational toxins this mandates continued long-term clinical observation of this cohort.

<https://pubmed.ncbi.nlm.nih.gov/18500711/>

**Synergistic Effect of WTC-Particulate Matter
and Lysophosphatidic Acid Exposure and the Role of RAGE:
In-Vitro and Translational Assessment**

Rachel Lam, et al.

Abstract

World Trade Center particulate matter (WTC-PM)-exposed firefighters with metabolic syndrome (MetSyn) have a higher risk of WTC lung injury (WTC-LI). Since macrophages are crucial innate pulmonary mediators, we investigated WTC-PM/lysophosphatidic acid (LPA) co-exposure in macrophages.

LPA, a low-density lipoprotein metabolite, is a ligand of the advanced glycation end-products receptor (AGER or RAGE). LPA and RAGE are biomarkers of WTC-LI. Human and murine macrophages were exposed to WTC-PM, and/or LPA, and compared to controls.

Supernatants were assessed for cytokines/chemokines; cell lysate immunoblots were assessed for signaling intermediates after 24 h. To explore the translatability of our in-vitro findings, we assessed serum cytokines/chemokines and metabolites of symptomatic, never-smoking WTC-exposed firefighters. Agglomerative hierarchical clustering identified phenotypes of WTC-PM-induced inflammation. WTC-PM induced GM-CSF, IL-8, IL-10, and MCP-1 in THP-1-derived macrophages and induced IL-1 α , IL-10, TNF- α , and NF- κ B in RAW264.7 murine macrophage-like cells. Co-exposure induced synergistic elaboration of IL-10 and MCP-1 in THP-1-derived macrophages. Similarly, co-exposure synergistically induced IL-10 in murine macrophages.

Synergistic effects were seen in the context of a downregulation of NF- κ B, p-Akt, -STAT3, and -STAT5b. RAGE expression after co-exposure increased in murine macrophages compared to controls.

In our integrated analysis, the human cytokine/chemokine biomarker profile of WTC-LI was associated with discriminatory metabolites (fatty acids, sphingolipids, and amino acids). LPA synergistically elaborated WTC-PM's inflammatory effects in vitro and was partly RAGE-mediated. Further research will focus on the intersection of MetSyn/PM exposure.

Keywords: RAGE; lysophosphatidic acid; particulate matter exposure; synergy.

<https://pubmed.ncbi.nlm.nih.gov/32560330/>

**Receptor for advanced glycation end-products
and World Trade Center particulate induced lung function loss:
A case-cohort study and murine model of acute particulate exposure**

Erin J Caraher, et al.

Abstract

World Trade Center-particulate matter(WTC-PM) exposure and metabolic-risk are associated with WTC-Lung Injury(WTC-LI). The receptor for advanced glycation end-products (RAGE) is most highly expressed in the lung, mediates metabolic risk, and single-nucleotide polymorphisms at the AGER-locus predict forced expiratory volume(FEV).

Our objectives were to test the hypotheses that RAGE is a biomarker of WTC-LI in the FDNY-cohort and that loss of RAGE in a murine model would protect against acute PM-induced lung disease. We know from previous work that early intense exposure at the time of the WTC collapse was most predictive of WTC-LI therefore we utilized a murine model of intense acute PM-exposure to determine if loss of RAGE is protective and to identify signaling/cytokine intermediates. This study builds on a continuing effort to identify serum biomarkers that predict the development of WTC-LI. A case-cohort design was used to analyze a focused cohort of male never-smokers with normal pre-9/11 lung function. Odds of developing WTC-LI increased by 1.2, 1.8 and 1.0 in firefighters with soluble RAGE (sRAGE) \geq 97pg/mL, CRP \geq 2.4mg/L, and MMP-9 \leq 397ng/mL, respectively, assessed in a multivariate logistic regression model (ROCAUC of 0.72). Wild type(WT) and RAGE-deficient(Ager^{-/-}) mice were exposed to PM or PBS-control by oropharyngeal aspiration.

Lung function, airway hyperreactivity, bronchoalveolar lavage, histology, transcription factors and plasma/BAL cytokines were quantified. WT-PM mice had decreased FEV and compliance, and increased airway resistance and methacholine reactivity after 24-hours. Decreased IFN- γ and increased LPA were observed in WT-PM mice; similar findings have been reported for firefighters who eventually develop WTC-LI. In the murine model, lack of RAGE was protective from loss of lung function and airway hyperreactivity and was associated with modulation of MAP kinases. We conclude that in a multivariate adjusted model increased sRAGE is associated with WTC-LI. In our murine model, absence of RAGE mitigated acute deleterious effects of PM and may be a biologically plausible mediator of PM-related lung disease.

<https://pubmed.ncbi.nlm.nih.gov/28926576/>

**Multiomics of World Trade Center Particulate Matter-induced
Persistent Airway Hyperreactivity.
Role of Receptor for Advanced Glycation End Products**

Syed H Haider, et al.

Abstract

Pulmonary disease after World Trade Center particulate matter (WTC-PM) exposure is associated with dyslipidemia and the receptor for advanced glycation end products (RAGE); however, the mechanisms are not well understood.

We used a murine model and a multiomics assessment to understand the role of RAGE in the pulmonary long-term effects of a single high-intensity exposure to WTC-PM. After 1 month, WTC-PM-exposed wild-type (WT) mice had airway hyperreactivity, whereas RAGE-deficient (Ager^{-/-}) mice were protected. PM-exposed WT mice also had histologic evidence of airspace disease, whereas Ager^{-/-} mice remained unchanged. Inflammatory mediators such as G-CSF (granulocyte colony-stimulating factor), IP-10 (IFN- γ -induced protein 10), and KC (keratinocyte chemoattractant) were differentially expressed after WTC-PM exposure. WTC-PM induced α -SMA, DIAPH1 (protein diaphanous homolog 1), RAGE, and significant lung collagen deposition in WT compared with Ager^{-/-} mice. Compared with WT mice with PM exposure, relative expression of phosphorylated to total CREB (cAMP response element-binding protein) and JNK (c-Jun N-terminal kinase) was significantly increased in the lung of PM-exposed Ager^{-/-} mice, whereas Akt (protein kinase B) was decreased.

Random forests of the refined lung metabolomic profile classified subjects with 92% accuracy; principal component analysis captured 86.7% of the variance in three components and demonstrated prominent subpathway involvement, including known mediators of lung disease such as vitamin B6 metabolites, sphingolipids, fatty acids, and phosphatidylcholines. Treatment with a partial RAGE antagonist, pioglitazone, yielded similar fold-change expression of metabolites (N6-carboxymethyllysine, 1-methylnicotinamide, N1+N8-acetylspermidine, and succinylcarnitine [C4-DC]) between WT and Ager^{-/-} mice exposed to WTC-PM. RAGE can mediate WTC-PM-induced airway hyperreactivity and warrants further investigation.

Keywords: airway hyperreactivity; lung injury; murine models;
occupational exposure; particulate matter.

<https://pubmed.ncbi.nlm.nih.gov/32315541/>

**Cardiovascular biomarkers predict susceptibility to lung injury
in World Trade Center dust-exposed firefighters**

Michael D Weiden, et al.

Abstract

Pulmonary vascular loss is an early feature of chronic obstructive pulmonary disease.

Biomarkers of inflammation and of metabolic syndrome predict loss of lung function in World Trade Center (WTC) lung injury (LI). We investigated if other cardiovascular disease (CVD) biomarkers also predicted WTC-LI.

This nested case-cohort study used 801 never-smoker, WTC-exposed firefighters with normal pre-9/11 lung function presenting for subspecialty pulmonary evaluation (SPE) before March 2008. A representative subcohort of 124 out of 801 subjects with serum drawn within 6 months of 9/11 defined CVD biomarker distribution.

Post-9/11 forced expiratory volume in 1 s (FEV1) at defined cases were as follows: susceptible WTC-LI cases with FEV1 $\leq 77\%$ predicted (66 out of 801) and resistant WTC-LI cases with FEV1 $\geq 107\%$ predicted (68 out of 801). All models were adjusted for WTC exposure intensity, body mass index at SPE, age on 9/11 and pre-9/11 FEV1.

Susceptible WTC-LI cases had higher levels of apolipoprotein-AII, C-reactive protein and macrophage inflammatory protein-4 with significant relative risks (RRs) of 3.85, 3.93 and 0.26, respectively, with an area under the curve (AUC) of 0.858. Resistant WTC-LI cases had significantly higher soluble vascular cell adhesion molecule and lower myeloperoxidase, with RRs of 2.24 and 2.89, respectively (AUC 0.830).

Biomarkers of CVD in serum 6 months post-9/11 predicted either susceptibility or resistance to WTC-LI. These biomarkers may define pathways either producing or protecting subjects from pulmonary vascular disease and associated loss of lung function after an irritant exposure.

Keywords: Airway inflammation; cytokines; pulmonary function testing.

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Biomarkers

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**Lysophosphatidic acid and apolipoprotein A1
predict increased risk of developing World Trade Center-lung injury:
a nested case-control study**

Jun Tsukiji, et al.

Abstract

Rationale: Metabolic syndrome, inflammatory and vascular injury markers measured in serum after World Trade Center (WTC) exposures predict abnormal FEV₁.

We hypothesized that elevated LPA levels predict FEV₁ < LLN.

Methods: Nested case-control study of WTC-exposed firefighters. Cases had FEV₁ < LLN. Controls derived from the baseline cohort. Demographics, pulmonary function, serum lipids, LPA and ApoA1 were measured.

Results: LPA and ApoA1 levels were higher in cases than controls and predictive of case status.

LPA increased the odds by 13% while ApoA1 increased the odds by 29% of an FEV₁ < LLN in a multivariable model.

Conclusions: Elevated LPA and ApoA1 are predictive of a significantly increased risk of developing an FEV₁ < LLN.

<https://pubmed.ncbi.nlm.nih.gov/24548082/>

**World Trade Center-Cardiorespiratory and Vascular Dysfunction:
Assessing the Phenotype and Metabolome of
a Murine Particulate Matter Exposure Model**

Arul Veerappan, et al.

Abstract

Vascular changes occur early in the development of obstructive airways disease. However, the vascular remodeling and dysfunction due to World Trade Center-Particulate Matter (WTC-PM) exposure are not well described and are therefore the focus of this investigation. C57Bl/6 female mice oropharyngeally aspirated 200 µg of WTC-PM53 or phosphate-buffered saline (PBS) (controls). 24-hours (24-hrs) and 1-Month (1-M) after exposure, echocardiography, micro-positron emission tomography(µ-PET), collagen quantification, lung metabolomics, assessment of antioxidant potential and soluble-receptor for advanced glycation end products (sRAGE) in bronchoalveolar lavage(BAL) and plasma were performed. 24-hrs post-exposure, there was a significant reduction in (1) Pulmonary artery(PA) flow-velocity and pulmonary ejection time(-PET) (2) Pulmonary acceleration time(PAT) and PAT/PET, while (3) Aortic ejection time(AET) and velocity time integral(VTI) were increased, and (4) Aortic acceleration time (AAT)/AET, cardiac output and stroke volume were decreased compared to controls. 1-M post-exposure, there was also significant reduction of right ventricular diameter as right ventricle free wall thickness was increased and an increase in tricuspid E, A peaks and an elevated E/A. The pulmonary and cardiac standard uptake value and volume 1-M post-exposure was significantly elevated after PM-exposure. Similarly, α-smooth muscle actin(α-SMA) expression, aortic collagen deposition was elevated 1-M after PM exposure. In assessment of the metabolome, prominent subpathways included advanced glycation end products (AGEs), phosphatidylcholines, sphingolipids, saturated/unsaturated fatty acids, eicosanoids, and phospholipids. BAL superoxide dismutase(-SOD), plasma total-antioxidant capacity activity, and sRAGE (BAL and plasma) were elevated after 24-hrs. PM exposure and associated vascular disease are a global health burden. Our study shows persistent WTC-Cardiorespiratory and Vascular Dysfunction (WTC-CaRVD), inflammatory changes and attenuation of antioxidant potential after PM exposure. Early detection of vascular disease is crucial to preventing cardiovascular deaths and future work will focus on further identification of bioactive therapeutic targets.

Conflict of interest statement

The authors declare no competing interests.

<https://pubmed.ncbi.nlm.nih.gov/32081898/>

**Biomarkers of World Trade Center Particulate Matter Exposure:
Physiology of Distal Airway and Blood Biomarkers that Predict FEV₁ Decline**

Michael D Weiden, et al.

Abstract

Biomarkers can be important predictors of disease severity and progression. The intense exposure to particulates and other toxins from the destruction of the World Trade Center (WTC) overwhelmed the lung's normal protective barriers.

The Fire Department of New York (FDNY) cohort not only had baseline pre-exposure lung function measures but also had serum samples banked soon after their WTC exposure. This well-phenotyped group of highly exposed first responders is an ideal cohort for biomarker discovery and eventual validation. Disease progression was heterogeneous in this group in that some individuals subsequently developed abnormal lung function while others recovered.

Airflow obstruction predominated in WTC-exposed patients who were symptomatic. Multiple independent disease pathways may cause this abnormal FEV₁ after irritant exposure.

WTC exposure activates one or more of these pathways causing abnormal FEV₁ in an individual. Our hypothesis was that serum biomarkers expressed within 6 months after WTC exposure reflect active disease pathways and predict subsequent development or protection from abnormal FEV₁ below the lower limit of normal known as WTC-Lung Injury (WTC-LI).

We utilized a nested case-cohort control design of previously healthy never smokers who sought subspecialty pulmonary evaluation to explore predictive biomarkers of WTC-LI. We have identified biomarkers of inflammation, metabolic derangement, protease/antiprotease balance, and vascular injury expressed in serum within 6 months of WTC exposure that were predictive of their FEV₁ up to 7 years after their WTC exposure.

Predicting future risk of airway injury after particulate exposures can focus monitoring and early treatment on a subset of patients in greatest need of these services.

<https://pubmed.ncbi.nlm.nih.gov/26024341/>

**Allergy and Lung Injury Among Rescue Workers
Exposed to the World Trade Center Disaster Assessed
17 Years After Exposure to Ground Zero**

Dennis L Caruana, et al.

Abstract

Objective: Investigate the following in rescue and cleanup workers exposed to the World Trade Center (WTC) disaster 17 years post-fallout: (1) allergic hypersensitivity; (2) spirometry; (3) impulse oscillometry; and (4) the reversibility of airway hyperresponsiveness and distal airways narrowing pre- and post-bronchodilator.

Methods: In subjects (n = 54) referred to our clinic from the WTC Health Program for management of allergy-immunology services, environmental allergy testing, impulse oscillometry (IOS), and spirometry results were retrospectively reviewed to determine the long-term impact of exposure to the WTC fallout.

Results: Rescue and cleanup workers exposed to the WTC fallout had a high incidence of allergic hypersensitivity and had evidence of permanent small airways dysfunction characterized by distal airways narrowing and airway hyperresponsiveness.

Conclusion: *Following exposure to the WTC disaster, the patients in our cohort developed allergic hypersensitivity and severe lung injury with only partial reversibility.*

<https://pubmed.ncbi.nlm.nih.gov/32404837/>



**Distal airway function in symptomatic subjects
with normal spirometry following World Trade Center dust exposure**

Beno W Oppenheimer, et al.

Abstract

Rationale: Following collapse of the World Trade Center (WTC), individuals reported new-onset respiratory symptoms. Despite symptoms, spirometry often revealed normal airway function. However, bronchial wall thickening and air trapping were seen radiographically in some subjects. We hypothesized that symptomatic individuals following exposure to WTC dust may have functional abnormalities in distal airways not detectable with routine spirometry.

Methods: One hundred seventy-four subjects with respiratory symptoms and normal spirometry results were evaluated. Impedance oscillometry (IOS) was performed to determine resistance at 5 Hz, 5 to 20 Hz, and reactance area. Forty-three subjects were also tested for frequency dependence of compliance (FDC). Testing was repeated after bronchodilation.

Results: Predominant symptoms included cough (67%) and dyspnea (65%). Despite normal spirometry results, mean resistance at 5 Hz, 5 to 20 Hz, and reactance area were elevated (4.36 +/- 0.12 cm H₂O/L/s, 0.86 +/- 0.05 cm H₂O/L/s, and 6.12 +/- 0.50 cm H₂O/L, respectively) [mean +/- SE]. Resistance and reactance normalized after bronchodilation. FDC was present in 37 of 43 individuals with improvement after bronchodilation.

Conclusions: Symptomatic individuals with presumed WTC dust/fume exposure and normal spirometry results displayed airway dysfunction based on the following: (1) elevated airway resistance and frequency dependence of resistance determined by IOS; (2) heterogeneity of distal airway function demonstrated by elevated reactance area on oscillometry and FDC; and (3) reversibility of these functional abnormalities to or toward normal following administration of a bronchodilator. Since spirometry results were normal in all subjects, these abnormalities likely reflect dysfunction in airways more distal to those evaluated by spirometry. Examination of distal airway function when spirometry results are normal may be important in the evaluation of subjects exposed to occupational and environmental hazards.

Trial registration: ClinicalTrials.gov NCT00395330.

<https://pubmed.ncbi.nlm.nih.gov/17890470/>

Estimation of Future Cancer Burden Among Rescue and Recovery Workers Exposed to the World Trade Center Disaster

Ankura Singh, et al.

Abstract

Importance: Elevated rates of cancer have been reported in individuals exposed to the World Trade Center (WTC) disaster, including Fire Department of the City of New York (FDNY) rescue and recovery workers.

Objective: To project the future burden of cancer in WTC-exposed FDNY rescue and recovery workers by estimating the 20-year cancer incidence.

Design, setting, and participants: A total of 14 474 WTC-exposed FDNY employees who were cancer-free on January 1, 2012; subgroup analyses were conducted of the cohort's white male population (n = 12 374). In this closed-cohort study, we projected cancer incidence for the January 1, 2012, to December 31, 2031, period. Simulations were run using demographic-specific New York City (NYC) cancer and national mortality rates for each individual, summed for the whole cohort, and performed 1000 times to produce mean estimates. Additional analyses in the subgroup of white men compared case counts produced by using 2007-2011 FDNY WTC Health Program (FDNY-WTCHP) cancer rates vs NYC rates. Average and 20-year aggregate costs of first-year cancer care were estimated using claims data.

Exposures: World Trade Center disaster exposure defined as rescue and recovery work at the WTC site at any time from September 11, 2001, to July 25, 2002.

Main outcomes and measures: (1) Projected number of incident cancers in the full cohort, based on NYC cancer rates; (2) cancer incidence estimates in the subgroup projected using FDNY-WTCHP vs NYC rates; and (3) estimated first-year treatment costs of incident cancers.

Results: On January 1, 2012, the cohort was 96.8% male, 87.1% white, and had a mean (SD) age of 50.2 (9.2) years. The projected number of incident cancer cases was 2960 (95% CI, 2883-3037). In our subgroup analyses using FDNY-WTCHP vs NYC cancer rates, the projected number of new cases in white men was elevated (2714 [95% CI, 2638-2786] vs 2596 [95% CI, 2524-2668]). Accordingly, we expect more prostate (1437 [95% CI, 1383-1495] vs 863 [95% CI, 816-910]), thyroid (73 [95% CI, 60-86] vs 57 [95% CI, 44-69]), and melanoma cases (201 [95% CI, 179-223] vs 131 [95% CI, 112-150]), but fewer lung (237 [95% CI, 212-262] vs 373 [95% CI, 343-405]), colorectal (172 [95% CI, 152-191] vs 267 [95% CI, 241-292]), and kidney cancers (66 [95% CI, 54-80] vs 132 [95% CI, 114-152]) (P < .001 for all comparisons). The estimated 20-year cost of first-year treatment was \$235 835 412 (95% CI, \$187 582 227-\$284 088 597).

Conclusions and relevance: We project that the FDNY-WTCHP cohort will experience a greater cancer burden than would be expected from a demographically similar population. This underscores the importance of cancer prevention efforts and routine screening in WTC-exposed rescue and recovery workers.

Conflict of Interest Disclosures: None reported.

<https://pubmed.ncbi.nlm.nih.gov/29710126/>

Some Thoughts on Exposure to the World Trade Center Wreckage and Cancer

Otis W. Brawley, MD, MACP

The terrorist attacks on September 11, 2001, are still unsettling nearly 17 years later. Time has not healed the pain. In addition to those killed, a number of people were harmed, some number of patients with myeloma, and a link to WTC exposure may become more apparent.

The article by Landgren and colleagues¹ also compares a cohort of 781 NY firefighters exposed to the WTC wreckage with citizens from the general population of Olmstead County, Minnesota. Both cohorts were screened for monoclonal gammopathy of undetermined significance (MGUS), the precursor of multiple myeloma, and for multiple myeloma. The firefighters were screened for MGUS, at ages 50 to 79 years, from December 2012 to October 2015. Compared with the screened cohort from Olmstead County, the age-standardized rate of MGUS was 1.76 times higher in the firefighters (relative risk [RR], 1.76; 95% CI, 1.34-2.29). In assessment for light-chain MGUS, the firefighters had a rate 3.13 times greater (RR, 3.13; 95% CI, 1.99- 4.93).

In noting the differences, one must appreciate that the fire-fighting profession is documented to be associated with a higher risk of MGUS and multiple myeloma compared with that of the general population.³ This study¹ comparing firefighters with people from a general population tends to show a higher than true relative risk. It would be preferable to compare the WTC-exposed firefighters with an intensively screened age-matched cohort of firefighters from another big city.

Sir Richard Doll famously demonstrated (with Sir Bradford Hill) that cigarette smoking caused lung cancer. He was an advocate of the idea that important cancer risk factors must have big relative risks. He argued that a single epidemiologic study cannot be persuasive until the lower bound of the 95% CI is greater than 3.⁴ Applying "Doll's rule," the relative risks in the study by Landgren and colleagues¹ are too small to be persuasive.

Another question is whether it is possible that while both cohorts were screened for MGUS and light-chain MGUS, the firemen were screened more intensively or aggressively than the Olmstead County cohort. A general rule of screening is "increased surveillance leads to increase disease incidence."

Overdiagnosis is a bias of screening.⁵ It is finding disease that, if never found, would never cause symptoms or harm. MGUS is an asymptomatic condition found in 3% or more of the US adult population. In a cohort of 1384 people with MGUS,⁶ 147 (11%) developed myeloma after a median follow-up of 34 years (range, 0-43.6 years), or 14,130 person-years. This cohort was also from Olmstead County, Minnesota. The data suggest that screening for MGUS is associated with overdiagnosis. More intensive testing might find more MGUS.

