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RESEARCH ARTICLE

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Cancer incidence in World Trade Center rescue and recovery workers by race and ethnicity

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Abstract

Introduction: It is unclear whether differences in health outcomes by racial and ethnic groups among World Trade Center (WTC) rescue and recovery workers reflect those of the population of New York State (NYS) or show distinct patterns. We assessed cancer incidence in WTC workers by self-reported race and ethnicity, and compared it to population figures for NYS.

Methods: A total of 61,031 WTC workers enrolled between September 11, 2001 and January 10, 2012 were followed to December 31, 2015. To evaluate the association between race/ethnicity and cancer risk, Poisson regression analysis was used to estimate hazard ratios (HR) adjusted for WTC exposure, age, calendar year, sex and, for lung cancer, cigarette smoking.

Results: In comparison to Whites, Black workers had a higher incidence of prostate cancer (HR = 1.99, 95% CI = 1.69–2.34) and multiple myeloma (HR = 3.57, 95% CI = 1.97–6.45), and a lower incidence of thyroid (HR = 0.41, 95% CI = 0.22–0.78) and colorectal cancer (HR = 0.57; 95% CI = 0.33–0.98). Hispanic workers had a higher incidence of liver cancer (HR = 4.03, 95% CI = 2.23–7.28). Compared with NYS population, White workers had significantly higher incidence of prostate cancer (HR = 1.26, 95% CI = 1.18–1.35) and thyroid cancer (HR = 1.80, 95% CI = 1.55–2.08), while Black workers had significantly higher incidence of prostate cancer (HR = 1.22, 95% CI = 1.05–1.40).

Conclusion: Cancer incidence in WTC workers generally reflects data from the NYS population, but some differences were identified that merit further investigation.

KEYWORDS
cancer incidence, race/ethnicity, world trade center

1 | INTRODUCTION

Beginning on the morning of September 11 and for more than 9 months after, tens of thousands of rescue/recovery workers were exposed to numerous harmful substances at the site of the World Trade Center (WTC) disaster.[1] Many of these exposures have been associated with an increased risk of developing cancer.

The impact of carcinogenic environmental exposures has been studied in several cohorts of WTC rescue and recovery workers.[2–5] Site contaminants derived from toxic fumes, dusts and combustion products, and included carcinogenic substances such as asbestos, benzene, heavy metals, silica, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls.[6–8]

Demonstrating the importance of long-term follow-up studies with adequate statistical power, our recent pooled analysis of three cohorts of WTC workers showed that greater intensity of WTC exposure was associated with an increased risk of melanoma, prostate, thyroid, and tonsil cancers.[9] Additionally, two recent analyses of melanoma and prostate cancer in WTC responders found significantly shorter latency/induction periods from time of WTC exposure to onset of illness, when compared to previous reports.[10,11] These cancers are characterized as well by disparities by race and ethnicity. In particular, the incidence of prostate cancer is higher in Blacks and that of melanoma and thyroid and oropharyngeal cancer is higher in Whites.[12]

In previous studies evaluating cancer incidence among WTC rescue/recovery workers, risk by race/ethnicity was not systematically investigated, and it is unclear whether differences by racial/ethnic groups in this population reflect those of the general population of responders (i.e., that of New York State [NYS]) or might show distinct patterns. In this study, we assessed cancer incidence among WTC workers by self-reported race and ethnicity (non-Hispanic White, non-Hispanic Black, and Hispanic) and compared their cancer incidence rates within this combined cohort and when compared to the general population of NYS. We hypothesize that patterns of cancer incidence in WTC workers by race and ethnicity reflect those observed in the general population of NYS.

2 | METHODS

2.1 | Study population

This was an observational cohort study, based on the Combined WTC Rescue/Recovery Cohort that was harmonized from three cohorts: the Fire Department of the City of New York (FDNY), the General Responder Cohort (GRC), and the WTC Health Registry (WTCHR). Details of the pooled cohort have been reported elsewhere.[13] This combined cohort encompasses a total of 61,031 WTC workers older than 18 years old, with self-reported information on race and ethnicity as Hispanic, non-Hispanic White, or non-Hispanic Black, and enrolled in one of the three cohorts between September 11, 2001 and January 10, 2013. We excluded workers with a history of cancer before the start of follow-up, those who died before enrollment, and those without information on race and ethnicity or recorded as other than those listed above. Details on enrollment of the three cohorts and collection of data, as well as the process of pooling and harmonization, justified by the methodological consistency between the cohorts,[14] have been reported.[13]

