Cancer incidence in World Trade Center-exposed and non-exposed male firefighters, as compared with the US adult male population: 2001–2016

Mayris P Webber 1,2, Ankura Singh 1,2, Rachel Zeig-Owens 1,2,3, Joke Salako 2,3, Molly Skerker 2,3, Charles B Hall 4, David G Goldfarb 2,3, Nadia Jaber 2, Robert D Daniels 5, David P Prezant 1,2,3

ABSTRACT

Objective To compare cancer incidence in Fire Department of the City of New York (FDNY) firefighters who worked at the World Trade Center (WTC) site to incidence in a population of non-WTC-exposed firefighters, the Career Firefighter Health Study (CFHS) cohort, and to compare rates from each firefighter cohort to rates in demographically similar US males.

Methods FDNY (N=10 786) and CFHS (N=8813) cohorts included male firefighters who were active on 11 September 2001 (9/11) and were followed until death or 31 December 2016. Cases were identified from 15 state cancer registries. Poisson regression models assessed cancers in each group (FDNY and CFHS) versus US males, and associations between group and cancer rates; these models estimated standardised incidence ratios (SIRs) and adjusted relative rates (RRs), respectively. Secondary analyses assessed surveillance bias and smoking history.

Results We identified 915 cancer cases in 841 FDNY firefighters and 1002 cases in 909 CFHS firefighters. FDNY had: higher rates for all cancers (RR=1.13; 95% CI 1.02 to 1.25), prostate (RR=1.39; 95% CI 1.19 to 1.63) and thyroid cancer (RR=2.53; 95% CI 1.37 to 4.70); younger median ages at diagnosis (55.6 vs. 59.4 years) and more localised disease when compared with CFHS. Compared with US males, both firefighter cohorts had elevated SIRs for prostate cancer and melanoma. Control for surveillance bias in FDNY reduced most differences.

Conclusions Excess cancers occurred in WTC-exposed firefighters relative to each comparison group, which may partially be explained by heightened surveillance. Two decades post-9/11, clearer understanding of WTC-related cancer risk requires additional years of follow-up to allow for the reported long latency of some solid tumours. Laboratory-based or animal-based modelling studies should be encouraged to identify and track workplace exposures in WTC-exposed and non-WTC-exposed firefighters.

INTRODUCTION

Firefighters are repeatedly exposed to occupational hazards, including known carcinogens.1 2 There have been over 200 peer-reviewed studies of firefighting and cancer, shown in PubMed,3-9 most published since 2000. Despite this proliferation of studies, the degree to which firefighting is associated with cancer incidence remains uncertain. A 2014 National Institute for Occupational Safety and Health (NIOSH) study found that a cohort of nearly 30 000 professional firefighters had a modest elevation in the rate of all-cancers combined (standardised incidence ratio (SIR)=1.09; 95% CI 1.06 to 1.12) compared with the general US population.9 A recent meta-analysis of 25 cohort studies, including the aforementioned NIOSH cohort, however, reported that the all-cancer risk for firefighters was similar to that of the general population (meta-relative risk=1.0; 95% CI 0.93 to 1.07).9 10

The World Trade Center (WTC) attacks on 11 September 2001 (9/11) exposed over 15 000 Fire Department of the City of New York (FDNY) firefighters and other rescue/recovery workers to
cases to those in the general population. This study is of importance as it serves as a benchmark for assessing the cancer risk associated with WTC exposure.

Studies of WTC-related exposures have shown elevated rates of specific cancers among firefighters who were present at the WTC site at the time of the 9/11 attacks. The current study aimed to assess if there was an increased risk of cancer among firefighters who were employed at the WTC site at any time between 11 September 2001 and 31 December 2016, compared to a matched cohort of firefighters who were employed by their respective departments on 11 September 2001.

METHODS
Study population
Inclusion required that FDNY and CFHS members be actively employed by their respective departments on 11 September 2001. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

FDNY cohort
The FDNY sample consisted of male firefighters who worked at the WTC site at any time between 11 September 2001 and 31 July 2002 (N=10,786). Male firefighters who did not report any WTC exposure (N=82) were excluded, as were WTC-exposed female firefighters (N=28) due to low numbers. Characteristics of the excluded female firefighters are shown in online supplemental table S1.

