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Clinical Study

The Prevalence of Cardiovascular Disease Risk Factors and Obesity in Firefighters

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Obesity is associated with increased risk of cardiovascular disease (CVD) mortality. CVD is the leading cause of duty-related death among firefighters, and the prevalence of obesity is a growing concern in the Fire Service. *Methods*. Traditional CVD risk factors, novel measures of cardiovascular health and a measurement of CVD were described and compared between nonobese and obese career firefighters who volunteered to participate in this cross-sectional study. *Results*. In the group of 116 men (mean age 43 ± 8 yrs), the prevalence of obesity was 51.7%. There were no differences among traditional CVD risk factors or the coronary artery calcium (CAC) score (criterion measure) between obese and nonobese men. However, significant differences in novel markers, including CRP, subendocardial viability ratio, and the ejection duration index, were detected. *Conclusions*. No differences in the prevalence of traditional CVD risk factors between obese and nonobese men were found. Additionally, CAC was similar between groups. However, there were differences in several novel risk factors, which warrant further investigation. Improved CVD risk identification among firefighters has important implications for both individual health and public safety.

1. Introduction

Sudden cardiac events account for approximately 45% of firefighter duty-related deaths in the US each year [1]. This is the highest occupational cardiovascular disease (CVD) proportionate mortality of any occupational group [2]. The reasons for this have been shown to be multifactorial, but early detection and treatment may be lifesaving. Obesity is one factor associated with significantly increased CVD mortality [3]. By the nature of their job, firefighters are called upon to engage in extremely strenuous activity in times of emergency. However, these periods of strenuous activity are relatively infrequent and may be interspersed among long periods of relative inactivity, which are known to contribute to obesity. Among this unique occupational group, whose members risk their lives for the sake of others, obesity has an impact beyond what is recognized in the general population. Obesity and CVD influence individual health and fitness for duty, which are critical for a firefighter's own well-being, the safety of their fellow firefighters, and public safety.

Firefighting requires high metabolic work output and muscular strength [4–7] and results in considerable cardiovascular and thermal strain [8–10]. Furthermore, firefighting is an occupation where a high level of fitness is recognized as necessary to safely perform required job activities [11]. However, there is growing evidence that firefighters may not be as fit as they should be to perform these duties, as decreased exercise and work capacity are associated with obesity [12, 13]. Several studies have found the prevalence of overweight and obesity among career firefighters to be

high, ranging from 32% to 40% for obesity and between 77% and 90% for combined overweight and obesity [14–17]. Soteriades et al. [17] reported the prevalence of obesity increased from 35% to 40% during a five-year follow-up study of career firefighters. High proportions of overweight and obesity also prevail in cohorts of younger firefighters. Among emergency responder recruits, the prevalence of overweight and obesity was 43.8% and 33.0%, respectively [13]. In another relatively young cohort (mean age 29.7 ± 8.0 years), approximately one-third of the firefighters were obese [18]. Among volunteer firefighters, the prevalence of obesity has been reported to be 41–43% [16, 19]. Thus, a high prevalence of obesity is not limited to specific populations within the Fire Service; rather, it is a universal concern for the Fire Service. Although obesity is commonly classified using BMI, there is the possibility that firefighters with low body fat and high muscle mass could be classified as overweight or obese, as has been reported in some athletic populations [20, 21]. However, a recent study of 677 firefighters showed infrequent misclassification of muscular firefighters as obese using BMI compared with percentage body fat or waist circumference [16].

Atypical working conditions and particular behaviors among firefighters likely contribute to the development of obesity. Although there is considerable variability among firefighters' activities depending upon location, size, and demographics of the fire department, evidence suggests that career firefighters spend 1–5% of their time in fire suppression activities compared with up to 65% of their time performing station and nonemergency duties [22]. Career firefighters commonly work 24-hour or rotating shifts, and the unpredictable nature of emergency calls leads to variable meal times and frequent reliance on "fast-food" meals. Furthermore, many departments do not mandate exercise or require that a specific fitness level be maintained following hire. Long sedentary periods, inadequate physical activity, poor dietary habits, and shift work may promote obesity [23, 24]. These factors have also been identified as chronic stressors that may increase CVD risk [25]. However, obesity is independently associated with increased CVD and mortality [3]. The high prevalence of obesity among firefighters, then, is particularly troubling since the leading cause of duty-related deaths among firefighters is sudden cardiac events.

