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Effects of Emergency Duties on Cardiovascular Diseases in Firefighters

A 13-Year Retrospective Cohort Study

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Objectives: This study aimed to examine the effects of firefighters' emergency duties on the incidence of cardiovascular disease (CVD). **Methods:** We used a 13-year follow-up in a nationwide retrospective cohort study. A total of 363,137 employees were recruited. The sex-and age-specific incidence of CVD (hypertension, angina pectoris, and acutemyocardial infarction [AMI]) in firefighters and public officials was estimated. **Results:** The overall age-specific sex-based incidence of CVD, except for hypertension, was higher in firefighters than in public officials. The age-stratified hazard ratios for the three types of CVD in male firefighters were also higher. AMI was more common in younger firefighters, whereas angina pectoris and hypertension were common in older firefighters. **Conclusions:** Firefighters' duties are more likely to increase the risk of CVD, and preventive strategies with proven benefits are required.

Keywords: cardiovascular disease, emergency duty, firefighter, hazard ratio, incidence rate, retrospective study

Firefighting is a highly hazardous and dangerous job, and firefighters' duties are at times extremely physically and mentally demanding. Firefighters are often exposed to dangerous environments, emergency situations, and irregular working hours because of the nature of their work. Their job involves heavy lifting and working in sometimes unstable positions while wearing clothing and protective devices in a hot environment and during emergency situations.[1] Firefighters are also exposed to hazardous chemicals as well as thermal and psychological stress.[2] Shiftwork, which may also increase the risk of coronary heart disease (CHD),[3,4] together with psychological stressors in an increasing number of emergency situations (ie, fires, natural disasters, traffic accidents, and emergent medical services) also contribute to the hazards experienced by firefighters.[5,6] Soteriades et al[7] reported that inadequate physical activity, unhealthy dietary habits, and shiftwork are the main occupational stressors of firefighters. In addition, emotional labor, which is recognized as a newly emergent job stressor in service workers, may increase occupational stress among firefighters. Most firefighters experience emotional dissonance and emotional conflict with customers while performing online duties. Recent studies have documented that these conflicts and emotional damage are related to burnout,[8,9] turnover intention,[10] posttraumatic stress disorder (PTSD) symptoms,[11] and suicidal ideation[12] in firefighters.

Occupational stress related to online duty may increase the risk of cardiovascular events in firefighters. The hazardous occupational factors of firefighters could cause physiological appraisals and lead to the precipitation of cardiovascular events. Long sedentary work followed by strenuous physical exertion[13] and immediate reaction to frequent alarms or calls increases the pulse rate.[14,15] During fire suppression, firefighters work at maximal heart rates while wearing approximately 50 pounds of protective equipment, sometimes for prolonged periods.[16,17] Heat stress and dehydration due to fluid loss can decrease the cardiac output despite sustained tachycardia.[18] Exposure to certain chemicals, including carbon monoxide, particulates, and other toxicants,[19] and intermittent exposure to noise[20,21] may increase blood pressure. Sympathetic activation from the initial alarm, physical workload, heat exposure, and dehydration are important stressors. Smith et al[19] reported that for every duty-related sudden cardiac death (SCD), nearly 17 nonfatal events occur, including acute myocardial infarction (AMI) or stroke. In their study, 38% of the firefighters were prehypertensive and 40% were hypertensive. A recent study by Martin et al22 found a surprisingly high prevalence of cardiovascular disease (CVD) risk factors among firefighters. Approximately 68% of the firefighters had two or more risk factors, such as smoking, hypertension, obesity, hypercholesterolemia, and sedentarism. This notable finding suggests that many firefighters may have multiple CVD risk factors and poor physical fitness.

Firefighters have a higher risk of illness and death due to cardiovascular events during periods of intense physical and emotional stress at work.[23,24] However, previous mortality studies, some of which have shown evidence of an increased risk of some cancer types and nonmalignant respiratory diseases, have not shown consistent evidence supporting the increased risk of death from CVD.[25,26] Firefighters are generally healthy as they enter the workplace, but they do not necessarily maintain that attribute over time. This means that firefighter duties may be associated with CVD risk. Unfortunately, little is known about the relationship between firefighter duties and CVD.

This study aimed to examine the relationship between firefighter emergency duties and CVD.