It has been suggested that the way to overcome the problem of overdiagnosis is to conduct a study comparing 2 coirreparably— in particular, the New York Rescue/Recovery workers who were at the World Trade Center (WTC) that day and who worked on the wreckage for months. They were exposed to numerous chemicals, many known to be carcinogens and toxins. These men and women are to be respected for the difficult work they did. They should also be compensated for all the injuries associated with their service and given the best care possible.

The WTC attack is an emotional subject. Cancer is also an emotional subject. There is a tendency to want to blame something for every diagnosed cancer. We often attribute cancer to some environmental exposure. When these WTC heroes are diagnosed as having a cancer, even a cancer common in the population, there is a natural tendency to assume it is due to their service at the WTC. We do justice to and honor these men and women by working hard to find the truth and determine the illnesses that are associated with their service.

In this issue of the JAMA Oncology, 2 articles report on firemen exposed to the toxic WTC wreckage on September 11, 2001, and the months after. **Landgren and colleagues¹ demonstrate that these workers may be at increased risk of multiple myeloma.** Singh and colleagues² provide projections for the expected excess of several cancers over the next 20 years.

Landgren and colleagues¹ searched medical registry records to construct a case series of 16 of 12 942 WTC-exposed firefighters diagnosed as having Multiple Myeloma.¹ The median time to diagnosis was 12 years after the attack (range, 1.0-15.7 years). The median age at diagnosis was 57 years (range, 38-76 years) The median age at diagnosis for Multiple Myeloma in the United States is 69 years, but that statistic includes persons of all ages, whereas the firefighter cohort was age restricted. Of the 14 firefighters for whom protein isotype and free light-chain data were available, half had light-chain multiple myeloma. Typically, about 20% of people with multiple myeloma have light-chain disease. There is some literature to suggest that light-chain multiple myeloma is more common in people who have myeloma after chemical or inflammatory exposures.

The 16 cases of multiple myeloma out of 12 942 WTC-exposed firefighters represent a small proportion. It is difficult to make a firm correlation with WTC service. There may be a latency period, and, over time, this group may have a larger horts and follow them, using death as an end point.⁷ However, this scenario would work only in diseases for which treatment is not very efficacious. Given the newer myeloma therapies, this type of study might not provide an accurate answer for this disease.

Singh and colleagues² used computer simulations to project cancer incidence for 14,474 WTC-exposed firefighters during the period January 2012 to December 2031. They project that 2960 cancers will be diagnosed (95% CI, 2883- 3037). For the 87.1% of the firefighters who are white men, they project 2714 cancers vs 2596 cancers in a control population. They expect excess cancer of the prostate (1437 vs 863), thyroid (73 vs 57), and melanoma (201 vs 131). It is

notable that they expect fewer colorectal cancers; unlike most other cancers, screening reduces colorectal cancer incidence.

The predicted increases in cancers of the prostate, thyroid, and myeloma are interesting. Excess incidence and mortality for these cancers have been previously reported in fire-fighters from other cities.^{3,8,9} Are the predicted increases due to WTC exposure or a career as a firefighter? These are also cancers associated with overdiagnosis. Are the predicted increases clinically significant? Are these excess cancers due to increased surveillance? Regimented screening for prostate and thyroid cancer clearly increases diagnosis.^{10,11}

In 2012, Li and colleagues¹² published results of a study of 55 778 New York State residents enrolled in the World Trade Center Health Registry. They found excess risk of prostate cancer, thyroid cancer, and multiple myeloma among persons enrolled compared with New York State residents from 2007 to 2008. They were guarded in drawing conclusions, noting the short follow-up, a small number of events, and multiple comparisons with no significant association with intensity of WTC exposures. Many individuals in the study cohort of Singh and colleagues are also in the cohort studied by Li et al.¹²

Landgren and colleagues¹ note that they cannot find an exposure gradient. They report that WTC-exposure may be a risk factor for the development of Multiple Myeloma and its precursor disease, MGUS. This is appropriately worded. The operative word is “may.” These trials, because of the size of cohort, cannot identify a small increase in cancer risk due to WTC exposure, and correlation does not mean causation.¹³ Perhaps this issue is beyond the limits of science.

<https://sci-hub.tw/10.1001/jamaoncol.2018.0498#>

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**Estimation of Future Cancer Burden
Among Rescue and Recovery Workers
Exposed to the World Trade Center Disaster**

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Abstract

Importance: Elevated rates of cancer have been reported in individuals exposed to the World Trade Center (WTC) disaster, including Fire Department of the City of New York (FDNY) rescue and recovery workers.

Objective: To project the future burden of cancer in WTC-exposed FDNY rescue and recovery workers by estimating the 20-year cancer incidence.

Design, setting, and participants: A total of 14 474 WTC-exposed FDNY employees who were cancer-free on January 1, 2012; subgroup analyses were conducted of the cohort's white male population (n = 12 374). In this closed-cohort study, we projected cancer incidence for the January 1, 2012, to December 31, 2031, period.

Simulations were run using demographic-specific New York City (NYC) cancer and national mortality rates for each individual, summed for the whole cohort, and performed 1000 times to produce mean estimates. Additional analyses in the subgroup of white men compared case counts produced by using 2007-2011 FDNY WTC Health Program (FDNY-WTCHP) cancer rates vs NYC rates. Average and 20-year aggregate costs of first-year cancer care were estimated using claims data.

Exposures: World Trade Center disaster exposure defined as rescue and recovery work at the WTC site at any time from September 11, 2001, to July 25, 2002.

Main outcomes and measures: (1) Projected number of incident cancers in the full cohort, based on NYC cancer rates; (2) cancer incidence estimates in the subgroup projected using FDNY-WTCHP vs NYC rates; and (3) estimated first-year treatment costs of incident cancers.

Results: On January 1, 2012, the cohort was 96.8% male, 87.1% white, and had a mean (SD) age of 50.2 (9.2) years. The projected number of incident cancer cases was 2960 (95% CI, 2883-3037). In our subgroup analyses using FDNY-WTCHP vs NYC cancer rates, the projected number of new cases in white men was elevated (2714 [95% CI, 2638-2786] vs 2596 [95% CI, 2524-2668]). Accordingly, we expect more prostate (1437 [95% CI, 1383-1495] vs 863 [95% CI, 816-910]), thyroid (73 [95% CI, 60-86] vs 57 [95% CI, 44-69]), and melanoma cases (201 [95% CI, 179-223] vs 131 [95% CI, 112-150]), but fewer lung (237 [95% CI, 212-262] vs 373 [95% CI, 343-405]), colorectal (172 [95% CI, 152-191] vs 267 [95% CI, 241-292]), and kidney cancers (66 [95% CI, 54-80] vs 132 [95% CI, 114-152]) ($P < .001$ for all comparisons). The estimated 20-year cost of first-year treatment was \$235 835 412 (95% CI, \$187 582 227-\$284 088 597).

Conclusions and relevance: We project that the FDNY-WTCHP cohort will experience a greater cancer burden than would be expected from a demographically similar population. This underscores the importance of cancer prevention efforts and routine screening in WTC-exposed rescue and recovery workers.

Conflict of Interest Disclosures: None reported.

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Multiple Myeloma and Its Precursor Disease Among Firefighters Exposed to the World Trade Center Disaster

Ola Landgren, et al.

Abstract

Importance: The World Trade Center (WTC) attacks on September 11, 2001, created an unprecedented environmental exposure to known and suspected carcinogens suggested to increase the risk of multiple myeloma. Multiple myeloma is consistently preceded by the precursor states of monoclonal gammopathy of undetermined significance (MGUS) and light-chain MGUS, detectable in peripheral blood.

Objective: To characterize WTC-exposed firefighters with a diagnosis of multiple myeloma and to conduct a screening study for MGUS and light-chain MGUS.

Design, setting, and participants: Case series of multiple myeloma in firefighters diagnosed between September 11, 2001, and July 1, 2017, together with a seroprevalence study of MGUS in serum samples collected from Fire Department of the City of New York (FDNY) firefighters between December 2013 and October 2015. Participants included all WTC-exposed FDNY white, male firefighters with a confirmed physician diagnosis of multiple myeloma (n = 16) and WTC-exposed FDNY white male firefighters older than 50 years with available serum samples (n = 781).

Exposures: WTC exposure defined as rescue and/or recovery work at the WTC site between September 11, 2001, and July 25, 2002.

Main outcomes and measures: Multiple myeloma case information, and age-adjusted and age-specific prevalence rates for overall MGUS (ie, MGUS and light-chain MGUS), MGUS, and light-chain MGUS.

Results: Sixteen WTC-exposed white male firefighters received a diagnosis of multiple myeloma after September 11, 2001; median age at diagnosis was 57 years (interquartile range, 50-68 years). Serum/urine monoclonal protein isotype/free light-chain data were available for 14 cases; 7 (50%) had light-chain multiple myeloma. In a subset of 7 patients, myeloma cells were assessed for CD20 expression; 5 (71%) were CD20 positive. In the screening study, we assayed peripheral blood from 781 WTC-exposed firefighters. The age-standardized prevalence rate of MGUS and light-chain MGUS combined was 7.63 per 100 persons (95% CI, 5.45-9.81), 1.8-fold higher than rates from the Olmsted County, Minnesota, white male reference population (relative rate, 1.76; 95% CI, 1.34-2.29). The age-standardized prevalence rate of light-chain MGUS was more than 3-fold higher than in the same reference population (relative rate, 3.13; 95% CI, 1.99-4.93).

Conclusions and relevance: Environmental exposure to the WTC disaster site is associated with Myeloma precursor disease (MGUS and light-chain MGUS) **and may be a risk factor for the development of Multiple Myeloma at an earlier age**, particularly the light-chain subtype.

Conflict of Interest Disclosures: None reported.

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9/11 Firefighters at Risk for Multiple Myeloma

No authors listed

Abstract

The largest study to date of responders to the World Trade Center attacks in New York, NY, on 9/11 reports that exposed firefighters have roughly twice the risk of developing multiple myeloma precursor disease as the general population. Moreover, firefighters who go on to develop multiple myeloma exhibit a younger age of onset and more aggressive disease than is typical.

Following the attacks on the World Trade Center (WTC) in New York, NY, on 9/11 (September 11, 2001), thousands of first responders were exposed to carcinogens in dust and gases. Since then, researchers have wondered about the possible impact on cancer rates. Although some studies have found an elevated risk of multiple myeloma and other cancers in first responders, others have not. In the most recent and largest study to date, exposed firefighters had roughly twice the risk of developing multiple myeloma precursor disease as the general population.

Moreover, ***“we found earlier age of onset and more aggressive multiple myeloma among World Trade Center–exposed firefighters compared to what is seen in the general population,”*** says lead author Ola Landgren, MD, PhD, of Memorial Sloan Kettering Cancer Center in New York, NY. ***“Taken together, these observations suggest World Trade Center exposure is a risk factor for myeloma.”***

Landgren says the study was triggered when physicians at his institution reported seeing aggressive cases of multiple myeloma in relatively young WTC responders. The researchers analyzed the 16 cases of multiple myeloma diagnosed among Fire Department of New York (FDNY) firefighters since 9/11. The median age at diagnosis was 57 years, roughly 12 years younger than the national average age at onset. In addition, the proportion of firefighters with CD20-expressing plasma cells, which are associated with a poorer prognosis, was roughly 3.5 times higher than has been reported in other multiple myeloma studies.

Next, the study capitalized on the FDNY’s WTC Health Program, which has a bank of blood samples from the regular health screenings it provides, to look at rates of multiple myeloma precursor disease. (Because precursor disease is more common and develops more rapidly after exposure to a carcinogen than multiple myeloma, it is easier to study.) After analyzing serum samples from 781 white, male, 50- to 79-year-old WTC-exposed firefighters, they found

the age-standardized prevalence for precursor disease was 7.63 per 100 people, whereas that for similar-aged men screened as part of a study in predominantly white Olmsted County, MN, was 4.34.

Although these results are striking, a consistent problem for this and other WTC studies has been identifying appropriate comparison groups, says Laurie Gold, PhD, of the University of Washington in Seattle. Here, "the comparison group may have been different from the World Trade Center responders in ways that had nothing to do with the carcinogens that the responders were exposed to after 9/11," she says. Unfortunately, no data exist for a comparison group of firefighters with no WTC exposure.

Another potential problem is that 11,769 WTC-exposed firefighters did not provide blood samples for analysis. Gold wonders whether individuals who supplied a sample may have been more likely to suffer from precursor disease. "Were they experiencing health symptoms that they hoped to have explained?"

Despite the limitations inherent in studying this problem, Landgren hopes that these findings will convince the WTC Health Program to add multiple myeloma screening to the list of services provided to exposed firefighters, and also spur interest in developing better strategies to protect firefighters from inhaling hazardous dust and fumes.

In the future, his team plans to expand their studies to other WTC-exposed individuals, including police officers and people who lived or worked in the area.

~ Kristin Harper

<https://cancerdiscovery.aacrjournals.org/content/8/7/OF3>



**Longitudinal Lung Function Decrements in Firefighters
Who Responded to the World Trade Center Disaster:
Important Insights for the Preservation of Lung Function in Future Disasters**

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Abstract

On September 11, 2001, the twin towers of the World Trade Center (WTC) in New York City were attacked by two hijacked commercial airplanes and subsequently collapsed. This heinous act of terrorism resulted in the deaths of 2,753 individuals, including 343 New York City firefighters who responded to the disaster.^{1,2} In this issue of CHEST, Aldrich et al³ report the results of a 13-year longitudinal study of spirometry results among 10,641 surviving firefighters with known smoking and body weight histories who were exposed to aerosolized dust following the collapse of the twin towers. This dust contained a highly toxic combination of pulverized building materials and chemical by-products of combustion and pyrolysis. The report published in this issue is a follow-up to two previous reports on lung function among firefighters at 1 year and 7 years following exposure to WTC dust.^{4,5} As such, it is the longest and most comprehensive study of longitudinal spirometry data among rescue and recovery workers who were exposed to toxic material during the response to a major environmental disaster. The results of this study are therefore extremely important for understanding the long-term effects of inhaling toxic aerosolized dust on lung function. Just as importantly, it is also the first study to report the effects of smoking and smoking cessation on longitudinal lung function decline caused by toxic exposures during a major environmental disaster.

The most discouraging finding reported in this study³ is that, after 13 years of follow-up, there is little recovery of lung function from the substantial average FEV1 decline of approximately 10% which was observed among firefighters during the first year following exposure to WTC dust. Those firefighters who arrived at the WTC site on the morning of the disaster had the heaviest dust exposure and continued to have significantly greater declines in FEV1 at the end of the 13-year follow-up period compared with firefighters arriving at later times. Of importance, the investigators cite references which show that the use of respiratory protection by firefighters, such as masks and respirators, was minimal during the first week following the collapse of the twin towers.^{6,7} The persistent and statistically significant dose-related decline in FEV1 following exposure to WTC dust indicates that the persistent lung function decrement was primarily the result of the toxic exposure alone, rather than the result of excess individual risks of developing abnormal lung function.

The magnitude of the persistent decline in FEV1 following exposure to WTC dust has important

implications for firefighters. Most significantly, the persistent long-term lung average function decrement of approximately 10% that was observed in this cohort of firefighters is unusual compared with the lung function decrements reported for smoke inhalation alone. For example, it has been reported that firefighters who experience heavy smoke exposure without the use of respiratory protection may have acute FEV1 declines in the range of 5% shortly after the exposure, but lung function typically returns to normal within days to weeks after the exposure.⁸⁻¹⁰

This finding suggests that the combined effects of the pulverized building materials and the chemical by-products of combustion and pyrolysis contained in WTC dust are significantly more toxic to the respiratory system than the effects of heavy smoke inhalation alone. Fortunately, despite the substantial and persistent decline in FEV1 during 13 years of follow-up, most firefighters exposed to WTC dust continued to have FEV1 values in the normal range. As Aldrich et al³ point out, this outcome can be attributed to the firefighters' excellent pre-exposure respiratory function and overall excellent health status. At the same time, it has been shown that the average 10% decline in FEV1 that occurred among firefighters during the first year after exposure to WTC dust is equivalent to 10 to 12 years of normal age-related FEV1 decline.⁵ Thus, the persistence of this large FEV1 decline over a period of 13 years raises considerable concern about the future adequacy of respiratory function as the firefighters exposed to WTC dust continue to age.

The pathophysiologic mechanisms underlying the increased toxicity of WTC dust have yet to be elucidated. However, from a purely practical point of view, the results of the study by Aldrich et al³ highlight two important considerations. First, they indicate that pre-employment lung function testing and rigorous employment standards are important for ensuring that firefighters have sufficient lung function reserve to maintain normal lung function following an acute decline in FEV1 of at least 10% that could result from a toxic inhalational exposure while responding to a major disaster. Second, this study highlights the utmost importance of firefighters wearing protective "turnout gear," including a self-contained breathing apparatus for the entire period of time they are responding to a fire that involves the collapse of a building or other structure. In this regard, it is prudent to recommend that firefighters should not remove their protective gear immediately after fires are extinguished if a structural collapse occurs. As this study points out, inhalation of dust containing pulverized building material and the chemical by-products of combustion or pyrolysis may cause substantial long-term lung dysfunction, even after a fire has been extinguished.

Another important finding in this study³ is the effect of smoking status on the magnitude of longitudinal lung function decline among firefighters exposed to WTC dust. Compared with never smokers, the average FEV1 at the end of the study period was 78 ml lower for former smokers who quit between September 11, 2001, and March 10, 2008; 198 ml lower for smokers who quit after March 10, 2008, and September 10, 2014; and 312 ml lower for current smokers. Each of these average FEV1 decrements was statistically significant compared with the average FEV1 of never smokers. The difference in average FEV1 between never smokers and former smokers who quit before September 11, 2001 was not statistically significant. Thus, former smokers had average FEV1 decline rates that were intermediate between never smokers and

current smokers. Furthermore, the earlier former smokers quit smoking relative to WTC dust exposure the greater the postexposure FEV1.

The effect of smoking status on the average FEV

of firefighters exposed to WTC dust has several important implications. First, it suggests that smoking status should be carefully evaluated during the pre-employment medical evaluation of future firefighters, and evidence of smoking cessation should be provided by smokers prior to being hired. Second, it provides strong evidence that the assessment of smoking status and aggressive smoking prevention or smoking cessation initiatives should be integral components of the preventive health care and health maintenance of all active duty firefighters. Finally, it demonstrates that the evaluation of smoking status and aggressive smoking prevention or smoking cessation initiatives should be integral components of all medical surveillance programs for firefighters who experience potentially toxic inhalational exposures during the response to a major disaster.

Although the recommendations made in this editorial may be intuitive to most pulmonologists, the results reported in the excellent article by Aldrich et al³ provide sufficient and long-needed evidence for all fire departments to consider adopting them as a matter of policy. The brave men and women who serve in our fire departments deserve no less.

<https://sci-hub.tw/10.1016/j.chest.2016.03.056>

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**Lung Function Trajectories in World Trade Center-Exposed New York City Firefighters Over 13 Years
The Roles of Smoking and Smoking Cessation**

By Thomas K. Aldrich, MD., et al.

Background: World Trade Center (WTC)-exposed Fire Department of the City of New York firefighters lost, on average, 10% of lung function after September 11, 2001, and >10% developed new obstructive airways disease. There was little recovery (on average) over the first 6 years. Follow-up into the next decade allowed us to determine the longer-term exposure effects and the roles of cigarette smoking and cessation on lung function trajectories.

Methods: We examined serial measurements of FEV1 from March 11, 2000, to September 10, 2014, among 10,641 WTC-exposed Fire Department of the City of New York firefighters with known smoking and body weight histories.

Results: The median number of FEV1 measurements during follow-up was 9; 15% of firefighters arrived at the WTC during the morning of September 11, 2001; and 65% never smoked. Firefighters arriving the morning of September 11, 2001 averaged lower lung function than did lesser exposed firefighters; this difference remained significant during most of follow-up ($P < .05$). Never smokers had significantly better lung function than current smokers; former smokers fell in between, depending upon their cessation date. Those arriving the morning of September 11, 2001 were more likely to have an FEV1 < lower limits of normal compared with those arriving between September 13, 2001, and September 24, 2001 (OR = 1.70, $P < .01$). Current smokers were more likely to have an FEV1 < lower limits of normal compared with never smokers (OR = 2.06, $P < .01$), former smokers who quit before September 11, 2001 (OR = 1.96, $P < .01$), or those who quit between September 11, 2001 and March 10, 2008 (OR = 1.49, $P < .01$).

Conclusions: *Thirteen years after September 11, 2001, most firefighters continued to show a lack of lung function recovery*, with the trajectory of decline differing by WTC exposure and smoking status. Unlike the immutable effect of WTC exposure, we demonstrated the benefit on lung function of smoking cessation in this unique occupational/environmental cohort.

Key Words: firefighting, occupational lung disease, pulmonary function test, smoking, World Trade Center

Abbreviations: FDNY, Fire Department of the City of New York; LLN, lower limit of normal; PFT, pulmonary function test; WTC, World Trade Center

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Elevated Prevalence of Moderate-to-Severe Hepatic Steatosis in World Trade Center General Responder Cohort in a Program of CT Lung Screening

By Xiangmeng Chen, MD, et al.

Abstract

Background and aims: To determine the prevalence of moderate-to-severe hepatic steatosis (HS) and associated risk factors in members of the World Trade Center (WTC) General Responder Cohort (GRC) who qualify for low-dose non-contrast computed tomography for lung cancer screening and compare them to non-WTC participants in the same screening program.

Methods: All participants gave written informed consent before participating in this IRB-approved study. Clinical variables and laboratory values were recorded. Hepatic attenuation measurement (Hounsfield unit; HU) was measured on low-dose computed tomography (LDCT) and a threshold attenuation value <40HU indicated moderate-to-severe HS. Bivariate and multivariable linear and logistic regression analyses were performed. Propensity scores (PS) were calculated and inverse probability weighting (IPW) was used to adjust for potential confounders when comparing the WTC with non-WTC participants.

Results: The prevalence of moderate-to-severe HS was 16.2% among 154 WTC participants compared to 5.3% among 170 non-WTC participants. In WTC members, moderate-to-severe HS was associated with higher BMI, higher laboratory liver function tests, and former smoking status. Using PS analysis and IPW to account for potential confounders, the odds ratio for moderate-to-severe HS was 3.4-fold higher (95% confidence interval: 1.7–6.7) in the WTC participants compared with non-WTC participants. Moderate-to-severe HS was also associated with higher BMI and former smoker status.

Conclusion: Prevalence of moderate-to-severe HS was more than 3-fold higher in the WTC-GRC group than in other participants.

