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Emergency Duties and Deaths from Heart Disease among Firefighters in the United States

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ABSTRACT

BACKGROUND

Heart disease causes 45% of the deaths that occur among U.S. firefighters while they are on duty. We examined duty-specific risks of death from coronary heart disease among on-duty U.S. firefighters from 1994 to 2004.

METHODS

We reviewed summaries provided by the Federal Emergency Management Agency of the deaths of all on-duty firefighters between 1994 and 2004, except for deaths associated with the September 11, 2001, terrorist attacks. Estimates of the proportions of time spent by firefighters each year performing various duties were obtained from a municipal fire department, from 17 large metropolitan fire departments, and from a national database. Odds ratios and 95% confidence intervals for death from coronary heart disease during specific duties were calculated from the ratios of the observed odds to the expected odds, with nonemergency duties as the reference category.

RESULTS

Deaths from coronary heart disease were associated with suppressing a fire (32.1% of all such deaths), responding to an alarm (13.4%), returning from an alarm (17.4%), engaging in physical training (12.5%), responding to nonfire emergencies (9.4%), and performing nonemergency duties (15.4%). As compared with the odds of death from coronary heart disease during nonemergency duties, the odds were 12.1 to 136 times as high during fire suppression, 2.8 to 14.1 times as high during alarm response, 2.2 to 10.5 times as high during alarm return, and 2.9 to 6.6 times as high during physical training. These odds were based on three estimates of the time that firefighters spend on their duties.

CONCLUSIONS

Certain emergency firefighting duties were associated with a risk of death from coronary heart disease that was markedly higher than the risk associated with nonemergency duties. Fire suppression was associated with the highest risk, which was approximately 10 to 100 times as high as that for nonemergency duties.

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Firefighting is known to be a dangerous occupation. What is less appreciated is that the most frequent cause of death among firefighters is heart disease rather than burns or smoke inhalation. Cardiovascular events, largely due to coronary heart disease, account for 45% of deaths among firefighters on duty.[1,2] In contrast, such events account for 22% of deaths among police officers on duty, 11% of deaths among on-duty emergency medical services workers, and 15% of all deaths that occur on the job.[2,3] The high rate of death from cardiovascular causes among firefighters raises questions about contributing factors. Possible factors, such as physical exertion, emergency responses, and dangerous duties, are not unique to firefighting; they are also characteristic of the work performed by police officers, military personnel, and persons in various other occupations.[4,5]

Various biologically plausible explanations for the high mortality from cardiovascular events among firefighters have been proposed. These explanations include smoke and chemical exposure, irregular physical exertion, the handling of heavy equipment and materials, heat stress, shift work, a high prevalence of cardiovascular risk factors, and psychological stressors.[6-13] Given these occupational risks, 37 U.S. states and 2 Canadian provinces provide benefits to firefighters in whom certain cardiovascular diseases have developed.[14] Nevertheless, the evidence linking firefighting to cardiovascular disease continues to be debated.[15-17] Therefore, whether deaths from coronary heart disease among firefighters are truly precipitated by their work and, if so, by which duties, remain important questions.

The findings in our previous case–control study of 52 deaths from coronary heart disease among on-duty firefighters provided preliminary evidence that coronary events may be triggered by specific firefighting duties.[18] First, the circadian pattern of deaths from coronary heart disease paralleled the pattern of emergency-response dispatches. Second, elevated risks of death were associated with fire suppression, alarm response, and physical training. To confirm these findings and further explore duty-specific risk factors for death from coronary heart disease, we conducted a study of all deaths that occurred among on-duty firefighters in the United States between 1994 and 2004.

METHODS

DEATHS AMONG FIREFIGHTERS

The U.S. Fire Administration, a branch of the Federal Emergency Management Agency, collects narrative summaries for all reported deaths associated with firefighting in the United States. From these publicly available summaries, we examined data on all deaths that occurred between January 1, 1994, and December 31, 2004.[2,19] The data included all firefighters who died while on duty, who became ill while on duty and later died, and who died within 24 hours after an emergency response or training. We excluded deaths that occurred during the first 48 hours after the September 11, 2001, terrorist attacks.

