


# Cardiovascular Disease Risk Factors by BMI and Age in United States Firefighters

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**Objective:** This study examined cardiovascular disease risk factors by BMI category in firefighters, the association of BMI and age with risk factor prevalence, and the prevalence of risk factors by BMI category within age groups.

**Methods:** Cardiovascular measures from the medical evaluations of 4,453 firefighters, performed between 2015 and 2018 at four occupational health clinics in the United States (South-West Cohort, Mid-Atlantic Cohort, South-East Cohort, and Mid-West Cohort), were analyzed cross-sectionally by BMI and age categories.

**Results:** Among female firefighters with normal weight, 25% had high blood pressure, 8% had low high-density lipoprotein cholesterol, and 0% had high glucose, whereas the prevalence in female firefighters with obesity was 57%, 45%, and 11%, respectively. Among male firefighters, there were independent and significant associations of BMI and age for the prevalence of high blood pressure, high cholesterol, high triglycerides, and high glucose. Higher BMI category was associated with a higher prevalence of high blood pressure, high triglycerides, and low high-density lipoprotein cholesterol within all age groups and with a higher prevalence of high glucose and high cholesterol within ages 40 to 49 and 50 to 59 years.

**Conclusions:** An increasing prevalence of risk factors with older age and higher BMI suggests that preventive strategies should be initiated in younger firefighters and aggressively promoted or mandated throughout firefighters' careers.

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## Introduction

Health experts have repeatedly warned about an obesity epidemic in the United States (1-3), and research suggests that having a high BMI is one of the top five risk factors in the world for attributable deaths and disability-adjusted life years (4). Obesity is associated with several negative health outcomes, including cardiovascular disease (CVD), cardiac enlargement, gallbladder disease, diabetes, several cancers, osteoarthritis, and sleeping disorders (5-10). In addition to being a significant predictor of coronary heart disease and heart failure (5,11), obesity is indirectly related to cardiovascular health through its association with several other

## Study Importance

### What is already known?

- ▶ Sudden cardiac events are the leading cause of on-duty death in the fire service, and higher BMI is associated with increased severity of cardiovascular disease risk factors in firefighters.
- ▶ Although both obesity prevalence and the incidence of sudden cardiac death increase with age in firefighters, the prevalence of cardiovascular disease risk factors by age and BMI in the fire service has not been reported.

### What does this study add?

- ▶ A higher BMI category was significantly associated, independent from age, with a higher prevalence of high blood pressure, high cholesterol, low high-density lipoprotein cholesterol, high triglycerides, high blood glucose, and prevalence of metabolic syndrome in firefighters.
- ▶ Within each decade of life, male firefighters with higher BMI categories were more likely to have high blood pressure, low high-density lipoprotein cholesterol, high triglycerides, and metabolic syndrome.

### How might these results change the direction of research or the focus of clinical practice?

- ▶ Health care providers who care for firefighters have a powerful opportunity to counsel firefighters on the risks of excess weight, recommend preventive strategies in younger firefighters, and aggressively promote healthy body weight throughout firefighters' careers.
- ▶ The factors driving the high obesity prevalence in the fire service should be examined in future research for the purpose of optimizing health promotion and wellness programs.

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CVD risk factors, including hypertension, high cholesterol, low high-density lipoprotein (HDL) cholesterol, high triglycerides, and diabetes (3,8,12,13). Therefore, obesity is a primary target for interventions to decrease overall cardiovascular risk.

Firefighters perform critical public safety work that requires substantial muscular exertion and the use of heavy personal protective equipment. Firefighting activities have been shown to induce extreme cardiovascular strain, evidenced by decreased stroke volume, impaired diastolic function, arterial stiffness, and increased coagulability (14-18). National statistics indicate that nearly 50% of duty-related deaths in firefighters are due to sudden cardiac events (19). Autopsy records from firefighter fatality examinations have additionally shown that a vast majority (~80%) of firefighters who succumbed to cardiac events had evidence of atherosclerotic CVD and a structurally enlarged heart (20). Obesity has been associated with a two-fold increased risk of left ventricular hypertrophy in firefighters (21), and other research with firefighters has found a positive relationship between BMI and both the severity of CVD risk factors (13,22-26) and the risk of on-duty cardiac fatalities (27-29). Despite the enormous implications of obesity on cardiovascular health, a high prevalence has been reported in the fire service (23,24,30-32), and recent studies have shown that obesity prevalence increases with advancing age (32).