CFHS cohort
The CFHS cohort included 29,992 firefighters from the Philadelphia, Chicago, and San Francisco Fire Departments, originally identified from department rosters, as previously described. We chose this referent group because they were subject to similar pre-hire fitness requirements, worked in urban environments, and worked at departments with retirement policies similar to FDNY’s. Study inclusion was limited to males who were actively employed on 11 September 2001 (N=8,813); 585 females were excluded (online supplemental table S1). Since we were missing information on the WTC exposure history of CFHS members, we considered this cohort to be non-WTC-exposed.

Demographic/background information
Data were obtained from employee databases and FDNY medical records, and death information from the Social Security Death Master File and the National Death Index. One additional FDNY death was identified from employee records. Smoking status (current, former or never smoker) and prior military service were ascertained from health surveys completed by FDNY firefighters during medical monitoring examinations. WTC-exposed FDNY members provided their initial arrival time at the WTC site, hereafter referred to as WTC exposure level, on their first post-9/11 health questionnaire. A similar health survey collected smoking status, occupational history and other background information from a sample of CFHS firefighters (N=28,562, 32.4%).

Cancer cases
Information on cancer diagnoses was obtained by probabilistic matching to state cancer registries, as described elsewhere. States were selected for linkage based on the residence information of active and retired FDNY and CFHS firefighters. The FDNY population was linked to Arizona, Connecticut, Florida, North Carolina, New Jersey, New York, Pennsylvania, South Carolina, and Virginia state cancer registries. The CFHS population was linked to Arizona, California, Florida, Illinois, Indiana, Michigan, New Jersey, Oregon, Pennsylvania, and Washington state. Ninety-eight percent of FDNY firefighters and 97% of CFHS firefighters resided in one of the states selected for linkage. Cancer cases defined as primary malignant tumours or in situ bladder cancers and diagnosed between 11 September 2001 and 31 December 2016 were analysed.

US cancer rates
We used the National Cancer Institute’s Surveillance, Epidemiology and End Results Program (SEER-21) data to obtain rates of all-cancers combined and some site-specific cancers in the US male population. Data were grouped by calendar year (2001 to 2016), race/ethnicity (non-Hispanic white, non-Hispanic Black, Hispanic, Asian and Native American) and 5-year age groups (15–19 to 85–89 years), and incidence rates calculated in these strata. We also obtained information on cancer stage at diagnosis and median age at diagnosis.

Statistical analyses
Selected characteristics of each cohort were compared by calculating means (±SD), medians (IQR) or proportions (%). T-tests, Wilcoxon Mann-Whitney U tests or χ² tests were performed, as appropriate. Follow-up time started on 11 September 2001 and ended on 31 December 2016 or, if earlier, date of death.

To examine trends over time, we graphed cancer incidence rates by calendar year in FDNY, CFHS and US males (SEER-21) using output from Poisson regression models of year and group predicting cancer cases, with the log of person-years as an offset, controlling for race/ethnicity and 5-year age group. To provide context for the interpretation of cancer risk in firefighters, with and without WTC exposure, our primary analyses involved estimating SIRs and 95% CIs for all-cancer sites combined (all cancers) and some site-specific cancers between 11 September 2001 and 31 December 2016, comparing each firefighter cohort with SEER-21 data. We used Poisson regression models with observed numbers of FDNY cancer cases as the outcome variable and the log of the expected case count in each demographic stratum, calculated by multiplying the stratum-specific SEER-21 rate with the number of person-years belonging to that stratum in the FDNY cohort, as an offset. We then ran these models using CFHS in place of FDNY data. Site-specific cancers were chosen based on our previous work examining post-9/11 cancer incidence in FDNY firefighters.