To extract study data, two reviewers independently examined the summary of each reported death that occurred while the firefighter was on duty. A third reviewer resolved any classifications that were not concordant between the first two reviewers. On the basis of the narrative reports, each death was classified as due to cardiovascular causes or to noncardiovascular causes. We then excluded those cases in which death occurred more than 24 hours after the on-duty incident or in which death resulted from a cardiovascular problem other than coronary heart disease (e.g., certain arrhythmias, stroke, aneurysm, or genetic cardiomyopathy).

All records of deaths that were classified by this process as being due to coronary heart disease were selected for further study. Data extracted from these records included the firefighter's age, sex, and job status (professional or volunteer); the date, cause, and mechanism of death; and the city and state of the fire department.

DUTIES AT THE TIME OF DEATH

On the basis of the summary report of each death, the deaths were classified according to the specific duty performed during the onset of symptoms or immediately preceding sudden death. These categories were fire suppression; alarm response; alarm return; physical training; emergency medical services, rescues, and other nonfire emergencies; and nonemergency duties. A death was classified as being associated with fire suppression if it occurred while the person was fighting a fire or at the scene of a fire after its suppression. Alarm response involved responses to

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emergency incidents, including false alarms. Alarm return included all events that occurred during the return from incidents and those that occurred within several hours after an emergency call. Physical training included all job-related physical-fitness activities, physical-abilities testing, and simulated or live fire, rescue, emergency, and search drills. We grouped together emergency medical services, rescues, and other nonfire emergencies in a separate category. Finally, we classified all of the following activities as nonemergency duties: administrative and fire-station tasks, fire prevention, inspection, maintenance, meetings, parades, and classroom activities.

TIME SPENT ON SPECIFIC DUTIES

We used data from several sources to estimate the average annual proportion of time that firefighters spend in each category. First, we directly derived point estimates from a municipal fire department (Cambridge Fire Department, Cambridge, MA), using fiscal year 2002 data, as in our previous study.[18] For Cambridge firefighters, the following information was available: the number of firefighters, the total number of alarms and emergency responses, the distribution of emergency calls and dispatches by hour of the day, a breakdown of the types of incidents involved in fire and nonfire emergency responses, the average time spent per incident and the average response time, and the estimated number of hours spent each week in training and fire-prevention activities. We refer to these data as the municipal estimate.

Second, to conduct a sensitivity analysis, we obtained two additional sets of estimates, one representing a level of emergency activity that was higher than that of the Cambridge Fire Department and the other representing a lower level of emergency activity. These estimates were derived with the use of data for the population served, the numbers of uniformed officers, and the number of emergency incidents and the types of incidents classified as fire and nonfire emergencies. To characterize the largest and busiest fire departments, an estimate was developed from 2005 survey data provided by the International Association of Fire Fighters (Moore-Merrell L: personal communication) for 17 large urban and suburban fire departments (the large metropolitan estimate). To represent firefighters in smaller communities with lower levels of emergency activity, an estimate was developed from nationwide National Fire Protection Association surveys conducted from 1994 to 2003 (the national estimate).[20]

STATISTICAL ANALYSIS

We made the initial assumption that if specific firefighting duties do not have a significant effect on the risk of death from coronary heart disease, then the number of such deaths that occur during any given firefighting duty should be directly proportional to the amount of time spent performing that duty. For example, if 10% of a firefighter's time is spent in responding to alarms, 10% of deaths from coronary heart disease should occur during alarm response. We then sought to determine whether this expected pattern is or is not supported by the actual data.

Using the chi-square goodness-of-fit test, we assessed whether the distribution of actual deaths associated with each duty was the same as that of expected deaths, based on the estimates of the average time dedicated to each firefighting duty. We used the three different time estimates (from the municipal, large metropolitan, and national data) to calculate the ratios of actual to expected deaths for each firefighting duty. The 95% confidence intervals (CIs) for these ratios were calculated on the basis of the multinomial distribution. Odds ratios for death from coronary heart disease during specific duties were calculated from the ratios of the observed to expected odds, with nonemergency duties used as the reference category. The 95% CIs for the estimated odds ratios were calculated with the use of the binomial distribution.

Using data from the 2000 firefighters census,[21] which stratifies firefighters according to their age (in decades) and job status (professionals or volunteers), we calculated the rates of death from coronary heart disease for specific duties according to age and job status. Our calculations were based on death counts in each category per 1 million person-years of risk, derived from the average number of firefighters at risk in each subgroup over the 11-year period of observation.

