Occupational Exposures and Symptoms among Firefighters and Police during the Carmel Forest Fire: The Carmel Cohort Study

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ABSTRACT: **Background:** From 2 to 5 December 2010, Israel experienced the most severe forest fire in its history, resulting in the deaths of 44 rescue workers. Little research exists on the health risks to emergency responders during forest fires, and there is no published research to date on occupational health among firefighters in Israel.

Objectives: To describe the exposures experienced by emergency responders to smoke, fire retardants and stress; the utilization of protective equipment; and the frequency of corresponding symptoms during and following the Carmel Forest fire.

Methods: A cohort of 204 firefighters and 68 police who took part in rescue and fire-abating activities during the Carmel Forest fire were recruited from a representative sample of participating stations throughout the country and interviewed regarding their activities during the fire and their coinciding symptoms. Unpaired two-sample *t*-test compared mean exposures and symptom frequency for firefighters and police. Chi-square estimates of OR and 95%CI are provided for odds of reporting symptoms, incurring injury or being hospitalized for various risk factors.

Results: Of the study participants, 87% reported having at least one symptom during rescue work at the Carmel Forest fire, with eye irritation (77%) and fatigue (71%) being the most common. Occupational stress was extremely high during the fire; the average length of time working without rest was 18.4 hours among firefighters.

Conclusions: Firefighters and police were exposed to smoke and occupational stress for prolonged periods during the fire. Further research is needed on the residual health effects from exposure to forest fires among emergency responders, and to identify areas for improvement in health preparedness.

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KEY WORDS: occupational health, forest fire, firefighters, police, Carmel Forest, smoke exposure

From 2 to 5 December 2010, Israel experienced the most severe forest fire in its history. The fires resulted in the deaths of 44 rescue workers and the hospitalization of many more for acute smoke inhalation and traumatic injury. While forest fires are not uncommon in Israel, the intensity and duration of smoke exposure during the Carmel Forest fire was unique for Israeli firefighters. Although the fires have been long extinguished, the initial, continued and delayed health effects on the firefighters and police involved in controlling the fire are unknown.

Forest fire combustion results in a mixture of coarse and fine particulates as well as gases. Although little research exists on the health effects from smoke and fire-retardant inhalation in firefighters following a forest fire, there is a growing body of literature documenting the specific impact of particulate matter on mortality. In a meta-analysis of 13 studies of air pollution and daily mortality, a 100 μg/m^3 increase in total suspended particulates resulted in a relative risk of 1.06 [1]. Mortality rates have been shown to increase by 1.1% to 8.3% for each 50 μg/m^3 increase in particulate concentration less than 10 μm in size (PM10) [2]. The devastating Southeast Asia forest fires in 1997 resulted in an associated daily mortality relative risk of 1.07 in Kuala Lumpur [3]. A study in a large urban area of 2 million people following a 2 day wildfire, however, did not result in a rise in daily mortality [4]. An increased rate in daily hospitalization was associated with particulate matter emitted from fires in the Brazilian Amazon region [5]. Most recently, a study in Athens, Greece, showed no significant increase in mortality following "small forest fires" but a 49.7% increase in mortality following "large forest fires" [6].

Particulates from wild fires may have unique toxicological properties as compared to particulates found in ambient air. Mice exposed to wildfire PM10 showed significant lung damage as measured by histological evaluation of inflamma-

PM = particulate matter

tory cells and total protein content of lung lavage fluid [7]. When compared to concentrated particulates from ambient air, the authors reported particulate matter from wildfires to be tenfold more damaging than normal air. In addition to fine and coarse particulates, firefighters are exposed to carbon monoxide, formaldehyde, acrolein, and benzene [8]. These exposures have been reflected in biomarker studies, demonstrating an increase in urinary methoxyphenols for firefighters after fighting a wildfire [9].

Although a large cohort study of emergency responders exposed to forest fires has not been previously conducted, there are multiple ongoing cohorts of rescue workers from the World Trade Center disaster. This literature has been invaluable in elucidating the acute and chronic health effects subsequent to the smoke exposures on 11 September 2001, including a decline in pulmonary function and increased respiratory symptoms and bronchial hyperactivity in firefighters [10,11]. Additional symptoms such as gastroesophageal reflux disorder and rhinosinusitis remain prevalent 4 years after the exposures [12]. The research undertaken in the World Trade Center cohort illustrates the potential importance of following emergency responders after an acute high exposure event.

