Building Evaluations That Translate Evidence & Research to Heart Evaluations and Related Training

BETTER HEART

Final Report

First Responder Health and Safety Laboratory

Health and Human Physiological Sciences

Skidmore College

May 2023

CONTENTS

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ACKNOWLEDGEMENTS

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We would like to express our appreciation to Beth Haigh who helped with the preparation of the final manuscript and Dr. Wesley Lefferts who contributed to creation of graphics and formatting of the document.

POTENTIAL CONFLICTS OF INTEREST

In order to produce the best possible recommendations and report, we included fire service personnel with an acknowledged interest in firefighter health and safety; health care providers who currently screen firefighters, including individuals who own occupational health clinics or hold leadership roles in those organizations; researchers who have received grant funding and participated in cardiovascular research in the fire service; and physicians and others who advocate for, provide and/or use coronary artery calcium scores in their current practice. There is a potential for the conflict of interest or the appearance of conflict of interest in each of these cases. However, broad participation from experienced individuals also provides a strength of the approach. For transparency, we have listed individuals who participated in the project and their role.

EXECUTIVE SUMMARY

The **BETTER HEART** (**B**uilding **E**valuations **T**hat **T**ranslate **E**vidence and **R**esearch for **H**eart **E**valuations **A**nd **R**elated **T**raining) project sought to use the latest medical information, research findings from studies of firefighters, and data from firefighters' occupational medical exams to develop enhanced, evidence-based guidelines for the detection of cardiovascular disease (CVD) in firefighters.

The BETTER HEART program brought together fire service leaders, occupational health experts, and researchers. The Core Multidisciplinary Project Team coordinated the efforts of the other groups while the Medical Advisory Team was responsible for making the recommendations for enhanced cardiac screening. As seen in Figure 1, these overlapping teams worked together to achieve the project's two primary goals.

Figure 1: Structure of Teams and Goals of the BETTER HEART Project

Core Multidisciplinary Project Team (CMPT) – Skidmore, Harvard, NIOSH, NIPSH, Advocate Lutheran General Hospital, Loudoun County (VA) Combined Fire Rescue System, Hanover Park FD, Broward County Fire Rescue

Medical Advisory Team (MAT) – Occupational Medicine Providers, Cardiologists, Primary Care Providers

Project Technical Panel (PTP) – Occupational Medicine Providers, Cardiologists, Primary Care Providers, Fire Service Partners [(Loudoun County (VA) Combined Fire Rescue System, Hanover Park FD, Broward County Fire Rescue, San Diego Fire-Rescue Department, IAFF, IAFC, NVFC, NFFF, FPRF)], Researchers

Develop Evidence-Based Enhanced Screening Guidelines. Conduct Pilot Program, and Create Training/Educational Material	**Create Report that Integrates Evidence-Based Screening Guidelines into a Broader Context of Medical Evaluations**
CMPT+MAT+PTP	**CMPT**

1. Synthesize current research literature and medical understanding of cardiovascular disease progression and detection.
2. Develop screening guidelines informed by data synthesized by CMPT, clinical experience, and fire service partners.
3. Review occupational medical records to better understand cardiovascular disease risk profile of firefighters.
4. Work with fire service partners (on CMPT and MAT) to implement pilot program to understand potential hurdles to adoption.
	1. Synthesize information from:
	   a. Medical literature
	   b. Current screening guidelines
	   c. Evolving/novel screening and diagnostic tools
	   d. Scientific research — Fire service and cardiovascular disease
	   e. Fire service data
	2. Create a report that can be used by health care providers, occupational health clinics, and fire service personnel.
	3. Work with fire service partners and national leaders to disseminate recommendations and accompanying educational material.

Approximately half of all annual on-duty firefighter deaths are related to CVD. These deaths affect all areas of the fire service, including wildland, volunteer, and career firefighters.

Data obtained from occupational medical evaluations from clinics across the country revealed that firefighters have concerning rates of traditional CVD risk factors. When considered in aggregate, approximately 69% had blood pressure values indicative of hypertension, 33% had elevated blood cholesterol, and 36% were obese based on body mass index (BMI). Moreover, when firefighters were grouped by age, 77% of those in their 50s had hypertensive blood pressure values, 40% had high cholesterol values, and 44% were obese. When individual firefighters were tracked over a 5-year period, 50% of firefighters gained more than 3% of their initial body weight, whereas only 12% lost 3% or more of their body weight, and 38% remained relatively weight stable. Importantly, among those who gained weight, their CVD risk factor profile worsened, while those who lost weight had a better CVD profile despite advancing age.

This data highlights the need for comprehensive wellness and fitness programs focused on CVD prevention as a complement to occupational medical exams.

The Core Project Multidisciplinary Team and the Medical Advisory Team (MAT) believe that an NFPA compliant occupational medical evaluation should form the foundation of cardiac screening for firefighters, including the use of maximal exercise stress testing as recommended. However, it is also clear that even when the current guidelines are fully implemented, they fail to identify some firefighters with underlying disease. The recommendations put forth in this document are intended to help identify additional firefighters with occult CVD so that they can be effectively treated.

The MAT was an assembled group of experts who considered the current state of science on CVD, published literature on CVD in the fire service, existing guidelines and current medical technology. Based on their review of information and clinical judgement they recommended that, if reasonable:

Firefighters should be screened for coronary heart disease using Coronary Artery Calcium scans at age 40 years, or earlier based on clinical judgement, such as in individuals with an intermediate or high Risk Score, or in those with risk factors and a family history of premature coronary artery disease.

Firefighters should be screened for structural heart disease (including left ventricular hypertrophy, cardiac chamber enlargement, valvular abnormalities) using echocardiography at age 40, or earlier in the presence of hypertension, obesity, and/or sleep apnea.

CHAPTER 1: UNDERSTANDING AND MITIGATING CARDIOVASCULAR RISK IN THE FIRE SERVICE

SUDDEN CARDIAC DEATH IN THE FIRE SERVICE

Firefighting is dangerous work, but only recently has the fire service begun to seriously consider ways to decrease the toll of CVD (coronary heart disease, hypertension, arrhythmias, heart failure and stroke). Decreasing preventable deaths in the fire service requires that firefighters are fit enough to do their work and that underlying CVD is detected and treated. National agencies are united in their assertion that all firefighters should receive an annual occupational medical evaluation aimed, in part, at detecting CVD. However, the most recent NFPA needs assessment reports that the majority of firefighters do not receive an NFPA compliant annual medical evaluation.

Firefighting is a unique occupation that involves emergency response activities that are physiologically and psychologically taxing. Many firefighting activities involve difficult physical work and the use of heavy, insulating personal protective equipment. Most epidemiological studies have found that firefighters have a similar risk of cardiovascular mortality (death) as the general population, or perhaps even lower due to the "healthy worker effect" (Choi, 2000) (Daniels, Kubale, & Yiin, 2014). But, occupational work that firefighters perform may trigger an acute cardiovascular event.

Specifically, the combination of occupational stressors, including peak physical exertion and psychological stress during firefighting, can **trigger** an acute cardiac event in firefighters with underlying CVD.

Though there is slight variability in the exact number of fatalities reported by different agencies, there is consistent consensus that sudden cardiac events are a leading cause of acute duty-related deaths, accounting for nearly 50% of such deaths. In fact, sudden cardiac death accounts for approximately seven times as many firefighter deaths as burn injuries (see Figure 2). In addition to cardiac-related fatalities, the NFPA reports several hundred non-fatal cardiac events (injuries) every year. These events often lead to significant lost time or disability-related retirements. Though there appears to be a decline in the number of duty-related sudden cardiac fatalities over the past decade, the number of deaths attributed to heart disease is still staggering. The BETTER HEART project hopes to decrease sudden cardiac events in the fire service by recommending enhanced screening protocols that extend beyond current 1582 recommendations.
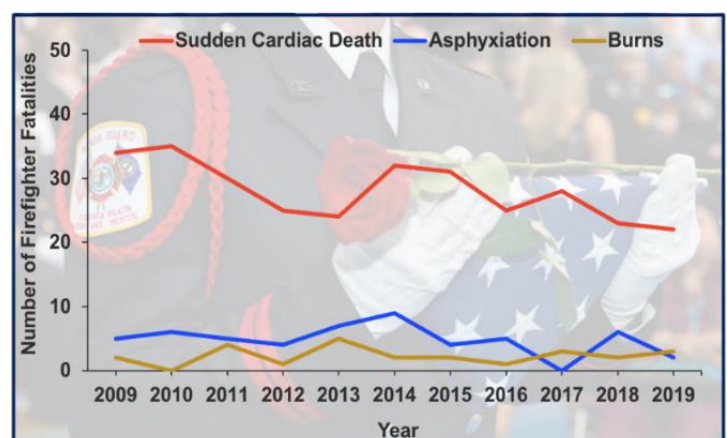