In a comprehensive review of CVD in US firefighters, investigators described the prevalence and control of traditional CVD risk factors, including obesity, hypertension, dyslipidemia, and smoking and made recommendations for preventive strategies to those charged with overseeing firefighting programs [25]. Recognizing the risk to individual firefighters, and to public safety, the National Fire Protection Association (NFPA) and the National Institute of Occupational Safety and Health (NIOSH) recommend medical screening of firefighters that includes major CVD risk factor identification.

Traditional risk factors have proven valuable in identifying individuals at risk for CVD in the general population. However, given the limitations of traditional risk factors in predicting cardiac events, there has been a continued quest to improve risk prediction. This has led to the search for and emergence of nontraditional risk factors or novel markers and tests associated with CVD. Two of these are high-sensitivity C-reactive protein (CRP) and vascular metrics. High-sensitivity C-reactive protein, an inflammatory marker, has been investigated based on the association of inflammation with CVD. Central blood pressures, measures of arterial stiffness, and estimates of myocardial blood supply can be obtained noninvasively and have been shown to be associated with CVD [26–30].

A sophisticated new technology, computed tomography (CT), is a noninvasive scan that can be used to detect coronary artery calcium (CAC). The amount of CAC is related to the degree of atherosclerotic burden [31, 32]. In contrast to traditional risk factors, CRP, and measures of vascular health, which indicate the likelihood of developing CHD, a CAC score greater than zero is an indicator of subclinical disease. Furthermore, studies have shown the CAC score to be an independent predictor for coronary heart disease (CHD) events [33–36] and to enhance predictive ability beyond that obtained via the use of traditional risk factors [35–37] in prediction models such as the Framingham Risk Score. The detection and quantification of CAC by CT scan is a highly accurate test for evidence of CHD; however, evidence supports restricted application of CAC testing for CVD risk in the general population [32].

Since firefighters are a unique occupational group who experience the highest rate of duty-related deaths due to sudden cardiac events, and who perform public safety work that may be jeopardized if they are suddenly incapacitated, the use of CAC scoring may provide information that outweighs negative factors such as the cost of the scan and exposure to radiation.

The purpose of this study was to compare traditional cardiovascular disease risk factors, novel measures of cardiovascular health, and a measurement of cardiovascular disease in nonobese and obese career firefighters.

2. Materials and Methods

2.1. Participants. The participants in this study were 116 male career (paid) firefighters from several municipal fire departments in upstate New York. Typically, career firefighters are found in communities of 25,000 or more people, whereas volunteer departments predominate in smaller communities [38]. Albany Medical Center approved the research protocol. Cardiac calcium testing was independently offered to all firefighters in the Albany region by a local cardiology group as part of a community service program. Participants who enrolled in the cardiac calcium testing were invited to participate in this research project, which involved additional testing for the detection of cardiovascular risk factors. Data were collected over a five-month period, with firefighters reporting to a municipal Fire Department Union Headquarters for descriptive measures, vascular assessment, and a venous blood draw. All participants provided written informed consent and completed a general health, physical activity, and nutrition questionnaire. Additionally, all participants provided consent for the investigators to review their

departmental medical records in order to assess the presence of traditional cardiovascular risk factors.

2.2. Descriptive Data. Height (to the nearest 0.001 m) and body weight (to the nearest 0.1 kg) were measured using a stadiometer and balance platform scale, respectively. The scale was calibrated prior to each data collection session. Participants were weighed in pants and shirt, and height was taken with shoes removed. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Waist circumference was measured at the widest point of the midsection using a standard tape measure as participants stood. Firefighters were assigned to BMI and waist circumference categories according to US government guidelines [39].

Body composition was assessed using a 3-site skin fold measurement. Skin folds were taken at the triceps, pectoral (chest), and subscapular sites. Body density was determined using the Jackson and Pollock equation [40], and body fat percentage was determined using the Siri equation [41].

Resting blood pressure (BP) was measured by trained medical personnel. The measurement was taken with the participant in the seated position after resting for ten minutes. Resting heart rate was captured over a 10-second interval during the assessment of vascular measures.