Keywords: liver attenuation, CT screening, liver disease, airborne particulate matter

Introduction

Liver disease can be a silent killer that produces few early symptoms. A common cause of liver disease worldwide is nonalcoholic fatty liver disease (NAFLD). In the US, prevalence estimates that are expected to rise through 2030 1. NAFLD spans the spectrum of simple hepatic steatosis

(HS) to steatohepatitis, and can result in the development of liver fibrosis, cirrhosis and hepatocellular carcinoma 2. Computed tomography (CT) has a high sensitivity and specificity for detecting moderate-to-severe HS 3, defined histologically by the presence of macrovesicular fat affecting at least 30% of hepatocytes. By reporting HS, radiologists can significantly increase the likelihood that a patient will receive follow-up testing for liver disease 4.

Fat reduces the attenuation value of the liver on CT, as measured by Hounsfield Unit (HU), with a threshold value of 40HU commonly used to detect HS 5–7. Using this threshold value, 6.2% of individuals in a colon cancer screening program had moderate-to-severe HS 8. A recent study of 170 individuals in a low-dose CT (LDCT) lung screening program in New York City, using the same threshold value, reported that 5.3% of participants had moderate-to-severe HS 9. The World Trade Center (WTC) attack resulted in the exposure of over 20,000 responders to dust, airborne particulate matter, and chemicals known to cause hepatotoxicity 10–14. A previous study of WTC-exposed firefighters found moderate-to-severe steatosis in 22% 15. Because CT screening is approved for WTC General Responder Cohort (GRC) participants who meet the age and smoking history criteria, there was a two-fold purpose for this study: 1) to determine the prevalence of moderate-to-severe HS and associated risk factors in members of the WTC undergoing LDCT screening for lung cancer in a National Institute of Occupational Health(-NIOSH)-approved program and 2) to compare the prevalence of HS in the WTC to non-WTC participants in the same screening program.

Materials and Methods

Participants

We reviewed baseline LDCT scans of the chest of all WTC participants who qualified for and participated in the National Institute of Occupational Safety and Health (NIOSH)-approved early lung cancer screening program between 2/2016–1/2017. Written informed consent was obtained according to a HIPAA-compliant protocol approved by the Mount Sinai IRB. Entry criteria were 55 to 77 years of age, a smoking history of ≥ 30 pack-years, and being either current smokers or quit within the last 15 years. The participants were interviewed at the time of the CT scan by a coordinator who obtained data on demographics, smoking history, height, weight, and body mass index (BMI) data. Self-reported medical comorbidities of diabetes, chronic obstructive pulmonary disease(COPD)/emphysema, and hypertension were recorded. Clinical laboratory values of aspartate aminotransferase(AST), alanine aminotransferase(ALT), and platelets were obtained from the WTC data center. The date of these tests ranged from 11 months before CT to one month after CT. The Fibrosis-4 (FIB-4) score, an indicator of hepatic fibrosis stage that takes into account age, AST, ALT and platelet levels, was calculated 16.

The prevalence of HS in the WTC participants was compared to the previously reported prevalence of 170 non-WTC current and former smokers who had participated in the same screening program between 8/2011–4/2016, had the same documentation of their background information, but different entry criteria 9. The non-WTC participants were asymptomatic ever-smokers,

aged 40 or older while the WTC participants were asymptomatic ever-smokers, aged 55 to 78 with at least 30 pack-years of smoking who were currently smoking or had quit within the 15 years of enrollment. Considerations of the differences in entry criteria is addressed in the statistical analysis paragraph.

CT imaging acquisition

All WTC and non-WTC participants underwent LDCT in the supine position in a single breath-hold without intravenous contrast. The scanning field of view spanned from the lung apices to the level of the adrenal glands. 148 WTC participants had CT performed on Siemens Somatom Definition Flash CT (120 kVp, 35–85mA, images reconstructed at 0.5-mm and 3.0-mm axial slice thickness) and 6 WTC participants were scanned on GE Medical Systems Revolution CT (120kVp, 52–58mA, images reconstructed at 0.625-mm and 2.5-mm axial slice thickness).

Liver CT attenuation measurement

Using the same accepted methodology previously described 9,17, liver attenuation(HU) was measured at the level of the portal vein in four sectors as defined by the Couinaud system (Figure 1) 17. In each sector, a 1.0cm² region of interest(ROI) was selected, avoiding lesions and large blood vessels. Using standard window settings (width 350HU; level 25HU) 9, the average liver attenuation, standard deviation(SD) and quartile measurements were calculated.

Other CT-derived data

The presence of emphysema was documented on each CT scan 18. The Ordinal Score for coronary artery calcifications(CAC) was determined 19 and a total Ordinal CAC Score(0 to 12), representing the sum of the CAC scores for each of the coronary arteries, was calculated. The Ordinal CAC Scores were divided into three categories of increasing disease severity(0, 1–3, and 4–12), as these were predictive of death from cardiovascular disease 19,20.

Statistical analysis of the WTC participants

Frequencies and descriptive statistics were obtained for all the variables. For continuous variables, histograms and Kolmogorov-Smirnov test were used to test for violation of the normality assumption. Bivariate and multivariable linear regression analyses were used to explore the relationship between liver attenuation and risk factors such as age, gender, diabetes, hypertension, COPD, cardiovascular diseases (CVD), and baseline CT findings of CAC and emphysema. Only factors with P-values \leq 0.10 in the bivariate model were retained in the multivariable model. Pairwise correlations among variables were computed using Pearson correlations coefficients(*r*) and multicollinearity was assessed with variance inflation factors(VIF). Potential two-way interactions between smoking, gender, and BMI on CT attenuation of the liver were assessed. Interactions were assessed by adding the interaction terms to the regression model

with main effects and covariates, interaction term with p -value <0.05 was considered as significant. Coefficient estimates with and without the interaction term were compared and interaction plots were also used to visualize the presence or absence of interactions among independent variables. Presence of a significant interaction indicates that the effect of one covariate on HS is different at different values of the other covariate. Probability and residual plots were used to detect violation of normality, homoscedasticity and independent errors assumptions. Liver attenuation values were then classified into one of two categories (liver attenuation <40 HU or ≥ 40 HU). The difference in the distribution of demographic and clinical characteristics was evaluated by t-test or nonparametric Kruskal Wallis test. For categorical variables, Chi-squared and Fisher's exact test were used.

Statistical comparison of WTC and non-WTC participants

To address the differences of the WTC and non-WTC participants, propensity score(PS) were calculated for each participant. For this comparison, PS was calculated using multiple logistic regression with the cohort assignment as the dependent variable (1 for WTC-GRC; 0 for non-WTC). The explanatory variables were all measured covariates available for both groups [age, gender, smoking status, pack-years, race, BMI, self-reported comorbidities of diabetes, hypertension, COPD]. The PS represents the probability of being a member of the WTC cohort, conditional on all the covariates used in the PS analysis. Covariate balance was examined by weighted Wilcoxon rank sum and weighted chi-square test. Inverse probability weighting(IPW) was then performed. To investigate the effect of cohort membership on liver attenuation, IPW adjusted odds ratio(OR) for the risk of liver attenuation <40 HU in the WTC cohort as compared with the comparison group was calculated using a multiple logistic regression in the weighted sample, additionally controlling for CAC score and presence of emphysema on CT. In a separate analysis, multivariable logistic regression was used to identify factors significantly associated with liver attenuation <40 HU in the WTC cohort, as described above. All statistical analyses were performed using SAS (Statistical Analysis System, version 9.4, Cary, NC).

Results **WTC participants**

Of the 154 WTC participants, 85.7% ($n=132$) were men and 66% ($n=102$) were Caucasian (Table 1). Diabetes, COPD and hypertension were self-reported by 29 (20%), 41 (30%) and 81 (57%) subjects. Liver attenuation values ranged from 17.6–68.2 HU (Figure 2), with a mean \pm standard deviation (SD) of 52.7 ± 11.1 HU. The prevalence of moderate-to-severe HS, using the cutoff of <40 HU, was 16.2% (25/154). The participants with <40 HU had a higher percentage of former smokers, a lower percentage with CT-confirmed emphysema, higher BMI, AST, ALT, and higher percentage with transaminase values above the ULN (Upper limit normal). Bivariate linear regression showed that lower liver CT attenuation was associated with being a former smoker ($p=0.047$), more pack-years of smoking($p=0.003$), higher BMI ($p<0.0001$), self-reported diabetes ($p=0.047$) and hypertension($p=0.03$), higher CAC score ($p=0.02$) and the absence of emphy-

sema ($p=0.01$) (Table 2). When these variables were considered simultaneously in the multivariable linear regression, lower liver CT attenuation was independently associated with higher BMI ($p<0.0001$) and higher CAC score ($p=0.01$) while the other variables (emphysema, smoking status, pack-years of smoking, and self-reported diabetes and hypertension) were no longer significant. Multivariable logistic regression analysis showed that no variable other than CAC score ($p = 0.03$) were significant discriminators between those below and above 40HU. Of the 154 WTC participants, 148(96%) had available laboratory test results. The median time between the baseline CT scan and these tests was -0.6 (IQR: -1.2 to -0.2) months. Comparison of the six participants without clinical laboratory test results to the 148 with these results revealed no significant differences. Among the 148 participants, the 25 with liver attenuation <40 HU had significantly higher transaminase levels than the 129 with liver attenuation ≥ 40 HU: median AST values were 26.5 IU/L vs. 20.0 IU/L ($p = 0.001$), median ALT values were 34.0 IU/L vs. 21.0 IU/L ($p < 0.0001$).

Comparison of WTC (n = 159) and non-WTC (n = 170) participants

As shown in Table 3, the WTC participants had a higher percentage of men (85.7% vs. 45.3%, $p < 0.0001$), were slightly younger (61.1 vs. 62 years of age, $p=0.04$), had more participants whose race/ethnicity was “other” (multi-racial or unknown) (24.0% vs. 1.8%, $p=0.04$), higher BMI (29.5 vs. 27.0, $p<0.0001$), current smokers (53.2% vs. 32.9%, $p=0.0002$), higher pack-years of smoking (47.6 vs. 29.1, $p<0.0001$), individuals with self-reported hypertension (56.6% vs. 27.6%, $p<0.0001$), and COPD (29.7% vs. 13.5%, $p=0.0005$) (Table 3). Self-reported diabetes was higher in the WTC participants compared with the non-WTC participants (20.3% vs. 12.4%, $p=0.06$). Because clinical laboratory values were available for only 76 (45%), non-WTC participants, these factors were not compared between the two groups. To adjust for the differences of the WTC and non-WTC participants, PS analyses were used for further analyses. The PS adjustment successfully balanced the baseline characteristics between two groups as there were no longer significant differences in the PS-adjusted comparisons shown in Table 3. The final adjusted OR needed to consider all significant variables included in Table 3 (gender, age, pack-years of smoking, BMI) as well as the LDCT findings of CAC and presence of emphysema. The average CAC score was: 2.0 vs. 1.5, $p=0.02$, and the presence of emphysema was: 58% vs. 56%, $p=0.37$, respectively for the WTC and non-WTC participants. The final adjusted OR for moderate-to-severe hepatic steatosis in the WTC participants was 3.4 (95% CI: 1.7 –6.7), even after adjustment for all these variables (Table 4).

Using an alternative approach, multiple logistic regression revealed that liver attenuation <40 HU was positively associated with being part of the WTC (OR=2.9, 95% CI:1.03–8.17), higher BMI (OR=1.10 per kg/M²) and it was negatively associated with being a current smoker (OR=0.41, 95% CI:0.17–0.99). The model adjusted for gender, pack years of smoking, self-reported diabetes, hypertension, and CAC score (Table 5). Although smoking is generally associated with lower BMI, we did not observe an interaction between smoking and BMI in this study.

Discussion

The most important results of our study were that the odds of having moderate-to-severe hepatic steatosis, defined by CT liver attenuation $<40\text{HU}$, was over 3-fold higher among WTC screening participants than among non-WTC participants enrolled in the same LDCT screening program with different entry criteria, before and after adjustment for all significant covariates.

The WTC cohort is a unique patient population whose clinical data have been recorded until the present time as part of the World Trade Center (WTC) Health Program. Numerous adverse health effects have been described in this patient population, findings in keeping with other studies, suggesting the significant epidemiologic link between the exposure to airborne particulates and adverse health effects. A longitudinal study of a large cohort of WTC rescue and recovery workers demonstrated a substantial burden of health problems, including a 9-year cumulative occurrence of asthma (27.6%), sinusitis(42.3%), and gastroesophageal reflux disease (39.3%) 21. Multiple studies have demonstrated lung function abnormalities in individuals exposed at the WTC disaster and in pre-clinical models 22,23. Hepatotoxic exposures are reported to continue for years after exposure to the toxin has stopped 24. Studies have also shown that ambient particulate matter (PM) exposure to lung is closely associated with pathogenesis of metabolic syndrome affecting non-pulmonary organs including the cardiovascular system, adipose tissue and liver. Inhaled particulates can enter the systemic circulation and concentrate in the liver, which serves as a major site of detoxification. Hepatotoxic exposures include particulate matter 11, air pollution 12, close proximity to major roadways 25 and to toxic waste sites 13, exposure to active and passive smoking 14, and to volatile chemicals 11. Animal studies confirm the hepatotoxic effects of airborne particulate matter (PM_{2.5}) and chemicals 26,27. Toxic exposures not only provoke a series of intrahepatic changes that can lead to liver failure and liver cancer, but have been shown to induce NAFLD 12. The differential associations with lung dysfunction and NAFLD may reflect distinct but overlapping pathophysiologic mechanisms of lung and liver disease after PM exposure. In a more general sense, ambient PM is known to induce systemic inflammation, oxidative stress response and vascular dysfunction, ultimately affecting multiple organs including liver and lungs.

Elevated BMI and obesity are more prevalent in the WTC responders compared to the general US population, with an obesity prevalence of 42–48.6% 28. A greater number of responders were overweight compared to the general US population (43% vs. 33%, respectively)28. Obesity was shown to be a major risk factor for liver steatosis due to the increased delivery of free fatty acids to the liver and an increase in hepatic lipogenesis associated with hyperinsulemia 29. A significant, yet small, association between weight gain and decline in lung function in the longitudinal follow up study in WTC responders was also shown 22. Polycyclic aromatic hydrocarbon(PAH), a toxic exposure recognized at the WTC site 30, was also related to obesity and the expression of a number of obesity-related cardiometabolic health risk factors 31. We also found that BMI was significantly higher in the WTC cohort than in the non-WTC participants. Our results are especially meaningful as we also found that liver function tests results were

significantly higher in WTC participants with CT liver density measurement <40HU, suggesting that moderate-to-severe HS may be accompanied by increased hepatocyte injury. A recent analysis of the National Health and Nutrition Examination Survey (NHANES) data showed that FIB-4>1.3(intermediate elevation) and/or >2.67(high elevation) were both significantly associated with increased liver-related mortality 32. These findings underscore the importance of providing additional work up for possible liver disease. Because the attenuation threshold used in this study excludes cases with milder degrees of HS of questionable clinical relevance, liver density measurement of <40HU may represent a useful diagnostic cutoff value for screening.

We acknowledge several limitations of our study. First, the sample size was limited and we lacked pathologic confirmation of HS. While non-contrast CT is valuable for detecting moderate-to-severe steatosis, detection of mild HS 33, is limited. The frequency of HS in the WTC cohort was compared to the non-WTC cohort, both enrolled in the same screening program at the same institution. To account for differences in the age and smoking history, PS methods were used to create groups with similar characteristics so that the effect of WTC exposure on HS could be compared. Assumption for PS analysis is that all covariates relevant to HS that differ between the two cohorts are accounted for, so that the analysis is limited by its inability to control for unmeasured confounders and measurement errors. Although WTC participants had significantly higher BMI and more likely to have diabetes compared to non-WTC participants, tests and diagnostics confirmed that our model balances the covariates and the two groups were comparable. Alcohol consumption 34,35 and steroid use have been shown to increase risk of HS 36,37, but data on alcohol consumption and steroid use was not available for either cohort. With the higher prevalence of COPD among WTC participants and steroids being one of most commonly prescribed medications for people with COPD, differential steroid use between the two cohorts may bias our results. As a result, there might be residual confounding due to the unaccounted effect of both alcohol consumption and steroid use. Future studies including alcohol and steroid use data are necessary to further examine the effect of hepatotoxic exposures in the WTC attack area.

In summary, members of the WTC General Responder Cohort have been affected by number of chronic health conditions; however, they have not been evaluated for liver disease. This is the first study to assess HS among the WTC general responder participants and to compare them to non-WTC participants in the same LDCT lung screening program. We have demonstrated that WTC participants have a significantly higher rate of HS. Overlapping pathophysiologic mechanisms of lung and liver disease after particulate matter exposure, smoking and obesity likely contribute to the development and higher rates of hepatic steatosis in this population. Further work is necessary to further elucidate the pathophysiologic mechanism behind the development of HS in this unique patient population and to investigate the long-term effects and potential for the development of liver disease. Based on these preliminary results, we suggest that WTC general responders with liver attenuation values <40HU should be referred to a hepatologist for further evaluation.

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Footnotes

Potential conflict of interest:

- Dr. Yankelevitz is a named inventor on a number of patents and patent applications relating to the evaluation of diseases of the chest including measurement of nodules. Some of these, which are owned by Cornell Research Foundation (CRF), are non-exclusively licensed to General Electric. As an inventor of these patents, Dr. Yankelevitz is entitled to a share of any compensation which CRF may receive from its commercialization of these patents. He is also an equity owner in Accumetra, a privately held technology company committed to improving the science and practice of image-based decision making (7 Corporate Drive, Clifton Park, NY 12065; Tel: 518-280-7530; <http://accumetra.com/>). Dr. Yankelevitz also serves on the advisory board of GRAIL (1525 O'Brien Drive, Menlo Park, CA 94025; Tel: 650-542-0372; <https://grail.com/>).
- Dr. Henschke is the President and serves on the board of the Early Diagnosis and Treatment Research Foundation. She receives no compensation from the Foundation. The Foundation is established to provide grants for projects, conferences, and public databases for research on early diagnosis and treatment of diseases. Dr. Claudia Henschke is also a named inventor on a number of patents and patent applications relating to the evaluation of pulmonary nodules on CT scans of the chest which are owned by Cornell Research Foundation (CRF). Since 2009, Dr. Henschke does not accept any financial benefit from these patents including royalties and any other proceeds related to the patents or patent applications owned by CRF.

Institution and Ethics approval and informed consent:

This work was performed at the Icahn School of Medicine at Mount Sinai in New York, NY. We reviewed baseline LDCT scans of the chest of all WTC participants who qualified for and participated in the National Institute of Occupational Safety and Health (NIOSH)-approved early lung cancer screening program between Feb 2016-Jan 2017. Written informed consent was obtained according to a HIPAA-compliant protocol approved by the Icahn School of Medicine at Mount Sinai IRB.

Disclaimer: None

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**Validation of Predictive Metabolic Syndrome Biomarkers
of World Trade Center Lung Injury:
A 16-Year Longitudinal Study**

By Sophia Kwon, DO,

Abstract

Background: Metabolic syndrome (MetSyn) predicted future development of World Trade Center lung injury (WTC-LI) in a subgroup of firefighters who never smoked and were male. An intracohort validation of MetSyn as a predictor of WTC-LI is examined in the cohort exposed to the World Trade Center (WTC) that has been followed longitudinally for 16 years.

Methods: Results of pulmonary function tests (n = 98,221) in workers exposed to the WTC (n = 9,566) were evaluated. A baseline cohort of firefighters who had normal FEV1 before 9/11 and who had had serum drawn before site closure on July 24, 2002 (n = 7,487) was investigated. Case subjects with WTC-LI (n = 1,208) were identified if they had at least two measured instances of FEV1 less than the lower limit of normal (LLN). Cox proportional hazards modeled early MetSyn biomarker ability to predict development of FEV1 less than the LLN.

Results: Case subjects were more likely to smoke, be highly exposed, and have MetSyn. There was a significant exposure dose response; the individuals most highly exposed had a 30.1% increased risk of developing WTC-LI, having MetSyn increased risk of developing WTC-LI by 55.7%, and smoking increased risk by 15.2%. There was significant interaction between smoking and exposure.

Conclusions: We validated the usefulness of MetSyn to predict future WTC-LI in a larger population of individuals who were exposed. MetSyn defined by dyslipidemia, insulin resistance, and cardiovascular disease suggests that systemic inflammation can contribute to future lung function loss.

Key Words:

lung injury, metabolic syndrome, validation, World Trade Center

Abbreviations:

DBP, diastolic BP; FDNY, Fire Department of New York; HDL, high-density lipoprotein; HR, hazard ratio; LDL, low-density lipoprotein; LLN, lower limit of normal; MetSyn, metabolic syndrome; PFT, pulmonary function test; PM, particulate matter; SBP, systolic BP; WTC, World Trade Center; WTC-HP, WTC Health Program; WTC-LI, WTC Lung Injury

Discussion

The FDNY cohort exposed at the WTC continues to have their health adversely impacted even after 16 years.^{49, 50, 51} Our previous pilot study focused on the contribution of MetSyn to the development of WTC-LI in a select group of nonsmokers requiring subspecialty pulmonary evaluation.²² To our knowledge, our current work is the first study to validate MetSyn biomarkers as a predictor of WTC-LI in a more representative cohort.

Our study indicates that MetSyn predicts WTC-LI, in contrast to other studies that purport possible lung injury predicting incident MetSyn.⁵² We show this temporality based on blood samples drawn early in the disease process, up to site closure on July 24, 2002, whereas the diagnosis of WTC-LI is after at least two PFT results showing a consistent FEV1 less than the LLN (mean of 92 months after 9/11). Dyslipidemia maintains its ability to predict WTC-LI in the larger cohort exposed to WTC PM. To our knowledge, ours is also the longest longitudinal study to show that MetSyn risk factors impart a higher risk of developing loss of FEV1 than does either PM or smoking exposure.

Our earlier model showed that dyslipidemia and heart rate independently increased the odds of developing WTC-LI. Our current investigation shows the continued associations of MetSyn biomarkers and WTC-LI. Moreover, we show that MetSyn biomarkers are more predictive than are smoking and WTC exposure intensity in predicting the development of WTC-LI. MetSyn risk factors are classically predictors of cardiovascular disease, but their implications in affecting future lung disease are novel and indicate reversible risks that may be therapeutic targets.