Figure 2: Fatality statistics based on NFPA firefighter fatality reports 2009–2019
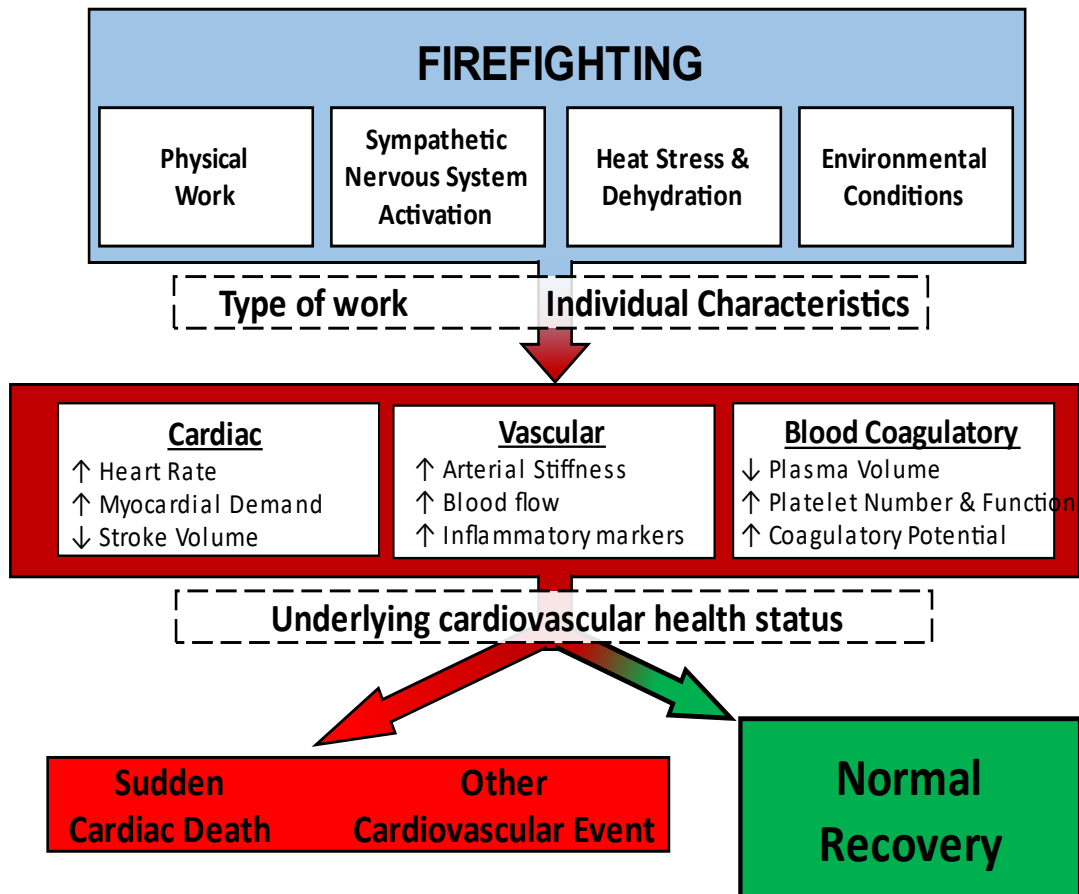
FIREFIGHTING

| Physical Work | Sympathetic Nervous System Activation | Heat Stress & Dehydration | Environmental Conditions |

Type of work — Individual Characteristics

Cardiac
↑ Heart Rate
↑ Myocardial Demand
↓ Stroke Volume

Vascular
↑ Arterial Stiffness
↑ Blood flow
↑ Inflammatory markers

Blood Coagulatory
↓ Plasma Volume
↑ Platelet Number & Function
↑ Coagulatory Potential

Underlying cardiovascular health status

Sudden Cardiac Death   Other Cardiovascular Event

Normal Recovery

Figure 3: Cardiovascular strain of firefighting. Modified from Smith et al. 2013

ACUTE CARDIOVASCULAR STRAIN OF FIREFIGHTING

Firefighting involves strenuous muscular work, sympathetic nervous system activation (adrenaline rush), heat stress, and dehydration, and it is performed in an environment that contains multiple hazards.

Figure 3 summarizes the effect of firefighting on the different components of the cardiovascular system: cardiac, vascular and blood/coagulatory. The graphic indicates that the work performed and the firefighters' individual characteristics (such as their physical fitness) will affect the magnitude of the cardiovascular response.

As summarized in the red block in the middle of the graphic, there are important changes in the work of the heart, the function of the vascular system, and the balance of the blood coagulatory system as a result of firefighting. During firefighting, heart rate and the overall work of the heart increase while the amount of blood pumped with each beat of the heart decreases (reduced stroke volume). Within the vascular system, arteries that supply blood to the muscles and skin increase in diameter to allow increased blood flow, but the arteries also become stiffer. Inflammation increases, which, along with increased blood pressure, may increase the risk of a plaque rupture. Firefighting also affects the blood

and its clotting ability. Firefighting leads to a decrease in blood volume because of dehydration, which makes the blood more viscous and harder to pump. Furthermore, several coagulatory factors in the blood increase, thus elevating the potential for blood clot formation.

These acute cardiovascular responses to firefighting reflect the strenuous nature of the work and are similar to what is seen during high-intensity athletic endeavors. Most firefighters recover from the stress of firefighting without incident. On-scene rehabilitation addresses heat stress and dehydration by providing an opportunity to rehydrate and allow the body to physically recover.

In firefighters with CVD, however, firefighting can trigger a sudden cardiac event. Firefighters are more likely to suffer a cardiac event during or after firefighting than during station/administrative duties. In a study which assessed firefighter fatality reports from 1999–2014, we found that sudden cardiac death was 112 times more likely to occur during or after fire suppression compared to station duties (Smith, Haller, & Korre, 2018).

We cannot keep firefighters from performing strenuous work, but we can — and must — do more to identify firefighters with underlying disease so that it can be treated, and preventable firefighter fatalities can be avoided. Annual medical evaluations with appropriate cardiac screening is an important step in protecting firefighters. It is also critical that firefighters actively participate in their own prevention and treatment plans.

TYPES OF CARDIOVASCULAR DISEASE

Cardiovascular disease (CVD) refers to several types of heart-related illnesses, including those that affect the heart structure, heart valves, blood vessels, and electrical system. A sudden cardiac event may be caused by a myocardial infarction (heart attack) or cardiac arrest (when there is an arrhythmia and the heart stops beating effectively). These two events can be caused by different underlying disease conditions, but there is considerable overlap in the risk factors.

Coronary heart disease (CHD), or **coronary artery disease** (CAD), is one type of CVD that occurs when atherosclerotic plaque builds up in a coronary artery leading to a reduction in blood flow (ischemia) to the muscles of the heart. This increases the potential for plaque rupture, leading to a myocardial infarction. **Hypertensive heart disease**, or a structurally enlarged heart, reflects a disease state that has damaged the heart and increases its susceptibility to arrhythmias, especially if the heart experiences ischemia.
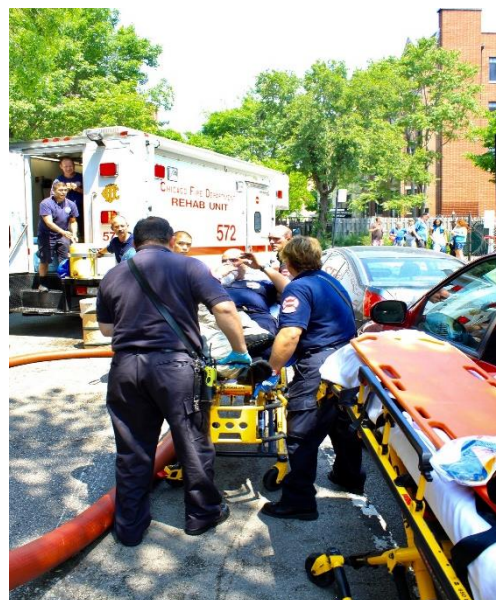
CORONARY HEART DISEASE

Coronary heart disease (CHD) is due primarily to atherosclerotic plaque in the coronary arteries. Atherosclerotic cardiovascular disease (ASCVD) is defined as the buildup of cholesterol plaque on the arterial walls. This atherosclerotic process begins with irritants such as high cholesterol, toxins from smoking or exposure, or high blood pressure damaging the inner vessel walls (endothelium). LDL cholesterol (bad cholesterol) enters the damaged artery, which causes inflammation. The cholesterol and cellular debris from the inflammatory process leads to plaque formation. Over time, this plaque becomes larger, more complex, and calcified.

As shown in Figure 4, growing plaque partially occludes the arteries, and reduces blood flow. During work/exercise/ firefighting, a partially occluded artery may limit the ability to increase blood flow to the heart, leading to ischemia and angina (this is sometimes called demand ischemia). Another potential outcome is that increased blood flow and blood pressure during work/exercise/firefighting may cause a plaque to rupture. If a plaque ruptures, the exposed and damaged arterial wall triggers a blood clot to form, and the subsequent restricted blood flow leads to a myocardial infarction (heart attack). A myocardial infarction may then cause an arrhythmia and sudden cardiac arrest.
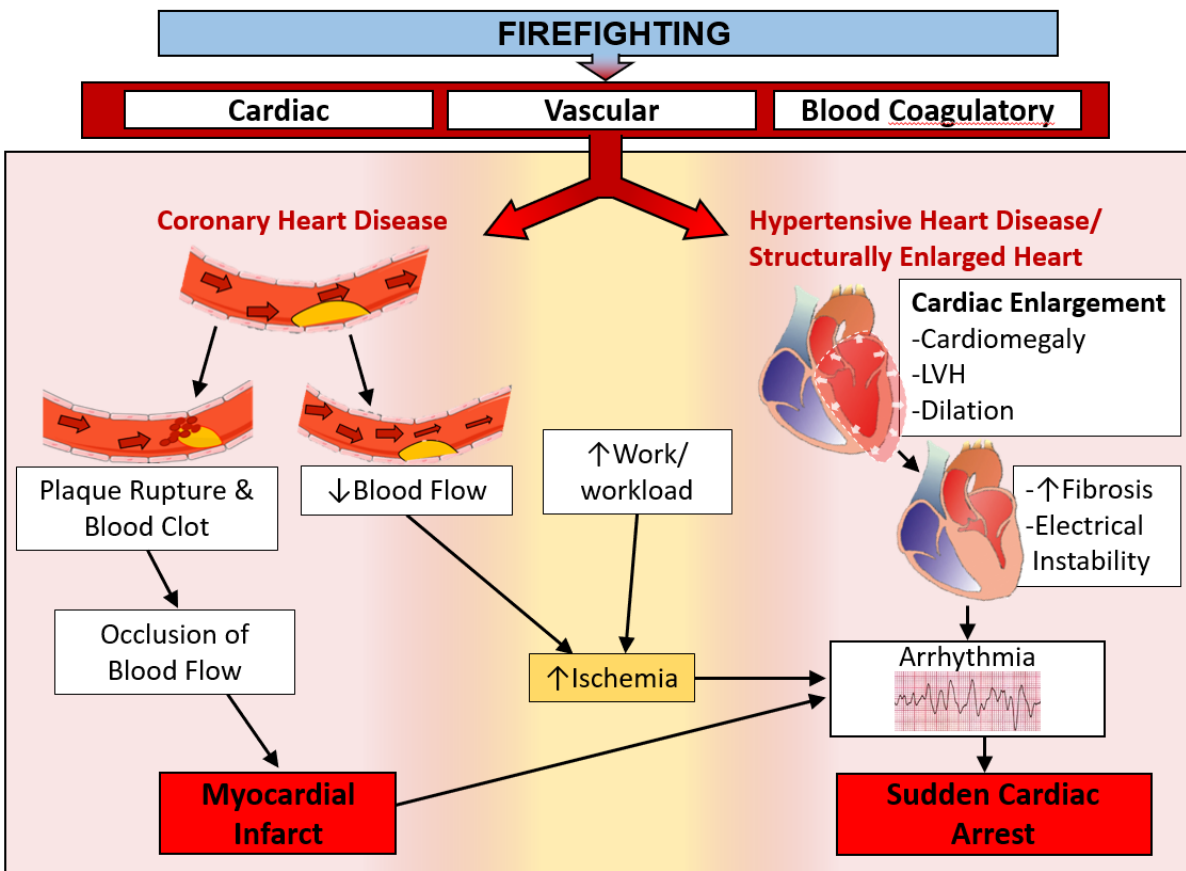