Several major CVD risk factors increase with age in both the general population (33) and firefighters (12,32,34). This translates directly to the cardiovascular safety of firefighters, as the highest incidence of on-duty sudden cardiac death is seen in firefighters ages 54 to 64 years (35). Given that obesity prevalence increases with age, it is necessary to consider both variables together to better understand the interaction of BMI with CVD risk factors. Such an investigation into major modifiable (obesity) and nonmodifiable (age) risk factors may help guide fire-service health and wellness programming to improve cardiac health and reduce on-duty cardiac fatalities. Currently, no studies to our knowledge have included a sufficient sample size to investigate CVD risk factors by BMI and age categories in firefighters. Therefore, the purpose of this paper was to describe measures of cardiovascular health and CVD risk factors based on BMI category in a large sample of firefighters, assess the association of BMI and age with CVD risk factors, and report the prevalence of CVD risk factors by BMI category within age groups.

## Methods

Assessments of BMI and CVD risk factors were obtained from firefighters who participated in department-required annual medical evaluations between the years 2015 and 2018. The medical evaluations were performed by four occupational clinics, which follow the National Fire Protection Association 1582 Standard on Occupational Medical Program for Fire Departments (36) and provide these services to fire departments on a contract basis. The four clinics served fire departments in southern Arizona (South-West Cohort), northern Virginia (Mid-Atlantic Cohort), central Florida (South-East Cohort), and the capital region of Indiana (Mid-West Cohort). Female firefighters from the South-East and South-West cohorts were not included in the analytical sample because of small sample sizes within BMI categories. Data on low-density lipoprotein (LDL) cholesterol, HDL cholesterol, and triglycerides were not available from one department ( $n = 256$ ), and medication usage was not available from one clinic ( $n = 366$ ). For the analysis including those variables that were not available, the

department or clinic was excluded. Data were combined to create a cohort of 4,453 US career firefighters ( $n = 4,225$  males and  $n = 228$  females). A deidentified database including descriptive characteristics and measures of cardiovascular health was shared with researchers at Skidmore College's First Responder Health and Safety Laboratory. The study protocol was reviewed and approved by the Skidmore College Institutional Review Board.

## Data collection

During the medical exams, height was assessed using a stadiometer, and weight was measured using a standard physician scale. Health care providers measured blood pressure using the auscultation technique, with firefighters in the seated position. Fasted blood glucose and cholesterol were assessed via a commercial laboratory analysis. The use of prescription medications was assessed using questionnaires.

## Definitions

All participants were grouped by age according to decade of life: 20 to 29, 30 to 39, 40 to 49, and 50 to 59 years old. Additionally, participants were divided into BMI categories of having normal weight ( $<25 \text{ kg/m}^2$ ), overweight (25-29.9), or obesity ( $\geq 30$ ) (37) for the main analyses, and the prevalence of obesity subclasses defined as class 1 (30-34.9), class 2 (35-39.9), and class 3 ( $\geq 40$ ) were reported (37). Having high blood pressure was defined as systolic blood pressure  $\geq 130$  mmHg, or diastolic blood pressure  $\geq 80$  mmHg, or taking antihypertensive medication (38). Having high cholesterol was defined as total cholesterol  $\geq 240$  mg/dL and/or taking lipid-lowering medication (39). Having high triglycerides was defined as  $\geq 200$  mg/dL (40), having high LDL cholesterol was defined as  $\geq 160$  mg/dL (40), and having low HDL cholesterol was defined as  $<40$  mg/dL for males and  $<50$  mg/dL for females (40). Having high fasting blood glucose was defined as  $>125$  mg/dL and/or taking medications related to blood glucose stabilization (41).

Metabolic syndrome was determined using a modified definition of the National Cholesterol Education Panel (NCEP) guidelines (39). Firefighters were considered to have metabolic syndrome if they had three or more of the following four NCEP metabolic syndrome criteria: high blood pressure with systolic blood pressure  $\geq 130$  mmHg and/or diastolic blood pressure  $\geq 85$  mmHg, triglycerides  $\geq 150$  mg/dL, blood glucose  $\geq 110$  mg/dL, and HDL cholesterol  $< 40$  mg/dL in males or  $< 50$  mg/dL in females. The NCEP guidelines include waist circumference ( $>102$  cm for males and  $>88$  cm for females) as a fifth criteria measure (39), but waist circumference was not measured at all occupational health clinics. Therefore, the prevalence of metabolic syndrome, defined as having three or more out of four (rather than five) criteria, is an underestimation of true metabolic syndrome prevalence in this firefighter cohort.

