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Mortality in Florida Professional Firefighters, 1972 to 1999

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Background *Exposure to occupational hazards among firefighters may lead to increased mortality from cancer, lung, or heart disease.*

Methods *Age- and gender-adjusted mortality rates of 34,796 male and 2,017 female Florida professional firefighters between 1972 and 1999 were compared with the Florida general population.*

Results *One thousand four hundred eleven male and 38 female firefighter deaths with known causes were identified. In male firefighters, mortality due to all causes and most non-malignant diseases was significantly less than expected. There was no excess overall mortality from cancer, but excesses existed for male breast cancer [standardized mortality ratio (SMR = 7.41; 95% confidence interval (CI): 1.99–18.96) and thyroid cancer (SMR = 4.82; 95% CI: 1.30–12.34)]. Mortality from bladder cancer was increased and approached statistical significance (SMR = 1.79; 95% CI: 0.98–3.00). Firefighters certified between 1972 and 1976 had excess mortality from bladder cancer (SMR = 1.95; 95% CI: 1.04–3.33). Female firefighters had similar morality patterns to Florida women except for atherosclerotic heart disease (SMR = 3.85; 95% CI: 1.66–7.58).*

Conclusions *Excess mortality risk from bladder cancer may be related to occupational exposure during firefighting. The thyroid cancer and breast cancer risk in males, as well as the excess risk of cardiovascular disease mortality noted in females warrant further investigation.* Am. J. Ind. Med. 47:509–517, 2005. © *2005 Wiley-Liss, Inc.*

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INTRODUCTION

Throughout history, fire and its control have been a central issue for human society, particularly in urban communities. An estimated one million persons in the United States are involved in firefighting [National Fire Protection Association, 2002]. The health effects of firefighting have long been a major interest of occupational health researchers since many toxic agents, including a variety of known carcinogens, have been measured at fire scenes [Caux et al., 2002]. It has been postulated that firefighters would demonstrate excess mortality from exposure-related diseases such as cancer, cardiovascular disease, and chronic obstructive pulmonary disease. However, findings of possible occupational associations have been inconsistent [Guidotti, 1995].

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The majority of epidemiological studies have focused on cancer because firefighters are exposed to known or potential carcinogens in the course of their work. Although increased overall cancer risk has not been observed in most studies [Howe and Burch, 1990], considerable epidemiological evidence suggests that firefighters may have excess mortality from leukemia, non-Hodgkin's lymphoma, multiple myeloma, and cancers of the brain and bladder [Golden et al., 1995]. Weaker, but still plausible, evidence links firefighting to increased mortality from melanoma and cancer of the rectum, colon, stomach, prostate, and lung [Golden et al., 1995].

Other studies have examined the mortality of firefighters for cardiovascular disease and chronic pulmonary disease. While Mastromatteo [1959] reported an increased mortality for cardiovascular-renal disease, more recent studies have found significant decreases in heart disease mortality among firefighters in Boston and in Sweden [Musk et al., 1978; Tornling et al., 1994]. Most epidemiological studies do not show an excess mortality risk from chronic obstructive pulmonary disease in firefighters as compared to the general population [Scannell and Balmes, 1995].

This retrospective cohort study was conducted to examine all cause and cause-specific mortality among Florida professional firefighters between 1972 and 1999. The main purpose of this study was to further examine whether firefighting increases cause-specific mortality in the largest cohort of male and female firefighters studied to date, and whether the mortality patterns of Florida firefighters were different from the previous studies.

MATERIALS AND METHODS

Firefighter Cohort

In 1972, the state of Florida began requiring certification for all its professional firefighters. Certification as a qualification for employment entails physical fitness testing, occupational training, and a written exam for competency. The Florida State Fire Marshal's Office provided the investigators with a data file containing the records of 79,733 professional and volunteer firefighters, including 39,455 complete records of certified professional firefighters. For purposes of this study, the certification date was considered the start date of firefighting exposure. Volunteer firefighters were excluded from this study because they did not have the certification data to determine the start date of their firefighting exposure.