Figure 4: Increased Risk of Sudden Cardiac Events (myocardial infarction or sudden cardiac arrest) due to heart disease processes

HYPERTENSIVE HEART DISEASE

A heart may increase in size and mass due to uncontrolled hypertension. This is a condition termed hypertensive heart disease. Cardiomegaly refers to a heart that is enlarged (heavy). The heart may also exhibit thickened ventricular wall, known as left ventricular hypertrophy (LVH). The walls of the heart can also become distended leading to an overall dilation of the heart. In general, structural enlargement leads to changes within the heart, such as fibrosis, that alter the electrical stability of the heart and increase the risk of arrhythmias (see Figure 4). Cardiomyopathy is a general term for a diseased heart (myocardium); this condition can either be acquired or inherited. Hypertrophic cardiomyopathy is a specific type of hypertrophy that refers to a genetic abnormality where the left ventricle is thickened. Cardiomyopathy is associated with increased risk of sudden cardiac death.

Hypertensive heart disease, which causes the heart to work harder, has long been recognized as a major non-genetic cause of left ventricular thickening. It is now apparent that other factors that cause the heart to work harder can also lead to a structurally enlarged heart, including coronary artery disease, valvular stenosis, and obesity. Structural enlargement of the heart interferes with electrical and mechanical functioning, thus increasing the risk of an arrhythmia and sudden cardiac arrest.

Hypertension is a complex and potentially devastating disease. In addition to leading to structural and functional changes in the heart, hypertension injures the lining of blood vessels (endothelium) and can lead to decreased blood flow, kidney damage, impaired healing and loss of vision.

INTERACTION OF CORONARY HEART DISEASE AND HYPERTENSIVE HEART DISEASE

It is possible to have both CHD and hypertensive heart disease, and there are important ways that the two disease conditions interact. Figure 4 highlights important ways that coronary heart disease and an enlarged heart can interact to lead to a fatal cardiac event. Ischemia, due to decreased blood flow to the heart as a result of coronary heart disease, can lead to a fatal arrhythmia, which is more common in individuals with a structurally enlarged heart. Thus, an individual with both conditions is at substantially increased risk of sudden cardiac death.

Coronary heart disease and hypertensive heart disease (or an enlarged heart) have many risk factors in common. Hypertension and obesity are both major risk factors for coronary heart disease and the development of a structurally enlarged heart. Hypertension damages the lining of the arterial wall in a way that advances atherosclerosis, and it requires the heart to work harder, thus leading to enlargement of the heart. Obesity increases total peripheral resistance in blood vessels and is associated with elevated blood pressure. Even when considered independently of hypertension, obesity is associated with greater heart size. In fact, a recent study found that an elevated BMI, indicating obesity, was the risk factor that best predicted greater heart mass (Korre, Porto, & Farioli, 2016).

Coronary heart disease can lead to ischemia, especially when the heart is working harder, such as during firefighting. Ischemia can result in angina, leading to arrhythmias. Further, a structurally enlarged heart is particularly vulnerable to arrhythmias.

CHAPTER 2: FIREFIGHTER CARDIOVASCULAR DISEASE RISK FACTORS

Occupational medical evaluations routinely screen for CVD by evaluating risk factors. Risk factors are traits or characteristics that increase the likelihood of developing disease. On a population level, screening for CVD has been used to help identify individuals who are at higher risk and who may benefit from advanced testing. This chapter outlines basic findings about CVD risk factors among firefighters based on occupational health records.

HYPERTENSION

Hypertension, or high blood pressure (>130/80 mmHg), is a disease condition itself, and it is also a major risk factor for coronary heart disease and stroke. Hypertension can also lead to cardiac remodeling (structural enlargement, specifically left ventricular hypertrophy) and is associated with an increased risk of sudden cardiac events. Hypertension is often called the "silent killer" reflecting the fact that it is very dangerous and that individuals often do not know they have hypertension. In the early stages of disease progression, hypertension does not have perceptible symptoms. Nonetheless, even early stages of hypertension cause significant damage to the vessels and heart. Recognizing the damage done by hypertension and the risk it poses, the American College of Cardiology/ American Heart Association (ACC/AHA) recently lowered the blood pressure values that defines a person as having hypertension. A blood pressure of >130 mmHg systolic blood pressure or >80 mmHg diastolic blood pressure is now considered hypertensive.

Unfortunately, hypertension is prevalent in firefighters. **We recently reviewed data from occupational health exams and found that 69% of firefighters met the criteria for hypertension (Khaja, et al., 2021).**

HYPERTENSION AMONG FIREFIGHTERS

A 20-year retrospective study of line-of-duty firefighter autopsies revealed that 80% of cardiac-related fatalities had both coronary heart disease and an enlarged heart (cardiomegaly and/or left ventricular hypertrophy) (Smith, Haller, & Korre, 2018). It is well-documented that hypertension is a major factor for both conditions. Additionally, evidence suggests that firefighters may be at greater risk for hypertension than the general population based on their exposure to smoke and particulate matter, psychological stress, noise, and disrupted sleep patterns (Khaja, et al., 2021).

Firefighters with even "mildly" elevated blood pressures are at an increased risk for a sudden cardiac event. All firefighters should routinely have their blood pressure measured, and action should be taken to manage high blood pressure as soon as it is detected. Exercise training is effective in lowering blood pressure by approximately 4-8 mmHg. Weight loss and dietary interventions can also help manage blood pressure. When lifestyle changes are not sufficient to control blood pressure, medications should be used. Often a combined approach is needed. It is critical that individuals remain compliant with their blood pressure medication. When blood pressure remains uncontrolled it continues to silently cause damage to the heart and blood vessels throughout the body.

PREVALENCE OF HYPERTENSION IN FIREFIGHTERS BY AGE COMPARED TO THE GENERAL POPULATION

As stated above, we have found a large percentage of firefighters have hypertensive blood pressure readings which is consistent with previous research. Our study included over 5,000 firefighters, including firefighters from four different geographic regions of the U.S. Due to the large number of firefighters involved in the study, we were able to investigate the relationships between age, BMI, and hypertension.

The study found that among male firefighters, the prevalence of hypertension increased with age; 45% of firefighters between the ages of 20-29 years were hypertensive, and the percentage with hypertension increased to 77% among 50-59-year-olds (Figure 5). The study also found that firefighters had a greater prevalence of hypertension than the general population for each age group that was studied. These results provide a concerning picture of hypertension in firefighters. The study also found that female firefighters over 50 years old had higher levels of hypertension than the general population. Furthermore, many firefighters were unmedicated or their hypertension was uncontrolled (Khaja, et al., 2021).
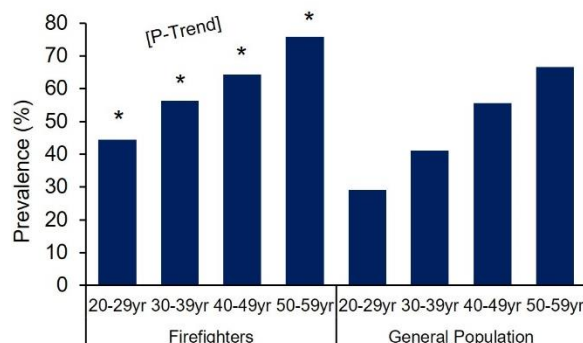

Figure 5: Prevalence of hypertension in male firefighters compared to the general population by decade (From Khaja et al, 2021).

Interestingly a 2012 study investigating the prevalence of hypertension in the U.S. workforce found that protective service workers (police and firefighters) had the lowest awareness of their hypertensive blood pressures, the lowest treatment of hypertension in those who were aware of the condition, and lowest prevalence of controlled blood pressure (Davila, et al., 2012).

Cardiovascular risks associated with hypertension are significant. Hypertension exacerbates ASCVD and can lead to structural changes in the heart including enlargement. An enlarged heart is directly linked to increased mortality regardless of the underlying etiology. Retrospective studies show that firefighters with hypertension are 3.5 times more likely to experience a fatal sudden cardiac event (Kales, Soteriades, & Christophi, 2007). Furthermore, firefighters who are normotensive are over 4 times more likely to survive a cardiac event than those with hypertension (Khaja, et al., 2021).

Firefighters with uncontrolled hypertension are at a significant risk for a sudden cardiovascular event making control of blood pressure paramount to firefighter well-being. Intervention related to prevention, management and treatment of hypertension are essential to prevent sudden cardiac events in firefighters.

This information reinforces the importance of early detection and treatment. Health care providers who evaluate and/or treat firefighters should aggressively counsel them on the importance of managing hypertension, educate them on effective strategies to lower blood pressure, and reinforce the importance of taking action to address this serious medical concern.

