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Cancer Morbidity of Professional Emergency Responders in Korea

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Background *Many professional emergency responders (ERs) who belong to the Korean National Emergency Management Agency (NEMA) have been cross-trained and serve multiple roles. As such, firefighters and other ERs in Korea are exposed to similar occupational hazards. This study was conducted to estimate cancer morbidity in male ERs and compare that with Korean men.*

Methods *The cohort was comprised of 33,416 male ERs working between 1980 and 2007, who were alive on December 31, 1995. Work histories were merged with the Korea National Central Cancer Registry (KNCCR) to assess cancer morbidity between 1996 and 2007. Standardized incidence ratios (SIRs) with reference to Korean men were analyzed.*

Results *SIRs with reference to national cancer rates were not significantly decreased for overall cancer (SIR = 0.97, 95% CI = 0.90–1.08) in all ERs. However, colorectal (SIR = 1.35, 95% CI = 1.07–1.67), kidney (SIR = 1.59, 95% CI = 1.00–2.41), and bladder (SIR = 1.77, 95% CI = 1.08–2.73) cancer, and non-Hodgkin's lymphoma (SIR = 1.81, 95% CI = 1.12–2.76) morbidities were significantly increased among all ERs. In firefighters, significantly increased cancer types were as same as those of all ERs. In non-firefighter ERs, colorectal (SIR = 2.51, 95% CI = 1.20–4.61) and bone and articular cartilage cancers (SIR = 9.53, 95% CI = 1.07–34.41) were significantly higher than those of Korean men.*

Conclusions *Korean firefighters showed excess morbidity in several cancer types, including colorectal and urologic cancers, and non-Hodgkin's lymphoma, demonstrating similar trends to previous studies for firefighters conducted in other countries. Increased incidence in these cancer types suggests occupational exposure to carcinogens and shift work.* Am. J. Ind. Med. 55:768–778, 2012. © *2012 Wiley Periodicals, Inc.*

KEY WORDS: emergency responders; firefighters; shift work; colorectal cancer; non-Hodgkin's lymphoma; prostate cancer

INTRODUCTION

In Korea, more than 1.5 million emergency responses (50,020 episodes of fire, 1,269,189 emergency medical aid, and 275,662 technical rescues) were provided by professional emergency responders (ERs) of the Korean National Emergency Management Agency (NEMA) in 2008 [NEMA, 2009].

Emergency response, which includes firefighting, is one of the most hazardous jobs. The Korean NEMA reported that 187 professional ERs died and 2,861 received compensation for work-related injuries and illnesses by the Korean Government Employees Pension

Abbreviations: SIR, standardized incidence ratio; SRR, standardized rate ratio; 95% CI, 95% confidence interval; KNCCR, Korea National Central Cancer Registry.

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Service (GEPS) from 1999 to 2008 [NEMA, 2010]. Work-related illnesses recognized by the GEPS include cancer, such as hepatocellular carcinoma, lung cancer, and leukemia. However, decisions on compensation for these cancers by GEPS were not based on exposure to carcinogens during employment, but based on the general working environment, including shift work and fatigue due to long working hours. Until recently, Korean society did not fully appreciate the health hazards faced by ERs, including firefighters. In 2003, the health and safety hazards of ERs were brought to light by the mass media. As a result, the Korean NEMA introduced specialized medical check-up programs for professional ERs in 2004.

No cancer morbidity and mortality studies have been conducted on ERs, including firefighters, in South Korea. Firefighters are exposed to many toxic combustion products, including known carcinogens such as arsenic, asbestos, benzene, benzo[a]pyrene, 1,3-butadiene, cadmium, formaldehyde, and sulphuric acid [IARC, 2010]. Previous studies have reported increases in several cancer types in firefighters compared to the general population [Vena and Fiedler, 1987; Hansen, 1990; Heyer et al., 1990; Beaumont et al., 1991; Demers et al., 1992, 1994; Guidotti, 1993; Tornling et al., 1994; Deschamps et al., 1995; Ma et al., 1998, 2005, 2006; Baris et al., 2001; Bates, 2007; Kang et al., 2008]. Recently, a meta-analysis of studies performed on firefighters and cancer incidence was conducted by the International Agency for Research on Cancer (IARC) Working Group. Their findings suggested that firefighters had a higher risk for non-Hodgkin's lymphoma, and prostate and testicular cancer [IARC, 2010]. Based on these findings, the IARC reclassified the exposure of firefighters to occupational hazards as ''possibly carcinogenic'' to humans (Group 2B) in 2008.

