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Cardiovascular Disease Risk Factors and Physical Fitness in Volunteer Firefighters

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ABSTRACT

International Journal of Exercise Science 12(2): 764-776, 2019. Forty-seven percent of volunteer firefighter line of duty deaths are caused by cardiovascular events. Aggressive cardiovascular disease (CVD) risk factor reduction and improved physical fitness could reduce CVD mortality within this population. We assessed CVD risk factors and physical fitness in a large cohort of volunteer firefighters to help establish a health and fitness profile of this population, which may serve as evidence for the need to initiate programs aimed at reducing morbidity and mortality caused by CVD in the volunteer fire service. Seventy-four male volunteer firefighters were assessed for eight CVD risk factors and anthropometric characteristics. Physical fitness was assessed via push-ups, sit-ups, and the YMCA step test. Sixty-eight percent of the firefighters had two or more CVD risk factors. The sample was considered obese via body fat percentage (25.3 ± 5.7%), 27% were hypertensive, 30% had hypercholesterolemia, and 46% were sedentary. The average number of sit-ups performed was 27.3 ± 10.5, which was ranked in the 25th percentile. The average heart rate after the YMCA step test was 160.2 ± 14.6 bpm, which was ranked very poor. The number of CVD risk factors and poor physical fitness in this cohort of volunteer firefighters was noteworthy. Most volunteer firefighters in our sample were at elevated risk for CVD and had inadequate physical fitness. This evidence conveys the need to initiate physical activity and nutrition outreach programs, led by health and fitness professionals, aimed at reducing firefighter morbidity and mortality within the volunteer fire service.

KEY WORDS: Heart disease, atherosclerosis, firefighting, obesity, metabolic syndrome, aerobic capacity, sedentary

INTRODUCTION

Cardiovascular disease risk factors and poor physical fitness are the main contributors to firefighter line of duty deaths from overexertion and subsequent adverse cardiovascular events (19). Accordingly, cardiovascular events account for 47 percent of volunteer firefighter line of duty deaths in the United States (18). Furthermore, some cardiovascular disease (CVD) risk factors are more prevalent in volunteer firefighters than the general public (34). This is

concerning because of the extreme physical, environmental, and emotional and mental stress firefighting places on human physiology, particularly the cardiovascular system (4). To meet these physiological demands of the job, firefighters are required to employ high levels of muscular strength and cardiorespiratory fitness in severely stressful and hazardous conditions.

In theoretical models developed by Smith and colleagues (26, 28), the interplay between lifestyle habits, medical risk factors, and physical fitness indicates that firefighters subjected to severe physical exertion may be more prone to acute cardiac events because the cardiovascular system is stressed and thus more susceptible to cardiac arrhythmias and thrombosis (26). In healthy individuals, these demands would not normally cause cardiovascular complications. However, in firefighters who have succumbed to sudden cardiac death during or shortly after firefighting operations, roughly 90% were found to have coronary atherosclerosis (11, 16). As such, increased sympathetic drive and shear stress in coronary arteries from firefighting activities in the presence of endothelial dysfunction and plaque buildup permits plaque disruption and thrombosis, which can cause myocardial ischemia and infarction (26). Therefore, the number of CVD risk factors a firefighter possesses combined with their physical fitness level provide a comprehensive look into the overall health of the people charged with protecting the lives and property of the public.

The available data regarding CVD risk factors and physical fitness in volunteer firefighters paints a grim outlook. A substantial proportion of volunteer firefighters are overweight (1, 24, 34), use tobacco (34), and have hypertension and hypercholesterolemia (1, 24), which puts them at an elevated risk of developing coronary heart disease (10). Additionally, volunteer firefighters were shown to have very poor aerobic capacity (31.5 ml·kg^{-1}·min^{-1}) when compared to the general population (37.8 ml·kg^{-1}·min^{-1} for a male, 40 years old) and career firefighters (39.6 ml·kg^{-1}·min^{-1}) (2, 5, 17, 30). Most risk factors contributing to heart disease can be modified by lifestyle changes such as exercise programs and healthy eating habits. These changes can improve the overall risk factor profile of volunteer firefighters. Therefore, health and fitness professionals are in a unique position to favorably modify risk factors in volunteer firefighters, especially obesity and hypertension.