Vital Status Determination and Person-Years

Vital status was determined by data linkages with the Office of Vital Statistics of the Florida Department of Health and Florida Department of Highway Safety and Motor Vehicles. The linkage with the Office of Vital Statistics provided date of birth, date of death, gender, cause of death, and other information. A firefighter with a linkage to the Department of Highway Safety and Motor Vehicles database was assumed alive unless there was a definite date of death. Finally, firefighters not linked to either of the above databases were linked with the federal Health Care Finance Administration (HCFA) database. Firefighters found in the HCFA database were considered alive at the end of study unless there was a definite date of death. Firefighters not found in any of these data linkages were declared "lost to follow-up." The underlying causes of death were abstracted from death certificates provided by the Office of Vital Statistics and coded using the International Classification of Diseases, ninth revision (ICD-9).

The certification date was used as the entry point into the study with January 1, 1972 being the earliest possible date; December 31, 1999 was used as the end of the study period. Since there was no information concerning the termination of firefighting, we assumed firefighters were exposed to firefighting from their certification date until they exited from the study. Exit from the study was defined as the date of death based on linkage with the Office of Vital Statistics or HCFA, or the end of the study period, whichever came first.

Statistical Analyses

Standardized mortality ratios (SMRs) were used to evaluate the general and cause-specific mortality risk separately for male and female firefighters. Comparisons were made using corresponding Florida general population rates as references. Separate SMRs were also calculated for firefighters certified between 1972 and 1976 since they had the most time to develop cancer from occupational exposures and represent 74% of all deaths (n = 1,003) and 43% of total person-years (216,539).

Age-adjusted SMRs were calculated according to the method of Breslow and Day [1987] along with their confidence intervals [Checkoway et al., 1989; Kelsey et al., 1996]. The age and calendar year groupings were in 5 year sets, starting in 1972 with age 20. All statistical analyses were performed using SAS version 8.02 [SAS Institute, 1990].

RESULTS

A total of 36,813 (93.3%) out of 39,455 professional firefighters were found in the data linkages; 34,796 men (94.5%) and 2,017 women (5.5%). Certification demographics for the entire cohort and for the firefighters who died are presented in Table I. The mean years certified for the female professional firefighters (mean $\pm$ SD: 8.7 ± 5.7) was significantly shorter than for the men (14.3 ± 8.6, $P < 0.001$).

TABLE I. Age at First Certification and Length of Time Certified in Florida Professional Firefighters

	Total (36,813)	Male (n = 34,796)	Female (n = 2,017)	*t*-test
	Mean ± SD	Mean ± SD	Mean ± SD	*P*-value
Entire cohort				
Age at first certification	27.9 ± 7.0	27.9 ± 7.0	28.1 ± 6.4	0.170
Years certified	14.0 ± 8.6	14.3 ± 8.6	8.7 ± 5.7	0.001
All deaths	n = 1,387	n = 1,349	n = 38	
Age at first certification	37.1 ± 10.7	37.0 ± 10.7	39.5 ± 12.9	0.194
Years certified	15.5 ± 7.5	15.6 ± 7.5	11.3 ± 7.1	0.006
Age at death	52.5 ± 12.7	53.1 ± 15.8	47.7 ± 15.9	0.004

Female professional firefighters who died had a significantly shorter years certified than their male counterparts (11.3 ± 7.1 vs. 15.6 ± 7.5; $P = 0.006$), and died at a significantly younger age (47.7 ± 15.9 vs. 53.1 ± 15.8; $P = 0.004$).

The number of firefighters certified and the mean age at certification by time period and gender are shown in Table II. There were a large number of male firefighters who were certified in 1972 when the certification program first started. Male and female firefighters certified in 1972 were also much older than their counterparts certified in other time period by an average of 8–10 years. The majority of female firefighters were certified after 1985 (78%); less than 3% of female firefighters were certified in 1970s.

SMRs for Overall and Non-Cancer Deaths

Table III summarizes SMRs, adjusted for age and calendar year, for overall mortality and specific non-cancer causes in male and female firefighters, using the Florida general population for comparison. Male professional firefighters were not at elevated risk for any non-cancer cause of mortality and had significantly lower mortality from all causes (SMR = 0.57; 95% CI: 0.54–0.60). For specific non-cancer causes, male firefighters had significantly reduced mortality from infectious diseases, allergic/endocrine diseases, circulatory system diseases, respiratory diseases, digestive diseases, genitourinary diseases, and external causes.