Striking differences in working conditions exist between firefighters and other ERs who provide emergency medical aid and technical rescues. However, many Korean professional ERs who belong to NEMA are cross-trained and serve multiple roles, depending upon the nature of the emergency. The hazards to which ERs are exposed vary with the nature of the emergency. During a fire event, ERs who provide medical aid and technical rescues are also exposed to toxic substances, similar to firefighters. Both non-firefighter ERs and firefighters work in shifts and under intense job stress [Kim et al., 2008; Ahn et al., 2011]. Recently, several studies concluded that shift work increased the risks of breast [Davis et al., 2001; Schernhammer et al., 2001, 2006; Hansen, 2001a,b; Lie et al., 2006], prostate [Band et al., 1996; Pukkala et al., 2002; Kubo et al., 2006; Conlon et al., 2007], and colorectal cancers [Schernhammer et al., 2003]. In summary, ERs, including firefighters, employed by the Korean NEMA, are exposed to similar occupational hazards such as shift work and work-related stress, as well as to chemical and physical hazards.

This study was conducted to investigate the incidence of cancer in Korean ERs employed by the Korean NEMA compared to that of the Korean general population. This study also investigated the association between exposure and cancer morbidity by comparing cancer incidence between firefighters and non-firefighter ERs.

MATERIALS AND METHODS

Cohort Definition and Data Collection

The cohort was comprised of all male professional ERs employed by the Korean NEMA for at least 1 month between January 1, 1980 and December 31, 2007, who were alive on December 31, 1995. The follow-up period encompassed the first day of employment or January 1, 1996, whichever occurred later, until the date of cancer diagnosis, or the date of death or December 31, 2007, whichever occurred first. Female workers were not included, because they comprised less than 5% of the workforce, most of whom were responsible for providing emergency medical aid and were relatively young (<50 years old). Vital status was based on employment and mortality records of the Korea National Statistical Office (NSO). The NEMA provided the workers' names, residence registration numbers (RRNs; a unique 13-digit number assigned to all Koreans), birth dates, dates of hire and termination of employment, and individual work histories. Work history was specified for successive periods at the NEMA and job classification. Nine job titles (firefighting, fire scene investigation, emergency medical aid, technical rescue, driving, piloting a ship, flying, computation and communication, others) were classified into two job categories based on firefighting experience (firefighter vs. non-firefighter). Firefighters included all first-line firefighters (pump, ladder, and operation chiefs) and second-line firefighters (drivers and division chiefs). However, we could not distinguish between the different task assignments. Non-firefighters included emergency medical aid and rescue men, ship and plane operators, ambulance drivers, fire scene investigators, computation and communication administrative staff, and stationary engineers.

Potentially confounding factors, such as smoking, alcohol, and physical exercise, were reviewed from 2000 to 2008 through data obtained from questionnaire surveys conducted by annual medical check-ups. This information was obtained from 33,042 of 33,416 workers in this cohort and compared to that of Korean men in the general population obtained during annual medical check-ups.

Cancer morbidity data were ascertained by the Cancer Registry maintained by the Korea National Cancer Center (KNCC), which has been estimated to have a >95%

ascertainment of cancer morbidity status for the Korean people [KNCCR, 2001]. KNCCR records include the 13-digit RRN, first date of diagnosis, type of cancer (International Classification of Disease [ICD]-10 code), and pathologic findings (M-code: Morphology). Diagnoses were primarily confirmed by pathologic findings at individual hospitals participating in the Cancer Registry and are classified according to the ICD-10. In 2005, among 142,610 malignant cases reported by individual hospitals, 114,944 cases (80.6%) were based on pathologic findings [KNCCR, 2007]. Study subjects were matched to the KNCC database using their RRNs. Follow-up assessments (person-years of observation) began for each worker on January 1, 1996 or the date of hire, whichever occurred later, and ended on December 31, 2007, the date of cancer diagnosis, or the date of death, whichever occurred first.

Statistical Analysis

The standardized incidence ratio (SIR) was calculated using the person-years and Mortality Computation Program (PAMCOMP) [Tornling et al., 1994]. The numerator of the SIR is obtained by summing the number of cancer cases (overall cancer and the type of cancer classified by the ICD-10), which occurred from January 1, 1996 to December 31, 2007, in the cohort across all strata with regard to age, calendar year, and job category. The denominator of the SIR is obtained by multiplying the stratum-specific rates in the Korean men by the corresponding number of person-years in the cohort and then adding the overall strata. In this study, 313,666 person-years of observation were jointly stratified into 10 age groups (20–24, 25–29, 30–34, ..., 65+), three calendar years (1996–1999, 2000–2003, and 2004–2007), and two job categories (firefighter vs. non-firefighter), that is, the SIRs of overall and individual cancers for all ERs were adjusted for age and the calendar year of diagnosis. Classification was based on a 1-year lag for all cancers. Reference cancer morbidity rates for Korean men were derived from data compiled by the KNCC between 1996 and 2007, which was calculated by the 10 age groups (20–24, 25–29, 30–34, ..., 65+) and three calendar years (1996–1999, 2000–2003, and 2004–2007).