2.3. Traditional CVD Risk Factors. Cardiovascular risk assessment was determined using current health and activity questionnaires from the present study and medical information from the firefighters' departmental records. Participants were stratified as low-, medium-, or high-risk for atherosclerotic CVD according to the number of risk factors and current signs and symptoms of known cardiovascular, pulmonary, and/or metabolic disease as detailed by the American College of Sports Medicine guidelines [42]. Traditional risk factors included age ≥45 years, smoking, hypertension, high cholesterol, diabetes, and family history of CVD. Smoking was identified as being a current smoker. Hypertension was defined as systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg by measurements on at least 2 separate occasions, or the use of antihypertensive medication. LDL cholesterol > 130 $mg \cdot dL^{-1}$ or total cholesterol > 200 $mg \cdot dL^{-1}$ or on lipid-lowering medication were used to identify high cholesterol. Diabetes was defined as fasting glucose ≥100 $mg \cdot dL^{-1}$ confirmed by measurements on at least 2 separate occasions. Family history of CVD was indicated by myocardial infarction or sudden death before 55 years of age in father or before 65 years of age in mother. For overall risk, low risk was defined as less than 45 years of age and asymptomatic with ≤1 CVD risk factor, whereas medium risk was 45 years of age or older or asymptomatic with ≥2 cardiovascular risk factors. Participants with known cardiovascular, metabolic or pulmonary disease or with ≥1 signs or symptoms of cardiovascular, metabolic or pulmonary disease (e.g., pain or discomfort in the chest or other areas that may result from ischemia, shortness of breath at rest or with mild exertion, dizziness or syncope, orthopnea or paroxysmal nocturnal dyspnea, ankle edema, palpitations or tachycardia, intermittent claudication, known heart murmur, unusual fatigue or shortness of breath with usual activities) were classified as high risk.

2.4. Novel Indicators of CVD. Blood was drawn from the antecubital vein after participants rested for a minimum of 5 minutes in the seated position. High-sensitivity C-reactive protein was quantified from venous whole blood at a local clinic.

Following a ten-minute rest period, radial pulse wave analysis (PWA) measurements were obtained in the seated position using applanation tonography (AtCor Medical, Sydney, Australia; software, SphygmoCor, version 7.01, AtCor Medical, Lisle, IL, USA). All PWA measurements were obtained by placing a tonometer over the radial measurement site and applanting the artery to obtain approximately 10 seconds of consistent pulse waves. Through the use of transfer functions, PWA at the radial artery was used to derive aortic pressure waveforms. The point where the incident and reflected wave merged was identified as the first shoulder of the aortic waveform. Augmented pressure (AP) was calculated as the pressure difference between the second and first shoulder and represents the contribution of the reflected wave to systolic pressure. Augmentation index (AIx) was defined as the ratio of the AP to the aortic pulse pressure and expressed as a percentage. Since the AIx is influenced by heart rate, values were normalized to a heart rate of 75 $b \cdot min^{-1}$ [43]. The travel time of the forward pressure from the aorta to the peripheral reflection site and back was also derived from the aortic waveform. The Buckberg subendocardial viability ratio (SEVR) was the ratio of the systolic and diastolic pressure time integrals expressed as a percentage. The duration of systolic ejection relative to the duration of the cardiac cycle was expressed as a percentage to obtain the ejection duration index.

2.5. Measure of CVD—Coronary Artery Calcium (CAC) Score. Chest computerized axial tomography scans were performed to evaluate CAC. Participants were scanned using a 64-slice computed tomography scanner (LightSpeed VCT 64-slice scanner, GE Medical Systems, Milwaukee, WI, USA). Scans were performed using 2.5 mm contiguous scans from the carina to the apex of the heart. Detector collimation was set at 64 channels, with a 0.625 mm per slice, gantry rotation speed at 350 ms per rotation, and tube voltage of 120 kV at a current of 300 mA. Coronary angiography was obtained during a short breath-holding period. Coronary artery calcium scores were calculated after reconstruction using the GE SmartScore Software (GE Medical, Milwaukee, WI, USA) using the AJ-130 scoring system [44]. The CAC score is used as a surrogate measure of plaque buildup in the coronary vessels and therefore may be extrapolated to predict risk of coronary disease. The CAC score was calculated by a physician blinded to all of the patient's clinical data. Coronary artery calcium scores were stratified using predetermined categories of 0, 1–100, 101–400, and >400, which have been reported with hazard ratios of 1 (reference), 6.09 (95% CI: 2.52–14.7), 9.58 (95% CI: 4.96–22.6), and

9.94 (95% CI: 4.06–24.3), respectively [34]. Scores in the two highest risk categories were reported to the study participants via one of the primary investigators, and the patient was given the opportunity for a follow-up appointment with a local cardiologist. All participants were given their results with contact information for a cardiologist.