Thirty-eight deaths occurred among female firefighters. Unlike their male colleagues, their mortality from circulatory system diseases was significantly elevated (SMR = 2.49; 95% CI: 1.32–4.25) as was their risk of cardiovascular mortality (SMR = 3.85; 95% CI: 1.66–7.58). Neither the overall mortality, the non-cancer mortality, nor any specific cause of mortality was significantly reduced in female firefighters.

SMRs for Cancer Deaths

The overall and site-specific cancer SMRs for male and female professional firefighters are presented in Table IV. Among male firefighters, 403 deaths (29%) were due to cancer; among female firefighters, 8 deaths (21.1%) were from cancer. Compared to the Florida general population, male professional firefighters exhibited significantly reduced mortality from overall cancer (SMR = 0.85; 95% CI: 0.77–

TABLE II. Number of Florida Firefighters Certified and Mean Age at Certification by Year and Gender

Year certified	Male		Female	
	N (%)	Mean age at certification Mean ± SD	N (%)	Mean age at certification Mean ± SD
1972	5,060 (14.5)	35.5 ± 8.4	41 (2.0)	43.5 ± 8.3
1973–1976	3,958 (11.4)	27.1 ± 6.8	18 (0.9)	27.2 ± 8.7
1977–1980	3,325 (9.6)	26.1 ± 5.9	56 (2.8)	25.9 ± 5.2
1981–1985	4,440 (12.8)	26.6 ± 5.8	261 (12.9)	26.8 ± 5.7
1986–1990	6,083 (17.5)	26.8 ± 5.7	511 (25.3)	27.6 ± 5.5
1991–1995	7,805 (22.4)	26.7 ± 6.0	679 (33.7)	28.2 ± 5.5
1996–1999	4,125 (11.8)	27.0 ± 6.3	451 (22.4)	28.8 ± 6.0

TABLE III. Standardized Mortality Ratio* (SMR) for Overall and Non-Cancer Deaths in Male and Female Florida Professional Firefighters

	Male firefighter			Female firefighter		
Cause of death	**Observed number**	**SMR**	**95% CI**	**Observed number**	**SMR**	**95% CI**
All deaths including cancer	1411	**0.57**	**0.54–0.60**	38	1.24	0.87–1.70
Infectious diseases	38	**0.16**	**0.11–0.22**	1	0.27	0.00–1.52
Tuberculosis	5	1.10	0.35–2.56	0		
Allergic/endocrine	22	**0.35**	**0.22–0.52**	0		
Diabetes	16	**0.45**	**0.26–0.73**	0		
Diseases of Blood	6	0.73	0.27–1.59	0		
Mental	14	**0.41**	**0.22–0.68**	0		
Nervous System	17	**0.54**	**0.31–0.86**	0		
Circulatory system	424	**0.69**	**0.63–0.76**	13	**2.49**	**1.32–4.25**
Cardiovascular	263	**0.73**	**0.65–0.83**	8	**3.85**	**1.66–7.58**
CNS vascular	54	0.80	0.60–1.05	0		
Respiratory diseases	35	**0.50**	**0.35–0.70**	3	2.88	0.58–8.43
Pneumonia	11	**0.34**	**0.17–0.62**	2	4.35	0.49–15.7
Emphysema	9	0.87	0.40–1.66	1	12.5	0.16–69.6
Asthma	0			0		
Digestive diseases	60	**0.57**	**0.43–0.73**	2	1.60	0.18–5.78
Cirrhosis	33	**0.49**	**0.34–0.69**	1	1.43	0.02–7.95
Genitourinary	6	**0.38**	**0.14–0.83**	0		
External causes	285	**0.45**	**0.40–0.50**	9	1.20	0.55–2.28
Accidents	162	**0.48**	**0.41–0.56**	4	0.95	0.26–2.43
Motor vehicle	90	**0.45**	**0.36–0.55**	2	0.68	0.08–2.45
Suicide	83	**0.55**	**0.44–0.68**	4	2.52	0.68–6.44

*The SMRs were adjusted for age and calendar year using mortality data between 1972 and 1999 for Florida men and women ages 20–100 as the reference population; significant findings are in bold.