## Statistical analysis

Descriptive data are presented as means (SE) in Table 1. Given the large sample size differences across the geographic locations and convenient nature of the fire departments that collected and provided data, all point estimates and statistical comparisons were calculated as though there was an equal number of observations in each of the four geographical locations (i.e., each geographical location contributed equally to a point estimate or the association across locations). Unadjusted mean cardiometabolic values and risk factor prevalence were estimated for all

**TABLE 1** Descriptive characteristics and CVD risk factor values in male and female firefighters by BMI category

	BMI (kg/m <sup>2</sup> )		
	<25	25-29.9	≥30
<b>Male firefighters</b>			
<i>n</i> (%)	498 (14)	1,930 (49)	1,797 (37)
White (%)	84	86	82 <sup>b</sup>
Age (y)	37.9 ± 0.5	40.7 ± 0.3 <sup>a</sup>	43.4 ± 0.3 <sup>ab</sup>
Height (m)	1.8 ± 0.0	1.8 ± 0.0	1.8 ± 0.0
Weight (kg)	76.1 ± 0.4	89.0 ± 0.2 <sup>a</sup>	108.5 ± 0.5 <sup>ab</sup>
Total cholesterol (mg/dL)	183.8 ± 1.6	192.7 ± 0.8 <sup>a</sup>	192.9 ± 0.9 <sup>a</sup>
LDL cholesterol (mg/dL)	109.5 ± 1.7	116.5 ± 1.0 <sup>a</sup>	119.6 ± 1.2 <sup>a</sup>
HDL cholesterol (mg/dL)	55.1 ± 0.7	49.4 ± 0.4 <sup>a</sup>	44.1 ± 0.4 <sup>ab</sup>
Triglycerides (mg/dL)	84.7 ± 2.7	114.1 ± 2.4 <sup>a</sup>	148.7 ± 3.3 <sup>ab</sup>
Blood glucose (mg/dL)	91.7 ± 0.7	94.8 ± 0.5 <sup>a</sup>	99.6 ± 0.6 <sup>ab</sup>
Systolic blood pressure (mmHg)	118.4 ± 0.5	121.2 ± 0.3 <sup>a</sup>	126.0 ± 0.4 <sup>ab</sup>
Diastolic blood pressure (mmHg)	76.2 ± 0.3	78.3 ± 0.2 <sup>a</sup>	81.3 ± 0.2 <sup>ab</sup>
<b>Female firefighters</b>			
<i>n</i> (%)	75 (34)	88 (39)	65 (27)
White (%)	93	76 <sup>a</sup>	87
Age (y)	39.9 ± 1.1	41.0 ± 0.9	39.9 ± 1.2
Height (m)	1.7 ± 0.0	1.7 ± 0.0	1.7 ± 0.0
Weight (kg)	64.7 ± 0.7	76.0 ± 0.7 <sup>a</sup>	94.8 ± 1.8 <sup>ab</sup>
Total cholesterol (mg/dL)	189.0 ± 3.4	191.3 ± 4.2	182.4 ± 5.1 <sup>ab</sup>
LDL cholesterol (mg/dL)	108.7 ± 2.7	114.8 ± 3.3	110.2 ± 4.7
HDL cholesterol (mg/dL)	65.7 ± 1.5	59.0 ± 1.5 <sup>a</sup>	51.8 ± 1.6 <sup>ab</sup>
Triglycerides (mg/dL)	73.3 ± 3.9	87.1 ± 9.7 <sup>a</sup>	101.7 ± 9.1 <sup>ab</sup>
Blood glucose (mg/dL)	86.8 ± 0.9	88.1 ± 1.0	92.2 ± 2.7 <sup>ab</sup>
Systolic blood pressure (mmHg)	114.9 ± 1.4	116.4 ± 1.1	123.2 ± 2.0 <sup>ab</sup>
Diastolic blood pressure (mmHg)	74.4 ± 0.9	74.8 ± 0.7	79.5 ± 1.2 <sup>ab</sup>

Data given as as means ± SE.

Statistical differences ( $P < 0.05$ ) for post hoc pairwise comparisons are indicated by superscript "a" for comparisons between obesity or overweight BMI categories with the normal-weight BMI category and superscript "b" for comparisons between the overweight and obesity BMI categories. Each geographical location of the fire departments was given equal weight in the point estimates and the prevalence of firefighters with normal weight, overweight, and obesity.

CVD, cardiovascular disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

ages combined across BMI categories for males and females separately; separate linear and logistic regression models were also conducted for each BMI category. Differences between mean cardiometabolic measures of firefighters with normal weight, overweight, and obesity in the full sample were tested using linear regression models, with a categorical variable for BMI category and geographical location. Post hoc pairwise comparisons were made between the three BMI categories. Logistic regression models were used to test for differences in the prevalence of CVD risk factors between BMI categories. The prevalence of a CVD risk factor was predicted for each BMI category and the odds ratios, which were unadjusted and adjusted for age, with 95% confidence intervals (CIs) reported using the normal-weight BMI category as the reference group.