The standardized rate ratio (SRR) of cancer incidence was calculated using the log-linear model (Poisson regression model) of the SPSS program. Categorical variables such as age and calendar year of diagnosis were included in the model, meaning that SRRs of overall and individual cancers for firefighters were adjusted for these variables. The SRR represents the ratio of the number of expected cases in the reference population (non-firefighter ERs), based on rates in the exposed group (firefighters), to the number of observed cases in the reference population (non-firefighter ERs). SRRs allow unbiased comparisons across exposure and other descriptive variables.

Ethics Statement

This work was approved by the Institutional Review Board (IRB) of Dongguk University Ilsan Hospital (2009-1-17).

RESULTS

Demographics

The study cohort of 33,416 workers was followed for 313,666 person-years. In all ERs, the mean age in 2007 and at first entry to the NEMA was 41.3 and 27.8 years, respectively. Mean employment duration as ERs was 15.2 years. Active workers by year 2007 comprised 84.6% of the cohort (28,271 workers).

Firefighters constituted 88.1% of the cohort (29,438 workers), and their mean job duration as a firefighter was 12 years (total job duration as ERs was 15.7 years). Firefighters were older (41.8 years old) and contributed to a higher proportion (16.6%) of retired workers compared to ERs who never experienced firefighting.

Non-firefighters comprised 11.9% of the cohort (3,978 workers), and their mean job duration as ERs was 11.5 years. They were younger (37.6 years old) and contributed to a lower proportion (6.3%) of retired workers compared to ERs who experienced firefighting (Table I).

Potentially confounding factors related to cancer morbidity were assessed based on a questionnaire survey administered during regular medical check-ups. The current smoking and overweight rates (BMI $>$ 25) of ERs were 37.6% and 30.6%, respectively, which are lower than those of Korean men in general (smoking rate 41.4% and overweight rate 34.2%). Among ERs, the prevalence of smoking and being overweight were not significantly different across job categories.

SIR With Reference to the General Korean Population

From 1996 to 2007, the number of cancers and number of all deaths were 486 (1.5% of the cohort) and 448 (1.3% of the cohort, including 157 cancer deaths), respectively. There was no follow-up loss. Among the 486 cases, we analyzed the SIRs and SRRs for each type of cancer with at least three cases to maintain the minimum statistical power.

In all ERs, SIRs for colorectal (N = 82, SIR = 1.35, 95% CI = 1.07–1.67), kidney (N = 22, SIR = 1.59, 95% CI = 1.00–2.41), and bladder cancer (N = 20, SIR = 1.77, 95% CI = 1.08–2.73), as well as of non-Hodgkin's

TABLE I. General Characteristic of Emergency Responders

			Experience of firefighting job			
	All emergency responders		Firefighting		Non-firefighting	
	N	%	N	%	N	%
No. of workers	33,416	100.0	29,438	88.1	3,978	11.9
Age in 2007						
20–29	2,538	7.6	1,988	6.8	550	13.8
30–39	13,731	41.1	11,549	39.2	2,182	54.9
40–49	10,972	32.8	10,086	34.3	886	22.3
50–59	4,564	13.7	4,267	14.5	297	7.5
60≤	1,611	4.8	1,548	5.3	63	1.6
Mean ± SD	41.3 ± 9.2		41.8 ± 9.3*		37.6 ± 7.8*	
Year at first employed						
≤1979	3,075	9.2	2,965	10.1	110	2.8
1980–1989	5,705	17.1	5,445	18.5	260	6.5
1990–1999	15,291	45.8	13,402	45.5	1,889	47.5
2000≤	9,345	28.0	7,626	26.9	1,719	43.2
Age at first employed						
<30	25,030	74.9	22,130	75.1	2,900	72.9
30–39	7,917	23.7	6,950	23.6	967	24.3
40≤	469	1.4	358	1.2	111	2.8
Mean ± SD	27.8 ± 3.7		27.8 ± 3.6*		28.2 ± 4.1*	
Duration of employment						
<10 years	10,124	30.3	13,857	47.1	2,017	50.7
10–19 years	14,952	44.7	10,891	37.0	1,671	42.0
≥20 years	8,340	25.0	4,690	15.9	290	7.3
Mean ± SD	15.2 ± 8.3		12.0 ± 8.0[a](15.7 ± 8.4*[,b])		11.5 ± 6.6*	
Employment status						
Active	28,271	84.6	24,543	83.4	3,728	93.7
Retired	5,145	15.4	4,895	16.6	250	6.3

*$P < 0.01$.
[a]Duration of employment as a firefighter.
[b]Duration of employment as ERs.

lymphoma (N = 21, SIR = 1.81, 95% CI = 1.12–2.76), were significantly higher than those of Korean men. There were no significantly decreased cancer types compared to Korean men.