WTC exposure was defined by (a) the date of first arrival to work on the WTC site, (b) if work was performed on the debris piles at the WTC site, and (c) exposure to the dust cloud in the immediate aftermath of the WTC attack.[13]

2.2 | Cancer incidence

Diagnosis of any primary cancer during 2002–2015 was used to assess cancer incidence in the WTC cohort. Twelve state cancer registries were used to identify cancer among this population by matching their name, gender, race, date of birth, addresses, and/or social security number, when available. The NYS Cancer Registry deduplicated the data set so that cancer cases would not be double-counted. The International Classification of Diseases for Oncology (ICD-O-3)[15] was used to classify cancer, and the Surveillance, Epidemiology, and End Results (SEER) Site Recode ICD-O-3 based on World Health Organization 2008 definitions[16] was used to classify cancer sites. Cancer sites, including prostate (males only), lung, thyroid, colorectal, breast (females only), stomach, liver, urinary bladder (including in situ cancer), kidney, and myeloma were selected for study since previously published population-based rates have demonstrated elevated risks in ethno-racial subgroups.

2.3 | Statistical analysis

Cancer incidence was estimated for WTC workers and was compared between ethno-racial groups as outlined above. Race and ethnicity were self-reported; the North American Association of Central Cancer Registries Hispanic Identification Algorithm was also used to assign Hispanic ethnicity for workers with missing information on ethnicity.[17] Poisson regression was used to assess the hazard ratio (HR) for cancer, together with 95% confidence intervals (CI), using non-Hispanic White workers as reference. Data were grouped in strata of person-time and cases by race/ethnicity, age, sex, and calendar year. Person-time accruals began 6 months after enrollment into a WTC rescue/recovery cohort so that prevalent cancers which had likely developed before September 11 were not misclassified as incident cases, and to account for potential self-selection bias (i.e., by participants who enrolled into a WTCHP cohort to receive augmented cancer coverage through the World Trade Center Health Program). Person-time ended on the date of death or the end-date of study (December 13, 2015). Models were adjusted for sex (as appropriate), age, smoking status, and calendar year. SAS software was used for analysis (v 9.4; SAS Institute Inc.).

TABLE 1 Baseline characteristics of WTC workers.

Characteristics		Statistics
Age 9/11/2001, median (IQR)		40.50 (34.25–47.50)
Follow-up time, median (years)		11.25 (10.50–12.50)
Sex, *n* (%)	Males	51,565 (84.5)
	Females	9466 (15.5)
Race/ethnicity, *n* (%)	Non-Hispanic White	44,505 (72.9)
	Non-Hispanic Black	6159 (10.1)
	Hispanic	10,367 (17.0)
Smoking status, *n* (%)	Never	36,140 (59.2)
	Ever	23,892 (39.2)
	Unknown	999 (1.6)
Initial arrival to WTC, *n* (%)	9/11/2001	26,120 (42.8)
	9/12/2001 to 6/30/2002	31,434 (51.5)
	Unknown	3477 (5.7)
Worked on pile, *n* (%)	Yes	23,671 (38.8)
Cohort membership, *n* (%)	FDNY	15,989 (26.2)
	GRC	26,612 (43.6)
	WTCHR	18,430 (30.2)

Abbreviations: FDNY, Fire Department of New York; GRC, General Responder Cohort; WTC, World Trade Center; WTCHR, World Trade Center Health Registry.

TABLE 2 Hazard ratio (HR) and 95% confidence intervals (CI) of cancer among Black and Hispanic WTC workers in comparison to Whites; 2002–2015.

