HHS Public Access

Author manuscript

Occup Environ Med. Author manuscript; available in PMC 2023 September 27.

Published in final edited form as:

Occup Environ Med. 2023 June ; 80(6): 297–303. doi:10.1136/oemed-2022-108703.

All-cause and cause-specific mortality in a cohort of WTC-exposed and non-WTC-exposed firefighters

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Abstract

Objective—To compare mortality rates in WTC-exposed Fire Department of the City of New York (FDNY) firefighters with rates in similarly healthy, non-WTC-exposed/non-FDNY firefighters, and compare mortality in each firefighter cohort with the general population.

Methods—10,786 male WTC-exposed FDNY firefighters and 8,813 male non-WTC-exposed firefighters from other urban fire departments who were employed on 9/11/2001 were included in the analyses. Only WTC-exposed firefighters received health monitoring via the WTC Health Program (WTCHP). Follow-up began 9/11/2001 and ended at the earlier of death date or 12/31/2016. Death data were obtained from the National Death Index, and demographics from the fire departments. We estimated standardized mortality ratios (SMRs) in each firefighter cohort vs. US males using demographic-specific US mortality rates. Poisson regression models estimated relative rates (RRs) of all-cause and cause-specific mortality in WTC-exposed vs. non-WTC-exposed firefighters, controlling for age and race.

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Author contributions: CBH and RZO designed the study, with significant input from PB and MPW. RZO, AS, MC, and RDD acquired the data. RZO, AS, and CBH analyzed and interpreted the data. AS drafted the manuscript, with critical revisions from RZO, CBH, MPW, DJP, RDD and PB. DGG validated the analyses. All authors approved the final manuscript. RZO and AS had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Results—Between 9/11/2001-12/31/2016, there were 261 deaths among WTC-exposed firefighters and 605 among non-WTC-exposed. Both cohorts had reduced all-cause mortality compared with US males (SMR[95%CI]=0.30 [0.26-0.34] and 0.60 [0.55-0.65] in WTC-exposed and non-WTC-exposed, respectively). WTC-exposed firefighters also had lower rates of all-cause mortality (RR=0.54, 95%CI=0.49-0.59) and cancer-, cardiovascular- and respiratory disease-specific mortality compared with non-WTC-exposed firefighters.

Conclusion—Both firefighter cohorts had lower than expected all-cause mortality. Fifteen years post-9/11/2001, mortality was lower in WTC-exposed vs. non-WTC-exposed firefighters. Lower mortality in the WTC-exposed suggests not just a healthy worker effect, but additional factors such as greater access to free health monitoring and treatment that they receive via the WTCHP.

Keywords

Occupational health; Epidemiology; Firefighters; Mortality

Introduction

Firefighters, emergency medical service (EMS) providers and other first responders who participated in rescue/recovery work at the World Trade Center (WTC) site on and after 9/11/2001 (9/11) were exposed to known and suspected carcinogens, irritants and other potentially toxic substances in the WTC dust and fires that burned at the WTC site.[1,2] In the two decades that followed, WTC rescue/recovery work was found to be associated with adverse health outcomes such as obstructive airway diseases, chronic rhinosinusitis, certain cancers, and posttraumatic stress disorder (PTSD).[3-9] The increased risk of these and other chronic illnesses in WTC-exposed rescue/recovery workers has not resulted in elevated mortality rates, however, when compared with general populations. Studies conducted in three different WTC rescue/recovery worker cohorts and, most recently, in a large combined cohort of WTC rescue/recovery workers showed significantly lower than expected mortality among participants compared with United States (US), New York State and New York City populations.[10-13] These findings may reflect healthy worker effects, a phenomenon in which workers experience better health outcomes than the general population because they were healthier at the time of their employment.[14] Alternatively, reduced mortality may be attributed, in part, to the no-cost health monitoring and treatment that WTC-exposed workers receive, even after their retirement, as part of the WTC Health Program.[15,16] No study has compared mortality rates in WTC-exposed workers to those in a comparable occupational cohort.