Additional primary analyses fit Poisson regression models assessing the associations between firefighter cohort and cancer rates, controlling for age on 9/11 and race/ethnicity. Adjusted
relative rates (RRs) and 95% CIs were estimated using cohort as the independent variable, cancer cases as the outcome, and log of person-years as the offset. The RR for melanoma was estimated from non-Hispanic white males (N=16 238) due to limited cases in non-whites. A sensitivity analysis assessed differences in FDNY and CFHS cohort cancer rates when only first primary cancer cases were included as the outcome; this analysis excluded individuals whose first cancers were diagnosed prior to 9/11 (N=229) and ended follow-up at the first diagnosis date.

Secondary analyses addressed possible surveillance bias, as previously described. Briefly, WTC-exposed FDNY firefighters undergo free health monitoring exams without copays, including for blood testing, and chest CT scans, as indicated, even after retirement. FDNY cancers could therefore be diagnosed earlier due to screenings that are not widely available to others. Accordingly, we categorised cases of lung, liver, thyroid or kidney cancer or Hodgkin or non-Hodgkin lymphoma diagnosed ≤6 months after chest CT scans and cases of prostate or haematological cancers diagnosed ≤6 months after routine blood tests as cases identified by screening (N=204), repeating the primary analyses after delaying the diagnosis dates of these cancers by 2 years. This time delay was chosen based on the 2-year average lead time for prostate cancers diagnosed in participants of a randomised cancer screening study who received annual screening. We also performed sensitivity analyses delaying diagnosis dates by 5 years.

We conducted two additional secondary analyses: we analysed the subset of 10 723 FDNY and 2856 CFHS firefighters for whom we had smoking information, repeating the RR analyses comparing FDNY and CFHS cancer rates with smoking status (ever vs never) included as a covariate in the Poisson regression models. We then explored a possible dose–response relationship between WTC exposure level and cancer within the WTC-exposed FDNY cohort only (N=10 786), redoing the RR analyses with an ordinal WTC exposure level variable ranging from lowest to highest—analyses with an ordinal WTC exposure level variable ranging from lowest to highest—analyses with an ordinal WTC exposure level variable ranging from lowest to highest—analyses with an ordinal WTC exposure level variable ranging from lowest to highest (table 1) in the models.

All analyses were performed in SAS (V9.4, SAS, Institute Inc., Cary, NC, http://www.sas.com). Yearly incidence rate graphs were created via PROC SGPLOT using a locally weighted smoothing (LOESS) function for estimates generated from the first Poisson regression models described above.

RESULTS
Selected characteristics of 10 786 WTC-exposed FDNY and 8813 CFHS firefighters are shown in table 1. FDNY firefighters were younger, on average, more likely to be white and nonsmokers, and less likely to be combat veterans compared with CFHS firefighters (p<0.001 for all). The FDNY cohort was also consistently younger at diagnosis compared with CFHS: for all cancers median (IQR)=55.6 (50.2–60.2) vs 60.0 (54.4–64.8) years and for every cancer subtype examined. Since 9/11, 92.7% of WTC-exposed male FDNY firefighters have had at least 1 prostate-specific antigen (PSA) test, 98.8% at least 1 complete blood count and 47.7% at least 1 chest CT. While we lack comparable data for the CFHS, 96% of those who completed the CFHS health survey reported a visit to a medical doctor within the previous 2 years.

Between 11 September 2001 and 31 December 2016, we identified 913 and 1002 incident cancer cases in 841 FDNY and 909 CFHS firefighters, respectively. Prostate cancer was the most common site-specific cancer in both groups (N=332 and N=358 in FDNY and CFHS, respectively), followed by melanoma of the skin (N=96) and non-Hodgkin lymphoma (N=55) in FDNY and lung cancer (N=83) and melanoma (N=70) in CFHS.