Similar to the results in our pilot, glucose level was not a significant predictor of WTC-LI.²⁰ Specifically, there was no increased risk of lung injury with cut points of either 100 or 126 mg/dL. We had hypothesized in our earlier work that insulin resistance would be a significant predictor if sufficiently powered in the larger group. This validation model suggests that the impact of glucose on lung function is either indirect or weaker than that of dyslipidemia.

This finding is in contrast to those of other studies that similarly have investigated insulin resistance and lung function.⁵³ This result is unlikely to be from a healthy worker effect, given that the prevalence of insulin resistance was approximately 18% in both case subjects and control subjects. Rather, this result may indicate that dyslipidemia is present earlier in the disease process than is insulin resistance.

The study design allowed us to explore multiple aspects of WTC-LI. In our pilot, we described WTC-LI as FEV1 less than the LLN at the time of subspecialty evaluation.²⁰ We now confirm in this more representative cohort that MetSyn biomarkers remain valid predictors of developing FEV1 less than the LLN at a single time point (secondary end point). By using the stricter definition for WTC-LI of being less than the LLN at least twice (primary end point), we potentially

have identified a population with greater long-term pulmonary health consequences of WTC exposure. Despite having the same baseline demographic characteristics, those in the primary end-point group had significantly lower PFT values at baseline and at WTC-HP entry. Although having slightly lower baseline PFT values conceivably can increase the likelihood of developing an FEV1 less than the LLN, the clinical difference is minute and likely would not have altered medical treatment.

We confirm the relevance of MetSyn as a risk for a persistent loss of FEV1 to less than the LLN. Long-term exposure to PM significantly increases LDL, cholesterol, and triglyceride levels and decreases HDL levels in pregnant rats and their offspring.⁵⁴ Additionally, adult women exposed to tobacco smoke in utero had higher triglyceride and lower HDL levels than did unexposed women, and female adolescents exposed in utero had significantly higher BMIs and waist circumference percentiles than did those who were unexposed.^{55, 56}

The constellation of respiratory diseases related to PM exposure through burn pits, improvised explosive devices, and sandstorms has been studied extensively and shows great potential as comparable cohorts.^{57, 58} Ambient pollution in China and its association with MetSyn also has been investigated.⁵⁹ Our findings can be applied to these cohorts to examine the effect of MetSyn characteristics as a potential screening tool for the development of future FEV1 less than the LLN.

Using the clinical markers of MetSyn as predictors of lung disease is advantageous in several ways. These biomarkers are easily attainable, are cost-effective to obtain, and can be replicated in many cohorts. Dyslipidemia, insulin resistance, obesity, and hypertension are also all potentially reversible causes of end-organ disease. Extending statin therapy and increasing glycemic control can be the targets of future studies.

There are several limitations to this study. Smoking status was self-reported, and no pack-year history or secondhand smoke exposure data were available. Also, case subjects with WTC-LI and control subjects had significantly different pre-9/11 FEV1 measurements. However, their average PFT values were well within the clinically expected normal values. It is not within the scope of this study to examine whether there was some genetic or innate predisposition to MetSyn or lung disease. However, studying the relevant multiomics of this cohort is an active area of research.²² Serum samples were not available from before WTC exposure or from when subjects first joined the FDNY.

It remains unclear to what extent, if any, diet, alcohol consumption, and exercise contributed to the metabolic signature of subjects with WTC-LI or whether a dietary modification would be useful in preventing, managing, or treating WTC-LI and similar processes. Specifically, a diet that is low in saturated fat intake and has a low ratio of omega-6 to omega-3 fatty acids may help to correct high ceramide levels and the imbalance in phospholipid-derived long-chain polyunsaturated fatty acid metabolites, which could have downstream beneficial effects on

inflammatory and insulin signaling pathways.^{60, 61, 62} In patients with advanced lung diseases such as COPD, branched chain amino acid supplements improve health outcomes.^{63, 64} Dietary interventions that have focused on weight loss in patients with obstruction show improvement of both FEV1 and FVC by as much as 22% in as little as 15 days.^{65, 66} With use of a very low-calorie diet, investigators have been able to achieve a 20-kg loss over a 6-month period; every 10% relative loss of weight led to a significant improvement of FVC by 92 mL and of FEV1 by 73 mL.⁶⁷ As patients decreased their BMI from 37 to 32 kg/m², the mean morning FEV1 and FVC increased.⁶⁸ Additionally, a 2008 study showed the effectiveness of calorie restriction and Mediterranean diets in reducing lipid levels.⁶⁹ Although moderating fats can be essential to maintaining a healthy diet, there is extensive literature that explores the potential health benefits of fats, such as n-3 and n-6 polyunsaturated fatty acids, that are high in a Mediterranean diet.^{70, 71} Additional research is needed to examine the impact of diet and other modifiable risks on WTC-LI progression.

This study lacks further assessment of biomarkers such as amylin and leptin.²⁰ In 2004, the Evaluation of COPD Longitudinally to Identify Predictive Surrogate Endpoints group investigated the repeatability of 34 biomarkers and found that only some were reproducible and correlated with measures of lung dysfunction.⁷² However, we are strongly encouraged by our result that pathways involved in metabolism have broad impacts on the immune and hormonal environment in the lung. Future investigations will seek to validate these biomarkers in this study's cohort and identify mechanistic pathways that lead to WTC-LI.

Examination of the primary end point shows that, compared with the other MetSyn criteria, having a BMI ≥ 30 is associated with the highest risk of developing WTC-LI. BMI is a surrogate for abdominal waist circumference, and BMI has been shown to be flawed as a biomarker in numerous studies.⁷³ However, we also see that this association is less powerful in the secondary end point and that dyslipidemia, particularly hypertriglyceridemia, is a pervasive predictor. We also showed that the cumulative effect of at least three MetSyn criteria is more powerful than any one factor alone. Therefore, we are cautious to not overinterpret the association of BMI > 30 as the strongest predictor of WTC-LI. The 3-D plot that shows stratification with other components of MetSyn supports this interpretation.

Conclusions

In summary, we have validated the usefulness of MetSyn biomarkers as predictors of WTC-LI in a larger more representative population of firefighters exposed at the WTC. These biomarkers are associated with dyslipidemia, insulin resistance, and cardiovascular disease and suggest MetSyn can contribute to future loss of lung function. Our data contribute to the growing body of literature investigating the complex associations between lung injury and reversible MetSyn risk factors.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6717118/>

**Post-9/11/2001 lung function trajectories by sex and race
in World Trade Center-exposed New York City emergency medical service workers**

Madeline Vossbrinck, et al.

Abstract

Objective: To determine whether lung function trajectories after 9/11/2001 (9/11) differed by sex or race/ethnicity in World Trade Center-exposed Fire Department of the City of New York emergency medical service (EMS) workers.

Method: Serial cross-sectional study of pulmonary function tests (PFTs) taken between 9/11 and 9/10/2015. We used data from routine PFTs (forced expiratory volume in 1 s (FEV1) and FEV1% predicted), conducted at 12-18 month intervals. FEV1 and FEV1% predicted were assessed over time, stratified by sex, and race/ethnicity. We also assessed FEV1 and FEV1% predicted in current, former and never-smokers.

Results: Among 1817 EMS workers, 334 (18.4%) were women, 979 (53.9%) self-identified as white and 939 (51.6%) were never-smokers. The median follow-up was 13.1 years (IQR 10.5-13.6), and the median number of PFTs per person was 11 (IQR 7-13). After large declines associated with 9/11, there was no discernible recovery in lung function. In analyses limited to never-smokers, the trajectory of decline in adjusted FEV1 and FEV1% predicted was relatively parallel for men and women in the 3 racial/ethnic groups. Similarly, small differences in FEV1 annual decline between groups were not clinically meaningful. Analyses including ever-smokers were essentially the same.

Conclusions: 14 years after 9/11, most EMS workers continued to demonstrate a lack of lung function recovery. The trajectories of lung function decline, however, were parallel by sex and by race/ethnicity. These findings support the use of routine, serial measures of lung function over time in first responders and demonstrate no sex or racial sensitivity to exposure-related lung function decline.

<https://pubmed.ncbi.nlm.nih.gov/27810938/>

**Estimating the time interval between exposure
to the World Trade Center disaster and incident
diagnoses of obstructive airway disease**

Michelle S Glaser, et al.

Abstract

Respiratory disorders are associated with occupational and environmental exposures. The latency period between exposure and disease onset remains uncertain. The World Trade Center (WTC) disaster presents a unique opportunity to describe the latency period for obstructive airway disease (OAD) diagnoses. This prospective cohort study of New York City firefighters compared the timing and incidence of physician-diagnosed OAD relative to WTC exposure. Exposure was categorized by WTC arrival time as high (on the morning of September 11, 2001), moderate (after noon on September 11, 2001, or on September 12, 2001), or low (during September 13-24, 2001). We modeled relative rates and 95% confidence intervals of OAD incidence by exposure over the first 5 years after September 11, 2001, estimating the times of change in the relative rate with change point models. We observed a change point at 15 months after September 11, 2001. Before 15 months, the relative rate for the high- versus low-exposure group was 3.96 (95% confidence interval: 2.51, 6.26) and thereafter, it was 1.76 (95% confidence interval: 1.26, 2.46). Incident OAD was associated with WTC exposure for at least 5 years after September 11, 2001. There were higher rates of new-onset OAD among the high-exposure group during the first 15 months and, to a lesser extent, throughout follow-up. This difference in relative rate by exposure occurred despite full and free access to health care for all WTC-exposed firefighters, demonstrating the persistence of WTC-associated OAD risk.

Keywords: World Trade Center; change point model; latency; obstructive airway disease; occupational exposure; rescue/recovery workers.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4108044/>



**The effect of World Trade Center exposure
on the latency of chronic rhinosinusitis diagnoses in New York City firefighters:
2001–2011**

By Jessica Weakley

To assess how the effect of World Trade Center (WTC) exposure on physician-diagnosed chronic rhinosinusitis (CRS) in firefighters changed during the decade following the attack on 9/11 (11 September 2001 to 10 September 2011).

Methods: We examined temporal effects on the relation between WTC exposure and the incidence of physician diagnosed CRS in firefighters changed during the decade following the attack on 9/11 (11 September 2001 to 10 September 2011). Exposure was grouped by time of arrival at the WTC site as follows: (high) morning 11 September 2001 (n=1623); (moderate) afternoon 11 September 2001 or 12 September 2001 (n=7025); or (low) 13–24 September 2001 (n=1200). Piecewise exponential survival models were used to estimate incidences by exposure group, with change points in the relative incidences estimated by maximum likelihood.

Results: Incidences dramatically increased after 2007 due to a programmatic change that provided free medical treatment, but increases were similar in all exposure groups. For this reason, we observed no change point during the study period, meaning the relative incidence by exposure group (high vs moderate vs low) of CRS disease did not significantly change over the study period. The relative rate of developing CRS was 1.99 (95% CI=1.64 to 2.41) for high versus low exposure, and 1.52 (95% CI=1.28 to 1.80) for moderate versus low exposure during the 10-year follow-up period.

Conclusions: *The risk of CRS in FDNY firefighters appears increased with WTC-exposure, and has not diminished by time since exposure.*

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4819651/>

It is unknown for how long new incident chronic rhinosinusitis is associated with exposure to the World Trade Center (WTC) disaster. Latency of chronic rhinosinusitis to any occupational exposure has not previously been researched. **There is an association of new onset chronic rhinosinusitis for at least a decade after exposure to the WTC disaster site. There is need for continued monitoring and treatment of worker with high levels of exposure to the WTC site.**

**Potential for diffuse parenchymal lung disease
after exposures at World Trade Center Disaster site**

By Jaime Szeinuk, María Padilla and Rafael E de la Hoz

Abstract

Objective: The diffuse parenchymal lung diseases (DPLDs) are a heterogeneous group of disorders that result from damage to the lung parenchyma. While the cause of most DPLDs remains unknown, extensive epidemiological and experimental evidence has linked exposure to environmental toxins to the pathogenesis of some of those diseases. The purpose of this review is to examine the potential relation between exposure to toxins released from the World Trade Center (WTC) collapse on September 11th, 2001 and the development of DPLD based on published evidence up to date.

Methods: We examine such evidence from two points of view, (1) exposure, and (2) histopathogenesis.

Exposure: Analyses of WTC-dust and particle size demonstrate that some portion of the dust was composed of particles small enough to penetrate deep into the lungs, reaching distal airways and alveoli. The presence of such particles has been confirmed in studies of induced sputum and bronchoalveolar lavage in WTC-exposed firefighters. **Histopathogenesis:** In vitro and animal experiments and patient evidence suggest that WTC dust is capable of inducing a pulmonary interstitial inflammatory response.

Results: To date, there have been limited clinical reports documenting the development of diffuse parenchymal responses following exposure to WTC dust. No single common pathologic response has been described. The one common denominator in the reports is that the individuals who developed disease were heavily exposed either during the disaster or during the initial 2-to-3 days following the disaster.

Conclusion: DLPDs are probably associated with heavy or extended exposure to the toxins released at the WTC disaster site. Coupled with the historical experience with exposures to occupational toxins this mandates continued long-term clinical observation of this cohort.

<https://pubmed.ncbi.nlm.nih.gov/18500711/>

Letters to the Editor

By Albert Miller, MD
Department of Medicine New York Medical College Valhalla, NY

World Trade Center Multiple Myeloma: Police Responders Only?

To the Editor: Moline et al.¹ have now published data on their cases of Multiple Myeloma in World Trade Center (WTC) responders, which they have cited at conferences and which have been picked up by the popular and medical press.² ***Of the eight cases, there was, if anything, a deficit in older subjects (who are the most likely to get this disease) and a surplus in those younger than 45 years, 4 versus 1.2 expected.*** This may be sufficient to warrant publication but does not prove causation of malignancy from WTC exposure. All the four younger patients were police. This raises questions; the article could equally be entitled “Multiple Myeloma in WTC Police Responders.” It is widely reported that various agents, to which police are exposed, may increase the risk for multiple myeloma, including vehicle exhaust and pesticides.³ Do the authors have information on myeloma incidence in police in New York City or elsewhere? Confirmation of this increase in multiple myeloma from another, carefully followed, group of WTC responders, NYC Firefighters, would be of interest. (Note that before September 11, 2001 increased multiple myeloma had been described in firefighters with at least 20 years of service.⁴) The report is subject to selection bias in that symptomatic subjects or those with major illness are more likely to present for monitoring. “Patients were asked to self-report any diagnosed conditions to a WTC Medical Monitoring and Treatment Program (MMTP) clinician during a baseline monitoring or treatment visit.” How many of the cases were identified among those already enrolled in the program? Did the others present to the program because of the diagnosis already established?

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[**Editors Note:** continue reading the MM peer review. The medical reports and the researchers position takes an about face as the statistics come in.]

Authors' Response

To the Editor: We thank Dr Miller for his letter regarding our publication on Multiple Myeloma (MM) in World Trade Center (WTC) responders. Dr Miller observes that the occurrence of four cases of MM in young WTC responders “does not prove causation from WTC exposure.” We whole-heartedly agree. Indeed, in our report, we carefully stated that “it is too early to say whether the risk of MM is truly increased among WTC responders.”

Because all four of the young WTC responders in our case series were police officers, Dr Miller asks reasonably whether there exist any previous reports of an increased incidence of MM in members of the law enforcement professions. ***We carefully searched the medical literature and were unable to find any such reports.***

Dr Miller opines that our report may be “subject to selection bias.” We recognize this possibility, and we carefully weigh it in our report. The magnitude of any selection bias depends in part on the size of the population of WTC responders. We estimated the response proportion as 50% to 70% of those eligible, which is reasonably high but still vulnerable to selective participation. Although selective response would not fully account for the excess found among younger participants, it may have influenced the patterns to some extent. Some cases presented after they had been diagnosed with MM. Others, however, developed MM after they had already been evaluated and are not subject to selection bias. It is also possible that other participants in the program have developed MM and have not returned for follow-up evaluations. Continued follow-up of this cohort as well as linkages with cancer registries should better inform us of disease rates in the upcoming years.

[***Editors Note:*** See the reports on MM that follow this one.]

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Multiple Myeloma in World Trade Center responders: a case series

Jacqueline M Moline, et al.

Abstract

Objectives: We report on cases of multiple myeloma (MM) observed in World Trade Center (WTC) responders registered in the WTC Medical Program.

Methods: Possible cases of MM diagnosed between September 11, 2001, and September 10, 2007, in responders were confirmed if they met the World Health Organization and Mayo Clinic diagnostic criteria.

Results: Among 28,252 responders of known sex and age, eight cases of MM were observed (6.8 expected). Four of these cases were observed in responders younger than 45 years at the time of diagnosis (1.2 expected). A slight deficit of MM cases was observed in responders older than 45 years (4 observed, 5.6 expected).

Conclusion: *In this case series, we observe an unusual number of MM cases in WTC responders under 45 years.* This finding underscores the importance of maintaining surveillance for cancer and other emerging diseases in this highly exposed population.

<https://pubmed.ncbi.nlm.nih.gov/19620891/>

Comment • Cancer Discov

doi: 10.1158/2159-8290 • July 2018

9/11 Firefighters at Risk for Multiple Myeloma

No authors listed

Abstract

The largest study to date of responders to the World Trade Center attacks in New York, NY, on 9/11 reports that ***exposed firefighters have roughly twice the risk of developing multiple myeloma precursor disease as the general population. Moreover, firefighters who go on to develop multiple myeloma exhibit a younger age of onset and more aggressive disease than is typical.***

<https://pubmed.ncbi.nlm.nih.gov/29764808/>

Sci Rep

doi: 10.1038/srep36305 • November 2016

**Proteomic Characterization of the World Trade Center
dust-activated mdig and c-myc signaling circuit linked to Multiple Myeloma**

By Kai Wu

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Abstract

Several epidemiological studies suggested an increased incidence rate of multiple myeloma (MM) among first responders and other individuals who exposed to World Trade Center (WTC) dust. In this report, we provided evidence showing that WTC dust is potent in inducing mdig protein and/or mRNA in bronchial epithelial cells, B cells and MM cell lines. An increased mdig expression in MM bone marrow was observed, which is associated with the disease progression and prognosis of the MM patients. Through integrative genomics and proteomics approaches, we further demonstrated that mdig directly interacts with c-myc and JAK1 in MM cell lines, which contributes to hyperactivation of the IL-6-JAK-STAT3 signaling important for the pathogenesis of MM. Genetic silencing of mdig reduced activity of the major downstream effectors in the IL-6-JAK-STAT3 pathway. Taken together, these data suggest that WTC dust may be one of the key etiological factors for those who had been exposed for the development of MM by activating mdig and c-myc signaling circuit linked to the IL-6-JAK-STAT3 pathway essential for the tumorigenesis of the malignant plasma cells.

<https://pubmed.ncbi.nlm.nih.gov/27833099/>

Association between World Trade Center exposure and excess cancer risk

By Jiehui Li, et al.

Abstract

Context: The terrorist attacks of September 11, 2001, resulted in the release of known and suspected carcinogens into the environment. There is public concern that exposures may have resulted in increased cancers.

Objective: To evaluate cancer incidence among persons enrolled in the World Trade Center Health Registry.

Design, setting, and participants: Observational study of 55,778 New York State residents enrolled in the World Trade Center Health Registry in 2003-2004, including rescue/recovery workers (n = 21,850) and those not involved in rescue/recovery (n = 33,928), who were followed up from enrollment through December 31, 2008. Within-cohort comparisons using Cox proportional hazards models assessed the relationship between intensity of World Trade Center exposure and selected cancers.

Main outcome measures: Cases were identified through linkage with 11 state cancer registries. Standardized incidence ratios (SIRs) adjusted for age, race/ethnicity, and sex were computed with 2003-2008 New York State rates as the reference, focusing on cancers diagnosed in 2007-2008 as being most likely to be related to exposure during September 11 and its aftermath. The total and site-specific incidence rate differences (RDs) per 100,000 person-years between the study population and the New York State population in 2007-2008 also were calculated.

Results: There were 1187 incident cancers diagnosed, with an accumulated 253,269 person-years (439 cancers among rescue/recovery workers and 748 among those not involved in rescue/recovery). The SIR for all cancer sites combined in 2007-2008 was not significantly elevated (SIR, 1.14 [95% CI, 0.99 to 1.30]; RD, 67 [95% CI, -6 to 126] per 100,000 person-years among rescue/recovery workers vs SIR, 0.92 [95% CI, 0.83 to 1.03]; RD, -45 [95% CI, -106 to 15] per 100,000 person-years among those not involved in rescue/recovery). Among rescue/recovery workers, the SIRs had significantly increased by 2007-2008 for 3 cancer sites and were 1.43 (95% CI, 1.11 to 1.82) for prostate cancer (n = 67; RD, 61 [95% CI, 20 to 91] per 100,000 person-years), 2.02 (95% CI, 1.07 to 3.45) for thyroid cancer (n = 13; RD, 16 [95% CI, 2 to 23] per 100,000 person-years), and 2.85 (95% CI, 1.15 to 5.88) for multiple myeloma (n = 7; RD, 11 [95% CI, 2 to 14] per 100,000 person-years). No increased incidence was observed in 2007-2008 among those

not involved in rescue/recovery. Using within-cohort comparisons, the intensity of World Trade Center exposure was not significantly associated with cancer of the lung, prostate, thyroid, non-Hodgkin lymphoma, or hematological cancer in either group.

Conclusions: Among persons enrolled in the World Trade Center Health Registry, there was an excess risk for prostate cancer, thyroid cancer, and myeloma in 2007-2008 compared with that for New York State residents; however, these findings were based on a small number of events and multiple comparisons. No significant associations were observed with intensity of World Trade Center exposures. Longer follow-up for typically long-latency cancers and attention to specific cancer sites are needed.

<https://pubmed.ncbi.nlm.nih.gov/23288447/>

Journal Occup Environ Med

doi: 10.1097/JOM.0b013e3181ad49c8 • August 2009

Multiple Myeloma in World Trade Center responders: a case series

Jacqueline M Moline, et al.

Abstract

Objectives: We report on cases of multiple myeloma (MM) observed in World Trade Center (WTC) responders registered in the WTC Medical Program.

Methods: Possible cases of MM diagnosed between September 11, 2001, and September 10, 2007, in responders were confirmed if they met the World Health Organization and Mayo Clinic diagnostic criteria.

Results: Among 28,252 responders of known sex and age, eight cases of MM were observed (6.8 expected). Four of these cases were observed in responders younger than 45 years at the time of diagnosis (1.2 expected). A slight deficit of MM cases was observed in responders older than 45 years (4 observed, 5.6 expected).