Firefighters are routinely exposed to hazardous materials and situations in their work environments.[17,18] The International Agency for Research on Cancer (IARC) has recently classified occupational exposure from firefighting as carcinogenic to humans.[19] While several studies have linked firefighting to an increased risk of cancer,[3,19-22] pulmonary dysfunction or obstructive airways diseases,[23,24] studies assessing all-cause and cause-specific mortality in non-WTC exposed firefighters compared with general populations have had inconsistent results.[20,21,25-29] Individuals seeking employment as career firefighters must meet strict pre-hire health and fitness requirements,[30] potentially creating an even stronger healthy worker hire effect[14,31] than observed in other working populations. In

the present investigation of mortality in WTC-exposed FDNY firefighters, we account for this potential healthy worker bias by using a referent cohort of non-WTC-exposed career firefighters, the same population included in our 2021 cancer study.[3] The main objective of the current study was to compare all-cause and cause-specific mortality rates in the WTC-exposed and comparison firefighter populations during the first 15 years following 9/11. We also compared mortality in each group of firefighters with that of the US general population during this time period. The results from this study should aid our interpretation of the previously observed protective associations between WTC rescue/recovery worker cohort membership and mortality, *i.e.*, whether lower mortality can be explained by the healthy worker hire effect or improved access to comprehensive care.

Methods

Study Population

The source population consisted of firefighters enrolled in the Career Firefighter Health Study, which includes career firefighters from FDNY as well as from the Chicago, Philadelphia, and San Francisco fire departments (CFD, PFD, and SFFD, respectively).[32] The non-FDNY group (N=29,992) was initially assembled by the National Institute for Occupational Safety and Health (NIOSH), using data from the fire department rosters, for a longitudinal study of firefighting and cancer.[20] To ensure that the FDNY and non-FDNY firefighters had a similar baseline status, current analyses were restricted to the subpopulation of male Career Firefighter Health Study firefighters who were actively employed by their respective fire departments on 9/11. We excluded 613 females due to low numbers in the FDNY group (Table S1). Male FDNY firefighters were required to have participated in rescue/recovery work at the WTC site any time between 9/11/2001-7/24/2002 to be considered WTC-exposed; those who died on 9/11 (N=341) or were not exposed (N=82) were excluded from the study. The final study population included 10,786 FDNY and 8,813 non-FDNY firefighters. This study was approved by the Albert Einstein College of Medicine/Montefiore Medical Center Institutional Review Board and a waiver of informed consent was obtained.

Demographic and Lifestyle Variables

Dates of birth and employment and race/ethnicity information were available via the FDNY employee database for FDNY members and the respective fire department roster data for CFD, PFD and SFFD members.[32] We obtained FDNY participants' WTC-exposure level, or initial arrival time at the WTC site, from their first post-9/11 FDNY health monitoring survey. FDNY firefighters who arrived at the WTC site on the morning of 9/11 were classified as having had the highest exposure, followed by those who arrived on the afternoon of 9/11, those who arrived any time on 9/12/2001, and, lastly, those with an arrival date of 9/13/2001 or later (lowest exposure level).[6] Smoking status (current, former, or never smoker) was taken from their most recent self-administered health survey. Between 2019-2020, a similar survey was used to collect smoking status and other health and lifestyle information from a subset of the CFD, PFD and SFFD participants (N=2,878, 32.7%), as detailed elsewhere.[32]

Deaths

Vital status data, including death dates and underlying causes of death, were obtained via linkages to the Centers for Disease Control and Prevention's National Death Index (NDI). We provided the following data to NDI for linkage: social security numbers (SSNs), names, sex, and dates of birth. Full SSNs were provided for 100% of FDNY and >99% of non-FDNY cohort members. The NDI has been shown to be highly sensitive, capturing between 87-98% of deaths.[33] At the time that Career Firefighter Health Study members' identifying information was provided to NDI for linkage, NDI had complete data through 12/31/2016.[32] All deaths that occurred between 9/12/2001 and 12/31/2016 were analyzed. Participants whose information did not match the NDI records were considered alive at the end of 2016. NDI provided an underlying cause of death for each match in the form of International Classification of Diseases codes, 10th revision (ICD-10).[34] When assessing cause-specific mortality, we used NIOSH's major cause of death categorization, which classifies the ICD codes for underlying cause of death into 28 major and 119 minor categories.[34,35] Demographic-specific US mortality rates for each of the 119 causes of death were obtained from NIOSH's Life Table Analysis System (LTAS) 1960-2019 rate file.[35]

Statistical Analyses

Participant follow-up began on 9/11/2001 and ended at the earliest of the following dates: death date or 12/31/2016. We estimated means (±SD) and proportions (%) to summarize demographic and other characteristics of the WTC-exposed FDNY and non-WTC-exposed firefighters. Fifteen non-WTC-exposed firefighters were excluded from the following analyses due to missing race/ethnicity information.

