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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *September, 2011*

Fire Fighter Suffers Heart Attack During Structural Fire Fighting Operations and Dies 8 Days Later – Kentucky

Executive Summary

On June 30, 2011, a 49-year-old male volunteer fire fighter (FF) responded to a residential structure fire. The FF, wearing full turnout gear and self-contained breathing apparatus (SCBA) on-air, climbed a 14-foot ladder to the second floor and performed exterior and interior fire suppression activities for about 30 minutes. After the fire was brought under control, he started to perform overhaul (mop-up) operations on the second floor when he suddenly collapsed. Crew members carried the FF down the stairs and outside the dwelling. Cardiopulmonary resuscitation (CPR) was begun as an ambulance was requested. The ambulance arrived, advanced life support was provided, and the FF was transported to the local hospital's emergency department (ED). In the ED, the FF regained a pulse but remained minimally responsive and was flown to a regional hospital where angioplasty was performed. Over the next 8 days, his condition did not improve and, after consulting with the family, the decision was made to remove the FF from life support. The attending physician pronounced him dead at 0434 hours on July 8, 2011. The death certificate listed "myocardial infarct" due to "cardiac arrest" as the cause of death. No autopsy was performed. Carboxyhemoglobin levels were not measured to test for carbon monoxide exposure. Given the FF's known underlying coronary artery disease (CAD), NIOSH investigators concluded that the physical exertion of responding to the call and suppressing the fire triggered his heart attack, which caused his death.

NIOSH investigators offer the following recommendations to address general safety and health issues. Had some of these recommended programs been in place, it is possible the FF's death may have been prevented.

Provide preplacement and annual medical evaluations to all fire fighters.

Ensure fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of National Fire Protection Association (NFPA) 1582.

Phase in a comprehensive wellness and fitness program for fire fighters.

Perform a preplacement and an annual physical performance (physical ability) evaluation.

Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

Perform an autopsy on all on-duty fire fighter fatalities.

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Introduction & Methods

On June 30, 2011, a 49-year-old male volunteer FF collapsed while performing fire suppression and mop-up activities at a structure fire and died 8 days later. NIOSH was notified of this fatality on July 8, 2011, by the U.S. Fire Administration. NIOSH contacted the affected Fire Department (FD) on July 11, 2011, to gather additional information, and on July 14, 2011, to initiate the investigation. On August 15, 2011, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Fire Chief
- Assistant Fire Chief
- Crew members
- Ambulance service paramedics
- FF's spouse

NIOSH personnel reviewed the following documents:
- FD training records
- FD standard operating guidelines
- FD incident report
- Emergency medical service (ambulance) incident reports
- Hospital ED records
- Regional hospital records
- Death certificate
- Primary care provider medical records

Investigative Results

Incident. On June 30, 2011, the FD was dispatched at 0305 hours to a fire in a two-story, wood frame, 2,000-square foot dwelling. The FF responded to the scene riding in Truck 122. Along with seven crew members, he arrived at 0312 hours. Engine 121 (a 1,000-gallon per minute pumper) with three crew members, Engine 123 (a 2,500-gallon tanker) with two crew members, Engine 125 (a 2,500-gallon tanker) with one crew member, and an additional fire fighter in his personal vehicle also responded. Weather conditions at this time included a temperature of 60 degrees Fahrenheit and relative humidity of 95% [Weather Underground 2011].

FD units arrived to find the second story of the dwelling heavily involved in fire. The dwelling was not occupied according to a person living on the property in another structure. Fire suppression efforts began with an exterior attack from the ground and from a 14-foot ground ladder. The FF, wearing full bunker gear and SCBA on air, climbed the ladder and performed exterior fire suppression activities until his SCBA bottle ran out of air (about 20 minutes). He descended the ladder, replaced the bottle, and climbed the ladder again to enter a second story window. There, he met other crew members. Shortly thereafter, the fire was extinguished and mop-up/overhaul began.

As crew members began to search for hot spots, the FF picked up the hoseline to extinguish a hot spot and suddenly said, "I've got to get out of here." He started to walk away but he collapsed (about 0343 hours). Crew members yelled out the window "man down" several times and carried the FF down the interior stairs and outside the structure.

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Investigative Results (cont.)

Crew members removed the FF's gear and SCBA and assessed him. He was unresponsive with a faint carotid pulse; he was not breathing. An ambulance was requested at 0346 hours, and a few seconds later his pulse stopped; CPR was initiated. An automated external defibrillator was retrieved from the engine and applied; two shocks were delivered without positive change in the FF's condition. CPR was continued.