ALTERED BLOOD LIPIDS

Measuring the amount of different lipids in the blood is an important screening tool for CVD risk stratification. Routine blood work (a lipid panel) provides information about total cholesterol, low-density lipoprotein cholesterol (LDL-C; bad cholesterol), high-density lipoprotein cholesterol (HDL-C; good cholesterol) and triglyceride levels.

ROLE OF LIPIDS IN THE CARDIOVASCULAR DISEASE PROCESS

Cholesterol accumulation in vessel walls is a hallmark of coronary heart disease (atherosclerotic disease). As discussed in Chapter 1, coronary heart disease is caused by atherosclerotic plaque buildup in arterial walls, which can lead to heart attack, stroke, aortic aneurysm, peripheral vascular disease, and other serious health conditions.

Altered or high levels of lipids create inflammation in the walls of large- and medium-sized arteries, increasing endothelial dysfunction that further exacerbates the CVD progression. Vascular inflammation promotes the growth of plaque, loosens plaque depositions, and can trigger blood clots. The pathogenic role of inflammation is a known contributor to coronary heart disease and participates in all phases of the atherosclerotic plaque development process. Atherosclerosis is a primary cause of ischemic heart disease and stroke.

Reducing cholesterol and triglycerides while increasing HDL levels are primary focuses of patient care treatment standards.

PREVALENCE OF HIGH LIPIDS IN FIREFIGHTERS

Occupational health clinics provided lipid values from over 4,500 firefighters from occupational medical evaluations in order to quantify prevalence of altered lipid profiles among firefighters (Moffatt, et al., 2021). Major findings include:

- 33% had high cholesterol
- 36% had high triglycerides
- 43% had low HDL cholesterol

Furthermore, the percentage of firefighters with detrimental lipid values increased with age (Table 1). Female firefighters generally had a lower prevalence of altered lipids than their male counterparts. Firefighters with altered lipid values should be coached on lifestyle interventions to mitigate worsening lipid risk profiles. Better eating habits and physical activity both positively affect lipid profiles. In fact, physical activity leads to considerable increases in HDL levels. The use of statins (drugs that can lower cholesterol) to reduce CVD progression should also be a consideration for firefighters and their health care providers.

Table 1: Percentage of firefighters with high cholesterol, low HDL, and high triglycerides by decade (From Moffatt et al, 2021).

	Age range (yrs)			
	20-29	30-39	40-49	50-59
High Cholesterol				
Male	3	9	23	40
Female	2	6	7	6
Low HDL				
Male	19	21	30	26
Female	15	24	25	33
High Triglycerides				
Male	5	8	16	14
Female	2	1	2	6

METABOLIC DISORDERS

The term cardiometabolic disease recognizes the overlap between metabolic disorders and CVD. Those with metabolic disorders typically have altered blood lipids, obesity and/or altered blood glucose.

METABOLIC SYNDROME AND CARDIOVASCULAR DISEASE

Metabolic syndrome is a disease process identified by a cluster of cardiometabolic risk factors. Metabolic syndrome is defined as having three or more of the following:

- Increased waist circumference
- Elevated blood pressure
- Elevated blood glucose
- Low HDL cholesterol
- Elevated triglycerides

The cardiometabolic disease process links risk factors that reflect metabolic dysregulation—such as obesity, altered blood lipids and elevated blood glucose—and CVD, including hypertension, with the risk of coronary heart disease and sudden cardiac death. Metabolic syndrome is increasingly prevalent in the general population.

PREVALENCE OF METABOLIC SYNDROME IN FIREFIGHTERS

In collaboration with our occupational health clinic partners, data was collected from firefighters based on routine occupational medical evaluations (Moffatt, et al., 2021). Data were categorized by age in decades (20–29, 30–39, 40–49, 50–59 years) and compared to the general population (Table 2). Because occupational medical evaluations do not routinely measure abdominal obesity, we were not able to evaluate firefighters for this risk factor. To determine if a firefighter had metabolic syndrome, we included those who had three or more risk factors that were measured during the medical evaluation using standard cut points.

Metabolic health metrics of firefighters worsens with age. Encouragingly, firefighters generally had a lower prevalence of metabolic syndrome than the general population, but it is important to note that our values would have been higher if we had measures of waist circumference to identify abdominal obesity. Furthermore, for firefighters over 50 years old, approximately 15% had metabolic syndrome — a serious condition that greatly increases risk of diabetes and coronary heart disease.

Table 2: Percentage of male and female firefighters with Metabolic Syndrome compared to the general population by decade (From Moffatt et al, 2021).

	Age range (yrs)			
	20-29	30-39	40-49	50-59
Males with Metabolic Syndrome (%)				
Firefighters	4	4	12	16
General Population	4	12	14	27
Females with Metabolic Syndrome (%)				
Firefighters	0	5	4	14
General Population	2	6	16	19

DIABETES

High blood glucose levels are associated with an increased risk of CVD, sudden cardiac events, and insulin resistance. Elevated blood sugars lead to vascular damage in the kidneys, eyes, and skin; altered immune function; nerve damage; and increased risk of dementia and Alzheimer's disease. The risk of CVD is especially high in individuals with diabetes, a high BMI, hypertension, and abnormal lipid values.

An analysis of firefighter fatalities found that diabetes was associated with a six-fold increased risk of experiencing a duty-related fatal cardiac event (Kales, Soteriades, Christoudias, & Christiani, 2003). Elevated blood glucose levels are an important component of metabolic syndrome and are a significant risk factor for diabetes mellitus.

Diabetes mellitus is a disorder in which the body does not produce enough insulin or respond normally to insulin, thereby causing blood sugar (glucose) levels to be abnormally high. Early in the progression of diabetes mellitus, insulin is produced by the pancreas, but due to abnormalities in muscle cells and excess fat, the liver becomes resistant to insulin. In this situation, the pancreas is unable to produce enough insulin to properly control blood sugar levels.

There is a direct link between insulin resistance and a high BMI and obesity. The more fatty the tissue within the body, the more resistant the cells become to insulin. Abdominal obesity (a large waist circumference) in particular has a detrimental impact on the body's ability to utilize insulin, thereby increasing the risk of developing insulin resistance and CVD. A waist circumference of >40 inches for men or >35 inches for women is a risk for metabolic syndrome and diabetes.

PREVALENCE OF HIGH BLOOD GLUCOSE IN FIREFIGHTERS

Table 3 reports the percentage of firefighters and general population by decade with high blood glucose levels. A lower prevalence of high blood glucose among firefighters may be due to the "healthy worker effect" and guidelines (1582) that preclude the hiring of candidates with insulin dependent diabetes and job restrictions for members with diabetes. Higher prevalence of high blood glucose with increasing age is concerning because of the risk of diabetes and cardiovascular events. Firefighters and their health care providers need to take aggressive steps to combat elevated blood glucose levels, including medication where appropriate, a regimented weight loss/control program, and ongoing medical assessments.

Table 3: Percentage of male and female firefighters with high blood glucose compared to the population by decade (From Moffatt et al, 2021).

| | Age range (yrs) | | | |
	20-29	30-39	40-49	50-59
Males with High Blood Glucose (%)				
Firefighters	1	1	4	11
General Population	4	6	10	26
Females with High Blood Glucose (%)				
Firefighters	2	1	2	7
General Population	1	4	11	18

OBESITY

Obesity is a significant clinical marker of potential underlying disease. Several national organizations have declared an obesity epidemic in the U.S., and the CDC has listed obesity as one of the top five risk factors for attributable deaths and disability-adjusted life years.

ROLE OF OBESITY IN CARDIOVASCULAR DISEASE

Obesity is a major health concern because it increases the risk of CVD and several other important health conditions, including:

- Coronary heart disease
- Structural enlargement of the heart (cardiomegaly and left ventricular wall thickness)
- Hypertension
- High cholesterol
- Diabetes
- Kidney disease
- Various cancers
- Gallbladder disease
- Osteoarthritis
- Sleeping disorders

The physiological mechanisms by which obesity leads to multiple diseases are complex, but they involve chemicals released from the adipose tissue (adipokines) and an inflammatory cascade. Excess adiposity leads to several pro-inflammatory effects in the vascular system, including adipocyte tissue dysregulation and decreased insulin sensitivity. The disruptive nature of these conditions can cause endothelial dysfunction (damage to the lining of the blood vessels), which is further related to atherosclerosis, hypertension, and hyperlipidemia.

Obesity among firefighters is especially concerning because it is associated with impaired work performance, an increased risk of work-related injuries, and an increased risk of sudden cardiac events (Mathias, Bode, Stewart, & Smith, 2020). Research has also shown that obesity in firefighters is associated with a four-fold increase in risk of duty-related coronary heart disease-related deaths (Geibe, et al., 2008). Furthermore, as discussed earlier, firefighter line-of-duty autopsy records indicate that nearly 80% of cardiac-related deaths had evidence of a structurally enlarged heart (Khaja, et al., 2021). This is likely related to the high prevalence of firefighter obesity. In a separate study, obesity was associated with a two-fold increased risk of left ventricular hypertrophy in firefighters (Soteriades, Targino, & Talias, 2011).

PREVALENCE OF OBESITY IN FIREFIGHTERS

A large portion of the U.S. population is overweight or obese. To a large extent, obesity in the fire service mirrors obesity in the general population. Our research has found that among a group of nearly 5,000 predominately career firefighters, approximately 37% of male firefighters were obese and 25% of female firefighters were obese (Moffatt et al, 2021).

ROLE OF AGE AND OBESITY ON CVD RISK

Aging is associated with a higher prevalence of CVD risk factors in both firefighters and the general population.