To examine how mortality rates in the firefighter populations compared with those of the US general population during the study period, we estimated SMRs and 95% confidence intervals (CIs). Stratum-specific all-cause and cause-specific US mortality rates, obtained from the LTAS 119 cause of death rate file for 1960-2019, were available for the following strata: sex, race (non-Hispanic white, non-white), and age group and calendar period in five-year intervals (2000-2004, 2005-2009, 2010-2014, and 2015-2019). We calculated the expected number of deaths over 9/11/2001-12/31/2016 in each firefighter population by multiplying the stratum-specific US mortality rates by the number of person-years in the corresponding stratum in both the WTC-exposed and non-WTC-exposed groups and then summing across strata to get the totals. Dividing the observed number of deaths by the total number expected in each population yielded the SMRs. Ninety-five percent CIs for the SMRs were estimated using Poisson assumptions (Byar's approximation).[36]

Poisson regression analyses controlling for age on 9/11 and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other) determined the association between firefighter group and mortality; first, the relative rate (RR) and 95% CIs were estimated for all-cause mortality in WTC-exposed vs. non-WTC-exposed firefighters using deaths as the outcome and the log of person-years as an offset. We then repeated this analysis with selected cause-specific mortality outcomes, including cancer-specific mortality, heart disease- and respiratory disease-related mortality, and suicide. These outcomes were selected

because they were the most common causes of death in the study cohort and/or they were found to be elevated in previous studies of mortality in rescue/recovery workers.[11,29]

In secondary analyses, we used Poisson regression models to measure associations between WTC exposure level and all-cause mortality. We estimated RRs (95% CIs) comparing mortality in each of the four WTC exposure intensity groups with that of the non-WTC-exposed group, controlling for age on 9/11 and race/ethnicity. We then restricted the analyses to the WTC-exposed FDNY population only and compared participants in the three higher exposure groups vs. those in the lowest exposure group, controlling for smoking status in addition to the above demographic variables. Sixty-three participants were excluded from the latter analysis due to missing smoking status (total N=10,723). Data analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, https://www.sas.com).

Results

Study Population Characteristics

As shown in Table 1, the male WTC-exposed FDNY population was slightly younger than the comparison firefighter population, with mean ages on 9/11 of 40.4±7.5 and 43.9±9.2, respectively. The WTC-exposed population also had a greater portion of participants who were non-Hispanic white compared with the non-WTC-exposed (93.8% vs. 69.4%), and, among the participants who completed a health survey, a greater proportion of self-reported never-smokers (66.4% vs. 56.4%). Among WTC-exposed FDNY firefighters, 99.8% (10764/10786) had at least one WTC Health Program visit during the study period, and the median number of medical monitoring visits between 9/11/2001 and 12/31/2016 was 10 (IQR: 7-11).

Over the study period there were 261 deaths among 10,786 WTC-exposed firefighters with a total of 163,583 person-years of follow up, and 605 deaths among 8,813 non-WTC-exposed firefighters with 130,971 person-years of follow up. The most common cause of death in the firefighter populations was heart disease, followed by digestive cancers, respiratory cancers, violence, and other injuries (Table 2).

Mortality in the WTC-Exposed and Non-WTC-Exposed Firefighter Populations compared with the US General Population

Both WTC-exposed and non-WTC-exposed male firefighters had significantly fewer deaths than expected based on US rates (SMR=0.30, 95% CI=0.26-0.33 and SMR=0.60, 95% CI=0.55-0.65, respectively; Table 2). The firefighter populations had lower than expected mortality in most of the major cause of death categories assessed. The reduction in mortality was statistically significant for the following causes of death: all cancers combined, digestive cancers, respiratory cancers, heart disease, other circulatory diseases, respiratory diseases, digestive diseases, diabetes, and mental disorders. However, only the WTC-exposed FDNY group had significantly reduced oral cancer-, kidney/urinary organs cancer-, other/unspecified cancer-, nervous system disorder-, transportation injury- and suicide-related mortality compared with the US population.