Conclusion: In this case series, we observe an unusual number of MM cases in WTC responders under 45 years. This finding underscores the importance of maintaining surveillance for cancer and other emerging diseases in this highly exposed population.

<https://pubmed.ncbi.nlm.nih.gov/19620891/>

**Performance of Self-Report to Establish Cancer Diagnoses
in Disaster Responders and Survivors, World Trade Center Health Registry,
New York, 2001–2007**

By Jiehui Li, MBBS, MS

Abstract

Objective: Large-scale disasters may disrupt health surveillance systems, depriving health officials and researchers of timely and accurate information needed to assess disaster-related health effects and leading to use of less reliable self-reports of health outcomes. In particular, ascertainment of cancer in a population is ordinarily obtained through linkage of self-reported data with regional cancer registries, but exclusive reliance on these sources following a disaster may result in lengthy delays or loss of critical data. To assess the impact of such reliance, we validated self-reported cancer in a cohort of 59,340 responders and survivors of the World Trade Center disaster against data from 11 state cancer registries (SCRs).

Methods: We focused on residents of the 11 states with SCRs and on cancers diagnosed from September 11, 2001, to the date of their last survey participation. Medical records were also sought in a subset of 595 self-reported cancer patients who were not recorded in an SCR.

Results: Overall sensitivity and specificity of self-reported cancer were 83.9% (95% confidence interval [CI] 81.9, 85.9) and 98.5% (95% CI 98.4, 98.6), respectively. Site-specific sensitivities were highest for pancreatic (90.9%) and testicular (82.4%) cancers and multiple myeloma (84.6%). Compared with enrollees with true-positive reports, enrollees with false-negative reports were more likely to be non-Hispanic black (adjusted odds ratio [aOR] = 1.8, 95% CI 1.2, 2.9) or Asian (aOR=2.2, 95% CI 1.2, 4.1). Among the 595 cases not recorded in an SCR, 13 of 62 (21%) cases confirmed through medical records were reportable to SCRs.

Conclusion

Self-report of cancer had relatively high sensitivity among adults exposed to the World Trade Center disaster, suggesting that self-reports of other disaster-related conditions less amenable to external validation may also be reasonably valid.

Identification and tracking of long-term physical and mental health effects of man-made and natural disasters often rely on self-reports of clinically diagnosed health conditions obtained longitudinally through questionnaires,¹ but the accuracy of such self-reported diagnoses is

often difficult to assess because of large sample sizes and limited funding. Accuracy of self-reported health data can depend on such factors as type of condition, study population demographics, and recall period length.^{2–9}

Linkage of cohort data with independent cancer registries enables assessment of cancer self-report accuracy and may reflect self-report accuracy of other endpoints for which no outside data are available. The sensitivity of self-reported cancer is reported to vary by site, treatment, and number of previous tumors.^{6,10–12} False-negative self-report of cancer diagnoses determined by comparison with cancer registry data is associated with older age,^{6,11,13} nonwhite race, increased time since cancer diagnosis,⁶ lower education level,^{2,8} male sex, and urban living.²

The World Trade Center (WTC) Health Registry (WTCHR) has followed a cohort of 71,434 people since 2003 to identify and track the long-term health effects of the September 11, 2011 (hereinafter 9/11), terrorist attacks through surveys.¹⁴ Although the WTCHR periodically requests to compare its data with those of other health registries, such as state cancer registries (SCRs) and the Statewide Planning and Research Cooperative System, the time lags between diagnosis and data availability for comparison often limits timely surveillance of emerging or rare health conditions. Thus, the accuracy of self-reported health information, including cancer diagnosis, provided by WTCHR enrollees at enrollment and in subsequent waves is important. We examined the performance of self-reported health data collected by the WTCHR, using cancer as an example, by comparing WTCHR survey data with data obtained via linkage with SCRs to validate self-reported cancer diagnosis. We also examined correlates of false-negative and false-positive reports.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4869085/>



Am J Ind Med

doi: 10.1002/ajim.22638 • September 2016

**Ten-year cancer incidence in rescue/recovery workers and civilians
exposed to the September 11, 2001 terrorist attacks on the World Trade Center**

By Jiehui Li, et l.

Abstract

Background: Cancer incidence in exposed rescue/recovery workers (RRWs) and civilians (non-RRWs) was previously reported through 2008.

Methods: We studied occurrence of first primary cancer among World Trade Center Health Registry enrollees through 2011 using adjusted standardized incidence ratios (SIRs), and the WTC-exposure-cancer association, using Cox proportional hazards models.

Results: All-cancer SIR was 1.11 (95% confidence interval (CI) 1.03-1.20) in RRWs, and 1.08 (95% CI 1.02-1.15) in non-RRWs. Prostate cancer and skin melanoma were significantly elevated in both populations. Thyroid cancer was significantly elevated only in RRWs while breast cancer and non-Hodgkin's lymphoma were significantly elevated only in non-RRWs. There was a significant exposure dose-response for bladder cancer among RRWs, and for skin melanoma among non-RRWs.

Conclusions: We observed excesses of total and specific cancers in both populations, although the strength of the evidence for causal relationships to WTC exposures is somewhat limited. Continued monitoring of this population is indicated. Am. J. Ind. Med. 59:709-721, 2016. © 2016 Wiley Periodicals, Inc.

Keywords: September 11 attacks; World Trade Center;
cancer incidence; environmental exposure.

<https://pubmed.ncbi.nlm.nih.gov/27582473/>

Prevalence of and factors associated with mammography and prostate-specific antigen screening among World Trade Center Health Registry enrollees, 2015-2016

By Janette Yung, et al.

Abstract

To compare the prevalence of mammography and prostate-specific antigen (PSA) testing in 9/11-exposed persons with the prevalence among the US population, and examine the association between 9/11 exposures and these screening tests using data from the World Trade Center Health Registry (WTCHR) cohort. We studied 8190 female and 13,440 male enrollees aged ≥ 40 years at survey completion (2015-2016), who had a medical visit during the preceding year, had no self-reported breast or prostate cancer, and did not have screening for non-routine purposes. We computed age-specific prevalence of mammography (among women) and PSA testing (among men), and compared to the general population using 2015 National Health Interview Survey data (NHIS). We also computed the adjusted prevalence ratio (PR) and 95% confidence interval (95% CI) to examine the relationship between 9/11 exposures and screening uptakes using modified Poisson regression. Our enrollees had higher prevalences of mammogram and PSA testing than the US general population. 9/11 exposure was not associated with mammography uptake. Proximity to the WTC at the time of the attacks was associated with PSA testing in the age 60-74 group (PR = 1.06; 95% CI = 1.00-1.12). Among rescue/recovery workers and volunteers (RRW), being a firefighter was associated with higher PSA testing than other RRW across all age groups (40-49: PR = 1.45, 95% CI 1.16-1.81; 50-59: PR = 1.33, 95% CI 1.22-1.44; 60-74: PR = 1.14, 95% CI 1.06-1.23). Screening activities should be considered when studying cancer incidence and mortality in 9/11 exposed populations.

Keywords: Breast; Cancer; Disaster; Mammography; Prostate; Prostate specific antigen; Rescue and recovery; Screening; WTC; World Trade Center.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6030231/>

Prevalence of and factors associated with mammography and prostate-specific antigen screening among World Trade Center Health Registry enrollees, 2015–2016

By Janette Yung

Abstract

To compare the prevalence of mammography and prostate-specific antigen (PSA) testing in 9/11-exposed persons with the prevalence among the US population, and examine the association between 9/11 exposures and these screening tests using data from the World Trade Center Health Registry (WTCHR) cohort. We studied 8190 female and 13,440 male enrollees aged ≥ 40 years at survey completion (2015–2016), who had a medical visit during the preceding year, had no self-reported breast or prostate cancer, and did not have screening for non-routine purposes. We computed age-specific prevalence of mammography (among women) and PSA testing (among men), and compared to the general population using 2015 National Health Interview Survey data (NHIS). We also computed the adjusted prevalence ratio (PR) and 95% confidence interval (95% CI) to examine the relationship between 9/11 exposures and screening uptakes using modified Poisson regression. Our enrollees had higher prevalences of mammogram and PSA testing than the US general population. 9/11 exposure was not associated with mammography uptake. Proximity to the WTC at the time of the attacks was associated with PSA testing in the age 60–74 group (PR = 1.06; 95% CI = 1.00–1.12). Among rescue/recovery workers and volunteers (RRW), being a firefighter was associated with higher PSA testing than other RRW across all age groups (40–49: PR = 1.45, 95% CI 1.16–1.81; 50–59: PR = 1.33, 95% CI 1.22–1.44; 60–74: PR = 1.14, 95% CI 1.06–1.23). Screening activities should be considered when studying cancer incidence and mortality in 9/11 exposed populations.

Introduction

Several studies of cancer among persons who were directly exposed to the World Trade Center terrorist attacks on September 11, 2001 (9/11) in New York City (NYC) have found a slight excess in the incidence of cancer overall (Li et al., 2012, Li et al., 2016; Solan et al., 2013; Zeig-Owens et al., 2011). Excess breast cancer rate among civilians exposed to WTC disaster has been reported (Li et al., 2016), and excess cases of thyroid and prostate cancer have been found in several different cohorts (Boffetta et al., 2016), and associated with higher levels of 9/11-related exposures (Moir et al., 2016; Solan et al., 2013).

One common characteristic of these types of cancer is that they are detectable by screening.

The US Preventive Services Task Force (USPSTF) recommends biennial screening mammography for women aged 50 to 74 years (Siu, 2016), but has discouraged PSA screening for prostate cancer since May 2012 (Moyer et al., 2012). Because federally-funded health care for 9/11-exposed persons is available through the World Trade Center Health Program (WTCHP), it is likely that persons who survived the 9/11 attacks have better access to medical care, and thus are offered cancer screening more often than the general population. For instance, health assessments including complete blood counts and prostate-specific antigen (PSA) test are offered every 12–18 months in the Fire Department of NYC (FDNY) (Boffetta et al., 2016; Zeig-Owens et al., 2011) to all participating male firefighters aged 45 years or older since 9/11 (Moir et al., 2016). Full medical exams including breast cancer screening are offered to non-FDNY exposed rescue/recovery workers who were enrolled in the World Trade Center Health Consortium (WTCHC) (Boffetta et al., 2016). It is unknown whether the observed excess in cancer incidence among 9/11-exposed persons is attributable to more rigorous screening of this population than of the general population.

We wished to examine whether 9/11-exposed persons underwent screening for cancer more frequently than the general population. We focused on screening for breast and prostate cancer because an increased incidence of each has been reported in previous WTC studies, and well-established national screening guidelines exist for both. We assessed the prevalence of screening for these two cancers among the World Trade Center Health Registry (“WTCHR”) enrollees to provide information on cancer screening in this population, and examined associations of 9/11-related exposures with mammography and PSA screening.

Methods

Study population

The WTCHR has been described in detail elsewhere (Brackbill et al., 2009; Farfel et al., 2008). Briefly, between September 12, 2003 and November 24, 2004, 71,431 people completed a computer-assisted (95%) or in-person (5%) enrollment interview on demographics, exposures incurred during and after the WTC disaster, and health information. WTCHR enrollees include rescue/recovery workers and volunteers (RRW) and community members not involved in rescue/recovery (Farfel et al., 2008). Since the enrollment survey (Wave 1), the Registry has conducted three follow-up surveys (Waves 2–4) via mail, website, or telephone interview to collect updated health information. The adult response rate for Wave 2, Wave 3, and Wave 4 was 65.2%, 60.4%, and 51.6%, respectively.

The Wave 4 adult survey, administered March 2015 through January 2016, was the first Registry survey to inquire about cancer screening. Therefore, Wave 4 participants (n = 36,864) were eligible for this study. We excluded participants who were younger than 40 years old at the time of the survey (n = 3005), had not have a medical visit for routine check-up within the past 12 months (n = 7426), and missing age or answers for each screening question (n = 1926). On Wave 4, we asked “When did you last visit a doctor for a routine check-up that was not for a

specific injury, illness, or condition?" The answers include "Within the last 12 months", "Over a year ago but less than 2 years ago", "2 or more years ago but less than 5 years ago", "5 or more years ago", and "Never in my life". Those who answered "Within the last 12 months" were considered as having a medical visit for routine check-up within the past 12 months, and therefore included in the study sample. For the screening questions, we asked "In the last 12 months, did you have a mammogram (for women) or a PSA test (for men)?" If participants answered "Yes" to the question, we further asked the purpose of their most recent screening test (i.e., as "part of routine examination", "because of a problem", "other reason", or "don't know"). The screening questions were adapted from the Cancer Control Supplement of the 2010 National Health Interview Survey (NHIS) (US Department of Health and Human Services, 2010). We excluded those who had screening for reasons other than routine examination to avoid the over-estimation of screening activity (n = 1323, including 374 women and 949 men). We also excluded women with self-reported breast cancer (n = 688) and men with self-reported prostate cancer (n = 866). The inclusion and exclusion criteria were adapted from a study that examined the PSA screening test in NHIS sample (Drazer et al., 2015). Our final sample for analysis included 21,630 participants, with 8190 women and 13,440 men.

The study was approved by the Institutional Review Board (IRB) at the New York City Department of Health and Mental Hygiene. The Centers for Disease Control and Prevention and New York City DOHMH IRBs approved the overall Registry protocols. Verbal consent was obtained from the participants at enrollment.

Study variables

The outcome variables of interest were self-reports of having a mammogram (for women) or PSA testing (for men) as "part of a routine examination" in the past 12 months.

The 9/11-related exposure variables were collected at Wave 1. These included Registry eligibility group, a dichotomous variable referring to either RRW or community members; proximity to the WTC site on 9/11 morning, defined as being south of Chambers Street in lower Manhattan on the morning of 9/11; and dust cloud/debris exposure on 9/11, defined as being outdoors in the dust and debris cloud resulting from the collapse of the WTC towers on 9/11.

Covariates included socio-demographic variables at Wave 4 (age, race/ethnicity, marital status, education level, household income, smoking status, and body mass index (BMI)), history of any clinician-diagnosed mental health disorders (PTSD, anxiety or depression), as previous literature reported under-utilization of screening for persons with mental health issues (Carney and Jones, 2006; Park et al., 2010), ever received services from WTCHP clinics, and family history of breast or prostate cancer. Family history of cancer was self-reported. We solicited this information using a skip pattern question structure. We asked "Has your biological father ever had cancers?" If yes, a follow-up question on type(s) of cancer is asked. The same method was used for asking cancer history of biological mother, biological brothers/sisters (include half-brothers/

sisters but not step-brother/sister), and any other blood relatives. We categorized biological parents or siblings as first degree relatives, all other blood relatives as second degree or further, and all others who reported none as no family history.

Statistical analyses

All analyses were performed using SAS software (SAS Institute, Cary, NC, v9.4). Statistical significance was set at a 2-sided alpha = 0.05 level. We computed the prevalence of mammography and PSA testing in the last 12 months by socio-demographic variables, family history of cancer, and various types of WTC exposures. We described and compared the age-specific prevalence of cancer screening by level of family history using Pearson's chi-squared test.

We also compared the age-specific prevalence of each screening in the last 12 months to the general population using 2015 NHIS data (CDC, 2015). NHIS is a nationally representative cross-sectional survey sample of the civilian non-institutionalized population. The NHIS sampling design involves stratification, clustering and over sampling of specific sub-groups. We extracted age, sex, type of cancer diagnosed, and times of most recent routine medical visit from the "sample adult" dataset, time of most recent PSA testing and reason for testing from the "sample cancer" dataset (CDC, 2015) to compute prevalence of mammography and PSA testing in the NHIS sample with comparable inclusion criteria. We incorporated sampling weights to adjust for the complex survey design (CDC, 2016).

We used modified Poisson regression with a robust error variance (Zou, 2004) to examine the associations of WTC disaster-related exposure variables with having a mammogram among women or PSA testing among men, adjusting for covariates. We stratified the analyses by age 40–49 and 50–74 years for mammography, and by age 40–49, 50–59, and 60–74 years for PSA testing.

Since high WTC exposure level has been reported to be associated with increased incidence of prostate cancer among RRW (Boffetta et al., 2016), we performed a sub-analysis of PSA testing among male RRW to explore whether rescue/recovery-specific exposures were associated with screening. Rescue/recovery-specific exposures included total number of days worked at the WTC site, date of first arrival with or without working on pile, and worker categories. Workers were categorized into the FDNY and other firefighters, NYC Police responders, sanitation workers, and all other workers, since routine health monitoring may vary between worker categories (Yip et al., 2016).

Results

Compared to female Wave 4 participants who were excluded, a higher proportion of female participants in the current study were non-Hispanic Black (17.7% vs 12.9%); widowed, divorced, or separated (28.6% vs 20.5%); or had health insurance (98.1% vs 91.3%). Compared to male Wave 4 participants who were excluded, male participants in this study were more likely to be

married or living with a partner (79.6% vs 72.9%) or have health insurance (98.3% vs 91.3%) (Supplemental Table). Table 1 shows the characteristics of the sample and prevalence of routine mammography and PSA testing by socio-demographic characteristics and WTC disaster-related exposures. The overall prevalence of mammography among women and PSA testing among men age 40 or older was 74.2% and 57.2%, respectively. Table 2 shows the prevalence of screening by age group and family history of each cancer. We observed an increase in age-adjusted prevalence of both screenings with closer level of family history.

Prevalence of and factors associated with mammography

The prevalence of mammography was higher in the 50–59 age group (78.0%) than in other age groups (Table 1). Women who were screened with mammography were predominantly non-Hispanic Black (79.6%), married or living with a partner (75.8%), with higher education (74.4%), higher household income (79.6%), or a first degree relative with breast cancer (79.9%). Mammography prevalence was lower in those with any history of clinician-diagnosed PTSD, anxiety or depression than those without (70.2% vs 76.4%). The prevalence of mammography was similar by WTCHR eligibility group, proximity to the WTC site and dust cloud exposure. The WTC exposure variables were not significantly associated with mammography after adjusting for covariates in both age groups (Table 3). However, mammography uptake in those ages 50–74 was associated with being non-Hispanic Black or Hispanic, higher household income, having a family history of breast cancer in any blood related relatives, and current or former smokers.

Prevalence of and factors associated with prostate-specific antigen testing

The prevalence of PSA testing (Table 1) was higher among men ages 60–74 (71.0%), non-Hispanic whites (59.6%), those who were married or living with a partner (58.5%), had some college or higher education (58.5%), a higher income (58.8%), were former smokers (60.5%), overweight (58.9%), ever received services from WTC health clinics (58.0%), or had a first degree relative with prostate cancer (70.7%). The prevalence of PSA testing was slightly lower in those with a reported history of any clinician diagnosed PTSD, anxiety, or depression than in those without (55.1% vs 57.9%). The prevalence of PSA testing was similar by WTCHR eligibility group, proximity to the WTC site and dust cloud exposure.

There was a significant association between proximity to the WTC site on 9/11 morning and PSA testing, adjusting for covariates among men ages 60 to 74 (OR = 1.06, 95% CI 1.00–1.12) (Table 4). In the same age group, PSA testing was also associated with higher education, higher household income, non-smokers, and having a first degree relative with prostate cancer. Among the youngest age group, PSA testing was significantly associated with non-Hispanic Black, higher income, obese or overweight, family history of prostate cancer in first degree relatives.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6030231/>

**Mortality among survivors of the Sept 11, 2001, World Trade Center disaster:
results from the World Trade Center Health Registry cohort**

Hannah T Jordan, et al.

Abstract

Background: The Sept 11, 2001 (9/11) World Trade Center (WTC) disaster has been associated with several subacute and chronic health effects, but whether excess mortality after 9/11 has occurred is unknown. We tested whether excess mortality has occurred in people exposed to the WTC disaster.

Methods: In this observational cohort study, deaths occurring in 2003-09 in WTC Health Registry participants residing in New York City were identified through linkage to New York City vital records and the National Death Index. Eligible participants were rescue and recovery workers and volunteers; lower Manhattan area residents, workers, school staff and students; and commuters and passers-by on 9/11. Study participants were categorised as rescue and recovery workers (including volunteers), or non-rescue and non-recovery participants. Standardised mortality ratios (SMR) were calculated with New York City rates from 2000-09 as the reference. Within the cohort, proportional hazards were used to examine the relation between a three-tiered WTC-related exposure level (high, intermediate, or low) and total mortality.

Findings: We identified 156 deaths in 13,337 rescue and recovery workers and 634 deaths in 28,593 non-rescue and non-recovery participants. All-cause SMRs were significantly lower than that expected for rescue and recovery participants (SMR 0.45, 95% CI 0.38-0.53) and non-rescue and non-recovery participants (0.61, 0.56-0.66). No significantly increased SMRs for diseases of the respiratory system or heart, or for haematological malignancies were found. In non-rescue and non-recovery participants, both intermediate and high levels of WTC-related exposure were significantly associated with mortality when compared with low exposure (adjusted hazard ratio 1.22, 95% CI 1.01-1.48, for intermediate exposure and 1.56, 1.15-2.12, for high exposure). High levels of exposure in non-rescue and non-recovery individuals, when compared with low exposed non-rescue and non-recovery individuals, were associated with heart-disease-related mortality (adjusted hazard ratio 2.06, 1.10-3.86). In rescue and recovery participants, level of WTC-related exposure was not significantly associated with all-cause mortality (adjusted hazard ratio 1.25, 95% CI 0.56-2.78, for high exposure and 1.03, 0.52-2.06, for intermediate exposure when compared with low exposure).

Interpretation: This exploratory study of mortality in a well defined cohort of 9/11 survivors pro-

vides a baseline for continued surveillance. Additional follow-up is needed to establish whether these associations persist and whether a similar association over time will occur in rescue and recovery participants.

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Estimation of Future Cancer Burden Among Rescue and Recovery Workers Exposed to the World Trade Center Disaster

By Ankura Singh, et al.

Abstract

Importance: Elevated rates of cancer have been reported in individuals exposed to the World Trade Center (WTC) disaster, including Fire Department of the City of New York (FDNY) rescue and recovery workers.

Objective: To project the future burden of cancer in WTC-exposed FDNY rescue and recovery workers by estimating the 20-year cancer incidence.

Design, setting, and participants: A total of 14 474 WTC-exposed FDNY employees who were cancer-free on January 1, 2012; subgroup analyses were conducted of the cohort's white male population (n = 12 374). In this closed-cohort study, we projected cancer incidence for the January 1, 2012, to December 31, 2031, period. Simulations were run using demographic-specific New York City (NYC) cancer and national mortality rates for each individual, summed for the whole cohort, and performed 1000 times to produce mean estimates. Additional analyses in the subgroup of white men compared case counts produced by using 2007-2011 FDNY WTC Health Program (FDNY-WTCHP) cancer rates vs NYC rates. Average and 20-year aggregate costs of first-year cancer care were estimated using claims data.