Table 1 Population characteristics

<table>
<thead>
<tr>
<th>Exposure group</th>
<th>WTC-exposed male FDNY firefighters active on 9/11</th>
<th>Male CFHS firefighters actively employed on 9/11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N</td>
<td>10 786</td>
<td>8813</td>
</tr>
<tr>
<td>Age on 9/11, mean±SD*</td>
<td>40.4±7.5</td>
<td>43.9±9.2</td>
</tr>
<tr>
<td>Race/ethnicity, N (%)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>10 121 (93.8)</td>
<td>6117 (69.4)</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>282 (2.6)</td>
<td>1589 (18.0)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>353 (3.3)</td>
<td>736 (8.3)</td>
</tr>
<tr>
<td>Other</td>
<td>30 (0.3)</td>
<td>371 (4.2)</td>
</tr>
<tr>
<td>Smoking status, N (%)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>373 (3.5)</td>
<td>189 (2.1)</td>
</tr>
<tr>
<td>Former</td>
<td>3233 (30.2)</td>
<td>1056 (12.0)</td>
</tr>
<tr>
<td>Never</td>
<td>7117 (66.4)</td>
<td>1611 (18.6)</td>
</tr>
<tr>
<td>Military combat experience, N (%)*</td>
<td>429 (4.0)</td>
<td>283 (3.0)</td>
</tr>
<tr>
<td>WTC site arrival time, N (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure group 1 (highest): Morning of 9/11</td>
<td>1741 (16.1)</td>
<td></td>
</tr>
<tr>
<td>Exposure group 2: Afternoon of 9/11</td>
<td>5683 (52.7)</td>
<td></td>
</tr>
<tr>
<td>Exposure group 3: 12/9/2001</td>
<td>1873 (17.4)</td>
<td></td>
</tr>
<tr>
<td>Exposure group 4: 13/9–24/9/2001</td>
<td>1315 (12.2)</td>
<td></td>
</tr>
<tr>
<td>Exposure group 5 (lowest): After 24 September 2001</td>
<td>174 (1.6)</td>
<td></td>
</tr>
</tbody>
</table>

| All cancers* | 55.6 (50.2–60.2) | 60.0 (54.4–64.8) |
| Prostate cancer* | 57.9 (53.3–62.4) | 60.4 (55.2–65.4) |
| Lung cancer | 60.4 (55.6–65.5) | 62.8 (57.9–67.2) |
| Kidney cancer | 56.0 (49.0–63.0) | 58.1 (54.7–63.2) |
| Non-Hodgkin lymphoma** | 53.6 (48.9–59.4) | 60.1 (50.1–65.3) |
| Melanoma (skin)* | 51.9 (45.5–57.8) | 61.2 (54.4–66.5) |
| Thyroid cancer** | 51.2 (44.0–56.5) | 59.0 (49.2–66.4) |
| Alive at end of follow-up, N (%)* | 10 525 (97.6) | 8208 (93.1) |
| Follow-up time (years), mean±SD* | 15.2±1.1 | 14.9±2.0 |

*P<0.001, **P<0.05.
†Includes Asian and Native American race categories.
‡Includes white males (N=16 238) due to limited cases in non-whites.
§Includes Hispanic white males (N=16 238) due to limited cases in non-whites.
¶N=10 723 who self-reported smoking status.
∥N=2856 who completed CFHS survey.
$N=10 429 who self-reported occupational history.

Cancer rates in firefighters (FDNY and CFHS) compared with US males (SEER-21)
Comparing median age at diagnosis across the three groups, we found that generally, FDNY firefighters had the youngest median age and SEER-21 the oldest. Similarly, there were differences in cancer stage at diagnosis: FDNY firefighters were usually diagnosed at an earlier, more localised disease stage (table 2).

Table 2 displays the race/ethnicity-adjusted and age group-adjusted cancer incidence rates by calendar year in the FDNY, CFHS and SEER-21 populations. Rates of prostate cancer (figure 1A), non-Hodgkin lymphoma (figure 1B) and melanoma of the skin (figure 1C) were consistently elevated in the FDNY cohort compared with US males; this was especially evident for prostate cancer rates after 2007. Prostate cancer and melanoma rates also appeared to be elevated in CFHS versus US males. In contrast, rates of lung cancer were lower in both firefighter cohorts than in US males (figure 1D).