In the U.S., 69% of all firefighters are volunteers (14). Thus, volunteer firefighters are an essential component of public safety. With this high dependence on volunteer firefighters and the potential for job-related cardiovascular events, it is important to evaluate the overall health and fitness of these individuals. Currently, comprehensive CVD risk factor data are almost entirely from career rather than volunteer firefighters. Additionally, the data available for volunteer firefighter fitness are minimal. Since it is apparent that physical fitness is directly related to overexertion-induced volunteer firefighter fatalities (13), data from investigations concurrently evaluating CVD risk and physical fitness should be made available. The health and safety of the public and the members of the volunteer fire service are at severe risk if firefighters become incapacitated from a cardiac event during emergency operations. Therefore, the purpose and unique aim of this study were to explore the prevalence of CVD risk factors and the physical fitness capabilities within a sample of volunteer firefighters. These data will improve our understanding of the CVD risk and physical fitness profile of volunteer firefighters. These new

data can be used to support the development of initiatives, similar to those that have already been established and utilized for career firefighters (20, 23), led by health and fitness professionals aiming to improve the health and fitness of at-risk volunteer firefighters.

METHODS

Participants

Seventy-eight volunteer firefighters attending a monthly departmental meeting were recruited to participate in the study. Four subjects were excluded from the study due to inadequate data for comparison. Of these, three female subjects were excluded because the amount of data generated was not sufficient to establish meaningful averages. One male, whose body weight was greater than the capacity of the scale, was also excluded. Seventy-four male firefighters remained (94.9%) for the complete analysis. The firefighters studied belonged to two different fire departments in Saginaw County, Michigan that serve approximately 46,000 people in residential, commercial, and rural areas. Combined, there are 106 volunteer firefighters on their rosters and they annually receive approximately 1,200 calls for service. Before participating in the study, all subjects were informed of the benefits and risks associated with the study and then signed an informed consent document, which was approved by the Saginaw Valley State University (SVSU) Institutional Review Board (IRB). All data were de-identified after the completion of testing. The study was deemed exempt and approved by the SVSU IRB.

Protocol

Anthropometrics: All assessments were completed at a local fire station during a monthly department meeting. Subjects wore athletic clothing without shoes for all anthropometric measurements. Standing height was measured to the nearest 0.1 cm using a calibrated portable stadiometer (QuickMedical, Issaquah, WA, USA). Body mass was measured to the nearest 0.01 kg using a calibrated electronic scale (HRM USA INC., Warminster, PA, USA). BMI was calculated as body mass in kilograms divided by height in meters squared (kg/m^2). Body fat percentage was determined using the male, three-site skinfold method (chest, triceps, and subscapular skinfold sites). The three-site formula for males was used to determine body density, which was then entered into the Siri equation to obtain the body fat percentage (2). To preserve reliability, all measurements were taken by two trained members of the research team in triplicate on the right side of the body with the subject standing. Calibrated Lange skinfold calipers were used for all measures (Beta Technology, Santa Cruz, CA, USA).

Fitness Testing: To assess core muscular strength and endurance, sit-up testing was administered using the standard protocol set forth by the YMCA (33). Push-up testing was performed, according to procedures set forth by the ACSM (2), to assess upper body muscular strength and endurance. Cardiorespiratory fitness was tested via the YMCA three-minute step test (33) while the subject's heart rate was recorded via an electronic heart rate monitor (Polar Electro Incorporated, Lake Success, NY, USA). Although measuring oxygen uptake during maximal exercise would have provided a more precise measure of cardiorespiratory fitness, we found the step test to be a suitable alternative because it is appropriate for testing many subjects in a short period of time. Furthermore, the act of climbing or stepping up stairs coincides well

with some of the most strenuous activities that firefighters perform, thereby improving the ecological validity of the test.

Cardiovascular Disease Risk Factors: Eight risk factors (age, family history of CVD, cigarette smoking, sedentary lifestyle, obesity, hypertension, dyslipidemia, and prediabetes) were assessed to evaluate the CVD risk of the volunteer firefighters in the sample. The participants self-reported information for the CVD risk factors outlined Table 1 by completing a questionnaire (except for obesity, which calculated from the measured weight and height). The risk factor criteria were adapted from guidelines for risk stratification previously used by the ACSM (2). However, due to the scope of the study not including the means to directly measure blood pressure on multiple occasions, blood cholesterol, or blood glucose we asked the participants to report whether their physician has told them that they have high blood pressure, high blood cholesterol, and/or high blood sugar. Each risk factor was dichotomized (yes or no) at the respective cut points outlined in Table 1.