Analyses were performed with the use of SAS software for Windows (version 8.02, SAS Institute), and StatXact (version 6.0). A P value of less than 0.05 was considered to indicate statistical significance, and all statistical tests for differences were two-sided.

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RESULTS

Between January 1, 1994, and December 31, 2004, 1144 firefighter deaths were reported to the U.S. Fire Administration. We classified 449 deaths as due to coronary heart disease (39%). Of these deaths from coronary heart disease, 144 (32%) occurred during fire suppression, 138 (31%) occurred during alarm response or return, and the remaining 167 (37%) occurred during other duties (Table 1).

Table 1. Deaths from Coronary Heart Disease among Firefighters, Classified According to Duty at the Time of Death.*

Duty	Deaths (N=449)
	no. (%)
Fire suppression	144 (32.1)
Alarm response	60 (13.4)
Alarm return	78 (17.4)
Physical training	56 (12.5)
Emergency medical services and other nonfire emergencies	42 (9.4)
Fire-station and other nonemergency duties	69 (15.4)

* Data are based on narrative summaries from the records of the U.S. Fire Administration, Federal Emergency Management Agency, for the period from January 1, 1994, to December 31, 2004.[19]

Table 2 shows the estimated proportion of time that firefighters spent each year in specific duties according to the three sources of fire-department activity data that we used. Among firefighters in Cambridge (our municipal data set), approximately 2% of duty time was spent in fire suppression. Among firefighters in our large metropolitan data set, approximately 5% of duty time was spent in fire suppression. Finally, among all firefighters in the United States (as represented in our national data set), approximately 1% of duty time was spent in fire suppression.

Table 3 shows the frequency of observed deaths from coronary heart disease according to duty as compared with the expected frequency. The observed distribution of deaths was significantly different from the expected distribution based on the estimates from each of the three data sources ($P<0.001$ for the three comparisons). The ratios of observed to expected deaths associated with the various duties of firefighters were consistently higher than 1, with the exception of nonfire emergencies and nonemergency duties. Although 32% of deaths occurred during fire suppression, this activity was estimated to account for as little as 1 to 5% of the average firefighter's professional time per year, so this duty was associated with the most significantly elevated ratios of observed to expected deaths.

Table 2. Fire Service Activity and the Estimated Proportion of Time Spent in Specific Firefighting Duties.*

Variable	Municipal Fire Department	Large Metropolitan Fire Departments	National Data
Fire service activity			
Population served (no.)	101,355	760,935±888,916	280,000,000
Uniformed firefighters (no.)	274	1063±785	1,082,855±14,446
Population served per firefighter (no.)	370	655±218	259±3
Emergency incidents (no./firefighter/yr)	44	92±24	18±2
Fire incidents (no./firefighter/yr)	2.0	7.0±6.3	1.7±0.1
Duties (% of annual time)			
Fire suppression	2	5	1
Alarm response	6	9	4
Alarm return	10	15	7
Physical training	8	8	8
Emergency medical services and other nonfire emergencies	23	34	15
Fire-station and other nonemergency duties	51	29	65

* Plus–minus values are means ±SD. Municipal data are from the Cambridge Fire Department, Cambridge, Massachusetts (2002).[18] Data for large metropolitan fire departments are from surveys of 17 large metropolitan fire departments conducted by the International Association of Fire Fighters (2005) (Moore-Merrell L: personal communication). National data are from annual national surveys conducted by the National Fire Protection Association (1994 through 2003).[20]

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Table 4 includes the odds ratios and 95% CIs for the risk of death from coronary heart disease among firefighters engaged in each emergency duty and physical training as compared with the reference category of nonemergency tasks. On the basis of the three estimates of the time that firefighters spent on particular duties, death from coronary heart disease was 12 to 136 times as likely to occur during fire suppression as during nonemergency duties. An increased risk was also consistently observed for other emergency duties, as compared with nonemergency duties; the risk was increased by a factor of 2.8 to 14.1 during alarm response, 2.2 to 10.5 during alarm return, and 2.9 to 6.6 during physical training.

Figure 1A shows the risk of death from coronary heart disease per 1 million firefighters per year (deaths per 1 million person-years) for each duty according to age group, and Figure 1B shows the risk of death according to job status (volunteer or professional). As might be expected, the risk of coronary heart disease generally increased with age for each type of duty, whereas the results for job status were mixed.