Cancer	White[a] *N*	Black *N*	Black HR (95% CI)	Hispanic *N*	Hispanic HR (95% CI)
All cancers combined	3060	415	1.05 (0.95–1.17)	337	0.65 (0.57–0.72)
Stomach	46	≤5	0.78 (0.28–2.18)	9	1.30 (0.63–2.69)
Colorectal	206	16	0.57 (0.33–0.98)	24	0.62 (0.39–0.98)
Liver	35	6	1.40 (0.54–3.61)	18	4.03 (2.23–7.28)
Lung[b]	224	27	0.86 (0.55–1.34)	15	0.41 (0.23–0.72)
Breast (female)	117	27	0.89 (0.57–1.38)	26	0.62 (0.40–0.96)
Prostate	841	195	1.99 (1.69–2.34)	78	0.62 (0.49–0.80)
Kidney	136	19	1.03 (0.61–1.74)	15	0.67 (0.39–1.16)
Bladder	147	10	0.63 (0.33–1.20)	7	0.35 (0.16–0.75)
Thyroid	185	11	0.41 (0.22–0.78)	19	0.42 (0.25–0.69)
Myeloma	38	18	3.57 (1.97–6.45)	7	1.14 (0.50–2.58)

Abbreviations: CI, confidence interval; HR, hazard ratio, adjusted for sex (as appropriate), age, and calendar year; N, number of cancers; WTC, World Trade Center.

[a]Reference category.

[b]HR additionally adjusted for tobacco smoking.

3 | RESULTS

A total of 61,031 WTC workers were included in the study. Most were male (*n* = 51,565, 84.5%) and a majority were non-Hispanic White (*n* = 44,505, 72.9%) with the remainder Hispanic (*n* = 10,367, 17.0%) and non-Hispanic Black (*n* = 6159, 10.1%) (Table 1).

During follow-up, 2857 participants diagnosed with at least 1 cancer were identified (cumulative incidence, 6.4%) in Whites, 394 in Blacks (6.4%), and 327 in Hispanics (3.2%). Details on the number of site-specific cancers by race/ethnicity are reported in Supporting Information: Table 1.

After stratifying the data by sex, findings in males were similar to those of the whole study population. Among White females, breast cancer was the most common type of cancer (2.0%) followed by thyroid (0.6%), and lung cancer (0.5%). A similar pattern was observed for Hispanics and Black female workers.

HR by race/ethnicity are also reported in Table 2. In comparison to White workers, Black workers showed similar incidence of all cancers combined, but Hispanic workers had significantly lower cancer incidence (HR = 0.65, 95% CI = 0.57–0.72). Compared to White workers, Black workers had a higher incidence of prostate cancer (HR = 1.99, 95% CI = 1.69–2.34) and myeloma (HR = 3.57, 95% CI = 1.97–6.45), and lower incidence of thyroid (HR = 0.41, 95% CI = 0.22–0.78) and colorectal cancer (HR = 0.57, 95% CI = 0.33–0.98). Hispanic workers had higher incidence of liver cancer (HR = 4.03, 95% CI = 2.23–7.28), and reduced incidence of prostate (HR = 0.62, 95% CI = 0.49–0.80), lung (HR = 0.41, 95% CI = 0.23–0.72), thyroid (HR = 0.42, 95% CI = 0.25–0.69), breast (HR = 0.62, 95% CI = 0.40–0.96), and bladder (HR = 0.35, 95% CI = 0.16–0.75) cancer (Table 2).

After stratifying by WTC pile work or early arrival at the WTC site, the incidence of prostate cancer remained elevated in Black workers; however, there was no significant difference in all cancer incidence between White and Black workers. The incidence of all cancers combined and prostate cancer was higher in White than among Hispanic workers across categories of working on WTC pile and time of arrival at WTC site (Table 3). As most FDNY cohort members were classified in the high-exposure categories, we repeated the analysis shown in Table 3 excluding the FDNY: the results were similar to those reported in Table 3.

TABLE 3 Hazard ratio (HR) and 95% confidence interval of cancer among Black and Hispanic WTC workers in comparison to White according to WTC pile and early arrival at WTC; 2002–2015.

		White[a]	Black		Hispanic	
WTC pile	Site	*N*	*N*	HR (95% CI)	*N*	HR (95% CI)
Yes	All cancers	1311	84	0.95 (0.76–1.18)	71	0.63 (0.49–0.80)
	Prostate	395	46	1.79 (1.32–2.43)	17	0.59 (0.36–0.95)
No	All cancers	1749	331	1.07 (0.95–1.21)	266	0.64 (0.56–0.74)
	Prostate	446	149	2.13 (1.75–2.59)	61	0.66 (0.50–0.88)
Arrival at WTC						
9/11 to 9/12	All cancers	1845	261	1.00 (0.87–1.14)	176	0.59 (0.50–0.69)
	Prostate	538	123	1.79 (1.47–2.18)	40	0.53 (0.39–0.74)
After 9/12	All cancers	1039	122	1.04 (0.86–1.25)	143	0.72 (0.60–0.85)
	Prostate	254	60	2.29 (1.73–3.04)	32	0.81 (0.56–1.17)

Note: Models control for sex (as appropriate), age, and calendar year.