Table 3A displays results of SIR analyses comparing cancer incidence in the FDNY and CFHS cohorts with expected
numbers based on SEER-21 rates. In the FDNY cohort, SIRs for all cancers, prostate cancer, thyroid cancer, melanoma of the skin, and non-Hodgkin lymphoma were significantly elevated, whereas among CFHS firefighters, prostate cancer and melanoma SIRs were significantly elevated. Lung cancer incidence was significantly lower than expectation in both cohorts.

After correction for possible surveillance bias by delaying the diagnosis dates of certain cancer cases by 2 years, the FDNY all-cancer incidence remained higher than expected compared with the US male population (SIR=1.09; 95% CI 1.02 to 1.16), as did the incidence of prostate cancer, thyroid cancer and melanoma (table 3B). In a sensitivity analysis that delayed diagnosis dates by 5 years, excess risks were substantially reduced. Some proportion of the excess prostate cancer risk may be due to WTC exposure; the incidence remained higher than expected compared with SEER-21.25 Overall, >80% of lung cancer cases in this subpopulation (43/52) were reported in ever smokers. After controlling for smoking status and demographics, FDNY members had higher rates of all cancer and of prostate cancer compared with CFHS (RR=1.26, 95% CI 1.09 to 1.45 and RR=1.29, 95% CI 1.05 to 1.59, respectively). Finally, when restricting our primary RR analyses to the FDNY population (N=10 786) we did not observe an association between increasing WTC exposure level and cancer rate (all-cancer RR=1.00, 95% CI 0.94 to 1.07).

DISCUSSION

On this, the 20th anniversary of 9/11, we set out to compare cancer rates in two firefighter cohorts, the WTC-exposed FDNY cohort and the non-WTC-exposed CFHS cohort, to each other and to rates among demographically similar men in the US population (SEER-21). The current investigation extended our previous study, which used CFHS data to estimate excess risk in WTC-exposed firefighters through 2009.20 Consistent with the previous study, we continue to report evidence of excess thyroid and prostate cancer risk in the FDNY firefighters compared with CFHS firefighters. Unlike in the previous study, however, we now also report excess risk for all-cancers combined.

We documented modest excesses of cancer risk in the WTC-exposed FDNY cohort in relation to each comparison group. First, comparing FDNY to the CFHS cohort, we found a 13% excess risk for all cancers, largely driven by prostate and thyroid cancer. After correction for possible surveillance bias in FDNY by delaying diagnosis dates of certain cancer cases by 2 and then 5 years, excess risks were substantially reduced. Some proportion of the excess prostate cancer risk may be due to WTC exposure on top of usual firefighting risks, as some chemicals, like PCBs, commonly found at building sites including the WTC, are known endocrine disruptors, interfering with androgen metabolism.27 This may have elevated the bioavailability of androgen, which could have been a factor in prostate cancer initiation. However, non-WTC-exposed firefighters may also at risk of PCB exposure through usual firefighting exposures.2 There is little biological evidence for increased thyroid cancer risk from exposures to environmental risk factors other than ionising radiation,24 which was not detected at the WTC site. There is some evidence regarding thyroid cancer in pesticide-exposed workers29-31; pesticides, however, were also not reported at the site.11-13 Alternatively, high rates of some cancers, including thyroid and prostate cancer, could have resulted from non-biological factors like enrollment in screening programmes,32 especially WTC-related health programmes.33-35 Evidence for non-biological factors due to screening include younger median age at diagnosis among the FDNY cohort for all cancers and cancer subtypes compared with CFHS and SEER-21.36
While the median ages at diagnosis were lowest for FDNY, CFHS median ages were also generally lower than SEER-21. Additional support for non-biological factors can be found in the staging data: cancers reported in SEER-21 were less likely to be classified as localised at time of diagnosis, although data from SEER-21 contained more unknown stages than either FDNY or CFHS. Occupational and WTC-related health programmes are designed for the early detection of cancer to minimise harm and improve survival. They clearly succeed in this mission, but may also overdiagnose occult, asymptomatic cancers.17-19 34 36

Previous evidence from five non-WTC-exposed firefighter studies consistently supports excess risks of prostate cancer and melanoma in firefighters.4 8–10 37 In our analyses, both firefighter cohorts had elevated rates of prostate cancer and melanoma relative to US males, although the SIRs for FDNY were higher. We proposed possible reasons for excess prostate cancer in firefighters above. As for melanoma, beyond UV exposure, melanoma has also been associated with PAH, PCB, aromatic hydrocarbons and other chemicals identified as present at the WTC11 13 and at non-WTC-related fires38.