Table 1. Risk Factors Assessed in Volunteer Firefighters [adapted from (2)]

Risk Factor	Criteria
Age	Positive for subjects who were 45 years old or greater.
Family History	Positive for subjects who stated that someone in their immediate family has experienced a heart attack or sudden death before the age of 55 in males or 65 in females.
Cigarette Smoking	Positive for subjects who stated that they currently smoke, have quit smoking within the past 6 months, or live with a smoker.
Sedentary Lifestyle	Positive for subjects who indicated that they do not achieve at least 30 minutes of moderate intensity physical activity on 3 or more days per week.
Obesity	Positive for subjects who either had a body mass index of greater than or equal to 30 kilograms per meters squared or had a waist circumference of greater than 40 inches.
*Hypertension	Positive for subjects who indicated that their physician has told them that they have high blood pressure.
*†Dyslipidemia	Positive for subjects who indicated that their physician has told them that they have high cholesterol.
*Prediabetes	Positive for subjects who indicated that their physician has told them that they have high blood sugar.

*Indicates modified risk factor criteria
†HDL-C ≥ 60 mg/dL is a negative risk factor that was not collected in this assessment.

Statistical Analysis

Descriptive statistics (means ± SD, frequencies, and ranges) were calculated for demographic, health-related, and physical fitness data. The total number of CVD risk factors for each subject

was tallied. Two or more risk factors were considered to be elevated risk (2). Physical fitness data were compared to established age and gender-specific norms (2, 15).

RESULTS

Descriptive Characteristics: Table 2 outlines the descriptive characteristics of the sample. The volunteer firefighters in our sample, on average, were considered obese by two measures: BMI and body fat percentage (2, 29). The age of the firefighters in our sample ranged from 20 to 69 years, demonstrating the diversity with regards to young and inexperienced versus senior volunteer firefighters.

Table 2. Descriptive Characteristics of Volunteer Firefighters (N = 74)

Variable	Mean or %	± SD	Min	Max
Age (years)	40.1	12.2	20	69
Height (meters)	1.8	0.07	1.6	2.0
Weight (kg)	102.2	23.5	57.8	190.7
BMI (kg/m^2)	32.2	6.6	21.6	57.1
Weight Status				
Normal weight (18.5 < BMI < 25)	10.8%	-	-	-
Overweight (25 < BMI < 29.9)	29.7%			
Obese (BMI ≥ 30)	59.4%			
Body Fat (%)	25.3	5.7	7.2	35.3
Body Fat Percent Ranking				
Very Lean	1.3%			
Excellent	6.8%			
Good	6.8%	-	-	-
Fair	20.3%			
Poor	17.6%			
Very Poor	47.3%			

Fitness Testing: The physical fitness capabilities of the firefighters are outlined in Table 3. The volunteer firefighters, on average, ranked in the very poor category for recovery HR after the YMCA step test. However, the firefighters ranked very good, on average, for push-ups.

Table 3. Fitness Testing Results of Volunteer Firefighters

Fitness Test and Ranking Spectrum	%	Mean Normalized Rank	Mean Raw Score	± SD	Min	Max
Sit-ups (reps/min)		25th percentile	27.3	10.5	0	49
n = 69						
Percentile Rank						
10th	39.1%					
20th	23.2%					
30th	10.7%					
40th	13.0%					
50th	8.7%					
60th	5.8%					
70th	0%					
80th	0%					
90th	0%					
Push-ups (reps/min)		Very Good	27.2	12.8	2	87
n = 72						
Ranking						
Needs Improvement	2.8%					
Fair	9.7%					
Good	8.3%					
Very Good	33.3%					
Excellent	45.8%					
YMCA Step Test (recovery HR, bpm)		Very Poor	160.2	14.6	125	184
n = 62						
Ranking						
Very Poor	96.8%					
Poor	3.2%					
Below Average	0%					
Average	0%					
Above Average	0%					
Good	0%					
Excellent	0%					

Cardiovascular Disease Risk Factor Assessment: Table 4 portrays the prevalence of each of the eight risk factors analyzed within the sample (age, family history of CVD, history of smoking, sedentary lifestyle, obesity, hypertension, dyslipidemia, and prediabetes). Overall, 60 percent were obese and 45 percent reported a sedentary lifestyle. However, only 9 percent were at risk for diabetes. Overall, 51 (68%) of the firefighters had two or more risk factors (Table 5).