2.6. Statistical Analysis. All data are presented as the mean and standard deviation unless otherwise noted. To explore the influence of obesity on select variables, firefighters were divided into two groups based on BMI: obese (BMI $\geq$ 30 kg·m^{-2}) or nonobese (BMI < 30 kg·m^{-2}). Analyses were also performed using obesity based on waist circumference, with classification as obese defined by waist circumference >102 cm and nonobese as waist circumference ≤102 cm. As age did not differ between groups, it was not used as a covariate in our analyses. Group differences were analyzed using an independent t-test for quantitative data and chi-squared analysis for categorical data. An alpha level of 0.05 was used for all analyses, and t-tests were two-tailed. All analyses were conducted using the IBM SPSS software (version 19.0).

3. Results

3.1. Descriptive Characteristics. The characteristics of the study population are listed in Table 1. Of the 116 male career firefighters who participated in this study, 51.7% were classified as obese based on BMI. The obese group was heavier and had a higher percentage of body fat and a larger waist circumference than the nonobese group. Additionally, mean brachial systolic pressure was 4 mmHg higher in the obese group than the nonobese group ($P = 0.043$). As shown in Table 2, additional partitioning of the groups by BMI revealed that only 5.2% of the firefighters were classified as normal weight, and several (3.4%) were classed as extreme obesity III. Distribution by BMI indicated that 51.7% of the men were characterized as obese, whereas 45.9% were at high risk for CVD based on waist circumference.

3.2. Measures Associated with Cardiovascular Disease. In Table 3, the influence of BMI on several traditional CVD risk factors is indicated. Prevalence of the risk factors did not differ with BMI group. The distribution of overall risk based on global risk assessment is also presented. The six risk factors were summed to obtain a second measure of total risk, and no differences were found between groups (nonobese: 1.1 ± 1.0; obese: 1.2 ± 1.0).

Novel markers of CVD risk are included in Table 4. Obese firefighters had significantly higher levels of CRP than nonobese firefighters (2.80 ± 2.01 mg·L^{-1} versus 1.81 ± 2.04 mg·L^{-1}; $P = 0.011$). For vascular measures, the central Buckberg SEVR differed between BMI groups, with the obese group having a lower mean value (168 ± 25%) than the nonobese group (181 ± 31%). The ejection duration index was higher in the obese group ($P = 0.041$).

Coronary artery calcium scores by BMI group are presented in Table 5. There was no effect of BMI group on the CAC score. The majority of CAC scores were in the lowest risk category; however, ten firefighters had a score greater than 100. One was identified in the highest risk category, with a CAC score of 966, and he was evaluated by a cardiologist within 24 hours of the study completion.

The same relationships between risk factors and obesity were observed using BMI and waist circumference as indicators of obesity; therefore, only the BMI-based data are presented as previous studies among firefighters typically stratified individuals by BMI.

4. Discussion

Consistent with previous research, this study found a high prevalence of obesity in a cohort of male career firefighters. Our study expands on previous research by reporting that excess weight did not affect the prevalence of traditional risk factors associated with CVD or the CAC score (a measure of global CVD burden). We did, however, find that the obese and nonobese firefighters differed in several novel or emerging risk factors, including high-sensitivity C-reactive protein and Buckberg SEVR. There is mounting evidence that obesity is a problem in the Fire Service. The prevalence of 51.7% in this study is higher than the prevalence of 19–39.7% among career firefighters reported in previously published studies [14–17, 45]. Of these studies, several were performed over a decade ago. Flegal et al. [46] reported a 4.7% increase in the age-adjusted prevalence of obesity in US men between 1999-2000 and 2007-2008. Considering the increased prevalence of obesity in the general population, the higher proportion of obesity in the current study is not entirely unexpected.