In firefighters, SIRs of colorectal (N = 72, SIR = 1.27, 95% CI = 1.01–1.59), kidney (N = 20, SIR = 1.56, 95% CI = 1.01–2.41), and bladder cancer (N = 17, SIR = 1.60, 95% CI = 1.01–2.56) and non-Hodgkin's lymphoma (N = 18, SIR = 1.69, 95% CI = 1.01–2.67) were significantly higher than those of Korean men; that is, significantly increased cancer types in firefighters were the same as those of all ERs. There were no significantly decreased cancer types in firefighters compared to Korean men.

In non-firefighters, SIRs of colorectal (N = 10, SIR = 2.51, 95% CI = 1.20–4.61) and bone and articular cartilage cancers (N = 2, SIR = 9.53, 95% CI = 1.07–34.41) were significantly higher than those of Korean men. However, bone and articular cartilage cancers comprised just two cases (Table II).

SIR by the Employment Duration

In all ERs, colorectal (N = 77, SIR = 1.35, 95% CI = 1.07–1.69), bone and articular cartilage (N = 6, SIR = 3.10, 95% CI = 1.13–6.75) and bladder cancer (N = 20, SIR = 1.87, 95% CI = 1.14–2.89), and non-Hodgkin's lymphoma (N = 19, SIR = 1.86, 95% CI = 1.12–2.91) morbidities in relation to employment duration were significantly increased at 10 years and beyond. However, SIRs of overall (N = 54, SIR = 1.57, 95% CI = 1.18–2.05), stomach (N = 15, SIR = 1.99,

TABLE II. Cancer Morbidity (SIR) of ERs by Job Duration (Reference: Korean General Population)

	All emergency responders			Firefighters			Non-firefighters		
	<10 years	≥10 years	Total	<10 years	≥10 years	Total	<10 years	≥10 years	Total
Person-years	50,838	262,827	313,666	115,318	166,510	281,829	7,666	24,171	31,837
All cancer (C00-C97)									
N	54	432	486	122	324	446	4	36	40
SIR	1.57	0.94	0.97	1.00	0.96	0.97	0.91	1.26	1.22
95% CI	1.18–2.05	0.85–1.03	0.90–1.08	0.83–1.19	0.86–1.07	0.88–1.06	0.24–2.32	0.89–1.75	0.87–1.66
Parotid gland (C07)									
N	0	3	3	1	2	3	0	0	0
SIR	—	2.47	2.14	2.26	2.38	2.34	—	—	—
95% CI	—	0.50–7.21	0.43–6.24	0.03–12.57	0.27–8.58	0.47–6.83	—	—	—
Esophagus (C15)									
N	0	6	6	0	6	6	0	0	0
SIR	—	0.74	0.72	—	0.94	0.75	—	—	—
95% CI	—	0.27–1.62	0.26–1.56	—	0.34–2.05	0.28–1.64	—	—	—
Stomach (C16)									
N	15	99	114	29	77	106	0	8	8
SIR	1.99	0.87	0.94	0.98	0.92	0.93	—	1.14	1.01
95% CI	1.11–3.27	0.71–1.06	0.77–1.33	0.66–1.41	0.72–1.14	0.76–1.13	—	0.49–2.25	0.44–1.99
Small intestine (C17)									
N	1	4	5	1	4	5	0	0	0
SIR	7.80	1.95	2.29	1.81	2.71	2.46	—	—	
95% CI	0.10–43.38	0.52–4.99	0.74–5.35	0.02–10.09	0.73–6.93	0.79–5.75	—	—	
Colon and rectum (C18–C20)									
N	5	77	82	20	52	72	2	8	10
SIR	1.26	1.35	1.35	1.35	1.25	1.27	3.98	2.30	2.51
95% CI	0.40–2.92	1.07–1.69	1.07–1.67	0.82–2.08	0.95–1.63	1.01–1.59	0.45–14.38	0.99–4.52	1.20–4.61
Liver and intrahepatic bile ducts (C22)									
N	11	64	75	21	53	74	0	1	1
SIR	2.25	0.72	0.80	0.97	0.80	0.84	—	0.19	0.17
95% CI	1.12–4.02	0.55–0.92	0.63–1.00	0.60–1.49	0.60–1.05	0.66–1.06	—	0.00–1.05	0.00–0.94
Gall bladder and external hepatic duct (C23–C24)									
N	0	8	8	2	5	7	0	1	1
SIR	—	0.93	0.89	1.04	0.76	0.82	—	2.18	1.98
95% CI	—	0.40–1.84	0.38–1.75	0.12–3.74	0.25–1.78	0.33–1.70	—	0.03–12.13	0.03–10.99
Pancreas (C25)									
N	2	8	10	4	5	9		1	1
SIR	3.94	0.84	1.00	1.80	0.93	0.95		1.88	1.69
95% CI	0.44–14.23	0.36–1.65	0.48–1.83	0.49–4.62	0.25–2.37	0.44–1.81		0.02–10.48	0.02–9.41
Larynx (C32)									
N	0	3	3	0	3	3	0	0	0
SIR	—	0.56	0.54	—	0.72	0.57	—	—	—
95% CI	—	0.11–1.65	0.11–1.58	—	0.15–2.11	0.11–1.67	—	—	—
Bronchus and lung (C33–C34)									
N	4	35	39	7	29	36	0	3	3
SIR	1.84	0.75	0.80	0.69	0.81	0.78	—	1.26	1.14
95% CI	0.50–4.72	0.53–1.05	0.57–1.08	0.28–1.43	0.54–1.16	0.55–1.09	—	0.25–3.68	0.23–3.34
Bone and articular cartilage (C40–C41)									
N	0	6	6	1	3	4		2	2