SUBJECTS AND METHODS

A cohort of 204 firefighters and 68 police (age 18–65) were recruited from a representative sample of stations throughout the country that participated in emergency response. Active recruitment of the cohort including direct recruitment, advertising and communication with occupational health clinics and municipal departments was conducted in collaboration with fire and police stations throughout the country. All stations that responded to the emergency at the time of the fire were contacted regarding participation in the study. Recruitment of the cohort followed a "community participatory" research model, where a committee of representatives from both the national police headquarters and individual fire stations were involved in planning the study design, development of the study instruments, and recruitment of participants. Pertinent findings have been conveyed to the study participants and to fire and police departments as results became available. Ethics approval of the study design and questionnaires was obtained from the University of Haifa's Faculty of Social Welfare and Health Sciences Ethics Committee.

PRIMARY OUTCOMES

A baseline symptom questionnaire was administered by a single interviewer from April through November 2011. The study questionnaire was compiled through an editorial process utilizing occupational health questionnaires from the U.S. Centers for Disease Control and Prevention as well as questionnaires used in follow-up surveys of firefighters following the World Trade Center attacks. The study instrument was initially pilot-tested on 30 firefighters and subsequently modified based on input from the participants. The study instrument includes demographic variables (age, gender, etc.) as well as questions related to respiratory and cardiovascular symptoms, general symptoms of fatigue and stress, and other symptoms associated with smoke exposure including rhinosinusitis and ocular irritation. Frequency of symptoms was reported for the period during the fire (acute) and continuing beyond 1 week from the last date of the fire (persistent). Questions regarding post-traumatic stress disorder (recurrent dreams, avoidance, sleep disturbance, etc.) were included in the symptom survey. Symptoms were assessed by frequency, both coinciding with the fire and in the subsequent period after the fire. A frequency scale with specific frequency definitions was used.

EXPOSURE ASSESSMENT

Exposure to wildfire smoke, chemical flame retardants and occupational stress were assessed by retrospective recall. Exposure levels were assigned by employing a modified job exposure matrix based on responses from an initial questionnaire dealing with the duration of exposures, times of exposures, severity of exposures, job type, and personal protection equipment used. Occupational stress was quantified by assessing the number of consecutive hours worked, perceived risk to personal safety, level of responsibility, and exposure to specific traumatic episodes.

STATISTICAL ANALYSIS

Descriptive statistics of both symptom frequency and exposure duration are presented for firefighters and police. The unpaired two-sample *t*-test compared mean exposures and symptom frequency for firefighters and police. Two-tailed *P* value of $\alpha = 0.05$ was used for significance. Chi-square estimates of odds ratio and 95% confidence interval are provided for odds of reporting symptoms, incurring injury, or being hospitalized for various risk factors. Analysis was conducted with SPSS 17.0.

RESULTS

A total of 272 subjects were recruited during the study. The participation rate among the firefighters was 86%, as compared to 83% for the police. The most common reason for non-participation was not having time to partake in the study. The average length of the interviews was 14.8 minutes (range 7–30 minutes). The study population was representative of current rescue workers who responded to the Carmel fire, of whom over 30% reported to stations in Haifa and the surrounding area. The demographic attributes of the 204 firefighters and 68 police officers surveyed during the study are presented in Table 1. The mean age of the study population was 36.8 years, 97% were male, 45% are current smokers and 78% reported

Table 1. Demographics of total cohort, frequency and averages for firefighters and police separately

	Total	Firefighters	Police	*P* value
N	272	204 (75%)	68 (25%)	–
Males	265 (97%)	203 (100%)	61 (90%)	‹ 0.01
Mean age (yr)	36.8	36.5	37.7	0.39
BMI (kg/m²)	26.3	26.2	26.5	0.57
Years in occupation	13.3	12.7	14.9	0.17
Ever-smoker	143 (59%)	106 (59%)	37 (58%)	0.88
Current smoker	111 (45%)	81 (45%)	30 (46%)	0.75
Second-hand smoke at work	184 (78%)	136 (77%)	47 (77%)	0.98
Preexisting chronic bronchitis	8 (3%)	7 (4%)	1 (2%)	0.16

Table 2. Exposure characteristics during the fire

	Total	Firefighters	Police	*P* value
Total time working in professional capacity (hr)	32.7	37.2	22.4	‹ 0.01
Total consecutive time working without sleep (hr)	16.3	18.4	11.9	‹ 0.01
Enveloped within smoke	182 (90%)	130 (92%)	52 (85%)	0.22
Total time enveloped within smoke (hr)	14.2	16.4	9.3	‹ 0.01
Within 100 m of smoke	172 (88%)	128 (94%)	44 (73%)	‹ 0.01
Total time within 100 m of smoke (hr)	15.5	20.2	4.9	‹ 0.01
Direct contact with fire retardants	77 (38%)	66 (46%)	11(18%)	‹ 0.01
No. of times directly sprayed by fire retardants	5.3	7.0	1.2	‹ 0.01
Used respirator	139 (68%)	117 (82%)	22 (35%)	‹ 0.01

second-hand smoke exposure at work. There was no significant difference between the two groups in any of the demographic variables reported except for gender, with more female participants among the police than the firefighters ($P < 0.01$).