Figure 6 presents the calculated 10-year risk of a cardiovascular event using the Framingham Risk Score (based on number and severity of risk factors) for firefighters who had normal weight (BMI 18.5–25), were overweight (BMI 25–30), and were obese (BMI >30), among different age groups. In every weight category, the 10-year risk of a cardiac event increased with age, but the risk was greater in the obese category. Among normal weight individuals who are over 50 years, the 10-year risk is only about half the risk for the obese group. Advancing age is an unavoidable factor that increases risk for cardiac events. In contrast, obesity is preventable and treatable and is known to have a substantial impact on overall morbidity and mortality.
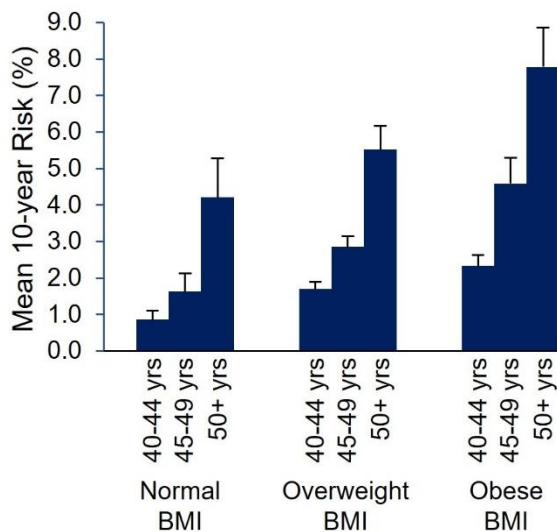

Figure 6: Percent of firefighters within 10-year ASCVD Risk Score based on age (yrs) and BMI category (From Hollerbach et al, 2020).

These findings emphasize the importance of prevention through earlier risk factor interventions, whether through lifestyle changes in diet or fitness or through medications. Healthcare providers who evaluate firefighters should aggressively counsel them on the importance of managing body weight as part of decreasing CVD, decreasing cancer risk, and improving job performance.

WEIGHT CHANGE AND CARDIOVASCULAR RISK

Working with our occupational clinical partners we tracked 656 firefighters from Northern Virginia over a 5-year period looking at changes in weight and CVD risk factors. On average, firefighters in this study gained 0.5–1.6 kilograms per year—but not all firefighters gained weight (12% lost more than 3% of body weight, 38% remained weight stable defined as within + or – 3% of body weight, and 50% gained more than 3% of body weight (BW)). Among firefighters who gained more than 3% of their body weight, they gained an average of 6.6 kilograms over the 5 years.

Table 4 presents the percentage of firefighters by weight change (lost, maintained, or gained weight over 5 years) who had major CVD risk factors at occupational medical evaluations performed 5 years apart.

Firefighters who gained weight also had an increase in BMI, total cholesterol, LDL cholesterol, and blood glucose; an increase in their 10-year risk of a CVD event was also noted. Of concern was also a marked decrease in their HDL, or good cholesterol.

Table 4: Percentages of firefighters with CVD risk factors at two occupational health exams conducted 5 years apart in those who lost weight, maintained weight, or gained weight (From Moffatt et al, 2021).

	Total Sample		Lost Weight (>3% of BW)		Maintained Weight (±3% of BW)		Gained Weight (>3% of BW)	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Obese (%)	27	36[*]	38	20[*]	26	29	25	45[*]
High Cholesterol (%)	9	14[*]	6	12	12	12	8	16[*]
Low HDL (%)	27	27	29	22	31	26	24	30[*]
High Blood Glucose (%)	1	3[*]	6	6	2	2	0	44[*]
High Blood Pressure (%)	56	44[*]	59	39[*]	61	42[*]	53	48

* statistically different from Time 1; p<.05.

HDL picks up excess cholesterol in the blood and takes it back to the liver where it is broken down and removed from the body. Thus, a decrease in HDL (or low HDL-c) is a negative finding in terms of health.

Although obesity is modifiable and manageable, Americans struggle considerably with losing weight. Almost half of Americans try to lose weight in a given year (Martin, Herrick, Srafraxi, & Ogden, 2018), and when successful, many struggle to maintain the weight lost. Fortunately, for those who are dealing with obesity, even modest weight loss yields cardiovascular benefits. Among firefighters, it has also been shown that increasing BMI is associated with a negative CVD profile (Bode, et al., 2021). Research consistently shows that firefighters and the general population tend to gain weight (and increase BMI) as they age. But, this is not inevitable. A fire service study using occupational medical evaluation data found that 12% of firefighters lost more than 3% of their body weight over a 5-year period. The firefighters who lost weight also had a significant reduction in BMI, total cholesterol, LDL cholesterol, and systolic and diastolic blood pressures, and a significant increase in HDL cholesterol, despite advancing age (Mathias, Bode, Stewart, & Smith, 2020). And, among those who maintained their weight within 3% of their body weight, there was not a detrimental change in CVD risk profile. This data clearly shows that many of the detrimental effects of aging can be mitigated by maintaining or losing weight.

Occupational health care providers and primary care physicians who care for firefighters have a powerful opportunity to counsel the fire service on the risks associated with excess weight and the possibility for health improvements with lifestyle changes as well as medication use, as needed. Hopefully, healthy weight will become a significant cultural value for the fire service and more firefighters will adopt healthy lifestyle choices, like exercise and healthy eating habits, that contribute to a healthy body weight.

TOBACCO USAGE

Tobacco use is the leading preventable cause of cancer and cancer deaths. Tobacco use causes lung cancer, and cancers of the mouth and throat, voice box, esophagus, stomach, kidney, pancreas, liver, bladder, cervix, colon and rectum. Sadly, cancers linked to tobacco use make up 40% of all cancers diagnosed (CDC Vital Signs).

Smoking is also a major cause of CVD. Those who smoke are 2 to 4 times more likely to develop CHD than non-smokers, and more than 2 times as likely to have a stroke. Smoking increases the risk of cardiac events and stroke through multiple mechanisms, including increasing blood pressure, raising triglycerides, lowering HDL (good) cholesterol, damaging blood vessels in the heart and brain, increasing the risk for blood clots, and increasing plaque build-up in blood vessels. Recent estimates indicate that smoking kills more than 440,000 Americans each year (AHA, 2021).

Smoking extracts a significant toll on firefighter health. It is a strong independent risk factor for on-duty CHD events, CHD-related retirements, and for CHD event case-fatality among firefighters. Among firefighters who suffered on-duty CHD fatalities, the prevalence of smoking was 40% to 50% (Kales, et al., 2003) which is much higher than the prevalence of smoking in the fire service population. The health risks associated with other forms of tobacco use are not as well studied in the fire service, but population data reveals that all tobacco use increases risk of cancer and CVD.

TOBACCO USE AMONG FIREFIGHTERS

The prevalence of current smoking likely varies based on region of the country, career status, and departmental policies. Jitnarin and colleagues conducted a study to examine tobacco use patterns in a large, national sample of U.S. firefighters and reported that the smoking prevalence was less than the U.S. population (~17% vs 21%), but the use of smokeless tobacco was higher than the U.S. general population (~14% vs 6%) (Jitnarin, et al., 2015).

Smoking is one of the leading preventable causes of death in the U.S., and it greatly increases the risk of sudden cardiac death (and cancer) among firefighters. Thus, it is important that policies and programs are put in place to decrease tobacco use among firefighters. The NFPA Standard on Fire Department Occupational Safety and Health Programs (NFPA 1500) requires all fire department facilities be designated smoke-free. It is also important that firefighters have access to tobacco cessation programs. Cessation has been shown to decrease the risk of CVD and death (Virani, et al., 2021).

Since the use of smokeless tobacco is higher in the fire service than the general population, tobacco cessation programs should target this use of tobacco as well because it is also associated with CVD and cancer. A study assessing firefighters' perceptions about smokeless tobacco cessation programs noted both intrapersonal barriers and lack of support from health providers and lack of enforcement of existing policies (Jitnarin, et al., 2021).

CHAPTER 3: MEDICAL SCREENING

There is a pressing need to reduce the number of cardiac events in the fire service, and occupational medical evaluations serve as an important role in meeting that goal.

CURRENT RECOMMENDATIONS IN THE FIRE SERVICE

NFPA 1582 Standard for Comprehensive Occupational Medical Program for Fire Departments is considered the industry standard for occupational medical evaluations for firefighters. As an "occupational medical evaluation" guideline, the NFPA 1582 Standard is intended to identify risks that could lead to a sudden incapacitation and risks that make a firefighter not suitable to be medically cleared for duty. NFPA 1582 also recommends screening for CVD risk factors, including total cholesterol, HDL cholesterol, LDL cholesterol, blood glucose, and blood pressure, with a goal to initiate early intervention and to slow disease progression in firefighters at risk, even if they are still medically cleared for duty.