Relative Rates of Mortality in the WTC-Exposed as compared with the Non-WTC-Exposed Firefighter Populations

Shown in Table 3 are the RRs for mortality in WTC-exposed compared with non-WTC-exposed firefighters during follow-up, after controlling for age on 9/11 and race/ethnicity. Between 9/11/2001 and 12/31/2016, male WTC-exposed FDNY firefighters had a significantly lower rate of all-cause mortality (RR=0.54, 95% CI=0.49-0.59) than male non-WTC-exposed, non-FDNY firefighters. We observed that the WTC-exposed group also had significantly reduced rates of mortality from all cancers combined, respiratory cancers, male genital cancers, kidney/urinary organs cancers, heart disease, other circulatory diseases, digestive diseases, respiratory diseases, and suicide. One exception was digestive cancer mortality, which was modestly elevated in the WTC-exposed vs. non-WTC-exposed firefighters and was driven by increased pancreatic cancer mortality among the WTC-exposed. Rates of lymphatic/hematopoietic cancer-related mortality and other injury-related mortality were similar in the two groups.

Secondary analyses comparing mortality in the four different WTC exposure intensity groups vs. in the non-WTC-exposed group yielded similar results. The overall rate of mortality was lower in each of the WTC exposure groups than in the non-WTC-exposed when controlling for demographic characteristics (Table S2). Finally, an internal analysis that compared FDNY firefighters in the three higher-level WTC exposure groups to those with the lowest exposure did not indicate a dose-response relationship between WTC exposure intensity and mortality (Table S3).

Discussion

Our study is the first to use an occupational cohort with similar work exposures as a comparison population when examining overall and cause-specific mortality in WTC-exposed workers. In the first 15 years post 9/11, we observed significantly lower rates of all-cause mortality in WTC-exposed firefighters compared with similar non-WTC-exposed non-FDNY firefighters in the Career Firefighter Health Study. This was in addition to observing lower all-cause mortality in male firefighters, both WTC-exposed and non-WTC-exposed, compared with the US male population. Our results showed 70% and 40% fewer deaths than expected in WTC-exposed and non-WTC-exposed male firefighters, respectively, based on US male mortality rates. These findings indicate strong healthy worker effects, and are consistent with many, though not all, previous studies of mortality in firefighters.[21,25-29] Since firefighters are subject to pre-hire screenings and strict health requirements,[30] those hired are healthier than the general population (i.e., the healthy worker hire effect).[14,31] The healthy worker survivor effect[31] was less of a concern in this study because we required that both the WTC-exposed and non-WTC-exposed participants be actively employed as firefighters on 9/11/2001, and therefore were similarly healthy at the start of follow-up. Both firefighter populations also had access to good healthcare, either via their respective fire departments/unions or via the WTC Health Program.

We also observed lower overall cancer mortality in all male firefighters vs. US males. Cancer-specific mortality was 60% reduced in the WTC-exposed cohort and 27% reduced in the non-WTC-exposed cohort. A recent study conducted in the full population of Chicago,

Philadelphia and San Francisco firefighters that made up the source population for our firefighter comparison cohort showed modestly elevated levels of cancer-specific mortality during the years 1950-2016.[29] That study, however, included older firefighters who were further from their dates of employment than those in our study and may have had less effective personal protective equipment when actively employed.[3,26] In that study, the mean year of hire was 1968. When analyses were restricted to ages <65 years old, cancer-specific mortality was not significantly different from the US general population (SMR=0.96, 95% CI=0.90-1.01).[29] These results showing elevated mortality vs. the US population in older but not younger firefighters highlight the attenuation of the healthy worker hire effect over time[37] and underscore the importance of finding an appropriate comparison population when assessing health outcomes in an occupational cohort.