Owing to inadequate sample sizes among females, the analyses including both age and BMI categories were only conducted with males. Based on an *a priori* objective, a focus of the analysis including both

age and BMI was to determine whether the likelihood of having cardiometabolic risk factors was higher among firefighters with a higher BMI and whether this was the case within each of the age groups. Descriptive estimates of risk factor prevalence were reported for each of the three BMI categories across each of the age groups. Analyses of general trends across age and BMI categories were conducted using logistic regression models that included both age group and BMI category modeled as continuous variables. A step-down approach for modeling age was used, starting with a quadratic function based on previous findings on the relationship of age and cardiometabolic health in the same dataset. Wald tests were conducted to determine whether the quadratic relationship was significant. The male sample was also stratified by age group, and the associations of BMI with the likelihood of having a particular cardiometabolic risk factor were examined within each age group with BMI category modeled as a continuous variable and categorically with normal weight as the reference group. The level of significance for all analyses was  $P < 0.05$  and was two-sided for all

**TABLE 2** Prevalence and ORs of CVD risk factors by BMI category in male and female firefighters (20-59 years old)

	Male firefighters					Female firefighters				
	% <sup>a</sup>	OR	95% CI	Adjusted OR	95% CI	% <sup>a</sup>	OR	95% CI	Adjusted OR	95% CI
<b>High blood pressure</b>										
Normal weight	38	Ref	–	–	–	25	Ref	–	–	–
Overweight	58	2.3	1.9-2.9	2.2	1.7-2.7	32	1.4	0.7-2.8	1.4	0.6-3.2
Obesity	81	7.0	5.5-8.8	6.2	4.9-7.9	58	4.0	1.9-8.6	5.7	2.3-14.3
<b>High cholesterol</b>										
Normal	11	Ref	–	–	–	4	Ref	–	–	–
Overweight	20	1.9	1.4-2.6	1.7	1.2-2.3	8	2.1	0.6-7.2	2.0	0.6-6.9
Obesity	26	2.8	2.0-3.8	2.2	1.6-3.1	6	1.5	0.4-5.4	1.4	0.4-5.2
<b>High LDL cholesterol</b>										
Normal weight	7	Ref	–	–	–	0	Ref	–	–	–
Overweight	10	1.6	1.1-2.3	1.5	1.0-2.2	8	–	–	–	–
Obesity	9	1.4	0.97-2.1	1.3	0.9-1.9	3	–	–	–	–
<b>Low HDL cholesterol</b>										
Normal weight	10	Ref	–	–	–	8	Ref	–	–	–
Overweight	20	2.2	1.6-3.1	2.2	1.6-3.0	26	4.2	1.6-11.3	4.2	1.6-11.2
Obesity	36	4.9	3.6-6.7	4.8	3.5-6.6	45	10.0	3.6-27.7	10.1	3.6-28.4
<b>High triglycerides</b>										
Normal weight	2	Ref	–	–	–	1	Ref	–	–	–
Overweight	10	5.7	2.9-11.2	5.3	2.7-10.5	2	1.6	0.1-18.4	1.4	0.1-16.7
Obesity	18	11.3	5.8-22.2	10.3	5.3-20.2	4	3.4	0.4-32.7	3.2	0.3-32.5
<b>High blood glucose</b>										
Normal weight	2	Ref	–	–	–	0	Ref	–	–	–
Overweight	3	1.2	0.6-2.4	1.1	0.5-2.0	0	–	–	–	–
Obesity	7	3.3	1.8-6.3	2.6	1.3-4.8	11	–	–	–	–
<b>Metabolic syndrome<sup>b</sup></b>										
Normal weight	2	Ref	–	–	–	0	Ref	–	–	–
Overweight	6	3.0	1.5-6.0	2.7	1.7-5.5	1	–	–	–	–
Obesity	18	13.4	5.4-20.9	9.3	4.7-18.2	10	–	–	–	–

Adjusted ORs were estimated using a logistic regression model that included age as a covariate.

BMI categories: normal (<25); overweight (25-29.9); obesity (≥30).

<sup>a</sup>Unadjusted prevalence of a risk factor.

<sup>b</sup>Meets three or more of the four available criteria for metabolic syndrome: systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg, triglycerides ≥ 150 mg/dL, blood glucose ≥ 110 mg/dL, and HDL cholesterol < 40 mg/dL in males or < 50 mg/dL in females.

CVD, cardiovascular disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein; OR, odds ratio; Ref, reference value.

tests. All analyses were conducted using Stata version 15.1 (StataCorp, College Station, Texas).