Perhaps more disconcerting than the prevalence at a single time point is the increase in the prevalence of obesity from 35% to 40% between 1996 and 2001 within a group of firefighters studied by Soteriades et al. [17]. Furthermore, weight gain was greater in younger firefighters (age <45 years) or those with a BMI $\geq$ 35 kg·m^{-2}. This information could have important implications in this cohort of firefighters, in which the majority of firefighters (52.6%) were younger than 45 years of age, and 16.3% had a BMI $\geq$ 35 kg·m^{-2}. Taking into account the 5% increase in obesity over 5 years to 40% in 2001 and the trend for increasing obesity in the aforementioned study by Flegal et al. [46], the prevalence of obesity in this study may not be surprising, though it is certainly troubling.

Misclassification of individuals with a high muscle mass and low body fat percentage as overweight or obese could occur when using BMI as a classification tool; however, recent evidence indicates that the false positive rate for BMI-derived obesity among a group of firefighters was low [16]. In fact, it was more likely that a career firefighter would be classified as obese by percentage body fat or waist circumference than by BMI. The mean body fat percentage in the obese group in the present study was 24.4 ± 3.8%, which is just below the 25% used to define obesity, thus it is possible that some individuals in this study classified as obese by BMI would not be so by percentage body fat. The low

Table 1: Participant descriptive characteristics (mean ± SD).

Characteristic	BMI < 30 (n = 56)	BMI ≥ 30 (n = 60)	P value
Age (yr)	44.4 ± 7.6	42.7 ± 7.4	0.214
Height (m)	1.758 ± 0.064	1.767 ± 0.067	0.458
Weight (kg)	84.5 ± 7.5	106.2 ± 13.1	<0.001
BMI ($kg \cdot m^{-2}$)	27.3 ± 1.8	34.0 ± 3.4	<0.001
Body fat† (%)	18.5 ± 4.4	24.4 ± 3.8	<0.001
Waist circumference (cm)	94.1 ± 6.4	110.7 ± 8.8	<0.001
Resting heart rate ($b \cdot min^{-1}$)	66 ± 10	69 ± 10	0.147
Systolic blood pressure (mm Hg)	131 ± 12	135 ± 12	0.043
Diastolic blood pressure (mm Hg)	84 ± 8	86 ± 8	0.279

BMI: body mass index; †determined using 3-site skinfold measurement and the Siri equation [41].

Table 2: Distribution of participants by body mass index and by waist circumference.

Classification	Frequency (n (%))
By BMI (n = 116)	
Underweight (BMI < 18.5)	0 (0)
Normal weight (18.5 ≤ BMI < 25)	6 (5.2)
Overweight (25 ≤ BMI < 30)	50 (43.1)
Total obesity (BMI ≥ 30)	60 (51.7)
Obesity I (30 ≤ BMI < 35)	41 (35.3)
Obesity II (35 ≤ BMI < 40)	15 (12.9)
Extreme obesity III (BMI ≥ 40)	4 (3.4)
By waist circumference (n = 111)	
Low risk† (≤102 cm)	60 (54.1)
High risk (>102 cm)	51 (45.9)

BMI: body mass index; †risk for obesity-associated risk factors.

Table 3: Influence of obesity on cardiovascular disease risk factors.

	BMI < 30 (n (%))	BMI ≥ 30 (n (%))	P value
Individual risk factor			
Age ≥ 45 years	25 (21.6)	30 (25.9)	0.564
Smoking	22 (19.0)	19 (16.4)	0.391
Hypertension	4 (3.4)	7 (6.0)	0.406
High cholesterol	7 (6.0)	9 (7.8)	0.696
Diabetes	1 (1.1)	1 (1.1)	0.926
Family history of CVD	2 (1.7)	4 (3.4)	0.452
Overall risk (n = 92)			
Low	11 (12.0)	9 (9.8)	
Moderate	19 (20.7)	26 (28.3)	0.625
High	13 (14.1)	14 (15.2)	