While the recent IARC classification and our 2021 cancer incidence study found evidence of increased cancer risk,[3,19] we did not observe increased cancer mortality among firefighters in this study. Differences in endpoints used between studies may partly explain inconsistent findings. Also, given small numbers of site-specific cancer deaths, the current study did not estimate cancer-specific risks; therefore, results are not directly comparable to IARC findings. The lack of tumor-specific analyses and differences in endpoints may preclude comparisons with the IARC classification, which stemmed from “sufficient” evidence in humans for excess mesothelioma and bladder cancer (a cancer site with relatively high survival) from firefighting exposure.

Findings from our present investigation are consistent with previous studies examining mortality in WTC-exposed rescue/recovery workers vs. general populations. Previous analyses in the WTC-exposed FDNY cohort found significantly lower than expected all-cause and cause-specific mortality when compared with the US general population,[10] as did a study in a larger cohort of WTC-exposed general responders.[12] Another mortality study involving WTC rescue/recovery workers enrolled in the WTC Health Registry used the New York City population as a reference group and found similar results, with reduced all-cause, heart disease-specific and respiratory disease-specific mortality.[11] In that cohort the SMR for suicide was significantly elevated, however, while in our cohort of WTC-exposed firefighters suicide rates were lower than expected. These contrasting results might be explained by differences in access to care, and in the study populations; the WTC Health Registry rescue/recovery worker cohort included police officers, construction workers, emergency medical services personnel, and volunteers in addition to firefighters.[38] Our use of US, rather than NYC, cause-specific mortality rates in SMR analyses may also have contributed to the observed differences in results.

Mortality rates in WTC-exposed FDNY firefighters were low even when compared with non-WTC-exposed non-FDNY firefighters. It is unlikely that healthy worker effects alone explain the lower rates in the WTC-exposed cohort. When directly comparing the two firefighter cohorts, we found that the rates of all-cause and cancer-specific mortality were 46% and 28% lower, respectively, in the WTC-exposed firefighters. The lower cancer-specific mortality rate was observed despite our 2021 cancer study showing a modestly higher incidence of all cancers combined in the WTC-exposed group vs. the non-WTC-exposed/non-FDNY group.[3] One limitation of our current analyses was that we did not

have individual-level information on routine firefighting exposures. We do not believe that the differences in mortality rates can be explained by differences in routine firefighting exposures, however, as all four fire departments are active in urban environments, use similar protective gear including a self-contained breathing apparatus, and practice similar approaches to fires and other Hazmat responses.[39] Rather, the improved mortality outcomes might be attributed to the comprehensive health monitoring and treatment provided to WTC-exposed rescue/recovery workers. Major mortality outcomes unlikely to be affected by WTC health monitoring and treatment, such as "other injury"-related mortality, were not significantly reduced in WTC-exposed vs. non-WTC-exposed firefighters, while most of the mortality outcomes that could potentially be impacted by WTC Health Program care had reduced rates. As part of the WTC Health Program, the WTC-exposed FDNY cohort receives routine medical monitoring exams, blood and urine tests, pulmonary function tests, and diagnostic procedures and treatment for WTC-related conditions, if needed. All of the above are provided at no cost to members, even after retirement.[15,16] Our data show that WTC-exposed firefighters had a high rate of healthcare utilization, with >99% attending at least one medical exam at FDNY after 9/11, and attending near annual medical monitoring visits between 9/11/2001 and 12/31/2016. Non-WTC-exposed firefighters enrolled in standard healthcare plans do not receive the same level of proactive health monitoring, cancer screening and case management. The WTC Health Program adheres, at a minimum, to cancer screening guidelines issued by the US Preventive Service Task Force.[40] These screening procedures, along with regular health monitoring exams, facilitate the early detection and treatment of certain types of cancer,[16] which may partly explain both the excess cancer cases and reduced cancer mortality in this population. For example, our 2021 cancer study showed elevated rates of prostate cancer in WTC-exposed firefighters compared with non-WTC-exposed/non-FDNY firefighters and US males,[3] but our current investigation in the same cohort found that male genital cancer mortality (which includes prostate cancer mortality) was lower compared with both reference populations. WTC-exposed FDNY firefighters were diagnosed with cancer at a younger age, on average, than those in the comparison population, and generally at an earlier, more localized stage of disease when treatment can be more effective.[3] A recent study of cancer survival in WTC-exposed responders, including but not limited to firefighters, found that responders enrolled in the WTC Health Program who were diagnosed with cancer had lower all-cause and cancer-specific mortality between 2005-2016 compared with a reference population of non-responders without WTC exposure from New York State. WTC responders with cancer who were not enrolled in the WTC Health Program, however, did not experience significantly lower mortality than the reference population.[41] Other non-occupational studies examining access to healthcare and cancer outcomes in the US have shown that more comprehensive health insurance coverage is associated with reduced cancer mortality.[42,43]