DISCUSSION

In this study, we used data from a nationwide registry of deaths among firefighters over an 11-year period and estimates from three different sources of time spent in various firefighting duties to estimate the duty-specific risks of death from coronary heart disease among firefighters. As compared with nonemergency duties, certain emergency duties and physical training were associated with an increased risk of death from coronary heart disease among firefighters. These findings are consistent with those of our previous, smaller study[18] and with an analysis of cardiac events that led to retirement from firefighting.[22]

Fire suppression, which represents only about 1 to 5% of firefighters' professional time each year, accounted for 32% of deaths from coronary heart disease and was associated with a risk of death from coronary heart disease that was approximately 10 to 100 times as high as the risk associated with nonemergency duties. We think that the most likely explanation for these findings is the increased cardiovascular demand of fire suppression.[8,11]

The risk of coronary heart disease events during fire suppression may be increased because

Table 3. Observed and Expected Distributions of Deaths from Coronary Heart Disease among On-Duty Firefighters, According to Duties.*

Duty	Observed Deaths (N=449)	Expected Deaths					
		Municipal Fire Department		Large Metropolitan Fire Departments		National Data	
		Expected Deaths (N=449)	Observed:Expected Deaths	Expected Deaths (N=449)	Observed:Expected Deaths	Expected Deaths (N=449)	Observed:Expected Deaths
	no. (%)	*no. (%)*	*ratio (95% CI)*	*no. (%)*	*ratio (95% CI)*	*no. (%)*	*ratio (95% CI)*
Fire suppression	144 (32.1)	9.0 (2)	16.0 (13.2–19.1)	22.4 (5)	6.4 (5.3–7.6)	4.5 (1)	32.1 (26.4–38.1)
Alarm response	60 (13.4)	26.9 (6)	2.2 (1.6–3.0)	40.4 (9)	1.5 (1.1–2.0)	18.0 (4)	3.3 (2.4–4.5)
Alarm return	78 (17.4)	44.9 (10)	1.7 (1.3–2.2)	67.4 (15)	1.2 (0.9–1.5)	31.4 (7)	2.5 (1.8–3.2)
Physical training	56 (12.5)	35.9 (8)	1.6 (1.1–2.1)	35.9 (8)	1.6 (1.1–2.1)	35.9 (8)	1.6 (1.1–2.1)
Emergency medical services and other nonfire emergencies	42 (9.4)	103.3 (23)	0.4 (0.3–0.6)	152.7 (34)	0.3 (0.2–0.4)	67.4 (15)	0.6 (0.4–0.9)
Fire-station and other nonemergency duties	69 (15.4)	229.0 (51)	0.3 (0.2–0.4)	130.2 (29)	0.5 (0.4–0.7)	291.8 (65)	0.2 (0.2–0.3)

* Municipal data are from the Cambridge Fire Department, Cambridge, Massachusetts (2002).[18] Data for large metropolitan fire departments are from surveys of 17 large metropolitan fire departments conducted by the International Association of Fire Fighters (2005) (Moore-Merrell L.: personal communication). National data are from annual national surveys conducted by the National Fire Protection Association (1994 through 2003).[20]

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Table 4. Risk of Death from Coronary Heart Disease among Firefighters Engaged in Emergency Duties and Physical Training as Compared with Firefighters Engaged in Nonemergency Duties.*

Duty	Municipal Fire Department		Large Metropolitan Fire Departments		National Data	
	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value
Fire suppression	53 (40–72)	<0.001	12.1 (9.0–16.4)	<0.001	136 (101–183)	<0.001
Alarm response	7.4 (5.1–11)	<0.001	2.8 (1.9–4.0)	<0.001	14.1 (9.8–20.3)	<0.001
Alarm return	5.8 (4.1–8.1)	<0.001	2.2 (1.6–3.1)	<0.001	10.5 (7.5–14.7)	<0.001
Emergency medical services and other nonfire emergencies	1.3 (0.9–2.0)	0.16	0.5 (0.3–0.8)	<0.001	2.6 (1.8–3.9)	<0.001
Physical training	5.2 (3.6–7.5)	<0.001	2.9 (2.0–4.2)	<0.001	6.6 (4.6–9.5)	<0.001
Nonemergency duties (fire station and other)	1.0		1.0		1.0	