METHODS

Study Design, Participants, and Data

We estimated the age-specific incidence rate of CVD among firefighters and public officials, and compared the firefighters'

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Conflict of Interest: None declared.

Ethics Consideration: This study was approved by the Institutional Review Board of Yonsei University for protecting the rights and privacy of the participants (approval no. CR318335) and was conducted in accordance with the World Medical Association Declaration of Helsinki.

Clinical significance: We found that younger firefighters aged 20 to 39 years showed higher HRs for AMI in both sexes than public officials. The magnitude of the HRs for AMI was higher in women than in men. Firefighters' emergency duties together with their occupational stressors may play a significant role in the development of CVD.

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TABLE 1. Distribution of Study Participants and Person-Years

Occupation	*N* (%)	Person-Years
Firefighter	24,493 (6.7)	321,920
Public official	338,644 (93.3)	4,138,666
Total	363,137 (100)	4,460,586

age-stratified hazard ratios (HRs) with those of public officials in a Korean sample using a 13-year follow-up in a nationwide retrospective cohort study. Firefighters and public officials were recruited from a Korean nationwide sample. Public officials who were selected as the control group were employees who handled administrative work of the national and regional governments. We analyzed claims data from the National Health Insurance Service between 2002 and 2014. The dataset was constructed to perform the FRESH Study, which aimed to promote the physical and mental health of firefighters using a lifetime health risk management system from 2015 to 2019.

Measures

The sex- and age-specific CVD incidence of firefighters and public officials was estimated by calculating the incidence cases per 100,000 person-years. The age-specific incidence of the three CVD types by sex was estimated using person-years. We calculated person-years as the time after the 1-year washout period, from January 1, 2003, to the onset of the CVD event.

In this study, we included three types of CVD: hypertension (I10, I11, I12, I13, and I15), angina pectoris (I20.0, I20.1, I20.8, and I20.9), and acute myocardial infarction (AMI) (I21.0, I21.1, I21.2, I21.3, I21.4, and I21.9) according to the International Classification of Diseases, tenth revision (ICD-10). The main diagnosis code (ICD-10) and the 1st to 4th sub-diagnosis codes in both inpatient and outpatient records were used to define CVD cases.

Statistical Analysis

Cox proportional hazard regression analysis was used to assess the HRs and 95% confidence intervals (95% CIs) for CVD between firefighters and public officials. All statistical analyses were performed using SPSS (Ver. 23) (IBM SPSS Statistics, New York, NY), and a P-value of<0.05, was considered significant.

RESULTS

A total of 363,137 participants (24,493 firefighters and 338,644 public officials) were included in this study. Their mean ages (standard deviation) were 39.55 and 9.06 years, respectively. The person-years of the participants were 321,920 for firefighters and 4,138,666 for public officials (Table 1).

Of the three types of CVD, the age-specific incidence of AMI was higher in firefighters than in public officials, and the trend increased with age in both sexes. The age-specific incidence of angina pectoris was higher in firefighters aged 40 to 49 and more than 50 years in men, and aged 20 to 29 and 40 to 49 years in women, than in public officials. The age-specific incidence of hypertension was higher in firefighters aged more than 50 years in men, and aged 20 to 29 and 40 to 49 years in women, than in public officials (Table 2).

According to the results of the Cox proportional hazard regression analyses, firefighters were more likely to develop CVD than public officials. Age-stratified HRs of the three types of CVD in firefighters were higher than those in public officials. AMI was more common in younger firefighters, whereas angina pectoris and hypertension were more common in older firefighters. Younger firefighters aged 20 to 39 years showed higher HRs for the three types of CVD than public officials in both sexes, and the HRs for the three types of CVD were higher in female firefighters than in male firefighters. The age-stratified HRs for AMI, angina pectoris (more than 40 years), and hypertension (more than 50 years) in male firefighters were higher than those in public officials, also, the age-stratified HRs for AMI (less than 40 years) and hypertension (20 to 29 and 40 to 49 years) in female firefighters were higher than those in public officials. AMI was more common in younger firefighters (HR: 2.267, 95% CI; 1.532 to 3.335 for 29 to 29 years, HR: 1.426 95% CI: 1.217 to 1.670 for 30 to 39 years, HR: 1.530, 95% CI: 1.328 to 1.762 for 40 to 49 years, and HR: 1.510, 95% CI: 1.200 to 1.902 for more than 50 years in men; HR: 4.745, 95% CI: 2.514 to 8.956 for 29 to 29 years, HR: 3.225, 95% CI: 1.819 to 5.719 for 30 to 39 years, HR: 2.066, 95% CI: 0.857 to 4.979 for 40 to 49 years, and HR: 1.461, 95% CI: 0.364 to 5.869 for more than 50 years in women) in both sexes. Hypertension was more common in older firefighters (40 to 49 years) in both sexes and in women; angina pectoris was more common in men (Table 3).