0.94). However, mortality was significantly increased from male breast cancer (SMR = 7.41; 95% CI: 1.99–18.96) and thyroid cancer (SMR = 4.82; 95% CI: 1.30–12.34). The mortality excess from bladder cancer approached statistical significance (SMR = 1.79; 95% CI: 0.98–3.00). The mortality from lung cancer in professional firefighters was similar to the Florida general population, while mortality from cancer of the buccal cavity/pharynx (SMR = 0.42; 95% CI: 0.17–0.87) and pancreas (SMR = 0.57; 95% CI: 0.29–0.99) were significantly lower. No statistically significant excesses in mortality resulted from brain tumors, prostate cancer, or cancers in other sites.

Among female firefighters there was no significant increase or decrease of overall cancer mortality or of any site-specific cancer including breast and lung.

SMRs in Subgroup of Male Firefighters Certified Between 1972 and 1976

The SMR results for the subgroup with the longest estimated occupational exposure—male firefighters certified between 1972 and 1976 (Table V)—were similar to those obtained for the full cohort. The overall mortality (SMR = 0.68; 95% CI: 0.64–0.73), as well as mortality from the following diseases, were significantly lower among firefighters than among the Florida general population: infectious, allergic/endocrine including diabetes, circulatory system, digestive, respiratory, and mental diseases, and external causes. The mortality results from blood and genitourinary diseases were not significantly different from the Florida general population. No excess mortality was found for any non-cancer cause in this subgroup of firefighters.

Compared to the full cohort, the SMR cancer results for firefighters certified between 1972 and1976 showed that the mortality from overall cancer was no longer significant. The mortality from thyroid cancer approached statistical significance. However, this subgroup had a significant excess mortality from bladder cancer (SMR = 1.95; 95% CI: 1.04–3.33). There were increases in mortality, but not statistically significant ones, from colon and skin cancer, mostly malignant melanoma. The significantly lower mortality from buccal/pharynx cancer was again observed in this subgroup of male professional firefighters (SMR = 0.38; 95% CI:

TABLE IV. SMR* for Cancer Deaths in Male and Female Florida Professional Firefighters

	Male professional firefighter			Female professional firefighter		
Cause of death (cancer site)	**Observed number**	**SMR**	**95% CI**	**Observed number**	**SMR**	**95% CI**
All-sites combined	403	**0.85**	**0.77–0.94**	8	1.03	0.44–2.03
Buccal/pharynx	7	**0.42**	**0.17–0.87**	0		
Digestive	93	0.86	0.70–1.06	1	0.88	0.01–4.92
Esophagus	10	0.65	0.31–1.20	0		
Stomach	12	0.86	0.52–1.42	0		
Colon	38	1.14	0.81–1.56	1	2.27	0.03–12.7
Rectum	7	0.94	0.38–1.93	0		
Liver	10	0.85	0.41–1.56	0		
Pancreas	12	**0.57**	**0.29–0.99**	0		
Respiratory	155	0.88	0.75–1.03	3	2.16	0.43–6.31
Larynx	0			0		
Lung and bronchus	155	0.93	0.79–1.09	3	2.22	0.45–6.49
Bone	1	0.52	0.01–2.91	0		
Skin	17	0.89	0.52–1.42	0		
Bladder	14	**1.79**	**0.98–3.00**	0		
Brain/CNS	13	0.66	0.35–1.13	0		
Thyroid	4	**4.82**	**1.30–12.3**	0		
All lymphopoietic	42	0.77	0.56–1.05	1	1.25	0.02–6.95
Lymphosarcoma	3	0.65	0.13–1.90	0		
Hodgkins	1	0.23	0.00–1.30	0		
Leukemia	14	0.84	0.46–1.42	0		
Prostate	21	1.08	0.67–1.65	n/a		
Breast	4	**7.41**	**1.99–19.0**	1	0.51	0.01–2.82

*The SMRs were adjusted for age and calendar year using mortality data between 1972 and 1999 for Florida men and women ages 20–100 as the reference population; statistically significant findings are in bold.