As shown in Figure 7, medical evaluations can range considerably from no medical evaluation required to going beyond the NFPA 1582 Standard. Evaluations may vary by location, the provider type, and the funding availability. Researchers of the BETTER HEART project believe that screening requirements should consistently meet NFPA 1582 as a *minimum* standard.
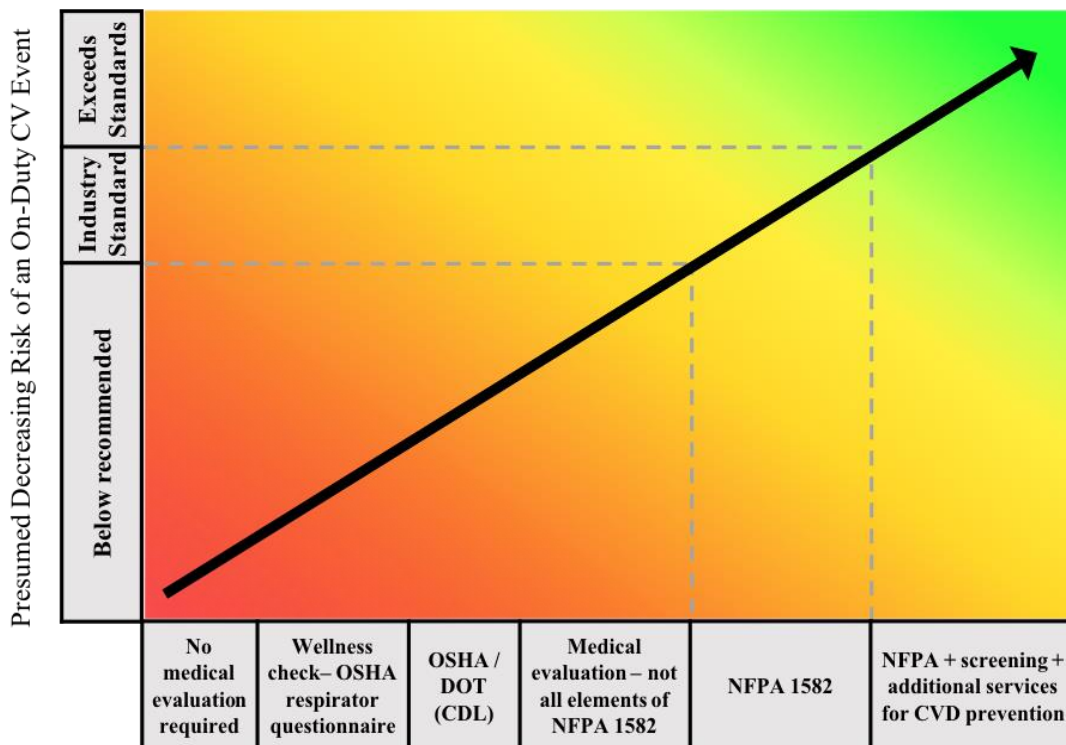

Figure 7: Provision of medical evaluations for firefighters (candidates and incumbents) (From Tobia et al, 2020).

SCREENING FOR CVD

Screening plays an important role in the primary prevention of CVD and is important in public safety professions where a cardiac event could lead to sudden incapacitation of an individual and impair the safety of others.

Atherosclerotic cardiovascular risk prediction tools are important in guiding decision-making about medication usage for primary disease prevention. Several screening tools that help assess risk level of individuals or detect abnormalities are presented in Table 5.

Major CVD risk factors are regularly assessed during occupational medical exams. The ACC/AHA atherosclerotic cardiovascular (ASCVD) Risk Score uses an algorithm to provide a 10-year risk of CVD event based on presence and severity of several individual risk factors. This tool is currently recommended by NFPA 1582 for asymptomatic firefighters over the age of 40 years. Newer risk calculators (Astro-CHARM) are available that used a younger population to develop algorithms and that included the use of coronary artery calcium (CAC) scan along with traditional risk factors to assess risk of a cardiac event (Khera et al, 2018).

Occupational health exams for firefighters also include obtaining a resting ECG (electrocardiogram) to detect the presence of arrhythmias or evidence of ischemia.

Echocardiograms are performed by trained technicians and provide ultrasound images of the heart. This tool can be used to assess heart size, and structural and functional features of the heart.

An exercise test is recommended for all firefighters (based on NFPA 1582) because cardiorespiratory fitness (CRF) is essential to perform the job and because fitness is a primary predictor of CVD (Ross et al., 2016). However, if the test does not include an ECG, it is not a screening tool for CHD. Exercise stress testing is typically used to evaluate individuals who have symptoms, (e.g., angina or shortness of breath) with exertion. This test involves obtaining an ECG while an individual performs progressively increasing exercise. The ECG may indicate signs of ischemia during exercise not present at rest, suggesting that a coronary artery has plaque that limits the ability to adequately increase blood flow.

Calcified plaque is a specific feature of advanced coronary artery atherosclerosis. The CAC scan is a rapid and reproducible CT scan that detects calcified plaque and uses an algorithm to quantify the amount of plaque. The test can be performed without any special preparation (withholding of medication, fasting). It is relatively inexpensive and widely available. A direct relationship exists between CAC scores and major adverse clinical cardiovascular outcomes in asymptomatic individuals (Greenland, et al., 2018).

The types of screening tools that should be employed are based on the goals of screening, the risk level of the population, and the cost/benefit decisions that are often made by policy makers. In the context of primary prevention of CVD, several national and international organizations have made recommendations on CVD screening. These recommendations are often made to guide treatment decisions.

Table 5: Cardiovascular Disease Screening Tools

Screening Tool	Description	Notes
CVD Risk Factors	**Modifiable risk factors** - High BP, high cholesterol, diabetes, smoking, obesity, low fitness. **Non-modifiable risk factors** - Age, family history of CVD, sex.	Routinely assessed to determine increased risk of CVD and to guide treatment.
ASCVD Risk Score	A weighted score based on number and severity of risk factors that assesses the 10-year risk for first CVD event.	Provides a quantifiable metric of 10-year risk of atherosclerotic CVD event. Several risk calculators are available.
Electrocardiogram (ECG)	Measures the electrical activity of the heart to evaluate for abnormalities related to ischemia and arrhythmias.	A resting ECG may fail to detect ischemia that occurs with exertion. An ECG is an insensitive tool to detect LVH.
Echocardiogram	Uses ultrasound to evaluate chamber dimensions, valve structure, and wall thickness. Can assess contractility abnormalities.	A common diagnostic tool to assess cardiac structure and function. Requires a skilled sonographer. Can screen for left ventricular hypertrophy.
Stress testing	A stress test assesses cardiac changes during exercise (usually on a treadmill). **Exercise Stress Testing (EST)** –uses ECG during exercise to assess ischemia or arrhythmias. **Treadmill Stress Echocardiogram –** assesses cardiac contractile changes following exercise.	The assessment of cardiorespiratory (CRF) fitness by exercise testing is recommended for all firefighters in NFPA 1582, partly because CRF is an important risk factor. Exercise Stress Testing to 12 METs (with or without imaging) is recommended for individuals with intermediate 10-year ASCVD risk.
Coronary Artery Calcium (CAC) scan	Uses computed tomography (CT) scan to evaluate calcified atherosclerotic plaque in coronary arteries. Provides an index of global atherosclerotic burden.	A relatively inexpensive and readily available tool to image coronary arteries. Exposes individual to some radiation exposure (similar to mammogram). Incrementally improves accuracy of 10-year ASCVD score to predict major adverse cardiac events.

CURRENT CAC SCREENING

While CAC scores are associated with the degree of CVD and with disease outcomes, there is still some uncertainty about when this test should be performed. Most of the guidelines that have been developed on the use of CAC have focused on the role of CAC in guiding decisions on statin treatment.

These guidelines generally do not recommend CAC testing for individuals with very low ASCVD Risk Scores (<5%), because they are unlikely to benefit from statin treatment, or for individuals with a very high (>20%) ASCVD Risk Score, because they should be treated with statins regardless of CAC scores. However, there is variability in current recommendations. In 2017, Society for Cardiovascular Computed Tomography (SCCT) produced an Expert Consensus Statement maintaining that it is appropriate to perform CAC testing in the context of shared decision-making in asymptomatic individuals without clinical CVD who are 40-75 years of age in the 5-20% 10-year ASCVD risk group and, selectively, in the < 5% ASCVD risk group (Hecht et al. 2017). The 2018 Cholesterol Guidelines adopted by the American College of Cardiology/American Heart Association (ACC/AHA) stated that CAC scoring is reasonable to guide the clinician-patient risk discussion for primary prevention in asymptomatic adults 40-75 years of age, with LDL-C of 70-189 mg/dL and at intermediate risk (≥7.5% - <20% 10-year ASCVD risk), or in selected patients at borderline risk (5.0% - 7.4% 10-year risk) if risk-based decisions for statin therapy remain uncertain (Grundy et al, 2018). The European Society of Cardiology/European Atherosclerosis Society (ESC/EAS) recommended that CAC scoring be considered as a risk modifier in patients at low or moderate risk of CVD (Mach, et al., 2020). The National Lipid Association has also provided recommendations on the use of CAC in those with an ASCVD risk score <20% (Orringer, et al., 2021). Unlike the other recommendations, the U.S. Preventive Services Task Force concluded that the current evidence was insufficient to evaluate the balance of benefits and harms of the addition of CAC scores to traditional ASCVD risk assessment (USPSTF, 2018).

CAC scoring has known benefits among borderline- to moderate-risk populations, especially when used with traditional risk factor-based assessments. Although not frequently studied, some literature also demonstrates a correlation between CAC score among asymptomatic younger individuals and increased CVD risk (Nakanishi, et al., 2016; Jin, et al., 2012). Furthermore, CAC can identify individuals at increased risk for CAD that would have been classified as low risk based on clinical assessment (Church, et al., 2007). Thus, CAC may have benefits across other populations to stratify CVD risk for intervention, though this requires more research studies.

RESEARCH ON CAC IN THE FIRE SERVICE

Importantly, no organizations have issued guidelines on the utility of CAC scores to identify coronary heart disease in workers who perform strenuous work or perform public safety duties where sudden incapacitation is a particular concern. There is some research, however, suggesting that CAC scores could be useful in the fire service. Santora et al. measured CAC scores

in 399 asymptomatic firefighters and found coronary calcium in 12 firefighters under the age of 45 years (highest value = 232) (Santora, et al., 2013). The authors also found that 87% of the firefighters had a higher CAC score (Agatson score) compared to the national data base. The authors concluded that firefighters have a high burden of coronary artery disease, and that the burden of CVD among firefighters is greater than would be anticipated based on age and coronary disease risk factors.

Similarly, a study by Pillutla and colleagues found that firefighters who had an abnormal finding on an exercise stress test had significantly higher CAC scores than a control group who had an abnormal finding on an exercise stress test and were matched by age and CVD risk factors (Pillutla, Li, Ahmadi, & Budoff, 2012). Ashen and colleagues assessed CAC and traditional risk factors among firefighters over 40 years and found that 39% had evidence of some calcium in their coronary arteries (CAC score > 0). This was considerably higher than expected based on the age, sex, and ethnicity of the study group (Ashen, Carson, & Ratchford, 2022). Importantly, 74% of those with CAC were not taking lipid lowering medication. The authors conclude that relying on atherosclerotic CVD risk scores alone would have missed the opportunity to identify firefighters with heart disease.