Exposures: World Trade Center disaster exposure defined as rescue and recovery work at the WTC site at any time from September 11, 2001, to July 25, 2002.

Main outcomes and measures: (1) Projected number of incident cancers in the full cohort, based on NYC cancer rates; (2) cancer incidence estimates in the subgroup projected using FDNY-WTCHP vs NYC rates; and (3) estimated first-year treatment costs of incident cancers.

Results: On January 1, 2012, the cohort was 96.8% male, 87.1% white, and had a mean (SD) age of 50.2 (9.2) years. The projected number of incident cancer cases was 2960 (95% CI, 2883-3037). In our subgroup analyses using FDNY-WTCHP vs NYC cancer rates, the projected number of new cases in white men was elevated (2714 [95% CI, 2638-2786] vs 2596 [95% CI, 2524-2668]). Accordingly, we expect more prostate (1437 [95% CI, 1383-1495] vs 863 [95% CI, 816-910]), thyroid (73 [95% CI, 60-86] vs 57 [95% CI, 44-69]), and melanoma cases (201 [95% CI, 179-223] vs 131 [95% CI, 112-150]), but fewer lung (237 [95% CI, 212-262] vs 373 [95% CI, 343-405]), colorectal

(172 [95% CI, 152-191] vs 267 [95% CI, 241-292]), and kidney cancers (66 [95% CI, 54-80] vs 132 [95% CI, 114-152]) ($P < .001$ for all comparisons). The estimated 20-year cost of first-year treatment was \$235,835,412.00 (95% CI, \$187 582 227-\$284,088,597.00).

Conclusions and relevance: We project that the FDNY-WTCHP cohort will experience a greater cancer burden than would be expected from a demographically similar population. This underscores the importance of cancer prevention efforts and routine screening in WTC-exposed rescue and recovery workers.

Conflict of interest statement

Conflict of Interest Disclosures: None reported.

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Association between World Trade Center exposure and excess cancer risk

By Jiehui Li, et al.

Abstract

Context: The terrorist attacks of September 11, 2001, resulted in the release of known and suspected carcinogens into the environment. There is public concern that exposures may have resulted in increased cancers.

Objective: To evaluate cancer incidence among persons enrolled in the World Trade Center Health Registry.

Design, setting, and participants: Observational study of 55,778 New York State residents enrolled in the World Trade Center Health Registry in 2003-2004, including rescue/recovery workers (n = 21,850) and those not involved in rescue/recovery (n = 33,928), who were followed up from enrollment through December 31, 2008. Within-cohort comparisons using Cox proportional hazards models assessed the relationship between intensity of World Trade Center exposure and selected cancers.

Main outcome measures: Cases were identified through linkage with 11 state cancer registries. Standardized incidence ratios (SIRs) adjusted for age, race/ethnicity, and sex were computed with 2003-2008 New York State rates as the reference, focusing on cancers diagnosed in 2007-2008 as being most likely to be related to exposure during September 11 and its aftermath. The total and site-specific incidence rate differences (RDs) per 100,000 person-years between the study population and the New York State population in 2007-2008 also were calculated.

Results: There were 1187 incident cancers diagnosed, with an accumulated 253,269 person-years (439 cancers among rescue/recovery workers and 748 among those not involved in rescue/recovery). The SIR for all cancer sites combined in 2007-2008 was not significantly elevated (SIR, 1.14 [95% CI, 0.99 to 1.30]; RD, 67 [95% CI, -6 to 126] per 100,000 person-years among rescue/recovery workers vs SIR, 0.92 [95% CI, 0.83 to 1.03]; RD, -45 [95% CI, -106 to 15] per 100,000 person-years among those not involved in rescue/recovery). Among rescue/recovery workers, the SIRs had significantly increased by 2007-2008 for 3 cancer sites and were 1.43 (95% CI, 1.11 to 1.82) for prostate cancer (n = 67; RD, 61 [95% CI, 20 to 91] per 100,000 person-years), 2.02 (95% CI, 1.07 to 3.45) for thyroid cancer (n = 13; RD, 16 [95% CI, 2 to 23] per 100,000 person-years), and 2.85 (95% CI, 1.15 to 5.88) for multiple myeloma (n = 7; RD, 11 [95% CI, 2 to 14] per 100,000 person-years). No increased incidence was observed in 2007-2008 among those not involved in

rescue/recovery. Using within-cohort comparisons, the intensity of World Trade Center exposure was not significantly associated with cancer of the lung, prostate, thyroid, non-Hodgkin lymphoma, or hematological cancer in either group.

Conclusions: Among persons enrolled in the World Trade Center Health Registry, there was an excess risk for prostate cancer, thyroid cancer, and myeloma in 2007-2008 compared with that for New York State residents; however, these findings were based on a small number of events and multiple comparisons. No significant associations were observed with intensity of World Trade Center exposures. Longer follow-up for typically long-latency cancers and attention to specific cancer sites are needed.

<https://pubmed.ncbi.nlm.nih.gov/23288447/>



**Estimating the Time Interval Between Exposure
to the World Trade Center Disaster and
Incident Diagnoses of Obstructive Airway Disease**

Michelle S. Glaser, et al.

Abstract

Respiratory disorders are associated with occupational and environmental exposures. The latency period between exposure and disease onset remains uncertain. The World Trade Center (WTC) disaster presents a unique opportunity to describe the latency period for obstructive airway disease (OAD) diagnoses. This prospective cohort study of New York City firefighters compared the timing and incidence of physician-diagnosed OAD relative to WTC exposure. Exposure was categorized by WTC arrival time as high (on the morning of September 11, 2001), moderate (after noon on September 11, 2001, or on September 12, 2001), or low (during September 13–24, 2001). We modeled relative rates and 95% confidence intervals of OAD incidence by exposure over the first 5 years after September 11, 2001, estimating the times of change in the relative rate with change point models. We observed a change point at 15 months after September 11, 2001. Before 15 months, the relative rate for the high- versus low-exposure group was 3.96 (95% confidence interval: 2.51, 6.26) and thereafter, it was 1.76 (95% confidence interval: 1.26, 2.46). Incident OAD was associated with WTC exposure for at least 5 years after September 11, 2001. There were higher rates of new-onset OAD among the high-exposure group during the first 15 months and, to a lesser extent, throughout follow-up. This difference in relative rate by exposure occurred despite full and free access to health care for all WTC-exposed firefighters, demonstrating the persistence of WTC-associated OAD risk.

DISCUSSION

We found an association between WTC exposure and new diagnoses of OAD that lasted throughout the 5-year post-September 11, 2001, follow-up period. This conclusion is supported by the statistically significant trend tests, the continued significant differences between the high- and low-exposure groups, and the nonexistence of a significant change point past 15 months. The increased relative rates demonstrate that this occupational/environmental exposure influenced diagnoses of OAD for longer than has previously been suspected. Although the relative rates remained elevated throughout the study period, the magnitude became attenuated at 15 months after September 11, 2001. The pre- and post-15-month change point relative rates were similar when analyzing OAD by asthma and nonasthma subtypes, suggesting that the observed association was not driven by a specific diagnosis.

In multivariable analyses, the associations we reported between WTC exposure and OAD were similar, regardless of which covariates were included in the models. We included smoking status and retirement in the final models because in previous studies, including our own, they were shown to be associated with an increased risk of OAD (2, 14, 21, 30).

Most of the cohort reported symptoms referable to the lower respiratory tract before the 15-month change point, including 72% of those who did not receive a diagnosis until after the change point. This is consistent with our prior report of highly prevalent lower respiratory symptoms in the first year after September 11, 2001 (26), followed by a decline in some symptom categories. For example, prevalence of cough declined from 54% in the first year after September 11, 2001, to 16% in the second year. Early symptom reports may represent acute inflammation, which resolved for some, was more troublesome for others leading to an early diagnosis, and yet for others, either waxed and waned or persisted, progressing at a slower rate and leading to a diagnosis at a later date. Early symptoms without an early diagnosis, however, may also occur, because some firefighters may have wished to continue working at the FDNY, despite symptoms. OAD diagnoses can lead to mandatory retirement, because these conditions potentially limit the safe performance of firefighting. Consequently, firefighters may try to avoid OAD diagnoses to allow them to continue employment. Nevertheless, we observed a consistent exposure-response gradient throughout the follow-up period, with the highest OAD incidence in the high-exposure group, suggesting that WTC exposure continued to influence OAD diagnoses throughout the 5-year follow-up period.

Whether and for how long latency periods occur following irritant exposures remains unknown. Studies of latency are difficult to find. When available, they may be limited by small numbers; imprecise measures of exposure; measurement only of duration of direct exposure, but not of the time interval between exposure cessation and disease diagnosis; and undocumented or unknown health care access that could have contributed to an observed long latency (10, 11, 13). Following the WTC disaster, we found a relationship between WTC exposure and newly diagnosed OAD that persisted for at least the first 5 years. The existence of a latency period for WTC-related irritant OAD in this cohort may be due to multiple simultaneous or sequential exposures to noxious gas, vapor, fumes, and particle forms (31–33) that were inhaled on numerous occasions. Additionally, immunologically mediated mechanisms have been shown to play a role in the development of OAD following WTC exposure in this cohort (34–36), although it is not known if they can differentiate between those with early versus late onset. Longer latency periods between exposure and the diagnosis of new-onset asthma might be expected for immunologically mediated asthma because time is needed to acquire “sensitization” to the causal agent (12) or for chronic inflammation or airway remodeling to occur. It is also possible that some of those diagnosed with OAD have an underlying case of bronchiolitis, similar to that reported in workers exposed to butter flavoring volatiles including diacetyl (37–43), in which latency ranged from 9 months to 14 years after exposure (37–43).

There are some potential limitations to this study. As mentioned above, given this cohort’s con-

tinued participation in the WTC rescue and recovery effort through July 24, 2002, it is possible that diagnoses might have been postponed in nonseriously ill firefighters. Additionally, there could have been an interaction between initial WTC exposure and subsequent or ongoing firefighting exposures for those, comprising most of the cohort, who did not retire shortly after September 11, 2001. We believe, however, that this issue is mitigated by the fact that retirement status was not significantly associated with OAD incidence and by our finding of a statistically significant WTC exposure-response gradient throughout the study period, indicating that WTC exposure continued to be associated with OAD diagnoses even during later periods. Further, there is no evidence that the high-exposure group had differential firefighting exposures after the WTC disaster. Nonetheless, it remains possible that OAD latency was a response to cumulative exposures, albeit driven by WTC exposure, and was influenced by an individual firefighter's exposure to, for example, the number or type of non-WTC fires or to nonoccupational exposures for which data are not available. Likewise, there could be an interaction with nonoccupational events such as respiratory viral infections (44). Finally, we acknowledge that, beyond the WTC disaster and other exposures, the susceptibility to develop OAD, like any disease, is, in part, influenced by genetic predispositions (3).

This study has numerous strengths. We were able to successfully implement a statistical method not previously used in the analysis of WTC-exposed cohorts to estimate the amount of time that WTC exposure was associated with new-onset OAD. This has broad applications for future WTC studies and for analyses of other exposure-response relationships that are not immediately obvious. In fact, we are hopeful that this technique can facilitate a better understanding of the relationship between acute or chronic occupational exposures and subsequent illness. Another strength is limited participation bias, because we knew the exposure status of all cohort members, and almost all were included in the study. Further, because this cohort did not have OAD prior to September 11, 2001, we are confident that these are incident diagnoses. All firefighters had free and unlimited access to medical treatment during this study period, which contributed to very limited loss to follow-up (6.4%) and provided an unparalleled opportunity for them to obtain a diagnosis without delay across all exposure levels. Because analyses focused on relative rates, our results were unaffected by potential confounders, such as the timing and initiation of treatment or season of diagnosis. Further, our results consistently showed a significant WTC exposure-response relationship with increased rates of OAD throughout the study period in all models. In future studies, we plan to use similar methodology to analyze OAD incidence beyond the first 5 years to determine if there are additional change points and to study post-WTC exposure symptom development and persistence.

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Conflict of interest: none declared.

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**The effect of World Trade Center exposure
on the latency of chronic rhinosinusitis diagnoses
in New York City firefighters: 2001–2011**

Jessica Weakley, et al.

Abstract

Objective: To assess how the effect of World Trade Center (WTC) exposure on physician-diagnosed chronic rhinosinusitis (CRS) in firefighters changed during the decade following the attack on 9/11 (11 September 2001 to 10 September 2011).

Methods: We examined temporal effects on the relation between WTC exposure and the incidence of physician diagnosed CRS in firefighters changed during the decade following the attack on 9/11 (11 September 2001 to 10 September 2011). Exposure was grouped by time of arrival at the WTC site as follows: (high) morning 11 September 2001 (n=1623); (moderate) afternoon 11 September 2001 or 12 September 2001 (n=7025); or (low) 13–24 September 2001 (n=1200). Piecewise exponential survival models were used to estimate incidences by exposure group, with change points in the relative incidences estimated by maximum likelihood.

Results: Incidences dramatically increased after 2007 due to a programmatic change that provided free medical treatment, but increases were similar in all exposure groups. For this reason, we observed no change point during the study period, meaning the relative incidence by exposure group (high vs moderate vs low) of CRS disease did not significantly change over the study period. The relative rate of developing CRS was 1.99 (95% CI=1.64 to 2.41) for high versus low exposure, and 1.52 (95% CI=1.28 to 1.80) for moderate versus low exposure during the 10-year follow-up period.

Conclusions: The risk of CRS in FDNY firefighters appears increased with WTC-exposure, and has not diminished by time since exposure.

Introduction

The 9/11 terrorist attacks on the World Trade Center (WTC) created a man-made disaster of devastating magnitude resulting in great volumes of dust and debris being released into the environment. It has been estimated that approximately 70% of the towers' structural components were pulverised during the collapse, producing small and large inhalable particulates.¹ Adverse short-term and medium-term respiratory effects of work at the WTC disaster site have

been widely documented in Fire Department of the City of New York (FDNY) first responders and others.^{2 3} We first reported WTC cough syndrome, demonstrated that work-related exposures to the disaster site increased the odds of aerodigestive symptoms up to 9 years post-11 September 2001, and showed that the prevalence of physician-diagnosed lower respiratory conditions, both self-reported and FDNY-physician diagnosed, remained elevated 7–9 years after working at the site.^{4 5} However, while the association between WTC exposure and lower respiratory conditions has been well documented, fewer studies have focused on upper airway disturbance such as chronic rhinosinusitis,^{6 7} a condition that can interfere with the demanding level of physical activity required to perform firefighting duties and may also inhibit the use of respirators and other breathing equipment.

CRS is a relatively common disorder that affects about 12.1% of the adult population.⁸ Risk factors include allergies, exposure to airborne irritants, immune system disorders and viral infections. About one in five people with CRS report asthma, the most common comorbidity with CRS.⁹ A defining symptom of CRS is nasal congestion, which can affect one's ability to breathe. This could interfere with satisfactory performance of any occupation requiring strenuous physical activity or respiratory mask use. CRS has also been associated with lost work productivity and occupational absenteeism.^{10 11}

In two previous studies we showed that new onset obstructive airways disease (OAD) was associated with WTC exposure for more than 5 years,¹² and for the first post-9/11 decade.¹³ We used innovative statistical methods—parametric survival models with change points—to examine the relationship between WTC exposure and new onset OAD in each study. For the current study, we extend the use of this methodology to address a similar question in CRS incidence. The study goal is to estimate the duration of the response gradient between different levels of WTC exposure and the incidence of new onset CRS among WTC-exposed FDNY firefighters.

Discussion

This is the first study to look at latency in diagnoses of CRS resulting from WTC exposure. We found that the effect of exposure to the WTC disaster on incident CRS diagnoses persisted for 10 years after initial exposure. Those with the highest exposure were twice as likely to develop CRS as the least exposed. We reported similar results in our previous study of OAD latency where new OAD diagnoses were associated with WTC exposure for at least 7 years.

While we believe that many new CRS diagnoses were associated with WTC exposure for 10 years post-9/11, our results need to be interpreted with caution. In 2007, programmatic changes allowed prescribed medications to be provided free for WTC-related conditions. This programme change was followed by substantial increases in the number of FDNY physician examinations and diagnoses of CRS in all three exposure groups. So while there was a change in the overall number of diagnoses at around 2007, the zero change point model shows that there was no change in the relative incidence of diagnoses in the moderate and high exposure groups when

compared with the lowest exposure group. When interpreting the time interval between WTC exposure and reported disease onset as indicated by diagnosis date, we are unable to distinguish between the natural history of the disease and the effects of increased surveillance due to the FDNY programmatic change, but we note that the exposure gradient remained through the end of follow-up.

The main limitation of this study is our inability to access the medical records of non-FDNY physicians. The change point analysis is based on the time of first FDNY-reported CRS diagnoses and we are unable to speculate on how the change point would have differed if FDNY members first were diagnosed by non-FDNY physicians. We also believe there is a possibility that CRS was generally overlooked by both patients and physicians in the first few years after 9/11 due to more severe morbidity associated with OAD in the patient population.^{2 15} Again, the time of the incident CRS diagnosis could be a reflection of the urgency to diagnose and treat other diseases soon after 9/11.

Despite these limitations, this study has several strengths. We relied on medical records and not self-reported disease, the latter being more subject to bias and therefore less accurate. While many large epidemiological studies use self-reports to estimate the disease burden in populations, we had access to all participants' FDNY medical records, which we mined for CRS diagnoses. We also used uniform and stringent diagnostic criteria, including a confirmatory abnormal sinus CT result or nasal laryngoscopy at any time during the follow-up period. There were low rates of loss to follow-up in this population, and finally, we used an exposure measure that has been validated in other studies.^{2 4 5}

Detection and treatment of rhinosinusitis is important given its impact on quality of life¹⁶ and its potential to lead to worsening asthma,¹⁷ of particular clinical significance given the high incidence of asthma in this and other cohorts of WTC-exposed responders post-9/11.^{4 5} Unique to this population of first responders with physically demanding jobs, rhinosinusitis makes it difficult for firefighters to wear respirators, a requirement for the safe performance of their duties.

In conclusion, this research supports the association of new onset CRS long after exposure to the WTC disaster site. It also confirms the need for continued monitoring and treatment of this highly exposed cohort.

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Patient consent: Obtained.

Ethics approval:
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**The Duration of an Exposure Response Gradient
between Incident Obstructive Airways Disease
and Work at the World Trade Center Site: 2001-2011**

Charles B. Hall, et al.

Abstract

Background: Adverse respiratory effects of World Trade Center (WTC) exposure have been widely documented, but the length of time that exposure remains associated with disease is uncertain. We estimate the incidence of new cases of physician-diagnosed obstructive airway disease (OAD) as a function of time since 9/11/2001 in WTC-exposed firefighters.

Methods: Exposure was categorized by first WTC arrival time: high (9/11/2001 AM); moderate (9/11/2001 PM or 9/12/2001); or low (9/13-24/2001). We modeled relative rates (RR) and 95% confidence intervals (CI) of OAD incidence by exposure over the first 10 years post-9/11/2001, estimating the time(s) of change in the RR with change point models. We further examined the relationship between self-reported lower respiratory symptoms and physician diagnoses.

Results: Change points were observed at 15 and 84 months post-9/11/2001, with relative incidence rates for the high versus low exposure group of 4.02 (95% CI 2.62-6.16) prior to 15 months, 1.90 (95% CI 1.49-2.44) from months 16 to 84, and 1.20 (95% CI 0.92-1.56) thereafter. Incidence in all exposure groups increased after the WTC health program began to offer free coverage of OAD medications in month 63. Self-reported lower respiratory symptoms in the first 15 months had 80.6% sensitivity, but only 35.9% specificity, for eventual OAD diagnoses.

Conclusions: New OAD diagnoses are associated with WTC exposure for at least seven years. Some portion of the extended duration of that association may be due to delayed diagnoses. Nevertheless, our results support recognizing OAD among rescue workers as WTC-related even when diagnosed years after exposure.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4449208/>

Bronchial Reactivity and Lung Function After World Trade Center Exposure

Thomas K. Aldrich, et al.

Abstract

Background: World Trade Center (WTC)-exposed rescue/recovery workers endured massive respiratory insult from inhalation of particulate matter and gases, resulting in respiratory symptoms, loss of lung function, and, for many, bronchial hyperreactivity (BHR). The persistence of respiratory symptoms and lung function abnormalities has been well-documented, whereas persistence of BHR has not been investigated.

Methods: A total of 173 WTC-exposed firefighters with bronchial reactivity measured within 2 years after September 11, 2001 (9/11) (baseline methacholine challenge test), were reevaluated in 2013 and 2014 (follow-up methacholine challenge test). FEV1 measurements were obtained from the late pre-9/11, early post-9/11, and late post-9/11 periods. Respiratory symptoms and corticosteroid treatment were recorded.

Results: Bronchial reactivity remained stable (within 1 doubling dilution) for most (n = 101, 58%). Sixteen of 28 (57%) with BHR (provocative concentration of methacholine producing a 20% decline in FEV1 <8 mg/mL) at baseline had BHR at follow-up, and an additional 27 of the 145 (19%) without BHR at baseline had BHR at follow-up. In multivariable models, we found that BHR baseline was strongly associated with BHR follow-up (OR, 6.46) and that BHR at follow-up was associated with an estimated 15.4 mL/y greater FEV1 decline than experienced by those without BHR at follow-up. Annual FEV1 decline was moderated by corticosteroid use.

Conclusions: Persistent BHR and its deleterious influence on lung function suggest a role for airway inflammation in perpetuation of WTC-associated airway disease. In future massive occupational exposure to inorganic dust/gases, we recommend early and serial pulmonary function testing, including measurements of bronchial reactivity, when possible, and inhaled corticosteroid therapy for those with symptoms or pulmonary function tests consistent with airway disease.

Key Words: airway disease, asthma, epidemiology, firefighting, occupational diseases

Abbreviations

BHR, bronchial hyperreactivity; FDNY, Fire Department of the City of New York; LLN, lower limit

of normal; MCT, methacholine challenge test; PC20, provocative concentration of methacholine producing a 20% decline in FEV1; RADS, reactive airway dysfunction syndrome; WTC, World Trade Center.