0.12–0.89). We did not find significant excess or reduced mortality from cancers of the lung, brain, or esophagus.

DISCUSSION

Non-Cancer Mortality

Consistent with the results from other cohort studies [Beaumont et al., 1991; Demers et al., 1992; Guidotti, 1993; Tornling et al., 1994; Baris et al., 2001], we found significant decreases in mortality from infectious, allergic/endocrine, circulatory system, respiratory, digestive, and genitourinary diseases, and from external causes. We did not find an increased mortality from cardiovascular or respiratory disease. The potentially negative health effects of firefighting on the respiratory and cardiovascular system may not appear until late in life, beyond the follow-up time for the relatively young firefighters in our study. Furthermore, the increased use of the self-contained-breathing-apparatus (SCBA) in the last two decades may have helped to protect the firefighters in our study from exposure to carbon monoxide and toxins that cause respiratory diseases.

Cancer Mortality

Firefighters are exposed to many known or suspected carcinogens (e.g., polycyclic aromatic hydrocarbons, benzene) and their risks for certain cancers such as lung and bladder cancer were expected to be increased. However, in the present study, no excess mortality was found for all cancers combined, cancer of the lung, colon, brain, or lymphopoietic tumors.

The ''healthy worker effect'' may help explain these findings. Choi [1992] estimated that the healthy worker effect reduces the overall death rate among workers to about 70%–80% of the rate in a reference general population. The effect may be even larger in firefighters since the firefighting profession demands better fitness than most occupations. In this study, a healthy worker effect stronger than most studies was observed (all cause SMR = 0.57). It should be pointed out that worksite health promotion programs aimed at reducing cardiovascular and cancer risk factors among Florida firefighters have been present in some fire departments since 1984 [Zimmerman et al., 1988], one of the targeted risk factors being obesity [Gerace and George,

TABLE V. SMR* in a Subcohort of Male Florida Professional Firefighters Certified Between 1972 and 1976

	Male professional firefighter		
Cause of death	**Observed number**	**SMR***	**95% CI**
All known causes	1003	**0.68**	**0.64–0.73**
Infectious diseases	18	**0.24**	**0.14–0.37**
Tuberculosis	5	1.60	0.51–3.73
Allergic/endocrine	16	**0.39**	**0.22–0.63**
Diabetes	11	**0.43**	**0.21–0.76**
Diseases of blood	6	1.33	0.48–2.89
Mental	12	**0.56**	**0.29–0.98**
Nervous system	14	0.71	0.39–1.20
Circulatory system	354	**0.73**	**0.66–0.81**
Cardiovascular	222	**0.76**	**0.66–0.86**
CNS vascular	47	0.91	0.67–1.22
Respiratory diseases	31	**0.60**	**0.41–0.86**
Pneumonia	9	**0.41**	**0.19–0.78**
Emphysema	8	0.88	0.38–1.74
Asthma	0		
Digestive diseases	53	**0.71**	**0.53–0.93**
Cirrhosis	29	**0.60**	**0.40–0.86**
Genitourinary	6	0.52	0.19–1.13
External causes	133	**0.51**	**0.43–0.61**
Accidents	73	**0.53**	**0.41–0.66**
Motor vehicle	38	**0.50**	**0.35–0.68**
Suicide	42	**0.64**	**0.46–0.87**
All cancers combined	330	0.89	0.80–1.00
Buccal/pharynx	5	**0.38**	**0.12–0.89**
Digestive	78	0.91	0.72–1.44
Esophagus	7	0.55	0.22–1.14
Stomach	10	0.92	0.68–2.00
Colon	33	1.22	0.84–1.72
Rectum	6	1.04	0.38–2.26
Liver	7	0.83	0.33–1.71
Pancreas	12	0.7	0.36–1.22
Respiratory	134	0.9	0.76–1.07
Larynx	0		
Lung and bronchus	134	0.96	0.80–1.13
Bone	1	1.06	0.01–5.92
Skin	15	1.21	0.68–2.00
Bladder	13	**1.95**	**1.04–3.33**
Brain/CNS	8	0.62	0.27–1.23
Thyroid	3	4.76	0.96–13.9
All lymphopoietic	27	0.76	0.50–1.10
Lymphosarcoma	3	0.94	0.19–2.76
Leukemia	8	0.74	0.3–1.45
Hodgkin's	0		
Prostate	19	1.07	0.3–1.45
Breast	3	6.98	0.65–1.68

*The SMRs were adjusted for age and calendar year using mortality data between 1972 and 1999 for Florida men ages 20–100 as the reference population; statistically significant findings are in bold.