Table 4. CVD Risk Factors in Volunteer Firefighters (N = 74)

Risk Factor	**Firefighters with Positive Risk Factor n (%)**
Age	26 (35.1)
Family History	19 (25.7)
Cigarette Smoking	17 (23)
Sedentary Lifestyle	34 (45.9)
Obesity	45 (60.8)
Hypertension	20 (27)
Dyslipidemia	22 (29.7)
Prediabetes	7 (9.5)

Table 5. Number of CVD Risk Factors in Volunteer Firefighters (N = 74)

Number of Risk Factors	**Number of Firefighters n (%)**
0	4 (5.4)
1	20 (27.0)
2	12 (16.2)
3	18 (24.3)
4	11 (14.9)
5	7 (9.5)
6	2 (2.7)

DISCUSSION

We aimed to add a novel contribution to the current literature surrounding firefighter health and fitness by examining the prevalence of CVD risk factors and the physical fitness capabilities

within a sample of volunteer firefighters. The most notable finding was in relation to the high prevalence of CVD risk factors. Sixty-eight percent of our subjects had two or more risk factors. Tobacco use, hypertension, obesity, sedentarism, and hypercholesterolemia represented modifiable risk factors with the highest prevalence in our cohort. Furthermore, the volunteer firefighters within our sample demonstrated relatively poor levels of physical fitness, with the exception of upper body muscular endurance.

Tobacco Use: In the present investigation, 23% of our sample reported tobacco use. This is comparable to another study that reported 30% of volunteer firefighters as tobacco users (34). Given that tobacco use has such a strong relationship with atherosclerotic cardiovascular and respiratory diseases, programs aimed at eliminating tobacco use in the fire service should be implemented to help reduce the risk of volunteer firefighters dying in the line of duty.

Hypertension: Hypertension coexists with vascular dysfunction and causes the heart to work harder and undergo pathological changes. In our sample, 27% self-reported to be hypertensive based on their doctor's diagnosis. This is higher than in some previously reported volunteer (20% (24); 36% (10)) and career (18% (27)) firefighter cohorts. Our data indicate that the rates of hypertension in volunteer firefighters may be increasing and would require swift intervention to reverse the current trend.

Obesity: Obesity is a key component of metabolic syndrome, which is strongly associated with developing cardiovascular disease, diabetes mellitus, and stroke. In our sample of volunteer firefighters, 61% were considered obese via skinfold-assessed body fat percentage. The prevalence of obesity in previous reports ranges from 35% in career firefighters (27) to 43% in volunteer firefighters (21, 24, 34). Similar to the rates of hypertension found in this study, the prevalence of obesity in volunteer firefighters may be on the rise and should thus be a focus of people in leadership positions who are capable of addressing this issue with a top-down approach.

Sedentary Lifestyle: Time spent in sedentary behaviors has a dose-response relationship with cardiovascular and all-cause mortality (31). To that end, we assessed sedentarism in volunteer firefighters and discovered that 46% of our sample self-reported as having lived a sedentary lifestyle. To our knowledge, there are no previous reports of this metric in volunteer firefighters. However, the proportion of sedentary firefighters in our sample corresponds to national averages that range from 43 to 48% (9, 12, 32). Due to the physical demands of firefighting and the CVD risks associated with being sedentary, volunteer firefighters should be encouraged to not only engage in regular, directed exercise but to also avoid long periods of sitting, lounging, driving, etc.

Hypercholesterolemia: Blood cholesterol has a causal link with the risk of developing coronary atherosclerosis (8). Therefore, the fact that 30% of our sample of volunteer firefighters reported that their doctor has diagnosed them with having high cholesterol is noteworthy, especially since a previous report indicated that only 19% of volunteer firefighters had high cholesterol

(24). These data indicate that lipid-lowering lifestyle or pharmacological therapies should be considered for any intervention program aiming to reduce CVD risk in volunteer firefighters.

Muscular Endurance: Muscular endurance was also assessed in this sample due to the high physiological demands firefighting places on skeletal muscles for repetitive, load-bearing movements. To our knowledge, this is the first study to assess muscular endurance in volunteer firefighters. Upper body and core muscular endurance were assessed via push-ups and sit-ups. In general, the results indicated that our sample of volunteer firefighters had adequate upper body fitness but severely lacked core muscular endurance. For sit-ups, the firefighters ranked poorly, which may place them at higher risk for suffering from lower back pain and other associated muscular injuries. However, the firefighters in our sample ranked "very good" when it came to push-ups, indicating that upper body muscular endurance was adequate. These findings cannot be placed within the context of previous work because they are new to the literature for this population.