Abbreviations: CI, confidence interval; HR, hazard ratio, adjusted for sex (as appropriate), age, and calendar year; N, number of cancers; WTC, World Trade Center.

[a]Reference category.

In comparison to the NYS general population, WTC workers had significantly lower incidence of all cancers combined. However, White WTC rescue/recovery workers had higher incidence of prostate cancer (HR = 1.26, 95% CI = 1.18–1.35) and thyroid cancer (HR = 1.80, 95% CI = 1.55–2.08) than NYS Whites, and they had lower incidence of liver (HR = 0.65, 95% CI: 0.45–0.92), bladder cancer (HR = 0.75, 95% CI = 0.63–0.89), and lung cancer (HR = 0.6, 95% CI = 0.52–0.68). Black workers had a higher incidence of prostate cancer (HR = 1.22, 95% CI = 1.05–1.40) and a lower incidence of lung (HR = 0.47, 95% CI = 0.31–0.71), colorectal (HR = 0.37, 95% CI = 0.22–0.62), and liver cancer (HR = 0.35, 95% CI = 0.14–0.84) compared with NYS Blacks. Hispanic workers had a lower incidence of lung cancer (HR = 0.4, 95% CI = 0.23–0.69) and colorectal cancer (HR = 0.53, 95% CI = 0.34–0.81) (Figure 1).

4 | DISCUSSION

In this report, cancer incidence was examined by race/ethnicity in WTC-exposed rescue/recovery workers. Compared with Whites, higher incidence of prostate cancer and myeloma was observed in Black workers and higher incidence of liver cancer was observed in Hispanics. White workers had significantly higher incidence of thyroid cancer compared with Black or Hispanic workers. Differences observed within the cohort of WTC workers reflected those observed in the general population of NYS, thus confirming our original hypothesis. However, the comparison between the cohort and the general population of NYS, after stratification by racial and ethnic group, showed that the increase in prostate cancer incidence was present in both Whites and Blacks, and that the increased incidence of thyroid cancer was restricted to Whites. In addition, the decreased incidence of lung cancer, which has been reported in the cohort as a whole,[9] was present in all three racial and ethnic groups.

For prostate cancer, Black workers had higher rates than Whites, consistent with previous findings in the US population.[18] However, compared to the NYS population, both Black and White WTC workers experienced a higher incidence of prostate cancer. Previous studies confirm the elevated incidence of prostate cancer among the WTC exposed.[2–5,9,19] The increased incidence could be related to carcinogenic exposure resulting from the WTC attack, including possible interaction with genes involved in the metabolism of environmental carcinogens. In addition, enhanced surveillance remains a plausible explanation for the excess of prostate cancer among WTC workers.[20,21] Previous research also has indicated that WTC-related prostate cancer shows a distinct pattern of gene expression that appears to be related to inflammatory and immune responses in prostate tissue.[22] Exposure to endocrine disruptors such as polychlorinated biphenyls found in the WTC buildings could also result in elevated levels of androgens that could be a contributing factor for prostate cancer.[23]

For thyroid cancer, the incidence was found to be higher in WTC Whites compared to the NYS population, consistent with previous findings.[2,3,5] This increase could be due to carcinogenic exposure to smoke or dust at the WTC site. Thyroid cancer is not only associated with radiation but also with environmental exposures such as polychlorinated biphenyls or particulate matter.[24] Moreover, WTC workers experienced more inflammatory diseases and altered inflammatory activities that may be related to increased cancer risk.[25–33] In addition, carcinogens released after the WTC attacks might have contributed to the two- to threefold greater risk of thyroid cancer among WTC-exposed workers compared to the