## Results

The average age across male firefighters with normal weight, overweight, and obesity was 37.9 years, 40.7 years, and 43.4 years, respectively, and across female firefighters was 39.9 years, 41.0 years, and 39.9 years, respectively. The sample consisted predominantly of White individuals (Table 1). Among males, 82% were non-Hispanic White individuals, 8% were non-Hispanic African American/Black individuals, 6% were Hispanic individuals, 2% were Asian individuals, and 2% reported their race as “other” (data not shown). Among females, 84% were non-Hispanic White individuals, 10% were non-Hispanic

African American/Black individuals, 4% were Hispanic individuals, 0.4% were Asian individuals, and 2% reported their race as “other” (data not shown). Among male firefighters, 14% had normal weight, 49% had overweight, and 37% had obesity as determined by BMI categorization, and the prevalence of obesity subclasses was 27% class 1, 7% class 2, and 2% class 3. Among female firefighters, 34% had normal weight, 39% had overweight, and 27% had obesity as determined by BMI categorization, and the prevalence of obesity subclasses was 16% class 1, 8% class 2, and 3% class 3. The unadjusted mean cardiovascular measures for all ages combined worsened significantly across BMI categories (normal weight to obesity) for both male and female firefighters. For the unadjusted and age-adjusted estimates among all ages combined, male firefighters with overweight and obesity were more likely to have high blood pressure, high cholesterol, low HDL cholesterol, high triglycerides, and three or more of the criteria for metabolic

**TABLE 3** ORs for CVD risk factors in male firefighters by BMI category, stratified by age group

	Age 20-29		Age 30-39		Age 40-49		Age 50-59	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<b>High blood pressure</b>								
Normal weight	Ref	–	Ref	–	Ref	–	Ref	–
Overweight	2.0	1.1-3.6	1.8	1.2-2.7	2.7	1.8-3.9	2.5	1.5-4.2
Obesity	3.4	1.8-6.5	6.2	4.0-9.7	7.6	5.1-11.4	7.2	4.1-12.7
<b>High cholesterol</b>								
Normal	Ref	–	Ref	–	Ref	–	Ref	–
Overweight	2.0	0.2-18.5	1.6	0.8-3.4	2.0	1.2-3.3	1.3	0.8-2.3
Obesity	4.3	0.5-38.6	1.9	0.9-3.9	2.5	1.5-4.1	2.0	1.2-3.5
<b>High LDL cholesterol</b>								
Normal weight	Ref	–	Ref	–	Ref	–	Ref	–
Overweight	3.1	0.4-26.2	1.6	0.8-3.2	1.5	0.8-2.7	0.9	0.4-1.9
Obesity	6.2	0.7-53.0	1.2	0.6-2.6	1.1	0.6-1.9	1.1	0.5-2.4
<b>Low HDL cholesterol</b>								
Normal weight	Ref	–	Ref	–	Ref	–	Ref	–
Overweight	1.7	0.9-3.5	1.8	1.0-3.1	2.6	1.5-4.7	3.1	1.3-7.5
Obesity	4.2	2.0-8.7	3.7	2.1-6.5	6.0	3.4-10.6	6.1	2.6-14.4
<b>High triglycerides</b>								
Normal weight	Ref	–	Ref	–	Ref	–	Ref	–
Overweight	4.2	0.5-34.4	4.5	1.4-14.9	9.3	2.3-38.5	3.1	0.9-10.4
Obesity	15.7	2.0-123.3	9.5	2.9-30.9	17.6	4.3-72.1	4.9	1.5-16.1
<b>High blood glucose</b>								
Normal weight	Ref	–	Ref	–	Ref	–	Ref	–
Overweight	0.6	0.0-9.1	0.7	0.1-4.0	0.9	0.3-2.8	1.5	0.5-4.3
Obesity	0.8	0.0-13.8	0.7	0.1-4.3	2.5	0.9-7.1	3.7	1.3-10.6
<b>Metabolic syndrome<sup>a</sup></b>								
Normal weight	Ref	–	Ref	–	Ref	–	Ref	–
Overweight	1.7	0.2-17.1	1.3	0.4-4.5	3.6	1.1-11.8	3.7	0.9-15.8
Obesity	10.7	1.3-85.3	5.9	1.5-16.5	12.6	3.9-40.2	10.5	2.5-43.7

ORs and 95% CIs were estimated using separate logistic regression models for each age group, with BMI modeled as a categorical variable.

<sup>a</sup>Meets three or more of the four available criteria for metabolic syndrome: systolic blood pressure  $\geq 130$  and/or diastolic blood pressure  $\geq 85$  mmHg, triglycerides  $\geq 150$  mg/dL, blood glucose  $\geq 110$  mg/dL, and HDL cholesterol  $< 40$  mg/dL.