DISCUSSION

The overall age-specific sex-based incidence of CVD, with the exception of hypertension, was higher in firefighters than in the control group of public officials, especially in male firefighters. The age-stratified HRs of the three types of CVD in male firefighters were higher than those in public officials. AMI was more common

TABLE 2. Comparison of Sex- and Age-Specific Incidence of Cardiovascular Disease Between Firefighters and Public Officials

		Male (Per 100,000 Person-Years)		Female (Per 100,000 Person-Years)	
Diagnosis	Age, yrs	Public Official	Firefighter	Public Official	Firefighter
Acute myocardial infarction	20 – 29	56.8777	128.7968	24.7332	118.6240
	30 – 39	99.6931	140.1244	41.5568	132.9493
	40 – 49	216.5498	324.6249	99.2614	221.1411
	>50	287.4959	442.4016	182.9139	260.0780
Angina pectoris	20 – 29	387.0458	389.9682	178.5144	213.5231
	30 – 39	689.0901	684.3421	400.6568	365.6105
	40 – 49	1473.9120	1542.6741	928.0104	1061.4772
	>50	1835.0454	2568.2275	1678.9316	1170.3511
Hypertension	20 – 29	910.7367	880.1116	357.1570	510.0830
	30 – 39	1808.2104	1607.0702	918.8372	908.4866
	40 – 49	3804.3740	3579.3426	2222.9688	3449.8010
	>50	5196.7528	5975.2945	4299.0824	4031.2094

TABLE 3. Comparison of Sex- and Age-Stratified Hazard Ratios and 95% Confidence Intervals for Cardiovascular Disease Between Firefighters and Public Officials

	Hazard Ratio (95% CI)					
	Total		Male		Female	
Diagnosis (Age Group in Years)	Public Official	Firefighter	Public Official	Firefighter	Public Official	Firefighter
Acute myocardial infarction (20–29 yrs)	1 (ref)	4.155 (3.041–5.677)	1 (ref)	2.267 (1.532–3.355)	1 (ref)	4.745 (2.514–8.956)
Acute myocardial infarction (30–39 yrs)	1 (ref)	2.375 (2.066–2.731)	1 (ref)	1.426 (1.217–1.670)	1 (ref)	3.225 (1.819–5.719)
Acute myocardial infarction (40–49 yrs)	1 (ref)	2.034 (1.776–2.330)	1 (ref)	1.530 (1.328–1.762)	1 (ref)	2.066 (0.857–4.979)
Acute myocardial infarction (>50 yrs)	1 (ref)	1.630 (1.300–2.044)	1 (ref)	1.510 (1.200–1.902)	1 (ref)	1.461 (0.364–5.869)
Angina pectoris (20–29 yrs)	1 (ref)	1.628 (1.361–1.948)	1 (ref)	1.005 (0.818–1.233)	1 (ref)	1.186 (0.745–1.889)
Angina pectoris (30–39 yrs)	1 (ref)	1.370 (1.289–1.456)	1 (ref)	1.004 (0.938–1.075)	1 (ref)	0.910 (0.646–1.282)
Angina pectoris (40–49 yrs)	1 (ref)	1.262 (1.187–1.341)	1 (ref)	1.065 (1.000–1.134)	1 (ref)	1.049 (0.702–1.566)
Angina pectoris (>50 yrs)	1 (ref)	1.370 (1.248–1.505)	1 (ref)	1.390 (1.264–1.529)	1 (ref)	0.690 (0.359–1.327)
Hypertension (20–29 yrs)	1 (ref)	1.794 (1.593–2.022)	1 (ref)	0.967 (0.844–1.108)	1 (ref)	1.431 (1.059–1.933)
Hypertension (30–39 yrs)	1 (ref)	1.357 (1.304–1.411)	1 (ref)	0.888 (0.851–0.928)	1 (ref)	0.988 (0.795–1.228)
Hypertension (40–49 yrs)	1 (ref)	1.212 (1.165–1.261)	1 (ref)	0.943 (0.904–0.982)	1 (ref)	1.541 (1.234–1.925)
Hypertension (>50 yrs)	1 (ref)	1.155 (1.086–1.227)	1 (ref)	1.117 (1.050–1.189)	1 (ref)	0.958 (0.673–1.364)