1996]. Moreover, a landmark bill requiring that new fire fighters be non-users of tobacco for at least one year prior to application was passed in the state of Florida in 1989. Since 1990 all incoming firefighters must sign an affidavit stating that they did not use any tobacco product [Gerace, 1990]. These measures could have further contributed to the lowered overall mortality as well as mortality for all-site combined cancer and site-specific cancers in male professional firefighters, and may have contributed to a stronger healthy worker effect.

Consistent with the majority of epidemiological studies of bladder cancer in firefighters [Vena and Fiedler, 1987; Guidotti, 1993], we found increased morality from bladder cancer in male firefighters (entire cohort: SMR = 1.79; 95% CI: 0.98–3.00; certified 1972–1976: SMR = 1.95; 95% CI: 1.04–3.33). This increased risk for bladder cancer does not appear to be due to tobacco smoking because other tobacco-related cancers, such as lung and buccal cavity/pharynx cancer, were not increased.

Many known or suspected human bladder cancer carcinogens such as polycyclic aromatic hydrocarbons and benzene have been found at fire scenes [Caux et al., 2002]. Other occupational chemical exposures known to cause bladder cancer include aromatic amines, solvents, benzidine, coal tars and pitches, and soot and oils [IARC, 1987; Gustavsson et al., 1988; Caux et al., 2002], substances which could be encountered by firefighters, particularly at fires in commercial establishments [Golden et al., 1995]. It is therefore plausible that the increase in this bladder cancer mortality among male firefighters was due to occupational exposures.

Unlike previous studies of male firefighters, we found an increased mortality from thyroid cancer (SMR = 4.82; 95% CI: 1.3–12.3). Epidemiologic evidence on the relation between occupational exposure to ionizing radiation and thyroid cancer has been inconsistent [Boice and Lubin, 1997]. However, Fincham et al. [2000] found an increase in thyroid cancer incidence among medical workers, probably due to low level exposure to radiation. Because only four deaths from thyroid cancer were observed in our study, this finding is tentative and requires further investigation.

Similar to thyroid cancer, there are no obvious occupational exposures to carcinogens for male breast cancer. Male breast cancer is a rare disease, and there are no previous reports on its association with firefighting. Again, our finding was based on only four deaths. The excess could be due to chance or errors in the death certificates, but deserves future exploration.

The present study did not find excess mortality from brain tumors or lung or lymphopoietic cancer that have been documented in some previous mortality studies of firefighters [Vena and Fiedler, 1987; Hansen, 1990; Demers et al., 1992; Ma et al., 1998]. One explanation could be that our study looked at a relatively young cohort with a follow-up period insufficient to allow these cancers to emerge. For example, a

significant increase in lung cancer was only seen in the group aged 60–74 [Hansen, 1990]. We did not observe large differences in SMRs for these cancers between the entire cohort and the cohort of firefighters certified between 1972 and 1976. However, it is worthy noting that the mean age of death in male and female firefighters was 53 years and 48 years, respectively. Even the firefighters certified between 1972 and 1976 were less than 60 years old on average at the end of the study (58.8 ± 9.7). This relatively young cohort has not reached to the age at which most cancers occur. Additionally, our cohort may have benefited from more frequent use of self-contained breathing apparatus compared to firefighters employed before 1950 who were included in most of the previous mortality studies [Vena and Fiedler, 1987; Heyer et al., 1990; Demers et al., 1992; Guidotti, 1993]. Furthermore, Vena and Fiedler [1987] observed that brain tumor was particularly elevated among firefighters hired during the 1940s. Other factors that may contribute to the discrepancy include misclassification bias because of lack of individual exposure data and lack of information on potentially confounding factors such as smoking, diet, and family history of cancer.