We also cannot rule out the role that behavioral factors may have had on mortality outcomes. Cigarette smoking, diet, alcohol consumption, and social support could contribute to differences in mortality rates. A main limitation of this study was our inability to control for these potential confounders in our analyses due to incomplete data. Ninety-nine percent of the FDNY firefighter population and 33% of the non-FDNY firefighter population provided their smoking status via a self-administered health survey. The latter group were all

alive at the end of this study's follow-up period, as they self-reported their smoking status during 2019-2020 on the Career Firefighter Health Study health survey.[32] The proportions of current smokers were 3.5% and 6.6% in these subsets of FDNY and non-FDNY firefighters, respectively. Therefore, current smoking differed between the two firefighter groups but remained lower than that in US males (16.7%) [44] Further, the FDNY group had a lower proportion of ever-smokers than the non-FDNY group (34% and 44%, respectively). These differences suggest a bias from smoking differences that may mask excess risk in FDNY firefighters; however, the crude mortality risk in FDNY ever-smokers (3.6% or 132/3,606) was lower than that of the non-FDNY cohort overall (6.9% or 605/8,813), therefore it is unlikely that greater mortality in the non-FDNY cohort could be entirely explained by higher smoking rates. Our categorical smoking variable may be an imperfect measurement of smoking exposures, although recent internal analyses within a large combined cohort of WTC-exposed rescue/recovery workers that used a similar categorical measure found current and former smoking to be associated with increased all-cause and smoking-related mortality.[13] Future analyses in the subset of the current study population who were alive at the time of the Career Firefighter Health Study survey completion could examine associations between firefighter group and mortality outcomes over a later follow-up period, controlling for self-reported smoking status.

There were also differences in the demographics of the two firefighter groups, with the FDNY cohort being slightly younger and overwhelmingly non-Hispanic white, characteristics associated with lower mortality rates.[45] We controlled for racial/ethnic group and age when comparing the firefighter populations to reduce confounding. Another study limitation was our use of US mortality rates instead of regional rates when estimating SMRs for all-cause and cause-specific mortality. Since the Career Firefighter Health Study population consists of firefighters from four disparate states/regions, an area expanded further by post-retirement mobility, we felt that US population mortality rates were most appropriate. Lastly, the 15-year post-9/11 follow-up period may be relatively short for some cancer-specific mortality, especially for some solid tumors. In our previous studies examining cancer incidence, we found that similar follow-up periods were long enough to detect elevated rates of certain cancers in WTC-exposed cohorts.[3,46] For example, prostate cancer incidence was elevated in WTC-exposed workers vs. the NY state population between 2007-2015 [46] These studies focused on incidence, however, and not mortality. We plan to continue monitoring both outcomes in these populations.

The main strength of our analyses was our use of a similar occupational cohort of males who were employed as career firefighters at urban fire departments as a reference population. By including a similar non-WTC-exposed firefighter referent group, we were able to reduce the potential for strong selection bias from the healthy worker hire effect, thereby uncovering a possible protective effect of WTC Health Program membership on mortality. More favorable mortality outcomes in WTC-exposed firefighters are therefore likely to be due to a combination of the comprehensive healthcare they receive, healthy worker effects, and possible differences in health behaviors. Future mortality analyses in the Career Firefighter Health Study population will involve additional years of follow-up, allowing us to obtain more complete information on health behaviors and to further explore the impact of aging and the attenuation of healthy worker effects over time.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

Funding/support:

This research was supported through the National Institute for Occupational Safety and Health (NIOSH) cooperative agreement numbers U01 OH011480, U01 OH011309 and U01 OHO11934, and contracts 200-2017-93326 and 75D301-22-P-15204.