BMI: body mass index; CVD: cardiovascular disease; risk factors and categories defined by ACSM guidelines [42]: smoking: current smoker; hypertension: systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg, confirmed by measurements on at least 2 separate occasions, or on antihypertensive medication; high cholesterol: LDL cholesterol >130 $mg \cdot dL^{-1}$ or total cholesterol >200 $mg \cdot dL^{-1}$ or on lipid-lowering medication; diabetes: fasting glucose ≥100 $mg \cdot dL^{-1}$ confirmed by measurements on at least 2 separate occasions; family history of CVD: myocardial infarction or sudden death before 55 years of age in father or before 65 years of age in mother. Overall risk: low: men <45 years of age, asymptomatic, 1 or less risk factors; moderate: men ≥45 or 2 or more risk factors; high: ≥1 signs or symptoms suggestive of cardiovascular, pulmonary, or metabolic disease or known cardiovascular, pulmonary, or metabolic disease (e.g., pain or discomfort in the chest or other areas that may result from ischemia, shortness of breath at rest or with mild exertion, dizziness or syncope, orthopnea or paroxysmal nocturnal dyspnea, ankle edema, palpitations or tachycardia, intermittent claudication, known heart murmur, unusual fatigue or shortness of breath with usual activities).

prevalence of normal weight may also be an artifact of BMI as the classification tool. However, we also found that 45.9% of the firefighters we studied had a waist circumference greater than 102 cm.

Although obesity is associated with diabetes, hypertension, and hypercholesterolemia [47], higher prevalences of these CVD risk factors were not found in the obese group. The finding for high cholesterol is consistent with that of Soteriades et al. [17] both at baseline and after five years of followup for high cholesterol. However, other studies have found increased prevalence of hypercholesterolemia or more negative lipid profiles with increasing BMI [13–15, 48]. Studies have also shown increased prevalence or elevated levels of systolic and/or diastolic blood pressures in obese firefighters [13, 14, 16, 17]. Although this study found no differences in the prevalence of hypertension, mean systolic BP obtained for descriptive purposes was higher in the obese group (P = 0.043). Increased systolic BP in firefighters is noteworthy as hypertension has been shown to be an independent predictor of on-duty coronary events [2, 49].

The hazard associated with one risk factor varies with the presence of others; therefore, multivariable risk assessment is recommended for estimating the risk of future CVD events at an individual level [50, 51]. As firefighting is a physically demanding occupation, we chose to stratify firefighters according to the American College of Sports Medicine (ACSM) guidelines, which take into account CVD risk factors [42]. Although risk classification did not differ between the obese and nonobese groups, approximately 3 out of 4 firefighters were classified as moderate- or high-risk. Based on ACSM recommendations, those at moderate risk would be advised to have a medical examination and exercise test prior to participation in vigorous physical activity.

Table 4: Influence of obesity on novel or emerging risk factors.

Parameter	BMI < 30	BMI ≥ 30	*P* value
Inflammatory marker ($n = 56$; $n = 55$)			
CRP ($mg \cdot L^{-1}$)	1.81 ± 2.04	2.80 ± 2.01	0.011
Vascular measures ($n = 56$; $n = 60$)			
Aortic systolic pressure (mm Hg)	118 ± 11	121 ± 13	0.169
Aortic diastolic pressure (mm Hg)	85 ± 8	87 ± 8	0.304
Augmentation index @ 75 (%)†	13 ± 10	11 ± 10	0.217
Time of reflected wave (ms)	150 ± 12	152 ± 13	0.354
Buckberg SEVR (%)	181 ± 31	168 ± 25	0.012
ED/period (%)	33 ± 4	34 ± 4	0.041

Values are mean ± SD. †Augmentation index normalized to a heart rate of 75 beats per minute. BMI: body mass index; CRP: high-sensitivity C-reactive protein; SEVR: subendocardial viability ratio; ED/period: ejection duration index.

Table 5: Influence of obesity on total coronary artery calcium scores.

CAC score	BMI < 30 (*n* (%))	BMI ≥ 30 (*n* (%))	*P* value
0	38 (32.8)	38 (32.8)	0.382
1–100	12 (10.3)	18 (15.5)	
101–400	6 (5.2)	3 (2.6)	
>400	0 (0)	1 (0.9)	

BMI: body mass index; CAC: coronary artery calcium.

For the 29.3% of participants in the high-risk category, a thorough medical examination and clearance would be recommended prior to participating in physical activity of any intensity. The importance of periodic medical examinations to assess CVD risk profiles cannot be underscored sufficiently. In a case control study, Kales et al. [2] found that most on-duty deaths occur in firefighters with underlying CHD and a high prevalence of CVD risk factors that are typically detectable in routine medical examinations. Yet, recent medical exams were lacking in 75% of the firefighters who died from on-duty CHD. This evidence suggests that the implementation of a policy requiring mandatory periodic medical evaluations could help reduce the number of deaths associated with CVD. Although the NFPA has issued a consensus standard that recommends that firefighters receive an annual medical evaluation, this standard is not required by law, and many fire departments have not adopted this recommendation. It should be noted, however, that the departments involved in the study all require annual medical evaluation consistent with the NFPA standard.