in younger firefighters, and the magnitude of the hazard risk for AMI was higher in women than in men. In contrast, angina pectoris and hypertension were more common in older firefighters.

Firefighters' duties, such as emergency response, emergency medical aid, and rescue, together with their occupational stressors, such as shiftwork, higher levels of job stress, emotional demands in customer service, and dangerous working environments may play a significant role in the development of CVD. Firefighters are prone to possible occupational cardiovascular risks, such as being sedentary for long periods, smoke exposure, noise, lack of sleep due to frequent calls, PTSD, extreme physical exertion, excess heat/dehydration, duty-specific hazards, physical training, and alarm responses. In addition, chronic stressors, such as inadequate physical activity, poor dietary habits, shiftwork, and psychological stress are associated with acute cardiovascular strain from firefighting, which, in turn, increases the risk of sympathetic activation, physical workload, heat stress, and dehydration.[7] A recent cohort study revealed that the standardized incidence ratios for all CVDs combined were higher in firefighters than in the population sample. The risk was also increased for most outcomes, including angina pectoris, AMI, chronic ischemic heart disease, and atrial fibrillation/flutter.[27]

It is well known that firefighters' main duties, such as firefighting or rescue, are hazardous tasks. It is commonly recognized that most on-duty deaths in firefighters are caused by burns and/or smoke inhalation. However, in the United States, the leading cause of duty-related deaths among firefighters is SCD.[19] Cardiovascular disease accounts for 45% of all firefighter-duty-related fatalities.[23] In the process of performing firefighting duties, several factors, including activation of the sympathetic nervous system, physical exertion, exposure to heat stress, dehydration, hazardous environmental conditions, and pollutants, precipitate cardiovascular strain.[19] Cardiovascular strain, in turn, leads to several interrelated adverse cardiovascular conditions, including increases in heart rate and blood pressure due to high levels of stress, reduction in plasma volume and changes in electrolyte concentration, and an increase in viscosity and changes in the coagulation mechanism. These cardiovascular changes aggravate the risk of plaque rupture, thrombus formation, or arrhythmia, and lead to the development of SCD or other acute cardiovascular events.[19]

Some studies have addressed the association between engaging in emergency duties and an increase in the risk of cardiovascular events. For example, Hunter et al[28] provided a pathogenic mechanism to address the relationship between firefighting and AMI in firefighters. Exposure to strenuous physical and emotional demands activates platelets, increases thrombosis, and reduces vascular vasomotor function. Increased thrombogenicity and damaged vascular function may be subordinate to increased body temperature and dehydration while performing firefighting duties.[29]

In the present study, we found that younger firefighters aged 20 to 39 years showed higher HRs for AMI in both sexes than public officials. The magnitude of the hazard risk for AMI was higher in women than in men. There are four possible explanations for this finding. The first possibility is that young firefighters who experienced PTSD while on duty were more likely to be at risk of AMI than older firefighters. PTSD, especially in young female firefighters, may increase the risk of AMI. Some studies have suggested that the prevalence of trauma exposure is higher among women[30,31] and younger firefighters,[32–34] which means that younger female firefighters may develop PTSD after experiencing a traumatic event. Numerous cohort studies have suggested that PTSD is an independent risk factor for AMI,[35–39] especially early age CVD mortality.[40] The second possibility is related to prescribing medications. In Korea, prescribing medications without correctly diagnosing the patient's disease is prohibited. Therefore, AMI sub-codes may be included to prescribe medication for firefighters who complain of chest pain. The third possibility is due to the "healthy worker survival effect," which means that older firefighters who left the traumatic place or transferred to areas to reduce their exposure to traumatic incidents are less likely to experience traumatic events than younger firefighters; however, the risks of AMI may be increased among younger firefighters. Fourth, the indirect experience of heart attack among older AMI firefighters makes young firefighters more sensitive to AMI symptoms or signs. In other words, there is a possibility that "circulatory somatizations of PTSD" occur more easily in younger firefighters than in older firefighters. In this case, AMI sub-codes should be written in the prescription of medications that relieve heart-related symptoms among younger firefighters. This finding is consistent with a previous report, which indicated that the performance of strenuous emergency duties was strongly related to an increased risk of SCD among young firefighters.[4]