Knowledge of CAC scores can also motivate lifestyle changes to manage CVD risk factors. In the EISNER study, volunteers were randomly assigned to get or not get a CAC scan and were followed for years. Those randomized to the CAC scanning group had favorable changes in blood pressure, LDL-C, abdominal obesity, and a lower Risk Score compared to those who were randomly assigned to the no CAC scan group (Rozanski et al, 2011). A meta-analysis also found that knowing one's CAC score can impact initiation and continuation of preventive medications. Those who received a CAC score > 0 were more likely to initiate aspirin and lipid-lowering medications, initiate antihypertension medication, increase exercise, and change dietary habits compared to those with a CAC score = 0 (Gupta, et al. 2017).

DEVELOPING ENHANCED GUIDELINES

The Medical Advisory Team (MAT), an assembled team of experts, recommends enhanced testing beyond what is stipulated by NFPA, via CAC scans and Echocardiogram to detect underlying CAD and structural heart changes. In the absence of specific published guidelines or randomized clinical control trials assessing the outcomes of those with and without CAC scans during the medical evaluation, the MAT made these recommendations for enhanced screening based on expert judgment considering:

- the ability of the CAC score to incrementally improve risk prediction;
- research suggesting that firefighters may have greater atherosclerotic burden than the general population;
- evidence that most firefighters who die of CVD have atherosclerosis and left ventricular hypertrophy and/or cardiomegaly; and,
- evidence that firefighting itself can trigger a cardiovascular event in individuals with underlying CVD.

BACKGROUND EVIDENCE

The MAT relied on published data and research, including:

- CVD is responsible for approximately 1 in 4 deaths in the U.S.
- Firefighting leads to significant cardiovascular strain (Smith, et al., 2016).
- Firefighters are approximately 50–100 times more likely to die of Sudden Cardiac Death (SCD) following firefighting duties versus station duties or non-emergency assignments (Kales, Soteriades, & Christophi, 2007; Smith, et al., 2019).
- It has been hypothesized that firefighting activity can *trigger* a cardiovascular event because of multiple stressors, including activation of the sympathetic nervous system, heavy muscular work, heat stress, dehydration, and exposure to products of combustion on the fire ground (Smith, Barr, & Kales, 2013; Kales & Smith, 2017).
- The factors related to SCD in the fire service are complex and include disease progression, occupational risk factors, individual behavior, CVD risk factors, and underlying disease substrates (Soteriades, et al., 2011).
- The cause of SCD among firefighters is most reported as myocardial infarction (heart attack) or cardiac arrest due to arrhythmia.
- 80% of SCD among U.S. firefighters occurred in individuals with autopsy-confirmed evidence of atherosclerosis **and** an enlarged heart (either cardiomegaly or left ventricular hypertrophy) (Smith, et al., 2018).
- Cardiac arrest due to arrhythmias may be more common than previously

understood. At autopsy, only 16% of cardiac-related fatalities had evidence of a coronary artery thrombus (Smith, et al., 2018); however, 87% had an enlarged heart (cardiomegaly or left ventricular hypertrophy) that increases the risk of arrhythmia and adverse cardiac outcomes (Shenasa, Shenasa, & El-Sherif, 2015; Vakili, Okin, & Devereux, 2001).

BASIC ASSUMPTIONS

The MAT made some assumptions during its work, including:

- Firefighters perform a critical public safety role and should receive the best screening possible to detect underlying disease so that it can be properly treated to prevent sudden incapacitation.
- NFPA 1582 is the industry standard for occupational medical programs, and our recommendations build upon it.
- Occupational medical screening has incorporated CVD screening for many years, relying primarily on assessment of modifiable disease risk factors.
- Techniques are becoming more readily available, and more affordable, to detect atherosclerosis in the coronary arteries (using CAC scans) and structural heart changes (echocardiography).
- Recommendations for cardiac screening of firefighters should not contradict current guidelines for the general population but may extend beyond them when appropriate.
- Firefighters will still be evaluated based on NFPA standards to evaluate risk of other heart conditions, such as A-Fib, and for metabolic disorders.

CHAPTER 4: BETTER HEART ENHANCED SCREENING RECOMMENDATIONS

The MAT (see page 4 for listing) made two recommendations for enhanced cardiac screening based on current medical literature, research related to firefighter cardiovascular health, and expert opinion.

RECOMMENDATION 1

Firefighters should be screened for coronary heart disease using Coronary Artery Calcium scans at age 40 years, or earlier based on clinical judgement, such as in individuals with an intermediate or high Risk Score, or in those with risk factors and a family history of premature coronary artery disease.

We used the following rationale to support this recommendation:

- CAC scans are readily available and relatively inexpensive ($50–$200) and provide direct evidence of coronary artery disease. This new screening method is far more effective in identifying individuals with CVD than relying on risk factor analyses; thus, it is more helpful in identifying firefighters who are at risk of a cardiac event, facilitating provision of appropriate medical management and lifestyle interventions to prevent or reverse disease progression.
- CAC scans before the age of 40 years is not recommended in most individuals as calcified atherosclerosis is less likely to be identified in this age group. CAC scans, however, can still be performed in individuals under the age of 40 on a case-by-case basis determined by clinical judgment if a healthcare provider considers the firefighter at a higher risk than estimated by Risk Score. Because risk calculators are heavily influenced by age, it is important for clinicians to have the option of doing a CAC to detect premature atherosclerosis in those who have elevated risk factors.
- By measuring CAC at a relatively young age (40 years), we increase the likelihood of identifying the atherosclerotic disease early, improving the likelihood of successful treatment.
- The purpose of an NFPA 1582 occupational medical exam is to identify firefighters at high risk for a sudden cardiac event so that they can be 1) referred for further evaluation and treatment, and 2) given work restrictions. Use of a CAC scan may assist with these goals. A CAC scan may also serve as a useful motivational tool to manage CVD risk factors.

Repeat scans:
- If the CAC score is > 0, repeat in 5 years, or as determined by primary care physician or cardiologist.
- If the CAC score = 0, repeat in 5-10 years, as scores may change in < 5 years.

DESCRIPTION OF CORONARY ARTERY CALCIUM SCANS

Coronary Artery Calcium (CAC) scans, or coronary calcium screening, are an effective clinical screen for atherosclerosis. As discussed in Chapter 1, atherosclerosis is the buildup of plaque in the coronary arteries. Over time this plaque becomes calcified. CAC scans literally take an image of the heart, scanning for any calcification on the vessel walls. The amount of calcium buildup shown in these scans is used to create a coronary calcium score. Health professionals who conduct these exams use CAC scores to calculate if patients have any evidence of calcium in their arteries (a score greater than 0) and to provide risk stratification or guide clinical care based on the calcium score. Figure 9 shows scanning images of a normal heart, one with moderate calcification and one with severe calcification.

Not only are these scans accurate in identifying coronary heart disease, but they have also become very affordable and accessible. The goal of enhanced screening is to detect disease early and to treat it effectively to lessen cardiac events.
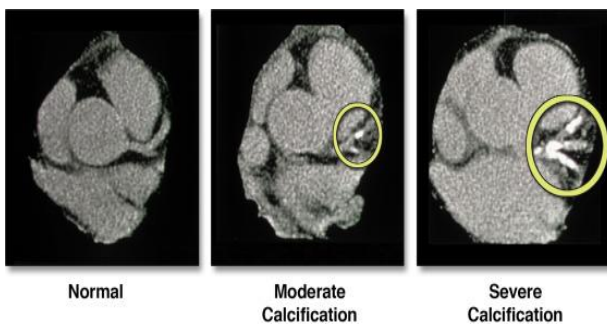

Figure 9: Cardiac Calcium Images

RECOMMENDATION 2

Firefighters should be screened for structural heart disease (including left ventricular hypertrophy, cardiac chamber enlargement, valvular abnormalities) using echocardiography at age 40 years, or earlier in the presence of hypertension, obesity, and/or sleep apnea.

We used the following rationale to support this recommendation:

- Echocardiography is readily available, relatively inexpensive ($200–$600) and provides useful information about the structure and function of the heart.
- Structural enlargement of the heart (left ventricular hypertrophy or cardiomegaly) is associated with a greater risk of arrhythmia (Shenasa, Shenasa, & El-Sherif, 2015; Vakili, Okin, & Devereux, 2001) and sudden cardiac death in firefighters (Smith, et al., 2018).
- Early identification of structural and functional abnormalities of the heart can help guide better management of systemic diseases that would otherwise be underappreciated or unrecognized in routine clinical practice.

DESCRIPTION OF ECHOCARDIOGRAMS

Echocardiograms are a non-invasive test that use ultrasound technology to create an image of the heart. This allows for the determination of a thickened ventricular wall (left ventricular hypertrophy) or enlarged heart size (cardiomegaly) that make the heart more vulnerable to sudden

cardiac arrest (see Chapter 2). The echocardiogram can also help detect valvular issues and functional changes associated with diastolic dysfunction or wall motion abnormalities. If structural abnormalities are noted, firefighters should be referred to a cardiologist. Fortunately, many changes are reversible if individuals follow treatment or prevention plans.

IMPLEMENTING RECOMMENDATIONS: PILOT PROGRAM RESULTS

Several fire service partners and occupational medicine clinics collaborated with the BETTER HEART team on developing the enhanced screening recommendations and offered to pilot the recommendations in their own departments. Unfortunately, the COVID-19 pandemic created major gaps in occupational health screening. During the early portion of the project, many clinics and fire departments postponed annual medical evaluations to prevent the spread of the virus, while later in the pandemic clinics were faced with staffing shortages.