Compared with US males, the FDNY cohort also had significantly elevated SIRs for all cancer, non-Hodgkin lymphoma and thyroid cancer. The elevated all-cancer risk was driven by prostate cancer. After correcting for possible surveillance bias, we

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Table 3A  Standardised incidence ratios (SIRs) of cancers in male FDNY and CFHS firefighters versus US males,24 11 September 2001–31 December 2016

<table>
<thead>
<tr>
<th>Site</th>
<th>FDNY case count</th>
<th>FDNY SIR</th>
<th>95% CI</th>
<th>CFHS case count</th>
<th>CFHS SIR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cancer sites*</td>
<td>915</td>
<td>1.15</td>
<td>1.08 to 1.23</td>
<td>1002</td>
<td>1.05</td>
<td>0.98 to 1.12</td>
</tr>
<tr>
<td>Prostate</td>
<td>332</td>
<td>1.70</td>
<td>1.53 to 1.88</td>
<td>358</td>
<td>1.22</td>
<td>1.11 to 1.35</td>
</tr>
<tr>
<td>Lung</td>
<td>44</td>
<td>0.53</td>
<td>0.39 to 0.72</td>
<td>83</td>
<td>0.71</td>
<td>0.57 to 0.89</td>
</tr>
<tr>
<td>Kidney</td>
<td>39</td>
<td>0.93</td>
<td>0.67 to 1.28</td>
<td>55</td>
<td>1.19</td>
<td>0.90 to 1.56</td>
</tr>
<tr>
<td>Non-Hodgkin lymphoma</td>
<td>55</td>
<td>1.39</td>
<td>1.06 to 1.83</td>
<td>43</td>
<td>1.04</td>
<td>0.77 to 1.41</td>
</tr>
<tr>
<td>Melanoma (skin)</td>
<td>96</td>
<td>1.59</td>
<td>1.30 to 1.96</td>
<td>70</td>
<td>1.39</td>
<td>1.07 to 1.79</td>
</tr>
<tr>
<td>Thyroid</td>
<td>46</td>
<td>2.37</td>
<td>1.78 to 3.17</td>
<td>15</td>
<td>1.01</td>
<td>0.61 to 1.67</td>
</tr>
</tbody>
</table>

*All malignant cancers (multiple primaries), and in situ bladder cancers.

CFHS, Career Firefighter Health Study; FDNY, Fire Department of the City of New York.
similarly observed elevated, although attenuated, SIRs. Despite our control efforts, surveillance bias concerns remain, as the US general population lacks access to comprehensive, no-copay healthcare like the WTC Health Program.34

The comparison group of CFHS firefighters is based on a subset of the original NIOSH cohort of 29 992 career firefighters.4 Cancer data from the original cohort study accrued a subset of the original NIOSH cohort of 29 992 career firefighters but only for the 32% of CFHS firefighters who completed the CFHS survey. Similarly, we had incomplete information on WTC exposure in the CFHS cohort. If CFHS firefighters who volunteered at the WTC site had exposures similar to those of active duty FDNY firefighters, misclassifying these CFHS members as non-WTC-exposed would have biased our estimated cancer RRs towards the null. Another limitation was that correcting for surveillance bias by lagging FDNY diagnosis dates of certain cancers was an imperfect way to mitigate screening effects, as the 2-year lag time may be insufficient. We found that applying a 5-year delay to the diagnosis dates mostly removed the excess cancer incidence observed in WTC-exposed FDNY firefighters. Asymptomatic cases in the US population, and to a lesser extent in the CFHS cohort, may go undiagnosed without regular physical exams or adherence to screening programmes. However, as cancer screening guidelines such as those from the US Preventive Service Task Force (USPSTF)42 and