* Municipal data are from the Cambridge Fire Department, Cambridge, Massachusetts (2002).[18] Data for large metropolitan fire departments are from surveys of 17 large metropolitan fire departments conducted by the International Association of Fire Fighters (2005) (Moore-Merrell L.: personal communication). National data are from annual national surveys conducted by the National Fire Protection Association (1994 through 2003).[20]

many firefighters lack adequate physical fitness, have underlying cardiovascular risk factors, and have subclinical or clinical coronary heart disease. Even new firefighter recruits may be overweight and have low-to-normal aerobic capacities.[23] Such problems are compounded during career tenure because more than 70% of fire departments lack programs to promote fitness and health.[1] Most fire departments do not require firefighters to exercise regularly, undergo periodic medical examinations, or have mandatory return-to-work evaluations after a major illness. In addition, several studies have shown the high prevalence of risk factors for cardiovascular disease among firefighters[24-29] as well as lower-than-expected exercise tolerance.[30,31] Moreover, two studies have shown that among firefighters who had fatal events[18] or nonfatal events[22] related to coronary heart disease while on duty, 26% and 18%, respectively, had previously received a diagnosis of coronary heart disease, peripheral vascular disease, or cerebrovascular disease, and among the remainder, smoking, hypertension, and diabetes mellitus were significantly more prevalent than among active firefighters in the control group. Likewise, in our study, the risk of death from coronary heart disease increased with age for all types of duty. Unexpectedly, professional and volunteer firefighters had different risks of death from coronary heart disease, depending on the type of duty performed, although for both groups, the risk was highest during fire suppression.

In parallel with our finding of a significantly increased risk of death from coronary heart disease during fire suppression, as compared with nonemergency duties, the risk was significantly elevated during physical training. This finding is consistent with investigations implicating intense physical activity as a strong triggering factor, especially among physically inactive persons.[32-35] Also consistent with the triggering hypothesis and with research documenting increased heart rates among firefighters responding to alarms[8,9] was our finding that the risk of death from coronary heart disease associated with alarm response and alarm return was approximately five to seven times as high as that associated with nonemergency duties. Emergency medical services and other nonfire emergency responses were not associated with a significant increase in risk. These findings are consistent with the much lower proportion of deaths from coronary heart disease among emergency medical services workers who are not firefighters[3] than among firefighters, and may reflect a lower level of exposure to physically demanding emergencies.

One limitation of our study is that the estimates of odds ratios for specific job duties are based on fairly wide approximations of time spent on different duties. The average work year of a professional firefighter in a major urban center is probably much different from that of a rural volunteer firefighter. In addition, there have been few if any comprehensive studies of how fire-

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fighters spend their time. Our estimate of the increase in risk is therefore subject to considerable uncertainty. However, even in the most conservative scenario (with the use of the time estimates from the large metropolitan fire departments), the risks associated with fire suppression remained remarkably high and were also significantly increased for alarm response, alarm return, and physical training.

Also, our three sets of risk estimates are not based on three completely distinct calculations. In each case, one set of national figures for "observed" deaths was used, and the resulting odds ratios represent risk relative to nonemergency duties, not absolute risks for one group of firefighters as compared with another. Our results should therefore not be used to suggest that the risk of death from coronary heart disease during fire suppression is higher in a small community fire department than in a large metropolitan fire department. Instead, the three calculations provide a range of estimates of the average risk for firefighters nationwide. Because only 14% of firefighters in the United States serve populations larger than 100,000 residents,[21] we think that the average risk for most firefighters probably falls between the risk based on estimates of time spent in particular duties that were derived from a single municipal fire department and the risk based on the nationwide time estimates. Our estimate that fire suppression accounts for 1 to 2% of annual work time (for the nationwide and municipal scenarios, respectively) is consistent with a study of a large fire department in Montreal,[36] where fire suppression accounted for 0.7 to 2.5% of annual work time.