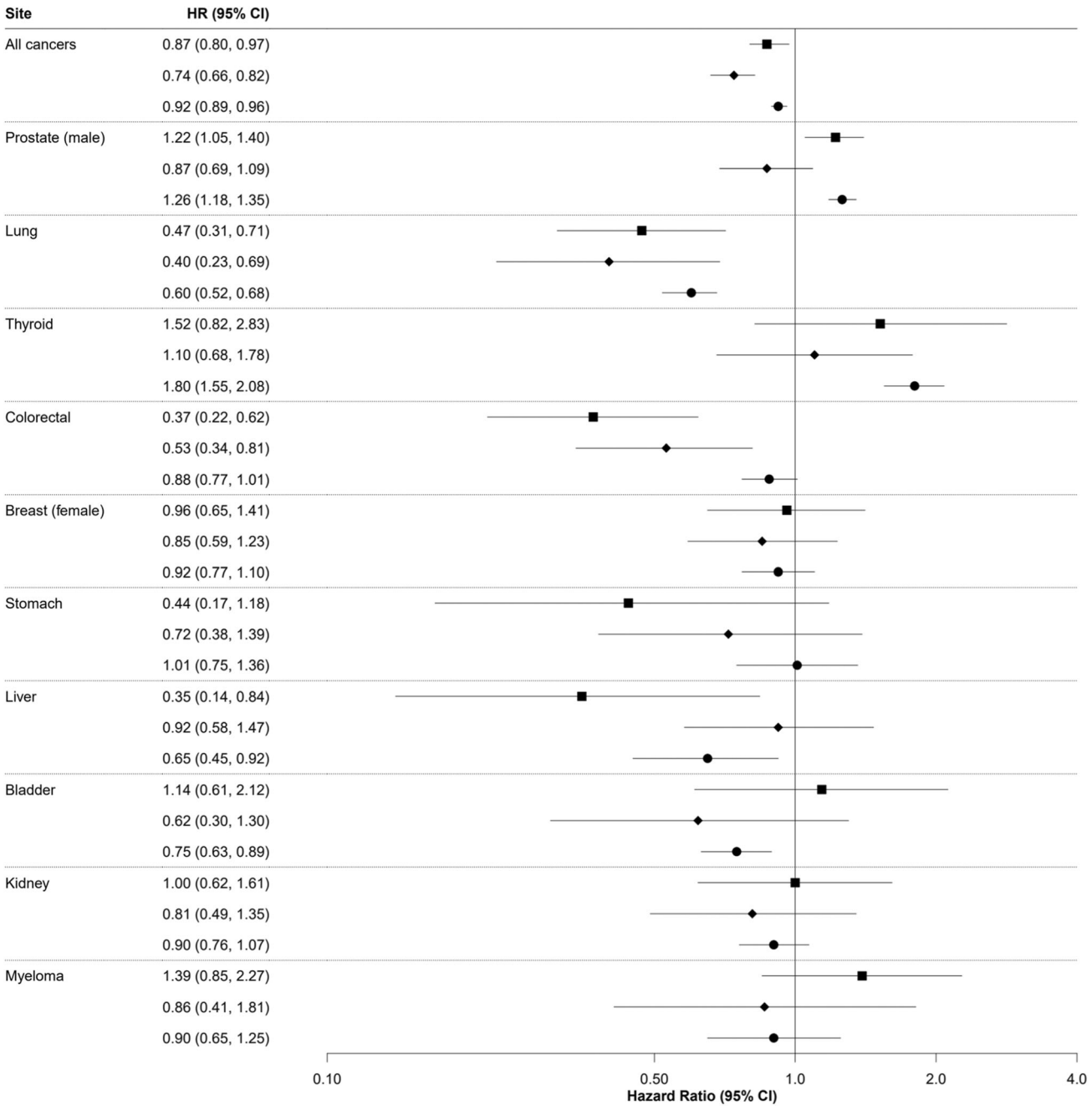

FIGURE 1 Hazard ratio and 95% confidence interval for cancer among WTC workers in comparison to NYS population (referent) based on race and ethnicity; 2002–2015. Square = non-Hispanic Black; Diamond = Hispanic; Circle = White. NYS, New York State; WTC, World Trade Center.

general population [2,14,19,34,35] WTC workers' access to chest imaging via WTCHP screening protocols might also have played a role in increased thyroid cancer diagnosis in WTC responders.[3,5,36–38]

Nationally, the incidence of myeloma is higher in Blacks than their White counterparts according to the SEER program.[39] However, both WTC workers and the NYS population showed equivalent differences in the incidence of myeloma between different racial/ethnic groups. Prior studies on risk of myeloma[3] after the WTC attack have produced inconsistent results, possibly because of the small number of cases of this neoplasm before combining the three cohorts for analyses.[19,40]