The ambulance (staffed with a paramedic and an emergency medical technician [EMT]) arrived on the scene at 0354 hours and found the FF unresponsive, with no pulse, and not breathing; CPR was in progress. The FF was placed onto a stretcher and loaded into the ambulance, which departed the scene at 0400 hours en route to the hospital's ED. While en route advanced life support, including intravenous line placement followed by administration of cardiac resuscitation medications, intubation, and cardiac monitoring, was initiated. Five shocks were delivered without positive change in the FF's condition. The ambulance arrived at the ED at 0404 hours, and the FF's care was transferred to the ED staff.

At 0417 hours, the FF regained a weak and intermittent pulse, and over the next 30 minutes his pulse eventually stabilized at 130 beats per minute with a blood pressure of 92/73 millimeters of mercury. The decision was made to transfer the FF via air ambulance to a regional hospital for advanced treatment at 0439 hours. The air ambulance arrived at 0500 hours but did not depart the local ED until 0610 hours. Because the FF's intubation tube placement was not verified in the field, capnography was performed, and proper placement was confirmed prior to departure [AHA 2010].

Upon arrival at the regional hospital, an echocardiogram revealed a severely decreased left ventricular ejection fraction (LVEF) of 15%–20%. Blood tests revealed elevated cardiac enzymes (troponin: 3.12 nanograms per milliliter [ng/mL]; normal level is < 0.06 ng/mL), (creatine-kinase: 2,847 units per liter [U/L]; normal level is 30–223 U/L), and (CKMB: 56.6 ng/mL; normal level is 0.0–5.8 ng/mL). A neurology consultation revealed hypoxic encephalopathy (lack of oxygen to the brain), due to the prolonged time with no pulse (about 30 minutes).

Cardiac catheterization revealed 90% stenosis in the left anterior descending coronary artery, 80% stenosis in the circumflex coronary artery, and 40% stenosis in the right coronary artery (which was stented in 2005). Angioplasty followed by stent placement in the left anterior descending coronary artery successfully improved blood flow in this artery. Over the next 8 days, however, the FF's condition did not improve and on July 8, after consulting with the family, the decision was made to remove the FF from life support. The attending physician pronounced the FF dead at 0434 hours.

Medical Findings. The death certificate listed "myocardial infarct due to cardiac arrest" as the cause of death. No autopsy was performed nor was the FF's blood tested for carboxyhemoglobin (a measure of carbon monoxide exposure). Because the FF wore an SCBA during fire suppression, his exposure to carbon monoxide was considered minimal and not thought to be a contributing factor to his heart attack.

In 1997, the FF was diagnosed with hypertension and prescribed a diuretic and a beta blocker, which subsequently controlled his blood pressure. In 2005, the FF was diagnosed with hypercholesterolemia

Investigative Results (cont.)

and diabetes mellitus. He was prescribed a statin to lower his cholesterol level and had excellent control. He was prescribed insulin for his diabetes with fair to poor control; blood sugars ranged from 45–343 mg/dL (normal is 70–105 mg/dL). His hemoglobin A1C (HA1C) (a measure of blood sugar control over months) ranged from 6.2% to 9.7%, but upon admission to the hospital during this incident was 15.2% (the desirable level is ≤ 7% [ADA 2009]).

In April 2005, the FF had a heart attack involving the inferior wall. He received emergent cardiac catheterization during which his right coronary artery was opened via angioplasty and stent placement. Following cardiac rehabilitation and medical management, the FF had no arrhythmia but did have residual mild to moderate heart failure (LVEF ranged from 38%–46%). His most recent imaging exercise stress test in August 2010 showed the FF exercising on the Bruce protocol [Sport Fitness Advisor 2011], for 9 minutes and 15 seconds (8.8 metabolic equivalents [METs]). His heart rate was 147 beats per minute (85% of the predicted maximum heart rate) before he stopped because of shortness of breath and leg fatigue. He had no angina or arrhythmias, but his electrocardiogram showed nonspecific T-wave abnormalities. His imaging study showed no perfusion in the inferior wall (due to his prior heart attack in 2005). Overall, the test was considered "a non-diagnostic study for ischemia."