Role of funder/sponsor:

NIOSH had no role in the design and conduct of the study; collection (excepting author contributions made by RDD), management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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KEY MESSAGES

What is already known on this topic:

Rescue/recovery workers who responded to the World Trade Center (WTC) disaster have lower mortality rates compared with general populations; these findings may have been influenced by healthy worker effects or better access to care.

What this study adds:

In the first 15 years post 9/11/2001, male firefighters, both WTC-exposed and non-WTC-exposed, had lower than expected all-cause mortality when compared with demographically similar US males. Further, WTC-exposed firefighters had significantly lower rates of all-cause and cause-specific mortality compared with non-WTC-exposed firefighters.

How this study might affect research, practice or policy:

Our findings suggest that lower mortality rates observed in WTC-exposed firefighters may be due, in part, to the no-cost health monitoring and treatment these firefighters receive as part of the WTC Health Program, over and above the advantage conferred by the healthy worker effect.

Table 1:

Population Characteristics

	Male WTC-exposed FDNY firefighters actively employed on 9/11/2001	Male non-FDNY, non-WTC-exposed firefighters actively employed on 9/11/2001
Total N	10,786	8,813
Age on 9/11, mean ± SD	40.4±7.5	43.9±9.2
Race/ethnicity, N (%) [a]		
Non-Hispanic White	10,121 (93.8)	6,117 (69.5)
Non-Hispanic Black	282 (2.6)	1,589 (18.1)
Hispanic	353 (3.3)	736 (8.4)
Other[b]	30 (0.3)	356 (4.0)
Smoking status, N (%)		
Current	373 (3.5)[c]	192 (6.6)[d]
Former	3,233 (30.2)[c]	1,062 (37.0)[d]
Never	7,117 (66.4)[c]	1,624 (56.4)[d]
WTC exposure/site arrival time, N (%)		
Morning of 9/11	1,741 (16.1)	
Afternoon of 9/11	5,683 (52.7)	
9/12/2001	1,873 (17.4)	
9/13/2001-7/24/2002	1,489 (13.8)	
FDNY medical monitoring visits during study period, median (IQR)	10 (7-11)	
Deceased by 12/31/16, N (%)	261 (2.4)	605 (6.9)
Deceased among ever-smokers, N (%)[e]	132 (3.6)	
Follow-up years, mean ± SD	15.2 ± 1.1	14.9 ± 2.0
Total follow-up years	163,583.4	130,971.0

[a] Excludes N=15 non-WTC-exposed firefighters missing race/ethnicity

[b] Includes Asian and Native American race categories

[c] N=10,723 who self-reported smoking status on most recent FDNY health monitoring survey

[d] N=2,878 who completed Career Firefighter Health Study survey during 2019-2020

[e] N=3,606 WTC-exposed FDNY firefighters who self-reported ever smoking. Smoking status was not available for deceased non-WTC-exposed firefighters as the Career Firefighter Health Study survey was only administered to firefighters alive in 2019-2020.

Table 2:

Standardized Mortality Ratios (SMRs) of all-cause and cause-specific mortality in male WTC-exposed FDNY and non-WTC-exposed non-FDNY firefighters vs. US males,[a] 9/11/2001-/12/31/2016