Although no department was able to obtain testing on all its firefighters, two departments were able to negotiate programs to test firefighters moving forward. One department (Loudoun County (VA) Combined Fire and Rescue System) was successful in negotiating funding from the county to pay the cost of the additional testing and then negotiated with its contracted occupational health care provider to arrange for the testing. That testing has now been initiated and we anticipate sharing lessons learned with the fire service as soon as possible. Another department (Indianapolis FD) worked with the occupational health care provider who delivers the medical screening (Ascension St Vincent), and one of the partner groups from the clinic offered to pay a large percentage of the cost of implementing the screening recommendations. From February through December of 2021, this group screened 668 firefighters. The coronary calcium screening detected some level of calcium in the majority of firefighters over 35 years of age, although few of them had "high" calcium scores. An important part of this program is a referral to specialists, including registered dieticians; advanced lipid screening; and, referral to cardiologists to manage lipid disorders and hypertension. One of the lessons learned was that many firefighters did not complete their referrals. We must continue to find ways to motivate firefighters to follow-up on the findings of their medical evaluations, including the need for specialty care.

These two examples point out that different models are likely to be successful in different departments based on structure, funding, and ongoing relationships with occupational health clinics. In some

communities, CAC scores are already being offered through voluntary programs based on local clinics or programs that have been provided by donors.

The cost of the screening is often noted as a concern. However, the cost of screening can often be negotiated with health care systems and many departments have found that the cost of the CAC scores are not prohibitive. Furthermore, the cost of not detecting underlying CVD must also be considered in discussions of financial cost. A firefighter who is not properly screened or evaluated for CVD misses an opportunity to treat the disease before it progresses to a cardiac event. Cardiac surgery and rehabilitation are very expensive. And, if a firefighter is able to return to work following a cardiac issue, it often requires a significant amount of time off of work with associated back fill costs. Additionally, it is important to note that unlike annual screening, the recommended tests (CAC and Echo) only need to be done every 5-10 years if no abnormalities are noted. Thus, we believe that, for a modest cost, the new recommendations will add useful information and provide an opportunity for early detection of occult CVD in some individuals.

In order to reduce cardiovascular events in the fire service, it is critical that every firefighter receives a medical evaluation by a health care provider who is familiar with the occupational stress of firefighting. However, the additional screening recommendations offer the potential to further reduce the burden of cardiovascular events in the fire service by using technology that is readily available in most locations.

LIMITATIONS

The recommendations provided in this report are intended to help identify CVD in asymptomatic firefighters at an early age so that disease may be managed more effectively. However, it is important to note that screening tools are not absolutely accurate at detecting disease, or ruling out disease. Table 6 indicates that a screening test may accurately indicate a person with the condition being tested for (true positive), or accurately detect a person without the condition (true negative) (both shown in green). However, screening tests may also fail to identify a person with a disease or condition (false negative), or may indicate the presence of a condition in a person who does not have disease (false positive) (shown in red).

Table 6: Matrix comparing screening test results to actual condition.

Test Result	Condition Present	Condition Not Present
Positive	True Positive	False Positive
Negative	False Negative	True Negative

Sensitivity is a measure how often a test correctly identifies an individual with the condition that is being tested for ("true positive" rate). A test with high sensitivity will identify almost everyone who has the disease and not lead to many false-negative results. **Specificity** is a measure of a test's ability to correctly identify an individual who *does not* have the condition that is

being tested for (also known as the "true negative" rate). A test with high specificity will correctly rule out almost everyone who *does not* have the disease and will not generate many false-positive results.

Being attentive to sensitivity and specificity of screening tests is important. One particular concern of a screening test is that false positive tests can lead to additional testing that is expensive, or invasive, or leads to emotional stress.

Another challenge in this context is that coronary heart disease exists on a continuum. An individual may have varying degrees of stenosis associated with atherosclerosis. Furthermore, the size of coronary plaque is not indicative of the likelihood of a plaque rupturing and causing a myocardial infarction. CAC scores are good at identifying individuals with a high risk of possible cardiovascular events and those with a low risk (CAC = 0) (Gagel et al, 2021). However, CAC scores only identify calcified plaque, not plaque that is most vulnerable to rupture.

Echocardiography is an excellent way to identify left ventricular hypertrophy, but it may also identify changes in cardiac size that are due to athletic training and that do not pose risk.

There is no perfect way to predict who will or will not experience a major adverse cardiac event. These recommendations are intended to enhance risk detection and help motivate prevention efforts directed at keeping firefighters safer and healthier as they protect their communities.

CARDIOVASCULAR DISEASE PREVENTION

The goal of this project was to develop evidence-based screening recommendations for the detection of CVD as a way to decrease preventable cardiac deaths. This report, which also discussed data on cardiac deaths, provided information on cardiac disease pathology and the prevalence of CVD risk factors in the fire service in order to provide context for the recommendations that were made. It seems prudent to also include information about CVD prevention in the report.

Those who are heavily invested in CVD prevention programs for firefighters have endorsed the concept of using CAC scores as part of a comprehensive CVD prevention program. This approach allows for the refining of the risk profile so that firefighters can be treated earlier and more effectively.

A recent study by Ashen and colleagues from Johns Hopkins assessed CAC and traditional risk factors among firefighters over the age of 40 years (Ashen et al, 2022). These authors found that 39% of the firefighters had evidence of some calcium in their coronary arteries (CAC score > 0) which is 91% higher than population estimates given the age, sex and ethnicity of the cohort. Importantly, 74% of those with coronary artery calcium were not taking lipid lowering medication. The authors conclude that relying on atherosclerotic CVD scores alone would have missed the opportunity to identify firefighters with atherosclerotic heart disease.

PREVENTATIVE STRATEGIES

- Exercise at least four to five days per week with a focus on aerobic activities such as biking, running, and walking that increase heart rate.
- Maintain a weight that is healthy for your size and avoid excess body weight, especially in the abdominal region. Losing excess weight has been shown to improve CVD risk factors.
- Include lots of fruits and vegetables in your diet and avoid overly processed and fatty foods. The foods you eat have a significant effect on vascular health.
- Avoid tobacco products of any kind, including smokeless and vaping.
- Protect airways from products of combustion while firefighting (including overhaul).
- Consider reducing alcohol intake, as excess alcohol is associated with CVD risk and cancer risk.

- Obtain annual medical evaluations and then **use** the results to guide your health choices. Medical screening is of very little use if you do not use the results. "Medically cleared" does not mean you are healthy.
- Diligently take the medications that are prescribed to you. Medicines for blood pressure will not affect how you feel, but they are critical to preventing vascular damage and to decreasing the risk of sudden cardiac events. Lipid lowering medications may be a necessary addition to dietary changes and increased activity.
- Practice good sleep patterns when you can. Although it is difficult to ensure a good night's sleep when you are on duty, it is critical that you try to get sufficient rest on your off days.

Photos courtesy of: Chief Tracey Reed, Fairfax County Fire and Rescue Department

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KEY TERMS

Angina: A condition caused by CVD manifesting in severe chest pain, often spreading to the shoulders, arms, and neck. The pain is caused by an inadequate blood supply/oxygen to the heart.

Atherosclerotic Cardiovascular Disease (ASCVD): The buildup of fatty deposits and plaque along the arterial walls, which can lead to coronary heart disease, cerebrovascular disease, or peripheral artery disease.

BETTER HEART: **B**uilding **E**valuations **T**hat **T**ranslate **E**vidence and **R**esearch for **H**eart **E**valuations **A**nd **R**elated **T**raining

Body Mass Index (BMI): BMI estimates body fatness. It is used to screen for weight categories that may lead to health problems. It is calculated by dividing a person's weight in kilograms by the square of height in meters.

Cardiac Remodeling: Molecular, cellular, and interstitial changes that manifest clinically as changes in size, mass, geometry, and function of the heart after a CVD-driven injury/infarct. The process results in poor prognosis because of its association with ventricular dysfunction and arrhythmias.

Cardiomegaly: An enlargement of the myocardium (heart) and usually a sign of an underlying medical condition.

Cardiovascular Disease (CVD): Disease of the heart and vascular system. CVD is a chronic disease process developing over time with the potential to negatively impact the heart (myocardium), the brain and the vascular system including the cardiac vessels.

Cholesterol: Produced by the liver and is needed for the construction and maintenance of cell walls, tissues, hormones, vitamin D, and bile acid. High cholesterol can lead to serious health conditions and CVD.

Coagulatory agents: Clotting factors that are proteins (agents) found in blood that work together to make a blood clot.

Coronary Artery Calcium (CAC) scan: A test that measures the amount of calcium in the walls of the coronary arteries. The results are used to determine a CAC score, which is a surrogate measure of overall plaque burden.

Dyslipidemia: Dyslipidemia means that the lipids (fats) within the blood stream are elevated. High cholesterol is the most common type of dyslipidemia.

Echocardiogram: A diagnostic testing process that utilizes ultrasound to provide an image of the heart muscle and valves.

Endothelial Function: The endothelium is a thin membrane that lines the inside of the heart and blood vessels. Endothelial cells release substances that control vascular relaxation and contraction as well as enzymes that control blood clotting, immune function, and platelet adhesion.

Framingham Risk Score: A sex-specific algorithm used to estimate the 10-year cardiovascular risk of an individual.

Hypertrophic Cardiomyopathy: A genetic abnormality where the left ventricle is thickened. This condition is associated with increased risk of sudden cardiac death.

Hypertension: Elevations in the normal pressure readings, also known as high blood pressure.

Metabolic Syndrome: A disease process characterized by the presence of several cardiometabolic risk factors known to increase the risk of CVD, sudden cardiac death, and diabetes.

Obesity: Obesity is defined as having too much body fat. Obesity is typically defined as a BMI $\geq$30, and is associated with increased risk of metabolic disease and cardiovascular disease.

Statins: Medications used to lower cholesterol.

Stroke Volume: The volume of blood pumped by the heart's left ventricle during each systolic cardiac contraction.

Structurally Enlarged Heart — Left Ventricular Hypertrophy: Left ventricular hypertrophy is enlargement and thickening (hypertrophy) of the walls of the heart's main pumping chamber (the left ventricle).

Triglycerides: Type of fat (lipid) found in the blood. Unused calories are converted into triglycerides and stored in fat cells for energy needed between meals. The appropriate range for triglycerides is <150 mg/dL.

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