In February 2011, the FF underwent an annual medical evaluation for his position as an EMT with the local ambulance service. No new problems were identified, and he was cleared for EMT duty and to wear a respirator. After the 2005 heart attack and up to the time of this incident, the FF expressed no symptoms or signs of heart problems.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of one fire station with 32 uniformed volunteer personnel. It served 4,500 city residents and 15,500 county residents in a geographic area of 660 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid state driver's license, pass a background check, and pass an interview by the county board of directors. The new member must attend meetings and in-house training to achieve the 150-hour Kentucky fire fighter status. The member is on probation for 1 year, must respond to 30% of the emergency responses, and maintain 20 hours of training annually. Probationary members wear black bunker gear with a red helmet to identify them as new members in training. For volunteer fire fighters, the state mandates a minimum of 150 hours training to become a certified fire fighter and 20 hours of annual training thereafter. The FF had 32 years of fire fighting experience and was a state-certified fire fighter. In addition to being a volunteer fire fighter, the FF had been employed as a Deputy State Fire Marshal since 1988 and was an EMT for the local ambulance service.

Preplacement and Periodic Medical Evaluations. The FD does not require preplacement or periodic (annual) medical evaluations for members. No annual SCBA medical clearance is required. An annual SCBA facepiece fit test is required. Members injured on duty must be evaluated by a state-approved workers' compensation physician who makes the final determination regarding return to duty. For his job as deputy state fire marshal, no preplacement or periodic medical evaluation is offered or required.

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Description of the FD (cont.)

Several members of the FD are employed part time with the local ambulance service, which requires preplacement and annual medical evaluations. The components of these evaluations include the following: complete medical history, physical examination (including vital signs), respirator clearance, hearing evaluation (whisper test), and vision screen.

Health and Wellness Programs. The FD has no formal wellness/fitness program, but strength and aerobic training equipment is available in the fire station. No physical ability test is required for candidates or annually for members. No health and wellness program is available through the FF's local ambulance job or the state fire marshal position.

Discussion

Atherosclerotic Coronary Artery Disease. In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2011; NHLBI 2011]. The FF had five CAD risk factors (age older than 45, male gender, high blood pressure, high blood cholesterol, and diabetes mellitus) and known CAD with a heart attack and stent placement in 2005.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Heart attacks typically occur

Discussion (cont.)

with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques.

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, the FF's cardiac enzymes were elevated, indicating an acute heart attack.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Albert et al. 2000]. Heart attacks in fire fighters have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The FF had responded to the alarm and performed fire fighting activities. These activities expended about 9 METs, which is considered moderate physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The FF had three conditions related to decisions about medical clearance for duty.

Discussion (cont.)

Coronary Artery Disease. NFPA 1582 considers a history of myocardial infarction and coronary angioplasty with stent placement to compromise a member's ability to safely perform most of the essential job tasks of fire fighting [NFPA 2007a]. The standard states that fire fighters with a history of myocardial infarction and coronary angioplasty with stent placement should be restricted from duty if any of the following criteria are present:

- Current angina pectoris even if relieved by medication
- Persistent significant stenosis in any coronary artery (greater than 70%)
- Lower than normal LVEF (<50%)
- Maximal exercise tolerance < 12 METs
- Exercise-induced ischemia or ventricular arrhythmias
- History of myocardial infarction, angina, or CAD with persistence of modifiable risk factor(s) for acute coronary plaque rupture (tobacco use, hypertension despite treatment, hypercholesterolemia, or HA1C >7% despite exercise and/or weight reduction) [NFPA 2007a].

The FF had four of these criteria (persistent stenosis, low LVEF, maximal exercise tolerance < 12 METs, and elevated HA1C.

After the FF's first heart attack in April 2005, he underwent a rigorous cardiac rehabilitation program. After passing subsequent maximal exercise stress tests, his cardiologist released him "to usual activities" in November 2006. Medical records indicated his cardiologist knew the FF was employed by the State Fire Marshal's Office and was an EMT with the local ambulance service. However, it is unclear if the cardiologist was aware that he was also a volunteer fire fighter who engaged in all phases of fire suppression. Although the FF was medically cleared on an annual basis by the ambulance service, he had not been medically evaluated as a fire fighter since 2006.

Beta Blocker Medication. In 1997 the FF was found to have hypertension. In 2005 after his first heart attack, he was prescribed an angiotensin-converting enzyme inhibitor and a beta blocker. The NFPA considers use of beta blockers to potentially preclude safely wearing the fire protective ensemble and safely climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces, and operating near electrical power lines and/or other hazards because of the risk for dehydration, electrolyte disorders, lethargy, and disequilibrium [NFPA 2007a].