The incidence of liver cancer among Hispanic workers was elevated when compared to White workers in this cohort. This may be a general pattern among the NYS population and not specific to WTC exposure, and is consistent with a previous report that shows Hispanics had a higher rate of hepatocellular carcinoma compared with White non-Hispanics.[41]

WTC workers had a lower incidence of all-cancers of lung and colorectal cancer compared to the NYS population. Differences in behavioral factors such as tobacco smoking[42] and physical activity[43] might explain these findings.

This is the first study that compares cancer incidence by race and ethnicity in WTC rescue and recovery workers. However, the study has several limitations. Some potential confounding variables are unknown, such as family history of cancer, diet, and occupational exposures outside of their work at the WTC. Lack of these data on non-WTC exposures cannot be overemphasized, as the main occupational groups in our cohort are police officers, construction workers, and firefighters. Moreover, we did not take socioeconomic status, income, and education into consideration; factors that would be highly related to race/ethnicity. There were inadequate numbers to investigate cancer risk among WTC workers not belonging to the three main race/ethnicity groups we assess here. In addition, we cannot exclude the risk of surveillance bias, since WTC workers have been followed more closely than the NYS population. Finally, we could not fully investigate the role of occupation since we lacked precise dates outlining years of service for much of the population.[26]

In conclusion, trends of cancer incidence among WTC workers reflect in part the characteristics of the NYS general population, but some patterns that diverge from NYS incidence figures, including those for prostate and thyroid cancers, were identified and merit further investigation.

AUTHOR CONTRIBUTIONS

Conceptualization: Malak Khalifeh, David G. Goldfarb, Rachel Zeig-Owens, Charles Hall, and Paolo Boffetta. *Methodology*: David G. Goldfarb, Rachel Zeig-Owens, and Charles Hall. *Software*: David G. Goldfarb, Moshe Z. Shapiro, Madeline Carwile, Christopher R. Dasaro, and Jiehui Li. *Validation*: Rachel Zeig-Owens, Charles Hall, and Paolo Boffetta. *Formal analysis*: Malak Khalifeh, David G. Goldfarb, Moshe Z. Shapiro, Madeline Carwile, Christopher R. Dasaro, and Jiehui Li. *Investigation*: Rachel Zeig-Owens, Andrew C. Todd, Jiehui Li, Janette Yung, Mark R. Farfel, Robert M. Brackbill, James E. Cone, Baozhen Qiao, Maria J. Schymura, David J. Prezant, Charles Hall, and Paolo Boffetta. *Resources*: Andrew C. Todd, James E. Cone, Maria J. Schymura, and David J. Prezant. *Data curation*: Malak Khalifeh, David G. Goldfarb, Rachel Zeig-Owens, Charles Hall, and Paolo Boffetta. *Writing—original draft*: Malak Khalifeh, David G. Goldfarb, and Paolo Boffetta. *Writing—review and editing*: Rachel Zeig-Owens, Andrew C. Todd, Moshe Z. Shapiro, Madeline Carwile, Christopher R. Dasaro, Jiehui Li, Janette Yung, Mark R. Farfel, Robert M. Brackbill, James E. Cone, Baozhen Qiao, Maria J. Schymura, David J. Prezant, and Charles Hall. *Supervision*: Rachel Zeig-Owens, Charles Hall, and Paolo Boffetta. *Project administration*: Rachel Zeig-Owens, Andrew C. Todd, James E. Cone, David J. Prezant, Charles Hall, and Paolo Boffetta. *Funding acquisition*: Charles Hall and Paolo Boffetta.

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CONFLICTS OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

DATA AVAILABILITY STATEMENT

Data are available upon reasonable request from the corresponding author once permission is sought and the request is approved by the Principal Investigators of the original cohorts and the steering committee for the combined cohort in accordance with the official data sharing plan.

ETHICS APPROVAL AND INFORMED CONSENT

This study was approved by the Institutional Review Boards (IRB) of the Albert Einstein College of Medicine, New York City Department of Health and Mental Hygiene, FDNY and New York State Department of Health. IRBs of Icahn School of Medicine at Mount Sinai and Stony Brook University granted exemptions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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