Female Firefighters

Our cohort contained a relatively small number of female firefighters. Their SMRs showed a significantly elevated mortality from circulatory system diseases. These findings are different from those found among male firefighters. The differing results might be due to gender differences in the level of occupational exposures (or confounding factors), different responses to certain toxic agents between males and females, or due to chance because of the small sample size. It should also be noted that female firefighters were younger and had a shorter follow-up time compared to the male firefighters.

In recent decades, research on occupational exposures has focused predominantly on men [Pottern et al., 1994], neglecting female workers because of insufficient numbers to provide meaningful results [Arena et al., 1999]. To date, there is no literature on the health effects of firefighting in female firefighters, even though increased risks with selected cancers among female workers have been reported in a number of other professions. For example, leukemia has been reported to be elevated among women employed in health-care professions [Skov et al., 1992; Burnett and Dosemeci, 1994; Linet et al., 1994], and lung cancer elevation has been found among women with potential exposure to asbestos while manufacturing gas masks and textiles [Botta et al., 1991; Rosler et al., 1994].

Some epidemiological data suggest that the potency of certain carcinogens may vary by gender. For example, several studies have found a greater risk of lung cancer in women from tobacco use than men [Brownson et al., 1992; Prescott et al., 1998]. Unfortunately, information on individual firefighting exposure and life style variables (e.g., tobacco use, drinking, physical activities) was not available, precluding our addressing the issue. Gender differences in levels of exposure are also a concern. There are several components to gender-based exposure differences within occupation. These include different assignment of job tasks based on gender, gender-specific approaches to performing the same tasks, and gender differences in the use of protective equipment [Blair et al., 1999]. Healthy worker effect gender differences have also been reported in the literature. Using data from the 1960 and 1970 Swedish censuses, Gridley et al. [1999] found that women employed in both 1960 and 1970 had increased overall cancer incidence; they concluded that there was no general healthy worker effect for cancer incidence among employed Swedish women. Further study of female firefighters is warranted.

Strengths and Limitations

This study is the largest firefighter study to date in terms of the number of firefighters and total person-years of follow-up. It is also the first study to examine the mortality experience in female firefighters.

Despite the strengths of this study, several limitations must be addressed in addition to the healthy worker effect and the relatively short follow-up time vis-à-vis the long latency of most adult cancers. For example, like many previous studies of firefighters, information was not available on specific individual occupational exposure and potential confounders, such as cigarette smoking and family history of cancer. However, in studies of occupation and cancer that have collected information on lifestyle factors among firefighter populations, most associations remained unchanged after controlling for cigarette smoking [Dubrow and Wegman, 1983; Axelson and Steenland, 1988]. The vast majority of studies have found no excess risk of lung cancer [Howe and Burch, 1990]; this agreement of results suggests that firefighters are not more likely to smoke than the general population or other occupational groups. In fact, surveys have found that the proportion of firefighters who smoke is similar to that in other service and ''blue-collar'' workers [Bates, 1987; Sama et al., 1990; Lee et al., 2004]. Moreover, the effects of tobacco use in the study population can be indirectly evaluated by examining other tobacco-associated cancers (e.g., larynx, bladder, cervical). An increase in these cancers is expected if the occupational group under study has a higher level of tobacco use than the general population. As noted, this increase was not found in this cohort of Florida firefighters.

Death certificates were used in this study for cause of death. While the misclassification of cause of death is likely non-differential for firefighters and general population, the observed numbers of deaths due to specific cancers were not

large (e.g., 14 male bladder cancer deaths). Under these conditions even minimal misclassification of cause of death could greatly influence SMR results. The 7% loss to follow-up could have also introduced some bias. Lack of precise exposure information, as is the case in many of the previous firefighter mortality studies, represents perhaps the most important study limitation.

CONCLUSION

In conclusion, this study provides no evidence for increased risks of overall mortality, all cancers combined, cancer of the lung, colon, and brain and lymphopoietic tumors among Florida professional firefighters. However, the significant excess of bladder cancer mortality in male professional firefighters may be related to occupational exposure; the findings on thyroid cancer and male breast cancer as well as the excess risk of cardiovascular disease mortality noted in females warrant further investigation. The presence of carcinogens in the firefighting environment warrants the continued use of protective equipment and further investigation of this population.

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