This study found that emergency duties, as the primary jobs of firefighters, may play a significant role in the development of CVD. An increased incidence of SCD among firefighters has been documented during certain emergency and strenuous duties, which can trigger SCD among individuals with underlying CHD and/or left ventricular hypertrophy.[19,42] Compared with nonemergency

duties, the risk of SCD was increased during fire suppression, alarm response, alarm return, and physical training. Risk ratios for SCD were higher among firefighters with a pre-existing history of cardiac conditions.[41]

Despite the strenuous characteristics of emergency duty, firefighters have strong risk factors for CVD, such as poor physical fitness and obesity. Previous studies have documented that on-duty CVD events do not occur randomly during firefighting or rescue. They frequently occur at certain times of the day and certain periods of the year, and take place overwhelmingly during strenuous duties than in nonemergency situations. Moreover, on-duty CVD events occur almost exclusively among susceptible firefighters with a history of CVD.[7]

This study suggests that firefighters' emergency duties are more likely to increase cardiovascular risks compared with the nonemergency duties of public officials. These findings indicate that preventive strategies or policies with proven benefits can be applied to firefighters. Furthermore, all fire departments should have entry-level medical evaluations as well as regular medical and fitness tests; also, they should require rigorous return to work evaluations after any significant illness.[7]

Firefighters generally show poor physical activity and high morbidity due to CVD risk factors. Due to the deleterious relationship between CVD risk factors, poor physical fitness, and deaths during firefighter line of duty, health professionals need to develop health promotion programs to reduce the CVD risk and improve the physical fitness in firefighters.[22] In this regard, the three recommendations of the National Institute for Occupational Safety and Health arising from the Fire Fighter Fatality Investigation and Prevention Programs should be considered: (1) mandatory preplacement and annual medical examinations for all firefighters; (2) wellness and fitness programs; and (3) annual physical performance evaluations.[2]

For firefighters as well as other workers, mitigating occupational risk factors other than strenuous work is likely to be effective. Although moderate exercise may reduce the trigger effects of extreme exertion, minimizing the overall risk involves the implementation of primary and secondary prevention measures. These measures include accelerating healthy behaviors (such as healthy food consumption, smoking cessation or heavy alcohol drinking, and regular physical activities) and modifying physical adversities, such as hypertension, diabetes, and obesity, that cause subsequent risks.[24]

The hazardous working environment of firefighters along with their emergent and dangerous duties may contribute to an increased risk of CVD. It is very surprising that the firefighters' health conditions are not better than those of other occupational groups, even if they are healthier than other employees when they are recruited. In addition, an occupational stress management program at the organizational level is strongly required to reduce the negative impact of emotional dissonance and conflicts with customers on duty, especially focusing on younger female firefighters. Recent investigations have found that a positive and cooperative organizational climate plays a pivotal role in reducing the adverse impacts of emotional labor and emergency duties.[9,10] Strategies and management to foster an authentic and friendly organizational climate are needed.

This study has some limitations. First, because we only used the ICD-10 codes to define each disease, the possibility of overestimating the incidence was not excluded. The second limitation was related to subgroup analysis. In Korea, firefighters are classified into four types (firefighting, rescue, emergency medical aid, and administration) according to their main duties. However, due to data limitations, we did not perform a subgroup analysis to compare the different types of firefighting work. Third, the "healthy worker effect" is an increasing problem. Compared with other public officers, firefighters are required to have higher levels of fitness to meet the physical demands of their jobs. Therefore, firefighters are expected to be in better general health and have a lower risk of CVD than the general population.2 We recommend that subgroup analyses of the incidence rate and HRs according to the firefighter's primary duty and region should be performed in the near future.

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