Cardiorespiratory Fitness: Cardiorespiratory fitness was assessed via recovery heart rate after completing the standardized YMCA step test. Overall, 99 percent of our sample ranked "very poor" on this test, indicating that they do not possess the necessary cardiorespiratory fitness level to conduct firefighting activities without placing severe strain on the cardiovascular system. The results of the present study are in concordance with the cardiorespiratory fitness ranking of volunteer firefighters that Swank et al. studied where the sample was, on average, ranked "very poor" via VO_2 max estimation from submaximal cycle ergometry (30). Another group of firefighters ranked "poor" after performing a submaximal treadmill test in order to estimate VO_2 max (13). Consequently, the available evidence suggests that volunteer firefighters' cardiorespiratory fitness needs improvement.

Strengths and Limitations: The primary strength of this study is that it is the first to concurrently investigate levels of cardiorespiratory fitness, muscular endurance, and CVD risk factors within a sample of volunteer firefighters. A preponderance of evidence (3, 6, 7, 25) is available to comment on CVD risk and physical fitness in career firefighters but less is known about the health and fitness of volunteer firefighters. A major difference between career firefighting and volunteer firefighting is how often the firefighter will respond to a call and subsequently the rate of exposure to hazardous situations. Nonetheless, volunteer firefighters are called to act in the same manner as career firefighters when responding to and operating at emergencies. An additional strength of this study was our inclusion of a wide range of ages, which is typically seen in the volunteer fire service, thereby increasing the generalizability of our findings to fire departments with this age and experience profile. This study is further strengthened by our use of the eight-factor CVD risk stratification model previously used by the ACSM. Risk factor assessments that are not comprehensive leave gaps in the risk factor profiles of the subjects being analyzed. The ACSM model consists of a wide array of risk factors, including medical, age, and lifestyle components. Future studies should use one of the latest risk factor analysis programs, such as those put forth by the American College of Cardiology or the Framingham Heart Study so that the progress of health initiatives can be tracked and population norms can be established.

Our study is not without limitations, and these are worth acknowledging. A weakness of the present study is the cardiorespiratory fitness measurement. The present study's step test only provided qualitative normative data, rather than estimated VO_2 max quantities. Additionally, our risk factor assessment did not provide insight into the subjects' high-density lipoprotein (HDL) cholesterol levels. If HDL is ≥ 60 mg/dL, then it is counted as a negative risk factor and reduces the number of positive risk factors by one.

Conclusions: Our findings suggest that the majority of volunteer firefighters may possess multiple CVD risk factors and inadequate physical fitness. We speculate that our sample of volunteer firefighters generally had poor physical fitness and a high prevalence of CVD risk factors because 1) most volunteer firefighters are balancing paying jobs, families, and other hobbies, which leaves little time for structured exercise; 2) being awakened at night to respond to calls for service causes substantial disruptions in sleep patterns and compounds stress which may lead to harmful physiological changes and dependence on unhealthy habits such as caffeine, alcohol, and tobacco use, among others; and 3) the typical American dietary pattern, which our participants likely followed, is high in calories and fat but low in fiber and phytonutrients, which may lead to weight gain, prediabetes, and reduced antioxidant capacity that could augment blood vessel damage and dysfunction from increased systemic inflammation. Thus, due to the deleterious relationship between CVD risk factors, poor physical fitness, and volunteer firefighter line of duty deaths, we recommend that health professionals initiate programs to aggressively reduce CVD risk factors and improve physical fitness in volunteer firefighters. Career fire departments may find it easier to integrate firefighter fitness and risk factor reduction programs due to their robust administrative structure and ample on-duty downtime. However, volunteer fire departments are unique in that their members do not normally spend their days at the station waiting for a fire call, which naturally permits time for directed physical activity, and tend to have limited financial resources. Health and fitness professionals should be tasked with reaching out to the leaders of volunteer fire departments in order to develop novel ways to launch fitness programs for volunteer firefighters. An online program developed for educating volunteer firefighters on topics related to their health, fitness, and nutrition has been established by the National Volunteer Fire Council (22), but its impact would be difficult to measure and track. Therefore, it will take professional, in-person outreach and formal programs supported by municipal leadership to properly address the decrements in physical fitness and elevated CVD risk of volunteer firefighters highlighted in this investigation.

Future research should aim to improve upon our methods of fitness assessment and CVD risk factor determination while developing interventions geared toward decreasing CVD risk factors and improving physical fitness in volunteer firefighters. Accordingly, our data indicate that scholars and practitioners within the health and fitness field have a unique opportunity to help reduce the number of volunteer firefighter line of duty deaths caused by overexertion and myocardial infarction.

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