In contrast to traditional risk factors, which were similar between groups, the mean CRP level was 54.7% higher ($P = 0.011$) in the obese group compared with the nonobese group. Obesity is associated with an increase in inflammatory markers, including CRP [52]. Elevated CRP in this cohort is a concern as considerable evidence points to an association between CRP and CVD events [53, 54]. In their meta-analyses, Buckley et al. reported a summary relative risk for incident CHD of 1.58 (95% CI: 1.37–1.83) for CRP levels greater than 3.0 $mg \cdot L^{-1}$ compared with levels less than 1.0 $mg \cdot L^{-1}$ based on good quality studies that adjusted for traditional CVD risk variables.

Pulse wave analysis was used to obtain novel measures associated with risk of CVD and several commonly reported indices. The lower Buckberg SEVR in obese firefighters is indicative of a lower supply to demand ratio of oxygen in the coronary arteries [55]. A difference in the ejection duration index was also found between groups ($P = 0.041$). No significant differences in measures of central pressure (systolic BP, diastolic BP, pulse pressure, and AP) or AIx were detected. Our results are similar to those of a recent study by Fahs et al. [18], which found differences in brachial systolic BP but no differences in AIx, AP, or aortic systolic BP, diastolic BP and pulse pressure among firefighters grouped by BMI tertiles.

There was no difference in CAC scores between obese and nonobese firefighters; however, for each BMI group CAC scores were distributed among the first three classifications. Previous studies have found the CAC score to be an independent predictor for CHD events [33–36, 56], but CAC cut points varied among studies. Nevertheless, studies showed that higher scores were associated with higher-risk ratios and a number of studies reported significantly increased risk for CAC scores around a cut point of 100 [27–29]. Based on the hazard ratios determined in a large ($n = 6814$) prospective study of asymptomatic participants, firefighters with a CAC score of 1–100 would be approximately 6 times more likely to experience a coronary event than those with a score of 0, whereas those with scores of 101–400 would be approximately 9.6 times more likely to suffer an event. The firefighter with a score >400 has almost 10 times greater risk than those in the referent group. Moreover, further diagnostic evaluation may be indicated for a score >400 [57], and additional tests and measures were undertaken for the firefighter in this study. Although only one firefighter was classified in the highest-risk category, it is concerning that the 39 firefighters (34%) with a CAC score between 1 and 400 would be at least 6 times more likely to experience a coronary event than individuals with a CAC score of 0.

This study has several limitations. Due to a low number of women, analyses were limited to men. The nonobese group was primarily composed of overweight firefighters, whose CVD risk profiles may have more closely resembled those of obese firefighters and biased results toward the null

hypothesis. Additionally, selection bias due to self-selection was possible, as all of the firefighter participants were enrolled following participation in a donated voluntary CAC test. There may have been a group of fit firefighters who chose to not participate because they felt they were at low risk, and likewise, there may have been very obese firefighters who were reluctant to participate. Also, there may have been firefighters who chose to not participate because they had additional concerns about the blinding of the data from management as well, and were concerned about being restricted from work, although the union hall was used for enrollment to provide additional reassurance.

5. Conclusions

We found a high prevalence of overweight and obesity within a cohort of male career firefighters. This fact is alarming because obesity is associated with increased risk of CVD, and most duty-related CVD events occur in firefighters with underlying CVD. Although obesity is associated with a cluster of CVD risk factors, no differences in reported traditional risk factors for CVD risk were found between obese and nonobese firefighters. Furthermore, we found no difference in CAC scores between obese and nonobese firefighters. However, we did detect significant differences in several novel markers of CVD between the obese and nonobese firefighters. The findings that obesity, a known risk factor for CVD, is associated with differences in novel risk factors indicate that further investigation into the use novel methods to assess CVD risk and inform clinical decisions has merit for firefighters and the public they serve.

Disclosure

M. W. Dailey is medical director for the Albany Fire Department.

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