(*Continued*)

TABLE II. (*Continued*)

	All emergency responders			Firefighters			Non-firefighters		
	<10 years	≥10 years	Total	<10 years	≥10 years	Total	<10 years	≥10 years	Total
SIR	—	3.10	2.69	1.33	2.37	1.98		11.98	9.53
95% CI	—	1.13–6.75	0.98–5.86	0.02–7.40	0.48–6.92	0.53–5.07	—	1.35–43.26	1.07–34.41
Prostate (C61)									
N	0	11	11	1	8	9	0	2	2
SIR	—	1.60	1.54	0.75	1.47	1.32	—	6.60	6.01
95% CI	—	0.80–2.86	0.77–2.76	0.01–4.16	0.63–2.89	0.60–2.51	—	0.74–23.83	0.68–21.70
Kidney (C64)									
N	3	19	22	6	14	20	0	2	2
SIR	2.49	1.51	1.59	1.62	1.54	1.56	—	2.39	1.99
95% CI	0.50–7.28	0.91–2.35	1.00–2.41	0.59–3.52	0.84–2.58	1.01–2.41	—	0.27–8.61	0.22–7.19
Bladder (C67)									
N	0	20	20	1	16	17		3	3
SIR	—	1.87	1.77	0.39	1.98	1.60		4.91	4.40
95% CI	—	1.14–2.89	1.08–2.73	0.01–2.18	1.13–3.22	1.01–2.56		0.99–14.34	0.88–12.85
Brain (C70–C72)									
N	1	3	4	2	2	4	0	0	0
SIR	0.95	0.42	0.48	0.74	0.42	0.53	—	—	—
95% CI	0.01–5.30	0.08–1.22	0.13–1.24	0.08–2.66	0.05–1.51	0.14–1.36	—	—	—
Thyroid (C73)									
N	4	16	20	9	10	19	0	1	1
SIR	1.17	0.91	0.95	1.21	0.86	1.00	—	0.66	0.50
95% CI	0.31–2.98	0.52–1.47	0.58–1.47	0.55–2.29	0.41–1.59	0.60–1.56	—	0.01–3.70	0.01–2.76
Non-Hodgkin's lymphoma (C82–C85)									
N	2	19	21	6	12	18	1	2	3
SIR	1.41	1.86	1.81	1.68	1.69	1.69	4.78	2.64	3.11
95% CI	0.16–5.08	1.12–2.91	1.12–2.76	0.62–3.67	0.87–2.96	1.01–2.67	0.06–26.61	0.30–9.55	0.62–9.08
Leukemia (C91–C95)									
N	4	10	14	7	6	13	0	1	1
SIR	2.47	0.83	1.03	1.60	0.75	1.05	—	1.03	0.83
95% CI	0.66–6.31	0.40–1.53	0.56–1.73	0.64–3.31	0.27–1.62	0.56–1.79	—	0.01–5.74	0.01–4.64
Lymphohematopoieticca (C81–C96)									
N	6	30	36	13	19	32	1	3	4
SIR	1.92	1.29	1.37	1.59	1.19	1.33	2.22	1.68	1.79
95% CI	0.70–4.19	0.87–1.84	0.96–1.89	0.84–2.71	0.72–1.86	0.91–1.87	0.03–12.33	0.34–4.91	0.48–4.58

N, number of case; SIR, standardized incidence ratio; CI, confidence interval.

95% CI = 1.11–3.27), and liver and intrahepatic bile duct cancers (N = 11, SIR = 2.25, 95% CI = 1.12–4.02) were significantly increased at fewer than 10 years of employment.