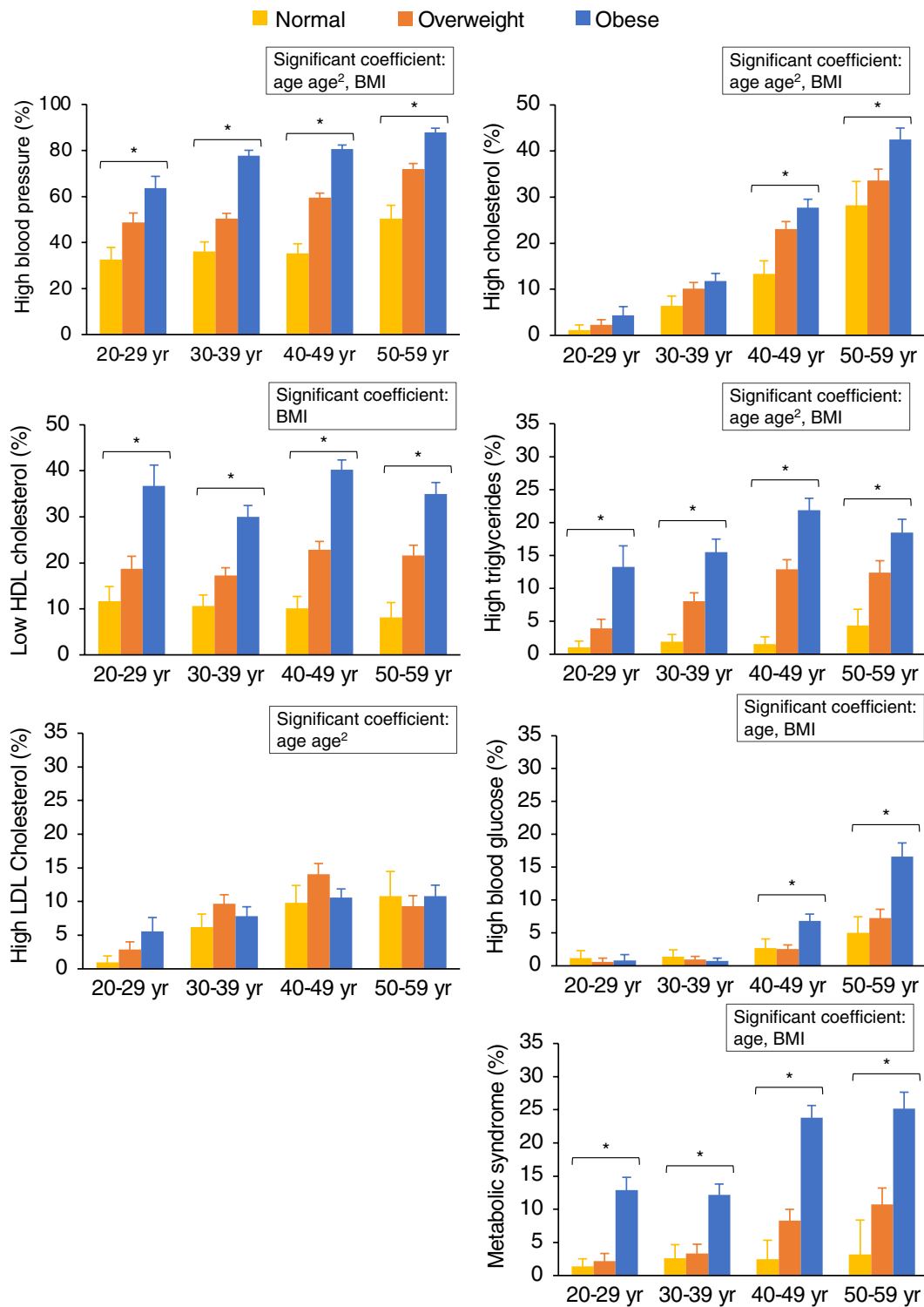
CVD, cardiovascular disease; OR, odds ratio; HDL, high-density lipoprotein; LDL, low-density lipoprotein; Ref, reference value.

syndrome compared with firefighters with normal weight; among females, firefighters with overweight were more likely to have low HDL cholesterol, and firefighters with obesity were more likely to have high blood pressure and low HDL cholesterol compared with firefighters with normal weight (Table 2). Among female firefighters with obesity, 58% had high blood pressure and 10% had metabolic syndrome, and among male firefighters with obesity, 80% had high blood pressure and 21% had metabolic syndrome.

The odds ratios from the logistic regression models of BMI category with CVD risk factors stratified by age group are presented in Table 3, and the descriptive prevalence of risk factors is shown in Figure 1. Analyses of general trends in which age and BMI categories were modeled as continuous variables with respect to the likelihood of having a particular risk factor are also reported in Figure 1. Increasing age group and

BMI category in male firefighters were significant and independently associated with a higher likelihood of having high blood pressure, high cholesterol, high blood glucose, and metabolic syndrome. There was a significant quadratic relationship between advancing age and a higher likelihood of having high blood pressure and high cholesterol. There was a significant quadratic relationship between age and the likelihood of having high triglycerides and high LDL cholesterol, with a predicted peak in firefighters between 40 and 49 years old; BMI was significantly associated with a higher likelihood of having high triglycerides but was not associated with a higher likelihood of having high LDL cholesterol. For low HDL cholesterol, only BMI was significantly associated with a higher likelihood of having low HDL cholesterol.