<table>
<thead>
<tr>
<th>Site</th>
<th>RR 95% CI</th>
<th>Site</th>
<th>RR 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cancer sites†</td>
<td>1.09 (1.02 to 1.16)</td>
<td>Prostate</td>
<td>1.55 (1.39 to 1.73)</td>
</tr>
<tr>
<td>Prostate</td>
<td>1.55 (1.39 to 1.73)</td>
<td>Lung</td>
<td>0.47 (0.34 to 0.65)</td>
</tr>
<tr>
<td>Lung</td>
<td>0.47 (0.34 to 0.65)</td>
<td>Kidney</td>
<td>0.85 (0.61 to 1.19)</td>
</tr>
<tr>
<td>Kidney</td>
<td>0.85 (0.61 to 1.19)</td>
<td>Non-Hodgkin lymphoma</td>
<td>1.29 (0.97 to 1.71)</td>
</tr>
<tr>
<td>Non-Hodgkin lymphoma</td>
<td>1.29 (0.97 to 1.71)</td>
<td>Melanoma (skin)§</td>
<td>1.59 (1.30 to 1.96)</td>
</tr>
<tr>
<td>Melanoma (skin)§</td>
<td>1.59 (1.30 to 1.96)</td>
<td>Thyroid</td>
<td>2.01 (1.47 to 2.75)</td>
</tr>
</tbody>
</table>

*Regression models adjusted for age on 11 September 2001 and race/ethnicity. †Diagnosis dates of some FDNY cancer cases (N=204) delayed by 2 years to account for potential surveillance bias. ‡All malignant cancers (multiple primaries), and in situ bladder cancers. §Analysis restricted to white males (N=16 238) due to low case counts in other race/ethnic groups. CFHS, Career Firefighter Health Study; FDNY, Fire Department of the City of New York; NA, not available; WTC, World Trade Center.
the American Cancer Society, become more widely accepted, these differences should become less pronounced. For firefighters, these cancer screening guidelines have been recommended since 1997 by the International Association of Firefighters. Although the fire departments represented in the CFHS cohort have had far less funding for cancer screening than FDNY, adjustment for surveillance bias only in the FDNY cohort could have led to an overestimation of this bias if the other departments’ screening practices are similar. Alternatively, if the fire departments in CFHS followed the 2012 USPSTF prostate cancer screening guidelines recommending against PSA screening between 2012 and 2016, while FDNY continued to carry out PSA screening throughout the follow-up period, the estimated RR for prostate cancer may have been biased away from the null. In a future study, we plan to further address potential surveillance bias by examining cause-specific mortality in the CFHS and FDNY populations, particularly among those diagnosed with cancer, as our current study found that the proportion of firefighters alive at the end of follow-up was greater in FDNY than in CFHS.

Clearer understanding of the WTC-related cancer risk for firefighters requires progress in at least two directions: additional years of follow-up to allow for the suspected long latency of some solid tumours; and, modelling studies (laboratory or animal based) to identify and track workplace exposures in WTC-exposed and non-WTC-exposed firefighters. These steps may aid our understanding of the complex relationships between WTC exposure, firefighting and cancer.

Author affiliations

1Division of Epidemiology, Department of Epidemiology and Population Health, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, New York, USA
2Bureau of Health Services, Fire Department of the City of New York, Brooklyn, New York, USA
3Pulmonary Medicine Division, Department of Medicine, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, New York, USA
4Division of Biostatistics, Department of Epidemiology and Population Health, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, New York, USA
5World Trade Center Health Program, Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio, USA

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ORCID iDs

Mayris P Webber http://orcid.org/0000-0002-8322-4573
Arkuna Singh http://orcid.org/0000-0002-8489-4850
Rachel Zeig-Owens http://orcid.org/0000-0002-8679-2306
Joke Salako http://orcid.org/0000-0003-2417-9810
Molly Skerker http://orcid.org/0000-0002-7511-610X
Charles B Hall http://orcid.org/0000-0001-9982-8120


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