Cause of death (NIOSH major category)[b]	FDNY			Non-FDNY		
	N	SMR	95% CI	N	SMR	95% CI
All	261	0.30	0.26-0.34	603[c]	0.60	0.55-0.65
Tuberculosis and HIV-related disease (01)	≤5[d]	N/A		≤5	N/A	
All cancers	86	0.40	0.32-0.49	205	0.73	0.64-0.84
MN buccal and pharynx (02)	≤5	0.15	0.00-0.86	≤5	0.65	0.21-1.51
MN digestive organs and peritoneum (03)	37	0.54	0.38-0.74	56	0.65	0.49-0.85
MN of pancreas	11	0.74	0.37-1.32	9	0.47	0.22-0.90
MN respiratory system (04)	12	0.19	0.10-0.34	55	0.63	0.48-0.83
MN male genital organs (07)	≤5	0.54	0.15-1.38	12	0.91	0.47-1.60
MN urinary organs (08)	≤5	0.25	0.05-0.74	15	1.01	0.56-1.66
MN other/unspecified sites (09)	15	0.40	0.22-0.66	37	0.87	0.61-1.20
MN lymphatic and hematopoietic tissues (10)	14	0.74	0.40-1.24	25	1.03	0.67-1.52
Benign and unspecified neoplasms (11)	≤5	0.72	0.08-2.58	≤5	0.31	0.00-1.72
Diseases of blood and blood-forming organs (12)	≤5	N/A		8	1.94	0.83-3.82
Diabetes mellitus (13)	≤5	0.14	0.04-0.36	14	0.38	0.21-0.64
Mental, psychoneurotic, and personality disorders (14)	7	0.39	0.16-0.80	6	0.33	0.12-0.72
Nervous system disorders (15)	≤5	0.15	0.03-0.44	15	0.63	0.35-1.03
Multiple Sclerosis	≤5	N/A		≤5	0.55	0.01-3.06
Other diseases of the nervous system	≤5	0.17	0.03-0.49	14	0.63	0.35-1.06
Heart diseases (16)	52	0.27	0.20-0.35	120	0.51	0.42-0.60
Other diseases of the circulatory system (17)	8	0.18	0.08-0.35	23	0.38	0.24-0.56
Diseases of the respiratory system (18)	14	0.31	0.17-0.51	36	0.57	0.40-0.79
Diseases of the digestive system (19)	8	0.13	0.06-0.26	24	0.42	0.27-0.62
Diseases of the skin and subcutaneous tissues (20)	≤5	N/A		≤5	1.4	0.16-5.05
Diseases of the musculoskeletal and connective tissue systems (21)	≤5	N/A		≤5	0.29	0.00-1.61
Diseases of the genitourinary system (22)	≤5	N/A		≤5	0.28	0.09-0.65
Symptoms and ill-defined conditions (23)	7	0.55	0.22-1.14	7	0.55	0.22-1.14
Transportation injuries (24)	9	0.24	0.11-0.46	22	0.77	0.48-1.16
Falls (25)	≤5	0.26	0.03-0.94	12	1.55	0.80-2.70
Other injury (26)	31	0.51	0.34-0.72	27	0.61	0.40-0.88
Fire in building	9	5.79	2.64-10.99	7	4.56	1.83-9.39
Violence (27)	20	0.34	0.21-0.53	34	0.79	0.54-1.10
Intentional self-harm (suicide)	17	0.36	0.21-0.58	31	1.01	0.68-1.43
Other and unspecified causes (28)	7	0.17	0.07-0.36	41	0.93	0.67-1.26

[a] US race-, age group-, and calendar period-specific mortality rates used as reference

[b] Categories based on International Classification of Diseases codes, 10th revision[34]

[c] Excludes N=2 missing race/ethnicity

[d] Cells with 5 or fewer deaths are noted as ≤5

Table 3:

Adjusted relative rates (RR) of deaths in male WTC-exposed FDNY firefighters vs. male non-WTC-exposed non-FDNY firefighters, 9/11/2001-12/31/2016

Cause of death (NIOSH major category)[a]	Adj. RR (95% CI)[b,c]
All	0.54 (0.49-0.59)
All cancers	0.72 (0.65-0.79)
MN digestive organs and peritoneum (03)	1.13 (1.03-1.26)
MN of pancreas (03, 13)	2.45 (2.19-2.75)
MN of the respiratory system (04)	0.39 (0.35-0.44)
MN of male genital organs (07)	0.84 (0.75-0.95)
MN of urinary organs (08)	0.59 (0.52-0.66)
MN of lymphatic & hematopoietic tissue (10)	0.93 (0.83-1.03)
Diseases of the heart (16)	0.61 (0.55-0.67)
Other diseases of the circulatory system (17)	0.74 (0.66-0.84)
Diseases of the respiratory system (18)	0.69 (0.62-0.77)
Diseases of the digestive system (19)	0.54 (0.48-0.60)
Other injury (26)	0.90 (0.81-1.01)
Intentional self-harm (suicide) (27; 116)	0.44 (0.39-0.50)

[a] Categories based on International Classification of Diseases codes, 10th revision[34]

[b] Regression models adjusted for age on 9/11/2001 and race/ethnicity

[c] Excluding N=15 missing covariates