When stratified by age group, increasing BMI category was associated with a higher likelihood of having high blood pressure, low HDL



**Figure 1** The prevalence of cardiovascular disease risk factors in male firefighters by age and BMI. Point estimates and standard errors were predicted from a logistic regression model, with age and BMI categories modeled as categorical variables, that included terms for age, BMI, and their interaction. The sample was then stratified by age group, and the significance of BMI within each age group was tested using a logistic regression model with BMI category modeled as a continuous variable. For the analyses of general trends, a step-down approach was taken, starting with age group modeled quadratically and including a term for BMI category. If a quadratic relationship was not statistically significant, then the model was conducted with only the lower-level term for age group and a term for BMI category. \*Indicates a significant association of BMI category with an outcome within an age group. The significant coefficients in the general trends models are reported in a box above the bar graph.  $P < 0.05$  was considered statistically significant. HDL, high-density lipoprotein; LDL, low-density lipoprotein.

cholesterol, high triglycerides, and metabolic syndrome across all age groups. Being in a higher BMI category was associated with a higher likelihood of having high cholesterol and a higher likelihood of having high blood glucose within the age groups 40 to 49 and 50 to 59 years.

## Discussion

This study was the first, to our knowledge, to examine the prevalence of CVD risk factors by age and BMI category in a large cohort of US firefighters. Our sample consisted predominantly of White individuals (82%), which is consistent with broader reports in the US fire service (42). We found a high prevalence of overweight (48%) and obesity (36%) in this public safety occupational group. Furthermore, among male and female firefighters with obesity, there was an alarmingly high prevalence of cardiometabolic risk factors: 81% and 58% had high blood pressure, 36% and 45% had low HDL cholesterol, and 18% and 10% had metabolic syndrome, respectively. Being in a higher BMI category was significantly associated, independent from age, with a higher prevalence of all the examined CVD risk factors in male firefighters, including high blood pressure, high cholesterol, low HDL cholesterol, high triglycerides, high blood glucose, and prevalence of metabolic syndrome. Within each decade of life, male firefighters with higher BMI categories were more likely to have high blood pressure, low HDL cholesterol, high triglycerides, and metabolic syndrome. BMI was also significantly associated with blood glucose and high cholesterol in male firefighters aged 40 to 49 and 50 to 59 years. These results indicate that male firefighters who are older and have obesity are more likely to have CVD risk factors, and firefighters with obesity in any decade of life have a greater likelihood of developing several CVD risk factors compared with firefighters with normal weight. Given that coronary heart disease is the leading cause of on-duty deaths in both older and younger firefighters (35), there is an urgency to better understand which firefighters are at greatest risk and to devise effective programming to mitigate that risk.

Among male firefighters in the current study, the prevalence of CVD risk factors was higher in firefighters with overweight and obesity compared with firefighters with normal weight, with the exception of high blood glucose, which was only different between those who were in the obesity and normal-weight BMI categories. These findings are consistent with previous studies that have assessed the relationship between obesity and CVD risk factors in the fire service. There is agreement that obesity in firefighters is strongly related to high blood pressure (13,24-26,31), and studies have also shown associations between obesity and the prevalence of high cholesterol (25), low HDL cholesterol (24,26), high triglycerides (25,26), and high blood glucose (26). However, not all studies have found that obesity is associated with CVD risk factors. Poston et al. found that obesity was consistently related to high blood pressure, but not other CVD risk factors, in a cohort of 478 Missouri Valley firefighters (23).

Most previous studies reporting CVD risk factors by BMI have not included female firefighters (13,22-26). The current study included a large cohort of female firefighters, and although the sample was not large enough to examine BMI within age groups, analyses among the full sample showed that female firefighters with obesity had a higher prevalence of high blood pressure and low HDL cholesterol than female firefighters with normal weight. Previous research has reported an average prevalence of 42% having high blood pressure (32), 20% having low HDL cholesterol (32), and 5% having metabolic syndrome in

female firefighters (43). When assessed by weight category, the results of the current study revealed that 25% of female firefighters with normal weight and 58% of female firefighters with obesity had high blood pressure, 8% of those with normal weight and 45% of those with obesity had low HDL cholesterol, and 0% of those with normal weight and 10% of those with obesity had metabolic syndrome. Our findings support the importance of actively protecting the cardiovascular health of both male and female firefighters in order to reduce overall cardiovascular risk and subsequent cardiac events.