The September 11, 2001 (9/11), terrorist attack on the World Trade Center (WTC) and its consequent collapse exposed thousands of Fire Department of the City of New York (FDNY) firefighters to unprecedented amounts of aerosolized dust and smoke.¹ One year later, nearly 20% had abnormal lung function, most with obstructive physiology,^{2, 3} and without meaningful recovery over the next 13 years.⁴ Symptoms of airway disease were even more prevalent and also persisted.⁵ New diagnoses of asthma increased over time, outpacing spirometric abnormalities.^{6, 7} Bronchial hyperreactivity (BHR) might explain airway disease and the high prevalence of airway symptoms in some subjects.⁸ Within 2 years of 9/11, we completed more than 400 studies of bronchial reactivity.^{3, 9, 10} Our current aim is to estimate the persistence of BHR and to explore relationships among BHR, respiratory symptoms, and lung function more than a decade after initial WTC exposure.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6026231/>

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**Sarcoidosis diagnosed after September 11, 2001,
among adults exposed to the World Trade Center disaster**

Hannah T Jordan, et al.

Abstract

Objective: Explore relationships between World Trade Center (WTC) exposures and sarcoidosis.

Methods: Sarcoidosis has been reported after exposure to the WTC disaster. We ascertained biopsy-proven post-9/11 sarcoidosis among WTC Health Registry enrollees. Cases diagnosed after Registry enrollment were included in a nested case-control study. Controls were matched to cases on age, sex, race or ethnicity, and eligibility group (eg, rescue or recovery worker).

Results: We identified 43 cases of post-9/11 sarcoidosis. Twenty-eight incident cases and 109 controls were included in the case-control analysis. Working on the WTC debris pile was associated with sarcoidosis (odds ratio 9.1, 95% confidence interval 1.1 to 74.0), but WTC dust cloud exposure was not (odds ratio 1.0, 95% confidence interval 0.4 to 2.8).

Conclusions: Working on the WTC debris pile was associated with an elevated risk of post-9/11 sarcoidosis. Occupationally exposed workers may be at increased risk.

<https://pubmed.ncbi.nlm.nih.gov/21860326/>

**The Effect of World Trade Center Exposure
on the Timing of Diagnoses of Obstructive Airway Disease,
Chronic Rhinosinusitis, and Gastroesophageal Reflux Disease**

Xiaoxue Liu, et al.

Abstract

Objectives: In a cohort of rescue/recovery workers exposed to the dust that resulted from the collapse of the World Trade Center (WTC), we assessed how a diagnosis of obstructive airways disease (OAD) affected the likelihood of a subsequent diagnosis of chronic rhinosinusitis (CRS) or gastroesophageal reflux disease (GERD). We also assessed whether OAD acted as a mediator of the association between exposure to the WTC rescue/recovery effort and CRS and GERD diagnoses.

Methods: In this prospective cohort study, we analyzed Fire Department of the City of New York physician diagnoses of OAD, CRS, and GERD that were first documented between September 11, 2001, and September 10, 2011, among 8,968 WTC-exposed firefighters. We used piecewise exponential survival models to evaluate whether OAD was a risk factor for either CRS or GERD and to assess OAD as a possible mediator.

Results: An OAD diagnosis significantly increased the risks for subsequent CRS [relative rate (RR), 4.24; 95% CI, 3.78–4.76] and GERD (RR, 3.21; 95% CI, 2.93–3.52) diagnoses. Further, 21% of the WTC exposure effect (high vs. low intensity) on GERD and 13% of the effect (high vs. low intensity) on CRS were mediated by a prior OAD diagnosis.

Conclusion: Individuals with an OAD diagnosis had elevated risks for subsequent diagnoses of CRS or GERD. Part of the effect of WTC exposure on CRS and GERD diagnoses is mediated by prior diagnoses of OAD; this mediation effect of OAD may reflect biological pathways or healthcare utilization practices.

Keywords: 9/11, firefighters, piecewise survival model,
aerodigestive, obstructive airways disease

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5296346/>

**Long-term Cardiovascular Disease Risk
Among Firefighters After the World Trade Center Disaster**

By Hillel W. Cohen, DrPH, MPH

Key Points-Question

Is World Trade Center exposure on and after September 11, 2001, associated with long-term cardiovascular disease risk in Fire Department of the City of New York firefighters?

Findings

In this cohort study of 9796 firefighters, age-adjusted incident rates of cardiovascular disease were higher for firefighters with greater World Trade Center exposure. Both acute World Trade Center as well as repeated exposure during 6 or more months at the World Trade Center site appeared to be associated with long-term elevated cardiovascular disease risk.

Meaning

These findings suggest the continued need for long-term monitoring of the health of survivors of disasters.

Abstract- Importance

Published studies examining the association between World Trade Center (WTC) exposure on and after September 11, 2001, and longer-term cardiovascular disease (CVD) outcomes have reported mixed findings.

Objective

To assess whether WTC exposure was associated with elevated CVD risk in Fire Department of the City of New York (FDNY) firefighters.

Design, Settings, and Participants

In this cohort study, the association between WTC exposure and the risk of CVD was assessed between September 11, 2001, and December 31, 2017, in FDNY male firefighters. Multivariable Cox regression analyses were used to estimate CVD risk in association with 2 measures of WTC

exposure: arrival time to the WTC site and duration of work at the WTC site. Data analyses were conducted from May 1, 2018, to March 8, 2019.

Main Outcomes and Measures

The primary CVD outcome included myocardial infarction, stroke, unstable angina, coronary artery surgery or angioplasty, or CVD death. The secondary outcome (all CVD) included all primary outcome events or any of the following: transient ischemic attack; stable angina, defined as either use of angina medication or cardiac catheterization without intervention; cardiomyopathy; and other CVD (aortic aneurysm, peripheral arterial vascular intervention, and carotid artery surgery).

Results

There were 489 primary outcome events among 9796 male firefighters (mean [SD] age on September 11, 2001, was 40.3 [7.4] years and 7210 individuals [73.6%] were never smokers). Age-adjusted incident rates of CVD were higher for firefighters with greater WTC exposure. The multivariable adjusted hazard ratio (HR) for the primary CVD outcome was 1.44 (95% CI, 1.09-1.90) for the earliest arrival group compared with those who arrived later. Similarly, those who worked at the WTC site for 6 or more months vs those who worked less time at the site were more likely to have a CVD event (HR, 1.30; 95% CI, 1.05-1.60). Well-established CVD risk factors, including hypertension (HR, 1.41; 95% CI, 1.10-1.80), hypercholesterolemia (HR, 1.56; 95% CI, 1.28-1.91), diabetes (HR, 1.99; 95% CI, 1.33-2.98), and smoking (current: HR, 2.13; 95% CI, 1.68-2.70; former: HR, 1.55; 95% CI, 1.23-1.95), were significantly associated with CVD in the multivariable models. Analyses with the all-CVD outcome were similar.

Conclusions and Relevance

The findings of the study suggest a significant association between greater WTC exposure and long-term CVD risk. The findings appear to reinforce the importance of long-term monitoring of the health of survivors of disasters.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6735414/>

**Validation of Predictive Metabolic Syndrome Biomarkers
of World Trade Center Lung Injury
A 16-Year Longitudinal Study**

By Sophia Kwon, DO

Abstract

Background: Metabolic syndrome (MetSyn) predicted future development of World Trade Center lung injury (WTC-LI) in a subgroup of firefighters who never smoked and were male. An intracohort validation of MetSyn as a predictor of WTC-LI is examined in the cohort exposed to the World Trade Center (WTC) that has been followed longitudinally for 16 years.

Methods: Results of pulmonary function tests ($n = 98,221$) in workers exposed to the WTC ($n = 9,566$) were evaluated. A baseline cohort of firefighters who had normal FEV1 before 9/11 and who had had serum drawn before site closure on July 24, 2002 ($n = 7,487$) was investigated. Case subjects with WTC-LI ($n = 1,208$) were identified if they had at least two measured instances of FEV1 less than the lower limit of normal (LLN). Cox proportional hazards modeled early MetSyn biomarker ability to predict development of FEV1 less than the LLN.

Results: Case subjects were more likely to smoke, be highly exposed, and have MetSyn. There was a significant exposure dose response; the individuals most highly exposed had a 30.1% increased risk of developing WTC-LI, having MetSyn increased risk of developing WTC-LI by 55.7%, and smoking increased risk by 15.2%. There was significant interaction between smoking and exposure.

Conclusions: We validated the usefulness of MetSyn to predict future WTC-LI in a larger population of individuals who were exposed. MetSyn defined by dyslipidemia, insulin resistance, and cardiovascular disease suggests that systemic inflammation can contribute to future lung function loss.

Metabolic syndrome (MetSyn) and particulate matter (PM) exposure are known independent risk factors for respiratory dysfunction, obstructive lung disease, and cardiovascular disease. MetSyn is a constellation of risk factors associated with end-organ disease affecting one-third of US adults.^{1, 2} Diagnosis is made by having three or more of following: abdominal obesity, insulin resistance, hypertriglyceridemia, low high-density lipoprotein (HDL) levels, and hypertension.¹

The link between obesity and lung disease has been attributed partially to mechanical stress

and mass loading. However, some studies have focused on the systemic effects of obesity and MetSyn through hormonal and immunoinflammatory biomarkers in the context of pollution exposure and respiratory decline.^{3, 4, 5, 6, 7, 8, 9} In the Cardiovascular Health Study, subjects with a systolic BP (SBP) > 160 mm Hg had significantly lower FEV1.¹⁰ Smoking also can induce insulin resistance and contribute to airways disease in the context of MetSyn.¹¹ Mechanistic studies linking MetSyn risk and airway disease suggest biological plausibility.^{12, 13, 14, 15, 16, 17}

We have focused on the well-phenotyped cohort from the Fire Department of New York (FDNY) exposed to the World Trade Center (WTC) who were enrolled in the WTC Health Program (WTC-HP).^{18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29} Our group has defined WTC lung injury (WTC-LI) as the development of FEV1 less than the lower limit of normal (LLN) (< 5th percentile on the basis of the Hankinson equations).^{17, 19, 20, 22, 30, 31, 32, 33, 34, 35, 36} In a pilot cohort of firefighters who were nonsmoking, had symptoms, and were exposed to the WTC, MetSyn biomarkers predicted WTC-LI.^{20, 30, 33, 37} We now assess the predictive abilities of MetSyn biomarkers in the development of WTC-LI in an expanded cohort that is more representative of FDNY rescue and recovery workers exposed to the WTC. We assess the effects of smoking and validate these biomarkers to identify prognostic indicators of disease. This assessment is a vital step in the investigation of MetSyn as a potentially modifiable risk factor for PM-associated lung disease.

Key Words: lung injury, metabolic syndrome, validation, World Trade Center

Abbreviations: DBP, diastolic BP; FDNY, Fire Department of New York; HDL, high-density lipoprotein; HR, hazard ratio; LDL, low-density lipoprotein; LLN, lower limit of normal; MetSyn, metabolic syndrome; PFT, pulmonary function test; PM, particulate matter; SBP, systolic BP; WTC, World Trade Center; WTC-HP, WTC Health Program; WTC-LI, WTC Lung Injury

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6717118/>



**Metabolic Syndrome Biomarkers of World Trade Center Airway Hyperreactivity:
A 16-Year Prospective Cohort Study**

Sophia Kwon, et al.

Abstract

Airway hyperreactivity (AHR) related to environmental exposure is a significant public health risk worldwide. Similarly, metabolic syndrome (MetSyn), a risk factor for obstructive airway disease (OAD) and systemic inflammation, is a significant contributor to global adverse health. This prospective cohort study followed N = 7486 World Trade Center (WTC)-exposed male firefighters from 11 September 2001 (9/11) until 1 August 2017 and investigated N = 539 with newly developed AHR for clinical biomarkers of MetSyn and compared them to the non-AHR group. Male firefighters with normal lung function and no AHR pre-9/11 who had blood drawn from 9 September 2001–24 July 2002 were assessed. World Trade Center-Airway Hyperreactivity (WTC-AHR) was defined as either a positive bronchodilator response (BDR) or methacholine challenge test (MCT). The electronic medical record (EMR) was queried for their MetSyn characteristics (lipid profile, body mass index (BMI), glucose), and routine clinical biomarkers (such as complete blood counts). We modeled the association of MetSyn characteristics at the first post-9/11 exam with AHR. Those with AHR were significantly more likely to be older, have higher BMIs, have high intensity exposure, and have MetSyn. Smoking history was not associated with WTC-AHR. Those present on the morning of 9/11 had 224% increased risk of developing AHR, and those who arrived in the afternoon of 9/11 had a 75.9% increased risk. Having ≥ 3 MetSyn parameters increased the risk of WTC-AHR by 65.4%. Co-existing MetSyn and high WTC exposure are predictive of future AHR and suggest that systemic inflammation may be a contributor.

Introduction

Metabolic syndrome (MetSyn) is a clinical diagnosis made by fulfillment of at least three of the five following comorbidity criteria: Abdominal obesity, insulin resistance, hypertriglyceridemia, low high density lipoproteins (HDL), and hypertension [1,2]. MetSyn and particulate matter (PM) exposure are known independent risk factors in the development of many diseases including cardiovascular disease and cancer [3]. MetSyn, classically a risk factor for cardiovascular disease, is now being investigated as a risk factor for pulmonary disease [4].

Obesity, one component of MetSyn, has been typically linked to restrictive patterns of lung disease through mechanical stress and mass loading. However, many recent studies have focused on the systemic effects of MetSyn, through hormonal and immunoinflammatory mediators, and

their association with pollution exposure and subsequent respiratory disease [5,6,7,8,9,10,11]. One study suggests that adipose tissue and adipokines such as C-reactive protein (CRP) and tumor necrosis factor- α (TNF- α) may contribute to a systemic low-grade inflammatory process leading to airway hyperreactivity (AHR) [12].

The association between MetSyn and the development of AHR has been seen in several studies [13]. Multiple cross-sectional studies have shown an increased prevalence of MetSyn or its constituents amongst those with diagnosed asthma or asthma-like symptoms [14,15,16]. A meta-analysis that included cohorts in the United States (US), Canada, and Europe reported that odds of incident asthma are increased by 50% in obese individuals, and that risk increased with body weight [17]. Two prospective studies investigated adults who were asthma-free at baseline and showed that obesity and insulin resistance were MetSyn risk factors that contributed to eventual asthma or asthma-like symptoms [17,18]. Murine studies showed that mice that developed insulin resistance from a high fat diet had increased airway resistance at baseline and after methacholine provocation, indicating a component of AHR [19].

AHR and PM exposure have also been strongly linked in numerous studies. In a cohort of asthmatic and non-asthmatic children exposed to freeway and non-freeway air pollution, there was a positive association between air pollution exposure and asthmatic children [20]. In a cohort study of 40 asthmatic children who attended school in close proximity to expressways, there was an increased risk of wheezing and shortness of breath [21]. In a cross-sectional study of adults over 50 years of age in low resource countries, 5.12% of cases were secondary to PM exposure, and the prevalence ratio of asthma after each 10 $\mu\text{g}/\text{m}^3$ increase of PM_{2.5} was 1.05 [22]. The World Trade Center (WTC) complex destruction on 11 September 2001 (9/11) led to the release of over 11,000 tons of PM, and exposed over 300,000 local workers, residents, and rescue and recovery workers [23]. An early study monitoring pulmonary function in firefighters from the Fire Department of the City of New York (FDNY) with World Trade Center Particulate Matter (WTC-PM) exposure had AHR prevalence of 40%, and over half of the studied group had persistent AHR in a follow-up exam 10 years later [24,25]. These studies established a significant association between exposure level and AHR [26].

Our initial work focused on inflammatory biomarkers, such as GM-CSF and MDC, in WTC-PM-exposed firefighters [27]. We also investigated amylin, leptin, and lipids in a subset of exposed firefighters with WTC lung injury (WTC-LI) as defined by a loss of forced expiratory volume in 1 second (FEV₁) to less than the lower limit of normal (LLN), and recently validated our findings of MetSyn associated with WTC-LI in the larger exposed group [4,28]. We now investigate the impact of MetSyn on the development of WTC-associated AHR.

Keywords: metabolic syndrome, airway hyperreactivity, World Trade Center

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6539892/>

**Pulmonary Fibrosis among World Trade Center Responders:
Results from the WTC Health Registry Cohort**

By Jiehui Li, et al.

Abstract

Dust created by the collapse of the World Trade Center (WTC) towers on 9/11 included metals and toxicants that have been linked to an increased risk of pulmonary fibrosis (PF) in the literature. Little has been reported on PF among WTC responders. This report used self-reported physician diagnosis of PF with an unknown sub-type to explore the association between levels of WTC dust exposure and PF. We included 19,300 WTC responders, enrolled in the WTC Health Registry in 2003–2004, who were followed for 11 years from 2004 to 2015. Exposure was defined primarily by intensity and duration of exposure to WTC dust/debris and work on the debris pile. Stratified Cox regression was used to assess the association. We observed 73 self-reported physician-diagnosed PF cases, with a PF incidence rate of 36.7/100,000 person-years. The adjusted hazard ratio (AHR) of PF was higher in those with a medium (AHR = 2.5, 95% CI = 1.1–5.8) and very high level of exposure (AHR = 4.5, 95% CI = 2.0–10.4), compared to those with low exposure. A test for exposure—response trend was statistically significant ($P_{\text{trend}} = 0.004$). Future research on WTC dust exposure and PF would benefit from using data from multiple WTC Health Program responder cohorts for increased statistical power and clinically confirmed cases.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6427469/>



**Editorial for “Long-Term Health Effects of the 9/11 Disaster”
in International Journal of Environmental Research and Public Health, 2019**

Robert M. Brackbill, et al.

The call for articles on the long term health effects of the 11 September 2001 terrorist attacks (9/11) has resulted in twenty-three papers that add a significant amount of information to the growing body of research on the effects of the World Trade Center (WTC) disaster almost two decades later. The attacks on 9/11 were a paradigm altering event in US history and have had major repercussions in the political landscape and response to terrorism. The toll of 9/11 includes the continued impact of accumulated health effects among those who were directly exposed to either the air pollution or re-suspended material that resulted from the collapse of the two WTC towers, and physical injuries or psychological trauma. This includes a wide range of physical and mental health disorders that continue to plague thousands of people 18 years later as well as newly identified conditions emerging as a result of prolonged disease latency. This was recently highlighted by the addition of “The Memorial Glade” at the WTC site that acknowledges illnesses and deaths years after the towers collapsed [1].

The articles in this special issue also demonstrate the importance of the medical monitoring of the wide range of populations exposed to unprecedented levels of physical and psychological insult from the 9/11 attacks. As such, the reports in this issue represent research findings from the clinics supported by World Trade Center Health Programs and the epidemiological follow-up by the World Trade Center Health Registry. Although the majority of the articles represent rescue, recovery, and clean-up workers (12), some other non-rescue recovery groups included in the special issue are residents of Chinatown, just 10 blocks from ground zero (Kung et al. 2019 [2]), and other residents of lower Manhattan (Antao et al. 2019 [3]).

Respiratory and lung problems are among the most prevalent and highly persistent physical health problems arising from 9/11 exposure to dust clouds from the collapsing building and the subsequent re-suspension of dust (Aldrich, 2010 [4]). In this issue, there are nine respiratory-related papers that provide new insights into the long term consequences of lung damage from 9/11 exposure not reported in previous research. These papers highlight the chronic and still emerging health sequela of 9/11 exposure. An analysis of cleaning practices by residents in lower Manhattan showed that cleaning with dry methods was associated with more types of respiratory symptoms than other cleaning methods (Antao, 2019 [3]). Other papers delved into the underlying physical and biological aspects of pulmonary illness among persons exposed to 9/11 (Liu, 2019 [5]; Kwon, 2019 [6]; Pradhan, 2019 [7]). Liu et al. (2019) used chest tomography (CT) and reported that firefighters with high intensity exposure on 9/11 had increased risk of bronchi-

al wall thickening, emphysema, and air trapping. They correlated the CT-identified abnormalities with respiratory symptoms. A second paper also evaluated the role of metabolic syndrome biomarkers (MSBs) among firefighters (e.g., elevated systolic blood pressure and insulin resistance) in airway hyperactivity (Kwon, 2019 [6]). They reported that given 9/11 exposure, having three or more MSBs increased airway hyperactivity beyond that associated with 9/11 exposure. Another paper that evaluated the bronchodilator response among community members exposed to 9/11 found that a proportion of small airway problems were irreversible, which was predicted by the bronchodilator response at initial visits (Pradhan, 2019 [7]). Two other papers evaluated the increased risk of asthma control issues and quality of life as a function of indoor allergens (Rojano, 2019 [8]) and air pollution/irritants (Yung, 2019 [9]). In addition, an emerging respiratory condition, pulmonary fibrosis (PF)—a common long term sequelae of occupational dust exposure—was documented in a paper based on data from the World Trade Center Health Registry for which there was evidence of a dose-response relationship with the level of exposure among rescue/recovery and other 9/11 workers and the likelihood of PF (Li, 2019 [10]).

Three other papers reported additional findings on a condition known as sarcoidosis (Cleven, 2019 [11]; Hena, 2019 [12]) and sarcoid-like granulomatous (Sunil, 2019). Sarcoidosis is a rare autoimmune disease that can affect any organ, but among rescue, recovery, clean-up workers, it has been previously reported as granulomatous disease involving the thoracic organs (Izbicki, 2007 [13]; Jordan, 2011 [14]), primarily among firefighters or other rescue, recovery, or clean-up workers arriving early at the WTC site. One paper in this issue describes sarcoidosis among community members who were patients at the WTC Environmental Health Center (Hena, 2019 [12]). Another paper focused on the genetic predisposition for sarcoidosis in a case control study (Cleven, 2019 [11]). Sunil (Sunil, 2019 [15]) reported a detailed pathology review of sarcoid like granulomatous disease (SGD). Out of seven cases, five were definite SGD and had high exposure to 9/11 WTC dust.