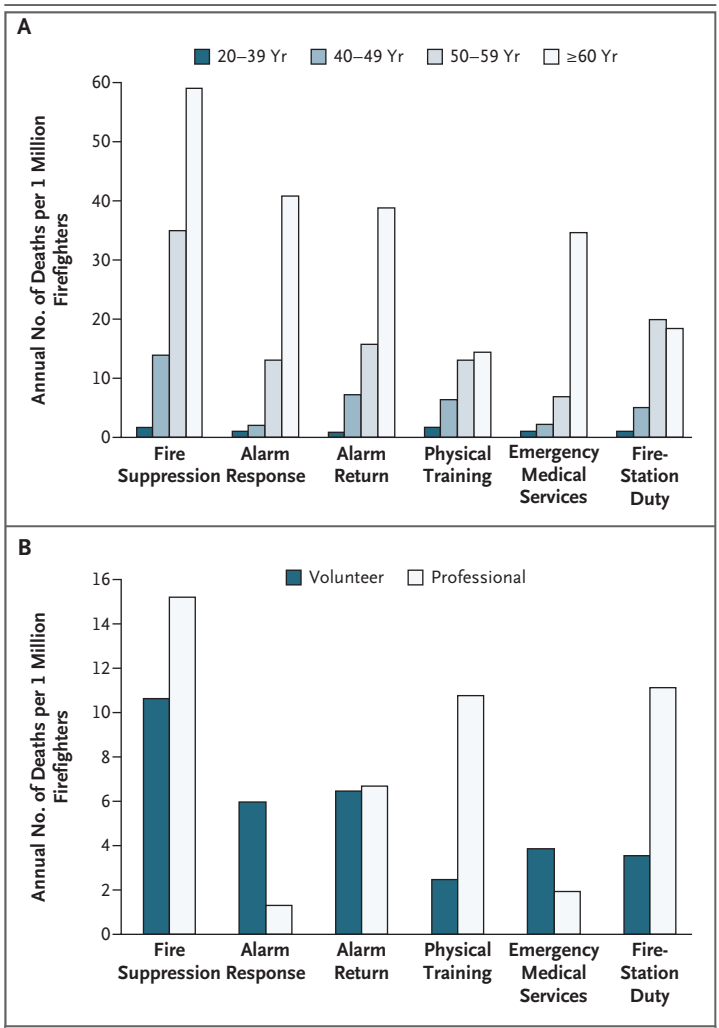

Figure 1. Duty-Specific Annual Risk of Death from Coronary Heart Disease among Firefighters, According to Age (Panel A) and Job Status (Panel B).

A second limitation of our study was the need to base our evaluation on brief narratives, which lacked autopsy information for some of the deaths. However, the misclassification of deaths due to inadequate information would have contributed to a random error, most likely diluting the results of our study toward the null hypothesis. Although 26 deaths from cardiovascular but not coronary heart disease were excluded, this small number was unlikely to bias the overall results in a specific direction.

A third limitation of our analysis was the starting assumption that the number of deaths from coronary heart disease that occur during any given firefighting duty should be directly proportional to the amount of time spent performing that duty. It is well established, for example, that the risk of coronary heart disease events varies according to the time of day,[37] as well as the season of the year.[38] In this study, we could not examine the circadian pattern of deaths. However, in our previous, smaller study[18] and in another, 10-year analysis,[2] 67 to 77% of deaths from cardiac causes among on-duty firefighters occurred between noon and midnight, as did more than 60% of emergency responses. This pattern is in stark contrast to the peak period for cardiovascular events in the general population, which is 6 a.m. to noon. With respect to season, deaths from cardiac causes among firefighters are most frequent in the winter, as they are in the general population. When we analyzed duty-specific risks

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separately for each of the four seasons, however, the resulting point estimates for each duty remained similar in magnitude and close to the range of our original confidence intervals. Finally, although we cannot completely account for the effects of the time of day and season, the highest estimates of these effects on event rates are at least an order of magnitude smaller than the relative risks we observed for specific duties.

In conclusion, we analyzed nationwide data on deaths among firefighters, as well as three separate estimates of time spent in various firefighting duties, to determine the duty-specific risks of death from coronary heart disease among firefighters. Our analysis showed that specific duties, especially fire suppression but also alarm response, alarm return, and physical training, are associated with significant increases in risk.

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Dr. Kales and Dr. Christiani report serving as paid expert witnesses, independent medical examiners, or both in workers' compensation and disability cases, including cases involving firefighters. No other potential conflict of interest relevant to this article was reported.

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