Although it is well understood that aging is associated with an increased prevalence of CVD risk factors in the general population (33), as well as increased incidence of cardiac events in firefighters (35), only one study with the fire service, to our knowledge, has assessed measures of cardiovascular health by age (44). In the current study of male firefighters, increasing age was associated with a higher likelihood of having high blood pressure, high cholesterol, high blood glucose, and metabolic syndrome, with an association that peaked between the ages of 45 to 50 years for the prevalence of high triglycerides and high LDL cholesterol. The nature of this quadratic relationship is likely due to an increase in lipid-lowering medication, which is more likely to be prescribed to males  $\geq$  45 years old and was not used to identify high triglycerides or high LDL cholesterol as a risk factor. Importantly, across all age groups of firefighters with normal weight, the prevalence of metabolic syndrome was  $<$  3%, and the prevalence of high blood glucose and high triglycerides was  $<$  5%.

When assessing CVD risk factors and BMI, it is important to examine age, given the general increase in obesity prevalence with increasing age (12,32,45). Few studies in the general population (12), and no studies (to our knowledge) in the fire service, have examined the associations of both BMI and age with CVD risk factors using the unique stratified approach of the current study. In a general population study assessing hypertension and dyslipidemia by age and BMI, Brown et al. showed a stepwise increase in CVD risk factor prevalence with increasing age and BMI category (12), which is consistent with the findings of the current study. The average prevalence of CVD risk factors in firefighters has been previously reported, though without context to inform which firefighters were at highest risk. Hypertension is of great concern in the fire service, with a reported prevalence of 44% in 20- to 29-year-olds (Khaja SU, Mathias KC, Bode ED, et al., unpublished data, 2021). However, this prevalence conceals the important involvement of excess weight, as 64% of 20- to 29-year-old firefighters with obesity in the current study had high blood pressure. There were also large differences in young firefighters' risk factor prevalence between BMI categories for low HDL cholesterol (12% in those with normal weight and 37% in those with obesity), high triglycerides (1% in those with normal weight and 13% in those with obesity), and metabolic syndrome (1% in those with normal weight and 14% in those with obesity). The same was true for older firefighters, particularly those with low HDL cholesterol, high triglycerides, high blood glucose, and metabolic syndrome. Ultimately, these findings reveal stunning increases in risk with being in a higher BMI category across all age groups, highlighting the importance of wellness interventions that promote healthy weight status throughout firefighters' careers.

Obesity is an independent risk factor for CVD and is known to be associated with "risk factor clustering" (12,24). A buildup of 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, which is further related to atherosclerosis, hypertension, and hyperlipidemia

(8,24). The cardiac stress induced by these conditions can lead to cardiac remodeling, such as left ventricular hypertrophy and cardiomegaly, significantly increasing the risk of arrhythmia (10,46). Obesity is a modifiable risk factor, and BMI is an easy and meaningful assessment for health management in firefighters. Although several studies have reported that the BMI of firefighters, when considered as a group, increases over time, not all firefighters gain weight. Mathias et al. reported that firefighters who lost weight over a 5-year period had a significant reduction in BMI, total cholesterol, LDL cholesterol, and systolic and diastolic blood pressures, as well as a significant increase in HDL cholesterol, despite their advancing age (30). 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 improvement with lifestyle changes (nutrition and physical fitness), as well as medication use, if needed.

To our knowledge, this study is the first to report on the relationship between obesity and CVD risk factors in both female and male firefighters and the first to further assess the associations of BMI and age with CVD risk factors. Although our sample was not nationally representative, it was one of the largest firefighter cohorts to be assessed in research, and it included firefighters from four geographic regions, with racial representation similar to that of the US fire service at large. Furthermore, our results were based on data from department-mandatory medical evaluations, eliminating potential selection bias. Although this study presents the cardiovascular health of firefighters by BMI and age, the analyses within this study are limited to observational conclusions and thus cannot determine causation and effect size of age and BMI. Future research should examine the effect of weight loss and other healthy lifestyle changes on reducing on-duty cardiac events in firefighters. The factors driving the high prevalence of obesity in the fire service should also be examined in future studies for the purpose of optimizing health promotion and wellness programs.

## Conclusion

The results of this study indicate that the majority of firefighters have overweight or obesity, and that those who are older and have obesity have the highest prevalence of CVD risk factors. There was an alarming level of risk factor prevalence among the firefighters with obesity in each age group. The combination of advancing age, excess weight, and associated risk factors is particularly concerning for firefighters, who perform arduous work under physically and psychologically stressful conditions. All firefighters should receive medical exams that include screening for CVD risk factors, including an assessment of BMI. Often, health care providers and firefighters alike are reluctant to initiate pharmaceutical treatment of CVD risk factors until firefighters are over 45 years old, as age becomes a risk factor. However, our data clearly show that increasing BMI category is associated with a higher prevalence of several CVD risk factors within all age groups, providing convincing evidence that preventive strategies should be initiated in younger firefighters and aggressively promoted or mandated throughout firefighters' careers. **O**

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occupational relevance of data. KCM managed data, performed statistical analyses, and contributed to the writing of the manuscript. All authors critically revised the manuscript for important intellectual content and provided final approval for the version to be published.

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