Among firefighters, bladder cancer (N = 16, SIR = 1.98, 95% CI = 1.13–3.22) morbidity in relation to employment duration was significantly increased at 10 years and beyond. However, there was no significantly increased cancer at less than 10 years of employment as a firefighter.

In non-firefighters, SIRs of bone and articular cartilage cancers (N = 2, SIR = 11.98, 95% CI = 1.35–43.26) were significantly increased in relation to employment duration at 10 years and beyond. However, there was no significantly increased cancer morbidity at <10 years of employment as ERs (Table II).

SRR of Firefighters Compared to Non-Firefighters

Compared to non-firefighters, firefighters did not show significantly increased or decreased cancer morbidity for overall (N = 446, SRR = 0.83, 95% CI = 0.59–1.16) or any type of cancer. Non-significant increases in cancer morbidity were observed for stomach (N = 106,

SRR = 1.09, 95% CI = 0.53–2.25), liver, and intrahepatic bile duct (N = 74 SRR = 5.10, 95% CI = 0.71–36.85), and thyroid cancers (N = 19, SRR = 2.17, 95% CI = 0.29–16.51), as well as leukemia (N = 13, SRR = 1.68, 95% CI = 0.22–13.06; Table III).

DISCUSSION

Limitations

This cohort, with its short follow-up time, and high proportion of active workers, revealed a large healthy worker effect on cancer morbidity. Eighty-five percent of workers in this cohort were actively employed at the end of their follow-up period (in 2007). As such, the outcomes were highly biased toward good health. In addition, the healthy worker effect might have influenced the mortality and morbidity of ERs, including firefighters, overshadowing the adverse health effects due to occupational hazards. In addition, ERs are required to maintain physical fitness throughout their employment. When we analyzed the medical check-up data of Korean male ERs (20–29 years old) compared to Korean men (KM; 20–29 years old), health status and lifestyle factors of ERs were significantly better than those of Korean men: systolic blood pressure (ER: 120.35 vs. KM: 122.4 mmHg), diastolic blood pressure (ER: 75.3 vs. KM: 76.8 mmHg), fasting blood sugar (ER: 86.6 vs. KM: 89.4 mg/dl), total cholesterol (ER: 174.7 vs. KM: 182.7 mg/dl), being overweight (BMI $\geq$ 25.0; ER: 18.2% vs. KM: 31.6%), and smoking (ER: 48.5% vs. KM: 51.6%) [Ahn et al., 2011]. These findings mean that healthy candidates were selected as ERs (healthy worker selection effect) and the nature of an ER's job might contribute to a good health status. Smoking [Van Duuren, 1968; Wynder and Hoffmann, 1968; Schuman, 1971; Doll and Peto, 1981; Boyle, 1997; Boniol and Autier, 2010; Huang and Chen, 2011] and obesity [Møller et al., 1994; Ballard-Barbash and Swanson, 1996; Galanis et al., 1998; Wolk et al., 2001; IARC, 2002; Calle et al., 2003; Belghiti, 2004; Calle and Kaaks, 2004; Regimbeau et al., 2007; Azagury and Lautz, 2011; Harvey et al., 2011] are well-known risk factors for several kinds of cancer. Thus, it would be reasonable to expect that cancer incidence among ERs would be lower than that of the general Korean population, considering the lower smoking and overweight prevalence of ERs. However, despite a large healthy worker effect and short follow-up period in this study, the SIRs of all cancers in the ERs were similar to those of Korean men. Additionally, the morbidity of several types of cancer in ERs were increased compared to Korean men, signifying that some malignancies may be work-related.

TABLE III. Cancer morbidity (SRR) of Firefighters (Reference: Non-Firefighters)

Type of cancer	N	SRR (95% CI)
All cancer	446	0.83 (0.59–1.16)
Parotid gland	3	—
Esophagus	6	—
Stomach	106	1.09 (0.53–2.25)
Small intestine	5	—
Colon and rectum	72	0.55 (0.26–1.19)
Liver and intrahepatic duct	74	5.10 (0.71–36.85)
Gall bladder and ext. hepatic duct	7	0.48 (0.06–3.94)
Pancreas	9	0.58 (0.07–4.58)
Larynx	3	—
Bronchus and lung	36	0.69 (0.21–2.26)
Bone and articular cartilage	4	0.24 (0.04–1.37)
Prostate	9	0.22 (0.05–1.05)
Kidney	20	0.69 (0.16–2.99)
Bladder	17	0.40 (0.12–1.40)
Brain and central nervous system	4	—
Thyroid	19	2.17 (0.29–16.51)
Non-Hodgkins lymphoma	18	0.52 (0.15–1.78)
Leukemia	13	1.68 (0.22–13.06)
Lymphohematopoietic cancer	32	0.81 (0.28–2.33)

SRR, standardized rate ratio; N, number of cases; CI, confidence interval.