The frequency and duration of inhalational exposure to smoke and flame retardants is presented [Table 2]. Estimated exposure to smoke, flame retardants, total working time, and consecutive working time without rest was significantly greater ($P < 0.01$) among firefighters than police. During the Carmel Forest fire 82% of firefighters and 35% of police used respirators. N95 respirators was the most common type used: 66% of firefighters and 16% of police used N95 respirators as compared to 15% of firefighters and 0% of police who used full, half-face, or SCBA respirators [Figure 1].

Eighty-seven percent of participants reported having at least one symptom during the rescue work at the Carmel Forest at any point. The most common symptom was eye irritation, with 77% reporting eye irritation at some point during the fire; 71% reported experiencing fatigue, 60% cough, 53% headache, 47% runny nose, 27% shortness of breath, 22% wheezing, and 19% chest pain. The most frequent symptom during the fire was fatigue, with 25% of participants reporting being fatigued "most of the time." Only 9 (4.4%) who directly took park in rescue work during the Carmel Forest fire received medical attention, 4 of whom were hospitalized. Hospital diagnoses included smoke inhalation, epistaxis, exposure to fire retardant, and dislocated shoulder. Twenty-seven percent of participants reported continuation of at least one symptom from the conclusion of the fire until 1 week after the fire. Fatigue and cough were the most common symptoms, with 23% of participants reporting symptoms at least some of the time. The frequency of symptoms experienced both during and after the fire is shown in Table 3. Overall, police reported more symptoms and greater frequency of symptoms than firefighters both during and after the fire. Participants who reported wearing a respirator were more likely to have experienced respiratory symptoms, although not significantly so (OR 0.69, 95%CI 0.37–1.28). When including the covariate smoke exposure into the model, participants who did not wear a respirator had roughly the same risk of coughing

OR = odds ratio
CI = confidence interval

Figure 1. Type of primary respirator utilized by emergency workers during the Carmel Forest fire

Firefighters	26	1	95	13	4	4
Mask type	None	Paper	N95	Half-face	Full-face	SCBA
						
Police	40	7	15	0	0	0

Table 3. Frequency of reported symptoms at the time of the fire and 1 week after the fire

	Total		Firefighters		Police	
	During	After	During	After	During	After
Cough	2.33	1.37	2.28	1.24	2.45	1.68
Wheezing	1.44	1.17	1.41	1.15	1.52	1.22
Shortness of breath	1.53	1.22	1.41	1.18	1.80	1.32
Headache	2.22	1.37	2.01	1.25	2.73	1.64
Burning eyes	3.03	1.24	3.06	1.19	2.93	1.34
Runny nose	2.08	1.24	2.22	1.15	1.75	1.45
Chest pain	1.36	1.17	1.27	1.12	1.55	1.30
Fatigue	2.99	1.46	3.09	1.38	2.77	1.63

Frequency scale: 1.0 = never, 2.0 = infrequently (1–2 days a week), 3.0 = occasionally (3–5 days a week), 4.0 = frequently (6–7 days a week), 5.0 = most of the time (multiple times daily)

(OR 0.99, 95%CI 0.50–1.92) or having respiratory symptoms than those who did wear a respirator.

Two questions regarding perceived risk to personal safety were asked: 57% responded that their personal safety was moderately to severely at risk, and 49% felt at moderate to severe risk of losing their life. Pearson coefficient of numerical response to the two questions was 0.85 ($P < 0.01$), indicating that the two risk estimates were highly correlated. Twenty-five percent (17% of firefighters and 44% of police) reported at least one acute stress-related symptom after the fire, while 10% (6% of firefighters and 21% of police) continue to have persistent difficulty sleeping, recurrent dreams and avoidance.