Diabetes Mellitus. NFPA 1582 provides guidance for fire department physicians to follow when treating diabetic fire fighters. The standard states that fire fighters with diabetes mellitus who require treatment with insulin should be restricted from duty unless the member meets all of the following criteria:

- Is maintained by a physician knowledgeable in current management of diabetes mellitus on a basal/bolus regimen using insulin analogs
- Has demonstrated over a period of at least 1 year the motivation and understanding required to closely monitor nutritional therapy and insulin administration
- Has a dilated retinal exam by a qualified ophthalmologist or optometrist that shows no higher grade of diabetic retinopathy than microaneurysms
- Has normal renal function on the basis of a calculated creatinine clearance greater than 60 milliliters per minute and absence of proteinuria
- Has no autonomic or peripheral neuropathy
- Has normal cardiac function without evidence of myocardial ischemia on cardiac stress testing (to at least 12 metabolic equivalent tasks [METS]) by EKG and cardiac imaging

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Discussion (cont.)

- Has a signed statement from an endocrinologist knowledgeable in management of diabetes mellitus as well as the essential job tasks and hazards of fire fighting that the fire fighter meets the following criteria:
    - Is maintained on a stable basal/bolus regimen using insulin analogs and has demonstrated over a period of at least 1 year the motivation and understanding required to closely monitor and control capillary blood glucose levels despite varied activity schedules through nutritional therapy and insulin administration
    - Has achieved stable control of blood glucose as evidenced by HA_1C consistently less than 8 when monitored at least twice yearly
    - Does not have an increased risk of hypoglycemia due to alcohol use or other predisposing factors
    - Has had no episodes of severe hypoglycemia in the preceding 1 year, with no more than one episode of severe hypoglycemia in the preceding 5 years
    - Is certified not to have a medical contraindication to fire fighting training and operations [NFPA 2007a]

The FF was an insulin-dependent diabetic and did not meet several of the above criteria for full fire fighting clearance. He did not achieve 12 METs on cardiac stress testing, did not have a signed statement from an endocrinologist regarding diabetes management and fire fighting activities, and did not have HA1C levels <8.0.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. Had some of these recommended programs been in place, it is possible the FF's death may have been prevented.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2007a]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, the FD is not legally required to follow this standard. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments to implement.

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and EMTs from the local emergency medical service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, City, or State. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the City,

Recommendations (cont.)

the State, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Ensure that fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a]. The FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty. The physician should review job descriptions and essential job tasks required for all FD positions and ranks to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. Although the FF underwent an annual medical evaluation by his local ambulance service company and was cleared for duty as an EMT in February 2011, the job requirements and medical clearance for a fire fighter are more demanding [NFPA 2007a].

Recommendation #3: Phase in a comprehensive wellness and fitness program for fire fighters.

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; NFPA 2008; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001].

Fire service health promotion programs have been shown to reduce coronary artery disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007].

Given the FD's structure, the NVFC program might be the most appropriate model [USFA 2004]. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #4: Perform a preplacement and an annual physical performance (physical ability) evaluation.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD to develop physical performance requirements for candidates and members who engage in emer-

Recommendations (cont.)

gency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b]. The typical workload of a structural fire fighter is somewhere between 10–12 METs [Sothmann et al. 1990; Gledhill and Jamnik1992], but during the FF's last exercise stress test he only achieved 8.8 METs.

Recommendation #5: Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR1 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans [OSHA 2011]. Kentucky operates an OSHA-approved state plan. Therefore, the FD is required to comply with this standard. The ambulance service medical evaluation cleared employees to wear half-face air-purifying respirators, not SCBA.

Recommendation #6: Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

To reduce the risk of improper intubation, the AHA and the International Liaison Committee on Resuscitation published recommendations in the "Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care" [AHA 2010]. These guidelines recommend confirming tube placement by primary and secondary methods. Primary confirmation is the five-point auscultation: left and right anterior chest, left and right midaxillary, and over the stomach. Secondary confirmation requires a technology test, either an end-tidal carbon dioxide detector or an esophageal detector device. In this incident, tube placement was verified by hearing no abdominal sounds; however, secondary confirmation was not performed until 0612 hours in the ED. This issue did not contribute to the FF's death. We make this recommendation to ensure that future advanced life support resuscitation efforts follow AHA guidelines.

Recommendation #7: Perform an autopsy on all on-duty fire fighter fatalities.

In 2008, the USFA published the Firefighter Autopsy Protocol [USFA 2008]. With this publication, the USFA hoped to provide "a more thorough documentation of the causes of firefighter deaths for three purposes:

1. to advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;

2. to help determine eligibility for death benefits under the Federal government's Public Safety Officer Benefits Program, as well as state and local programs; and

3. to address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).