In addition to respiratory disease, other long term adverse health outcomes of WTC-related exposure include neurologic conditions and cancer. Papers in this issue focused on these emerging conditions including peripheral neuropathy (Colbeth, 2019 [16]), paresthesia (Thawani, 2019 [17]), and thyroid cancer (van Gerwen, 2019 [18]; Tuminello, 2019 [19], see Gargano, 2018 [20] for a review of non-respiratory physical health conditions). Two studies focused on neuropathic conditions that included peripheral neuropathy among New York City firefighters and emergency medical workers (Colbeth, 2019 [16]) and paresthesia among community survivors who received treatment at one of the WTC Health programs (Thawani, 2019 [17]). Potential exposures for neuropathic conditions on 9/11/2001 and afterward included heavy metals and complex hydrocarbons. Both studies used the self-reporting of unusual and painful sensations such as prickling, burning, or aching pain in the limbs. Colbeth et al. reported a 35% increase in the likelihood of peripheral neuropathy symptoms among those with the highest 9/11 exposure versus low/no exposure. Similarly, Thawani et al. reported a significant hazard ratio of 1.4 for paresthesia among persons who had a job that required cleaning-up materials resulting from building fires and buildings collapsing. The physical health outcome of cancer was represented by two pa-

pers on thyroid cancer (Tuminello, 2019 [19]; van Gerwen, 2019 [18]). Thyroid cancer has been identified as a cancer with a higher expected incidence among potential WTC-exposed persons (Zeig-Owens, 2011 [21]; Li, 2016 [22]; Solan et al., 2013 [23]). Tuminello (2019) evaluated the possibility that increased surveillance for thyroid cancer among WTC survivors could account for the elevated thyroid cancer incidence. In another study (van Gerwin, 2019 [18]) that evaluated thyroid cancers derived from the same population, the authors compared the pathological characteristics of cancer tumors of WTC exposed to non-WTC cases in order to assess whether there were more false positives among the WTC exposed that would suggest a surveillance bias.

The high prevalence of adverse mental health, especially post-traumatic stress disorder (PTSD), has been documented among survivors of 9/11 (Brackbill, 2009 [24]; Stellman, 2008 [25]), in addition to the persistence of PTSD (Pietrzak, 2014 [26]; Maslow, 2015 [27]; Welch, 2016 [28]). A number of papers in this issue addressed the characteristics of those receiving or not adequately receiving mental health treatment and some measurement of the effectiveness of treatment (Jacobson, 2019 [29]; Kung, 2019 [2]; Rosen, 2019 [30]; Bellehsen, 2019 [31]). Based on data from the World Trade Center Health Registry (WTCHR), 38% of enrollees reported they had utilized mental health counseling or therapy sometime in the 15 years after 9/11, with younger persons more likely to seek counseling, but older persons perceiving treatment to be helpful (Jacobson, 2019). Those with persistent PTSD perceived treatment to be less helpful. Another paper also used WTCHR information to characterize unmet mental health care needs for a specific subgroup of Asian WTCHR enrollees, who typically underutilize mental health services (Kung, 2019 [2]). Among the 2300 Asian WTCHR enrollees included in the study, 12% said that they had an unmet mental health care need, for whom 69% reported attitudinal barriers (e.g., I do not need to see a doctor) to utilizing mental health care, 36% said there were cost barriers (e.g., lack of health insurance), and 28% had access barriers (e.g., where to go for doctor, childcare, transportation issues). Two other 9/11 mental health papers used information on patients enrolled in a community WTC Health Program (Rosen, 2019 [30]) and rescue/recovery worker health program (Bellehsen, 2019 [31]). Among patients who reached the criteria for PTSD at the first visit, 77% continued to meet the criteria for PTSD 3 to 4 years later (Rosen, 2019 [30]). Further analysis indicated that some reduction in PTSD symptoms was associated with treatment. The second paper evaluated the extent to which patients were receiving evidence-based treatment (EBT) by community health providers. Like the Rosen et al. paper, they employed baseline and follow-up information in addition to providers reporting their use of EBT. However, after an independent review, 12% of the patients were likely to have received full EBT, and another 40% received some elements of EBT.

Some papers in this issue fittingly addressed the long-term effects of 9/11 exposure on both physical and mental functioning. For instance, Brackbill et al. (2019) [32] assessed the self-reported physical and mental health functioning of persons who were injured on 9/11 15 years after the attack. The severity of injury was associated with physical functioning, but not with mental health functioning; PTSD history also had a significant additive influence on the effect of injury on physical functioning. Using a more objective measure of functionality referred to as handgrip

strength, which is a measure of general health status and biomarker of aging, Mukherjee (2019 [33]) reported that rescue/recovery workers with probable PTSD had significantly lower HGS than those without PTSD or depression. Apart from functionality and physical loss, there is concern that persons exposed to 9/11 could be at greater risk of cognitive impairment, memory loss, or confusion at a faster rate than would be expected normally with age. Seil (2019) [34], using the WTC Health Registry data, derived levels of protective factor or cognitive reserve (based on educational level, employed or not, social support, and level of physical activity) for cognitive impairment and found that higher levels of cognitive reserve were associated with less self-reported memory loss for both persons with and without a history of PTSD. Two other aspects of quality of life are represented by papers on early retirement and post-2019 (Yu, 2019 [35]). Among the Lower Manhattan residents and area workers, a history of PTSD and the number of 9/11 related chronic conditions were associated with early retirement (retired before 60). In addition, income loss among those who retired was more likely among those with the highest level of exposure. In the quality of sleep study, it was reported that 9/11 related co-morbidities including gastroesophageal reflux disease, chronic rhinosinusitis, PTSD, anxiety, and depression were associated with a great proportion of sleep related complaints (Ayappa, 2019 [36]). With the presence of these co-morbidities, apnea had no significant impact on sleep quality.

The papers in this special issue clearly document the continued long term effects of the September 11, 2001 WTC disaster on a wide range of health and quality of life issues. They underscore the need for ongoing health monitoring of these highly exposed populations while also representing the cutting edge research on subject areas from the biological underpinnings of 9/11 related respiratory disease to the effectiveness of treatment for mental health problems related to 9/11. This work continues to inform the World Trade Center Health Program for those most affected by the disaster. While this is a uniquely exposed population, this large body research will inform responses to, and the monitoring of, populations exposed to future human caused and natural disasters.

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Conflicts of Interest

The views in this editorial are those of the authors and do not necessarily represent the official position of the World Trade Center Health Program, the National Institute for Occupational Safety and Health, and the Centers for Disease Control and Prevention.

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Short-term and medium-term health effects of 9/11

Sharon E Perlman, et al.

Abstract

The New York City terrorist attacks on Sept 11, 2001 (9/11), killed nearly 2800 people and thousands more had subsequent health problems. In this Review of health effects in the short and medium terms, strong evidence is provided for associations between experiencing or witnessing events related to 9/11 and post-traumatic stress disorder and respiratory illness, with a correlation between prolonged, intense exposure and increased overall illness and disability. Rescue and recovery workers, especially those who arrived early at the World Trade Center site or worked for longer periods, were more likely to develop respiratory illness than were other exposed groups. Risk factors for post-traumatic stress disorder included proximity to the site on 9/11, living or working in lower Manhattan, rescue or recovery work at the World Trade Center site, event-related loss of spouse, and low social support. Investigators note associations between 9/11 exposures and additional disorders, such as depression and substance use; however, for some health problems association with exposures related to 9/11 is unclear.

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World Trade Center cough—a lingering legacy and a cautionary tale

By Paul D Scanlon

No abstract available

ONE year has passed since the terrorist attacks in New York and at the Pentagon. As we struggle to address important issues related to the health consequences of warfare and terrorism, a simple question has arisen: Did working on the rescue and recovery operation at the World Trade Center have an effect on health? In this issue of the Journal, Prezant and colleagues report on their findings among New York City firefighters exposed to the early environmental conditions during and after the collapse of the World Trade Center on September 11, 2001.¹

Prezant et al. recognized in the days after September 11, 2001, that many firefighters reported cough related to exposure at the site of the World Trade Center. In many, the cough was immediate in onset, and in most it was short-lived. However, during the subsequent months, a large number of firefighters were found to have severe persistent cough and dyspnea; these persons required extended medical leave from firefighting duties. The authors dubbed their condition “World Trade Center cough.”

Among the authors are members of the medical staff of the Fire Department of New York (FDNY), persons responsible for the medical aspects of the routine respiratory-protection program for the firefighters. The medical staff members also manage the medical clearance to work, as well as authorization of medical leave for work-related conditions. As part of the respiratory-protection program, results of lung-function testing performed before September 11, 2001, were available for all firefighters. For this study, the authors obtained respiratory questionnaires, spirometry results, and chest radiographs for all of the firefighters affected by World Trade Center cough. They also performed methacholine challenges in a sample of exposed but nondisabled firefighters.

Three percent of the workforce of the FDNY was killed in the collapse of the World Trade Center; an additional 3 percent had long-term respiratory disability. Of those, less than half had returned to firefighting duties at the end of a seven-month period of observation. The major findings of the study are that, of those who were present at the collapse of the World Trade Center, 8 percent had disabling persistent cough associated with reduced forced vital capacity (FVC) and forced expiratory volume in one second (FEV₁), and 23 percent had bronchial hyperresponsiveness as indicated by the results of methacholine challenge. Disabling cough and bronchial hyperresponsiveness developed in fewer of those who were exposed to the World Trade Center site on subsequent days. The firefighters with World Trade Center cough had reduced lung function as indi-

cated by spirometry. Since testing was performed under different conditions than those used for routine “respiratory clearance” testing, some of the reduction in FVC and FEV1 among firefighters with symptoms is probably due to methodologic differences and some to difficulty in performing maneuvers.² It may be surprising that the decreases in FVC and FEV1 were proportional despite the fact that the clinical and radiographic manifestations of exposure all suggest that the exposure-related injury was mostly to the airways. Although this observation was somewhat unexpected, it is well known that some patients with airway diseases such as asthma have a normal ratio of FEV1 to FVC, a finding sometimes referred to as a nonspecific pattern.

There was a strikingly high incidence of symptoms of new onset associated with gastroesophageal reflux disorder. The authors used questionnaire responses to define gastroesophageal reflux disorder as “heartburn, regurgitation, [and] retrosternal burning”; this is a set of symptoms that may be sensitive but nonspecific, particularly in a cohort of patients with symptoms of disabling cough. The authors note that gastroesophageal reflux disorder, when present, was unlikely to have been the precipitating cause of cough, but that it might have served to perpetuate symptoms. They note that the group with predominantly upper-airway symptoms, defined to include nasal symptoms and gastroesophageal reflux disorder, had a far more favorable outcome than those with predominantly lower-airway symptoms. That finding is not surprising, however, given that patients with lower-airway predominance included all those with abnormal results on spirometry and chest radiography. The authors intend to follow their study cohort, and subsequent data on the evolution of symptoms, along with spirometric and airway-responsiveness data, will be of considerable interest.

Information presented on the use of respirators for environmental protection raises a challenging question that cannot be addressed medically but that should be addressed administratively. Why was adherence to procedures for the use of respiratory protection so low? Less than 22 percent of the firefighters without World Trade Center cough reported frequent respirator use in the first week. Of those with the cough, 93 percent reported that they used their respirators “rarely or not at all” on day 1, 85 percent on day 2, and 76 percent on days 3 to 7. Frequent use was reported by 65 percent during week 2. This level of use occurred despite the fact that there was coughing during the first day of exposure. The lack of adequate protection is understandable in the context of the disaster. The firefighters were trying to save the lives of thousands of innocent victims, knowing they were placing their own lives in jeopardy. Many other factors may have contributed to nonadherence, such as discomfort related to heat and other environmental conditions, clogging of respirator cartridges with dust, and inadequate access to or supply of replacement cartridges.^{3,4} Whatever factors contributed to nonadherence, this study shows that adverse health effects were the result.

We do not know what environmental constituents at the World Trade Center site caused cough and air-way hyperresponsiveness. Although the Centers for Disease Control and Prevention did not identify harmful levels in air samples, the sampling was undertaken after most airway injury had already occurred.⁵ It is tempting to blame the dust, which was so visually impressive on

September 11, but the authors point out that there is little evidence to suggest that inorganic dust causes acute airway hyperresponsiveness. Inhalation of smoke from fires can cause airway hyper-responsiveness⁶ through a variety of constituents, including reactive oxygen species, volatile organic compounds, and other products of combustion.

The persistent disability related to respiratory exposures on and after September 11 provides important lessons for our civil defense. Disasters of a similar scale are possible in the future. It is important that the medical profession, in conjunction with government agencies, prepare to provide the best possible protection for our citizens, including rescue workers and health care workers. As a society, we must be prepared for poorly defined threats, including those due to biologic agents, radiation, and chemical agents. Damage can be restricted through careful preparation, containment of the site, and scrupulous observance of protective protocols during rescue efforts. We must be aware that an overwhelming disaster may surpass our ability to contain damage. Those who form the front line in dealing with disasters must be trained to observe the best possible protocols for saving victims and preserving their own health for the sake of society's ongoing need for their skills. Careful preparation and scaled response are our best immediate options.⁷

Health care professionals have organized to influence national and international policy in the past. During the Cold War, organizations such as Physicians for Social Responsibility had an important influence in ending the nuclear arms race. If the threat of terrorism grows, our profession may again be called to take a stand for national and international policies that reduce the risk of mass disaster.

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Reactive Fallout of World Trade Center Dust

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Abstract

The collapse of the World Trade Center (WTC) of New York City after the attack on September 11, 2001 constituted a major acute environmental disaster (1, 2).

In this issue of AJRCCM (pp. 54–62), Banauch and co-workers (3) describe a prospective study of firefighters and other rescue workers of the Fire Department of New York City (FDNY), who were exposed to dust and smoke in the hours and days after the collapse of the buildings. Their main purpose was to assess how many subjects would develop symptomatic persistent bronchial hyperresponsiveness. Such asthma that is acquired after acute inhalation injury is known as “reactive airways dysfunction syndrome” (RADS) (4), a term that has gained wide acceptance, mainly because of its acronym rather than because of its actual meaning (5).

The 151 rescue workers studied by Banauch and coworkers (3) were classified into a highly exposed group (arrival on site within 2 hours of the collapse of the buildings) and a moderately exposed group (arriving later that day or the next day). They underwent spirometry and a methacholine challenge at 1, 3, and 6 months. The main practical outcome of the study was that 20% of highly exposed and 8% of moderately exposed subjects qualified for the diagnosis of RADS at 6 months. Are such high figures credible? In my opinion, yes. The protocol of the study, the performance of the tests, and the analysis of the data, as they are presented, approach the best that could be achieved given the circumstances. Of course, no study is perfect and the findings will need replication and verification in some way or other.

In fact, these figures could even be regarded as minimum estimates because participants were selected, by design, toward the healthier portion of the population. Current smokers and subjects with self-reported allergy were excluded, as were those taking asthma medication. We do not know the actual levels of exposure of the FDNY workers during the first few days, when levels were highest and presumably most relevant. Nevertheless, if one assumes, for the sake of simplicity, a 10-fold difference between the high and moderate exposure, then it can be calculated, on the basis of conventional dose–response relationships (expressing response in probit units against the logarithm of dose), that an exposure 10 times lower than the moderate exposure could result in RADS in 2% of the exposed population. The incidence is likely to be higher among people, such as community residents or other workers, having greater susceptibility

than firefighters who likely represent a healthier than average population. Given the existence of a background prevalence of a few percent with bronchial hyperresponsiveness in the general population, however, it would be extremely difficult to attribute causality with any certainty.

This brings me to the problem of the medicolegal recognition of RADS in individual victims of inhalation injury. In relatively easy cases, such as here in the nonsmoking FDNY firefighters who did not have atopy and who benefited from medical surveillance that included spirometry, it would take a very unwilling expert to deny a diagnosis of RADS on the grounds that there is no proof of the absence of bronchial hyperresponsiveness before the injury. In practice, however, we are often faced with more difficult cases, such as the isolated smoker or the subject with atopy—possibly an immigrant day laborer (6)—claiming that he became asthmatic and can no longer work, engage in sports, or play saxophone because he performed a very dirty job as an industrial cleaner or a demolition worker for a few days or weeks but without any major identifiable inhalation injury. One of the important contributions of the paper by Banauch and coworkers (3) is the demonstration that, contrary to what is often implied (7, 8), RADS does not require a clinically severe inhalation injury necessitating medical care, let alone hospitalization. This notion was already present in the few other cohort studies on RADS (9, 10). Another novel aspect of this article is also that RADS may be an outcome of injury by particulates. Experimental studies should determine which chemical constituents and/or physical characteristics of this complex aerosol are critical in causing acute and chronic injury. Further research should be done to find out why some people develop persistent bronchial hyperresponsiveness after injury, whereas the majority do not. Therapeutic issues also need to be addressed, particularly the value of inhaled glucocorticoids.

RADS is not the sole respiratory aftershock of the WTC disaster. The same group of researchers reported that 3% of FDNY workers developed “WTC cough” (11), defined as “persistent cough that . . . was accompanied by respiratory symptoms severe enough for FDNY physicians to place the worker on medical leave for at least four consecutive weeks.” Interestingly, WTC cough was also accompanied by symptoms of gastroesophageal reflux in almost all subjects. Although there was a relation between WTC cough and RADS, the overlap between both entities is not perfect, in that only half of those with WTC cough also qualified for RADS. The authors also described a rarer condition, namely acute eosinophilic pneumonitis, in one, and possibly five other rescue workers (12, 13).

The exposure of the FDNY firefighters was unusual mainly because of the dramatic context and the scale of the disaster and perhaps not so much because of the type of exposure sustained. Thus, workers doing similar dirty jobs, in similarly intense work schedules and without adequate respiratory protection, conceivably are also at risk of developing disabling cough, asthma, acute eosinophilic pneumonia, granulomatous pneumonitis (14) and, why not, “idiopathic” lung fibrosis, without being involved in an epidemiologic survey. On a more global scale it is worth pointing out that many disaster victims will not be so “lucky,” such as the thousands (how many?) of victims of the gas leak in Bhopal (5) or firefighters (15) and other direct and collateral

victims of fires and building destructions caused by war. Although after 9/11 health research should be encouraged, one cannot but believe that this is yet another manifestation of the lack of equity in respiratory health research (16).

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Cough and bronchial responsiveness in firefighters at the World Trade Center site

David J Prezant, et al.

Abstract

Background: Workers from the Fire Department of New York City were exposed to a variety of inhaled materials during and after the collapse of the World Trade Center. We evaluated clinical features in a series of 332 firefighters in whom severe cough developed after exposure and the prevalence and severity of bronchial hyperreactivity in firefighters without severe cough classified according to the level of exposure.

Methods: "World Trade Center cough" was defined as a persistent cough that developed after exposure to the site and was accompanied by respiratory symptoms severe enough to require medical leave for at least four weeks. Evaluation of exposed firefighters included completion of a standard questionnaire, spirometry, airway-responsiveness testing, and chest imaging.

Results: In the first six months after September 11, 2001, World Trade Center cough occurred in 128 of 1636 firefighters with a high level of exposure (8 percent), 187 of 6958 with a moderate level of exposure (3 percent), and 17 of 1320 with a low level of exposure (1 percent). In addition, 95 percent had symptoms of dyspnea, 87 percent had gastroesophageal reflux disease, and 54 percent had nasal congestion. Of those tested before treatment of World Trade Center cough, 63 percent of firefighters (149 of 237) had a response to a bronchodilator and 24 percent (9 of 37) had bronchial hyperreactivity. Chest radiographs were unchanged from precollapse findings in 319 of the 332 with World Trade Center cough. Among the cohort without severe cough, bronchial hyperreactivity was present in 77 firefighters with a high level of exposure (23 percent) and 26 with a moderate level of exposure (8 percent).

Conclusions: Intense, short-term exposure to materials generated during the collapse of the World Trade Center was associated with bronchial responsiveness and the development of cough. Clinical and physiological severity was related to the intensity of exposure.

<https://pubmed.ncbi.nlm.nih.gov/12226151/>

Intrauterine stress and male cohort quality: the case of September 11, 2001

By Tim A Bruckner and Jenna Nobles

Abstract

Empirical research and the theory of natural selection assert that male mortality more than female mortality responds to ambient stressors in utero. Although population stressors may adversely damage males that survive to birth, the rival culled cohort hypothesis contends that males born during stressful times may exhibit better health than males in other cohorts because fetal loss has “culled” the frailest males.

We tested these hypotheses by examining child developmental outcomes in a U.S. birth cohort reportedly affected in utero by the September 11, 2001 attacks.

We used as outcomes the Bayley cognitive score and child height-for-age from the Early Childhood Longitudinal Study-Birth Cohort. Previous research demonstrates a male-specific effect of 9/11 on California infants born in December 2001.

We, therefore, compared cognition and height of this cohort with males born prior to the 9/11 attacks.

We controlled for unobserved confounding across gender, season, and region by using triple-difference regression models ($N = 6950$). At 24 months, California males born in December scored greater than expected in cognitive ability (coef = 9.55, standard error = 3.37; $p = 0.004$).

We observed no relation with height. Results remained robust to alternative specifications.

Findings offer partial support for the culled cohort hypothesis in that we observed greater than expected cognitive scores at two years of age among a cohort of males affected by 9/11 in utero. Contemporary population stressors may induce male-specific culling, thereby resulting in relatively improved development among males that survive to birth.

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Short-term and medium-term health effects of 9/11

Sharon E Perlman, et al.

Abstract

The New York City terrorist attacks on Sept 11, 2001 (9/11), killed nearly 2800 people and thousands more had subsequent health problems. In this Review of health effects in the short and medium terms, strong evidence is provided for associations between experiencing or witnessing events related to 9/11 and post-traumatic stress disorder and respiratory illness, with a correlation between prolonged, intense exposure and increased overall illness and disability. Rescue and recovery workers, especially those who arrived early at the World Trade Center site or worked for longer periods, were more likely to develop respiratory illness than were other exposed groups. Risk factors for post-traumatic stress disorder included proximity to the site on 9/11, living or working in lower Manhattan, rescue or recovery work at the World Trade Center site, event-related loss of spouse, and low social support. Investigators note associations between 9/11 exposures and additional disorders, such as depression and substance use; however, for some health problems association with exposures related to 9/11 is unclear.

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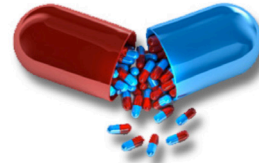


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This book is a follow-up to The Ground Zero Model by Heinz Pommer & Colleagues which I published in mid-June, 2020. The peer review in this new book describes the diseases, disorders and deaths of American Civilians and First Responders living and working in NYC. Physicist Heinz Pommer, Physicist Dr. David Madlener, Physicist Dr. François Roby, Physicist Andreas Pieper and my small contribution to the Ground Zero Model proves, unequivocally, that 9/11 was a nuclear event and the peer review contained in this current volume supports that certain assertion. These books were not created or printed for profit. We have all been richly rewarded by speaking truth to unbridled, harrowing and monstrosly powerful and influential profiteers. All proceeds are donated to charity and the books are priced as low as allowed by the various vendors. The PDF's are always free at my web site at Academia.edu.

It's critically important that 'The Ground Zero Model' and this book, 'Ground Zero: The Peer Review,' are shared widely. Americans and the world need to know the truth. It's now up to you to do your part and share these books far and wide. We've done ours.

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