DISCUSSION

Our findings show that the vast majority of emergency responders, both firefighters and police, at the Carmel Forest fire reported at least one symptom during the fire, while a minority continued to have symptoms more than once a week in the months following the fire. As would be expected, firefighters on average had greater inhalational exposure to smoke and flame retardants during the fire than police. This is due in part to increased total time spent involved in rescue activities: firefighters spent on average 66% more time involved in work activities at the Carmel Forest during the fire. Even after controlling for total time spent in work activities at the Carmel Forest, firefighters had greater inhalational exposure to smoke and flame retardants.

Interestingly, despite the greater exposures among firefighters, police consistently reported greater frequency of symptoms than firefighters. It is unlikely that this is due to differences in baseline health status between police and firefighters, as we did not see significant differences in body mass index, smoking status, age, or preexisting respiratory conditions between the two groups. One possible explanation is the significant lack of utilization of protective respirators among the police when compared to firefighters. Even when we restrict our analysis to participants who had direct contact with smoke, we still see a scarcity of police utilizing proper respiratory protection. The most common reasons for not using a respirator was unavailability (34%) and that the wind was blowing the smoke in the opposite direction (26%).

One possible explanation for the elevated frequency of symptoms among police is recall bias, as police officers due to prior professional experience or training may differentially emphasize certain health outcomes in a retrospective survey. We see a similar pattern in terms of psychological symptoms: police were 3.5 times more likely to report persistent difficulty sleeping, intrusive thoughts and avoidance behaviors ($P < 0.01$). This may be related to the fact that all the emergency workers who died during the fire were police and prison officers. Another possible explanation is simply that firefighters through their professional experience are conditioned to the hazards and exposures that accompany forest fires. High resilience has been associated with relatively fewer psychological symptoms after a traumatic event [13]. It is conceivable that firefighters have developed a higher level of communal resilience specifically when responding to fire-related traumas.

Exposures to occupational stressors – such as risk to personal safety, extended work shifts and prolonged periods without sleep – occurred frequently among the emergency responders surveyed. Our finding of 18.4 hour consecutive work shifts without sleep is consistent with previous reports of wildfire fighting efforts in other countries [14]. Findings from a cross-sectional study of firefighters after the Athens forest fires of 2007 indicate that emergency workers with higher exposures to occupational stress may be at high risk for developing psychological impairment [15]. A positive significant association between occupational psychosocial stressors and subjective symptoms has been documented in other occupational cohorts in Israel [16]. We report a high proportion of participants experiencing PTSD-type symptoms following the Carmel Forest fire. It is unknown how many of the participants have been diagnosed with PTSD by a health professional and what services have been made available to them, highlighting the need for further surveillance in this group.

While symptoms in some workers continue to persist, it is important to note that continued symptoms among participants cannot be directly attributed to exposures in the Carmel Forest fire. This is primarily because all the rescue workers surveyed in this study are actively working and consequently continue to have occupational exposures. This also brings to light a major limitation in the study: findings are selectively biased to a healthy working population. The study cohort is not entirely representative of the base popu-

PTSD = post-traumatic stress disorder

lation of emergency workers who responded to the Carmel Forest fire, since workers who either lost their lives or were significantly injured as a result of their exposures in the fire were not available for recruitment into the study. Our results are likely selectively biased in the downward direction: i.e., reported exposures and symptoms being underestimated.

Interesting in its own right is the demographic and occupational history data of this population. The mean age of both police and firefighters is around 37 years. When compared to the mean age of emergency responders in other countries, this is relatively high [17,18]. The proportion of workers surveyed who currently smoke or have ever smoked is much higher than in the general Israeli population [19], although it is consistent with the rates of smoking among firefighters in Europe [18] and South America [17]. The proportion of participants who reported second-hand smoke exposure at work is also notably higher than other occupations in Israel; however, it is consistent with occupational exposures among police elsewhere [20].

Cohort studies of police and urban firefighters have been conducted in the past, but a prospective cohort of emergency workers involved in forest fires is lacking. Although we present baseline symptom and exposure characteristics of the cohort, continued follow-up will help to elucidate long-term health effects from the Carmel and other forest fires in this population. Relatively little is known about the health status and occupational health programs for firefighters and police in Israel. A survey of Israeli firefighters in 1998 indicated a greater decline in respiratory function and audiometry than in the general population, as well as an elevated risk of exposure to hemotoxic agents [21]. Further work is needed to identify potential areas for improvement in the health and preparedness of Israel's emergency workers, as well as the long-term health effects and pulmonary function.

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"Paraprosdokians" – figures of speech in which the latter part of a sentence or phrase is surprising or unexpected, frequently humorous e.g.,

Where there's a will, I want to be in it

If I agreed with you, we'd both be wrong

War does not determine who is right – only who is left