In this study, 88.1% of Korean ERs experienced firefighting due to job rotation even though their primary tasks include emergency medical aid on site and technical rescue. As such, most Korean ERs are exposed to similar occupational hazards, although the exposure intensity differs. It was impossible to quantify individual exposure to carcinogens, such as benzene, formaldehyde, polycyclic aromatic hydrocarbons, and heavy metals, during firefighting. Quantification of exposure was assessed by the frequency of attendance at fire events as recorded by fire logs. However, detailed fire logs were first recorded in 2000 in Korea. In addition, it remains difficult to quantify exposure levels using a fire log alone. Therefore, we classified job duration as a surrogate variable for exposure intensity.

Recently, shift work that involves circadian disruption has been designated as a Group 2A (agents probably carcinogenic to humans) carcinogenic exposure by the IARC [IARC, 2010]. The IARC Working Group concluded that evidence for an association between breast cancer and shift work (involving night work) was consistent in various studies. In addition, increased risk of prostate, colon, and endometrial cancers have been reported in very few studies of shift work [IARC, 2010].

ERs whose job it is to provide emergency medical aid and rescue and others, excluding office administrative staff, employed by the Korean NEMA, are exposed to the same shift work as firefighters.

Low cancer incidence is a major limitation of this study for the analysis of specific exposure categories. The broad grouping of job categories (firefighting vs. non-firefighting) limits the interpretation of the observed associations related to exposure. This limitation exists not only between two different job categories but also within the same job category. Even when classifying firefighters with the same job duration, exposure differed according to the status of respiratory protection, the intermittent nature of exposures and their tasks, and the fact that not all firefighters actually combat fires [IARC, 2010]. In a Montreal study, only 66% of fire department personnel were first-line firefighters (i.e., those who combat fires) [Austin et al., 2001]. Among non-firefighters, men entering the fire scene to save lives may be exposed to more fire smoke than that of second-line firefighters. However, ERs with computation and communication tasks were not exposed to fire smoke. Therefore, the interpretation of this study's results related to smoke exposure requires careful consideration.

Concordance With Previous Studies

In this study, a high proportion (88.1%) of firefighters had similar cancer morbidity to those of other ERs. The presence of statistically different morbidity between all ERs and those of firefighters might be attributed by the statistical number of workers assessed. Therefore, cancer morbidity reported in this study centered around firefighters. There have not been published studies on cancer morbidity of other ERs, such as emergency medical aid and rescue workers, as in this study.

There have been many cancer morbidity and mortality studies among firefighters in the USA and other developed countries. After 1990, three meta-analyses on studies on firefighters and cancer were conducted [Howe and Burch, 1990; LeMasters et al., 2006; IARC, 2010]. The first meta-analysis conducted by Howe and Burch in 1990 examined the extent of cancer risk among firefighters in 11 mortality studies. They found an increased association with brain tumors, malignant melanoma, and multiple myeloma. In our study, only two cases of malignant melanoma and one case of multiple myeloma occurred among firefighters. Therefore, we did not analyze these cancers statistically. The SIR of brain tumor of firefighters (SIR = 0.53, 95% CI = 0.14–1.36) was lower than that of Korean men. The incidence of this type of cancer was very low among the Korean population. Therefore, study cohorts with short follow-up durations, such as this study, could not expect to observe a significant increase or decrease. Further follow-up is needed to identify the relationship between firefighting and rare cancer types.

Another meta-analysis evaluated 32 studies and found that cancer risk was significantly elevated in 10 of 21 cancer types. Four cancer types, testicular and prostate cancer, multiple myeloma, and non-Hodgkin's lymphoma, showed the strongest evidence of association. Eight additional cancer types (i.e., cancers of skin, brain, rectum, buccal cavity and pharynx, stomach, and colon, malignant melanoma, and leukemia) were listed as possibly associated with firefighting [LeMasters et al., 2006].

Our study showed that the SIRs of prostate cancer in all ERs (SIR = 1.54, 95% CI = 0.77–2.76), firefighters (SIR = 1.32, 95% CI = 0.60–2.51), and non-firefighters (SIR = 6.01, 95% CI = 0.68–21.70) were not significantly increased. Compared to non-firefighters, firefighters (SRR = 0.22, 95% CI = 0.05–1.05) showed a non-significant decrease in prostate cancer morbidity. Recently, some studies showed that prostate cancer was related to shift work associated with circadian disruption [Band et al., 1996; Pukkala et al., 2002; Kubo et al., 2006; Conlon et al., 2007]. ERs in Korea have done shift work with 24 hr on and 24 hr off. This work pattern might cause a statistically insignificant increase in prostate cancer among ERs. Non-firefighters, excluding office workers (426 workers, 10.7% of non-firefighters and 1.3% of all ERs), also have shift work responsibilities, which might cause a non-significant increase in prostate cancer compared to Korean men. However, careful interpretation is needed considering non-significant increase in prostate cancer compared to firefighters.

Among chemical carcinogens measured at fires, benzene [Burgess et al., 1979; Brandt-Rauf et al., 1988; Jankovic et al., 1991; Bolstad-Johnson et al., 2000; Austin et al., 2001; Ahn et al., 2011], benzo[a]pyrene [Turkington, 1984; Jankovic et al., 1991; Feunekes et al., 1997; Bolstad-Johnson et al., 2000], 1,3-butadiene [Andreae and Merlet, 2001; Austin et al., 2001], formaldehyde [Lowry et al., 1985; Brandt-Rauf et al., 1988; Bolstad-Johnson et al., 2000; Andreae and Merlet, 2001; Burgess et al., 2001; Ahn et al., 2011], tetrachloroethylene [Brandt-Rauf et al., 1988], and trichloroethylene [Brandt-Rauf et al., 1988] are confirmed or probable carcinogens that cause lymphohematopoietic cancers, such as leukemia and non-Hodgkin's lymphoma. Thus, the increase in the incidence of lymphohematopoietic cancer, especially non-Hodgkin's lymphoma, observed in this study and previous meta-analyses may genuinely be work-related due to exposure to benzene and other chemicals during firefighting.

Among eight possible cancer types associated with firefighting according to a study conducted by LeMasters et al. [2006], our study showed significant increases in colorectal cancers in all ERs (SIR = 1.35, 95% CI = 1.07–1.67), firefighters (SIR = 1.27, 95% CI = 1.01–1.59), and non-firefighters (SIR = 2.51, 95% CI = 1.20–4.61). Comparing to non-firefighters, firefighters (SRR = 0.56, 95% CI = 0.26–1.19) showed a non-significant decrease in colorectal cancer morbidity. Known risk factors of colon

cancer include obesity, high caloric intake, and lack of physical activity. In addition, shift work has been identified as a new risk factor for colorectal cancer [Schernhammer et al., 2003]. Non-firefighters include office workers without shift work responsibilities. However, office workers perform tasks that require much less physical activity than firefighters. Therefore, a significant elevation in colorectal cancer morbidity in non-firefighters, including office workers, compared to Korean men and firefighters must be carefully interpreted, due to the interactions with shift work and relatively low physical activity. Further follow-up and more detailed analyses are needed to elucidate the interactions between physical activity and shift work among ERs.

In addition to the results of the three meta-analyses described above, our study showed significantly increased kidney (SIR = 1.56, 95% CI = 1.01–2.41) and bladder cancer (SIR = 1.60, 95% CI = 1.01–2.56) morbidity in firefighters. Bladder cancer risk in firefighters has been shown to be elevated inconsistently. Some studies have shown significantly increased bladder cancer risk [Vena and Fiedler, 1987; Ma et al., 2005; Ma et al., 2006], but others have not [Giles et al., 1993; Aronson et al., 1994; Demers et al., 1994; Baris et al., 2001]. Emitted chemicals at fires, such as polycyclic aromatic hydrocarbons, particularly benzo[a]pyrene, may cause bladder cancer, and aldehyde may act as a tumor promoter [Hansen, 1991]. Therefore, increased bladder cancer morbidity must be carefully interpreted. Causal relationships between carcinogen exposure during firefighting and bladder cancer should be further investigated. Kidney cancer risk in firefighters also showed inconsistent results. Some studies showed significantly increased risk [Guidotti, 1993; Ma et al., 1998; Baris et al., 2001], but others did not [Giles et al., 1993; Aronson et al., 1994; Demers et al., 1994]. Trichloroethylene emitted at fires [Brandt-Rauf et al., 1988; Austin et al., 2001] may cause renal cell carcinoma. Therefore, renal cell carcinoma among firefighters is worthy of attention.

CONCLUSION

This study investigated cancer morbidity in Korean ERs, including firefighters, and demonstrated the importance of addressing issues of selection, such as healthy worker and survivor effects, and confounding, for analyses of associations between exposure and health effects. This study demonstrated increased cancer morbidity in Korean ERs, but the interpretation of these findings is hampered by the small numbers of cancer cases, healthy worker effects, and limited exposure histories of individual workers, which were assessed using broad job categories but not task assignments. Increases in non-Hodgkin's lymphoma, and kidney and bladder cancers in firefighters must be carefully interpreted within a background of carcinogen exposure during firefighting. In addition, the increased morbidity of colorectal cancer of all ERs related to shift work is worthy of attention. In the future, when more cancer morbidity data become available, the implication of work-related health effects may become much clearer.

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