Work 50 (2015) 285–294
DOI 10.3233/WOR-131796
IOS Press

Lifestyle and safety practices of firefighters and their relation to cardiovascular risk factors

Adrienne C. Eastlake, Brad S. Knipper, Xinjian He, Barbara M. Alexander* and Kermit G. Davis
Department of Environmental Health, University of Cincinnati, Cincinnati, OH, USA

Received 10 May 2013
Accepted 9 September 2013

Abstract.
BACKGROUND: In the United States, over 50% of the deaths of on-duty firefighters are classified as sudden cardiac deaths. A holistic view of the multiple risk factors and their relation to the prevalence of cardiovascular disease (CVD) is necessary to determine a baseline for prevention.
METHODS: This study surveyed 154 firefighters in a large Midwestern county about their individual exposure to particulates, noise, heat stress, skin contamination, and physical stress; lifestyle factors such as exercise, diet, smoking, and alcohol consumption; health status; and demographic factors.
RESULTS: Consumption of whole grains and alcohol were associated with a reduction of the risk of heart disease, while higher Body Mass Index (BMI) scores and increasing age were associated with increased risk of heart disease.
CONCLUSIONS: Although firefighters are exposed to substantial occupational risks, only lifestyle factors were found to significantly predict CVD and related health issues. BMI is a modifiable risk factor, which, if controlled, could appreciably improve health outcomes.

Keywords: Cardiovascular disease, firefighters, exposure, body mass index, high cholesterol

1. Background

There are approximately 1.1 million firefighters in the United States; 768,000 (70%) are volunteer firefighters and 335,000 (30%) are career firefighters [29]. The number of injuries and fatalities caused by burns and smoke inhalation has been greatly reduced due to advances in the personal protective equipment used by firefighters [35]. The current leading cause of on-duty death among firefighters is heart disease or cardiovascular disease (CVD) [14]. Sudden cardiac death is responsible for 50% of the on-duty deaths of volunteer firefighters and 39% of the on-duty deaths of professional firefighters [15]. Heart disease accounts for 45% of on-duty firefighter deaths in the United States [27].

Firefighting can put unusually high demands on firefighters' bodies via physical stress, environmental exposures, and emotional stress [20,41]. High stress levels may contribute to the high incidence of on-duty cardiac deaths during firefighting activities. The following symptoms may be experienced due to heavy physical exertion: increased heart rate and thermal stress caused by increased ambient temperature combined with dehydration. Due to the association between modern fire protection gear and increased load on the cardiovascular system [32], both governmental and professional organizations have developed guidelines for improving the cardiovascular health of firefighters. These guide-

*Corresponding author: Barbara Alexander, National Institute for Occupational Safety and Health, Centers for Disease Control, U.S. Department of Health and Human Services, 5555 Ridge Avenue, Cincinnati, OH 45213, USA. Tel.: +1 513 841 4581; Fax: +1 513 841 4506; E-mail: BAlexander@cdc.gov.

lines call for medical evaluations to ensure that firefighters have the physical ability and capability to perform the essential tasks associated with the job, medical clearance for respirator use, and training to ensure that firefighters are aware of the risks of not using personal protective equipment properly [4,36]. Unfortunately, compliance with these guidelines has not been universal [36] and evidence suggests, that volunteer firefighters may be less healthy than the general population regardless of occupation [44]. This is despite many initiatives to improve health status [38]. The prevention of burn and smoke inhalation injuries [35] has diminished these injuries as a cause of mortality and shifted awareness to cardiovascular disease (CVD) as a cause of firefighter mortality.

Firefighters are also exposed to many environmental issues such as: carbon monoxide, hydrogen cyanide, environmental tobacco smoke, noise exposure, aerosolized chemicals, and airborne particulate matter. Previous studies have indicated that exposure to noise without wearing hearing protection may pose a threat to a person's overall cardiovascular health [16, 39]. Firefighters may be exposed to up to 120 decibels due to siren noise. Huss et al. [24] determined that exposure to aircraft noise was associated with mortality from heart attack; in fact the relationship indicated a dose-dependent relationship based on the sound level and the duration of exposure [24]. High exposure to particulates and chemicals can occur during the period following extinguishing a fire, a process commonly referred to as "overhaul". Research suggests that most exposures (50%) occurring during overhaul resulted from firefighters removing their self-contained breathing apparatus (SCBA) when extremely hot conditions and intense physical labor [9] can still be experienced. During overhaul, harmful particulates and vapors may still exist in the air even though they are not visible to the naked eye. Some of these toxicants (carbon monoxide, hydrogen cyanide, particulate matter) are associated with cardiovascular disease [36]. In addition to the occupational exposures to particulates and vapors, firefighters' bodies are often put under a lot of stress given the high physical demands during overhaul which requires movement in a hot and humid environment while still wearing gear.

Finally, it is important to note that these occupational cardiovascular risk factors are also accompanied by personal cardiovascular risk factors such as family history, lifestyle factors, and hypercholesterolemia [36]. High Body Mass Index (BMI) has shown to be a significant risk factor for CVD in firefighters [40]. Baur et al. [6] studied 968 randomly selected male career firefighters from 11 different stations in the Midwestern United States [6]. Results indicated that only 12.4% of the firefighters who qualified for the study were of normal weight, 50.8% were overweight (BMI between 25.0 and 29.9) and 36.8% were obese (BMI greater than 30.0) [6]. Poston et al. [34] determined that the prevalence of obesity and being overweight in firefighters exceeded the average for the general population in the United States [34]. Furthermore, it has been determined that a one unit increase in the BMI scale is related to a 5% increase in risk of job disability [28]. While several other factors are known to contribute to the risk of cardiovascular disease, it is suspected that physical fitness of the individual firefighter is one of the greatest contributing factors for CVD [13].

Sudden cardiovascular death represents the number one preventable cause of death for on-duty firefighters. Due to the numerous risk factors that contribute to cardiovascular death, a comprehensive evaluation of CVD risk factors is necessary to understand which factors likely to have the greatest impact on CVD in firefighters. Most of the risk factors stem from two distinct areas: physical and psychological burden and lifestyle factors. Excellent previous work has provided an initial understanding of the physical factors that contribute to cardiovascular disease in firefighters [14,17,27,28]. These studies have been performed in both controlled and experimental settings [3] as well as large cohorts and cross-sectional trials [5,21,31,36,41]. Further, previous work has shown that the weight and bulkiness of modern fire protection gear may also contribute to cardiovascular stress [32], making it necessary to address ergonomic equipment concerns. Studies investigating the psychological stress in firefighters have demonstrated that "positive" psychological factors such as coherence and social support can be protective and that "negative" psychological factors, such as work overload, ambiguity and conflict, are not [33,37]. In all, the objective of the current study was to comprehensively evaluate the occupational exposures (physical and psychological), lifestyle factors and demographic characteristics of firefighters in Midwest fire departments.

2. Methods

2.1. Study design

Information was collected using a survey developed during the Occupational Health, Hygiene, and

Safety Workshop at the University of Cincinnati that focused on three categories: occupational risk factors, lifestyle risk factors, and demographic characteristics. The survey was comprised of 15 questions targeting particulates, heat stress, noise, dermal exposure, job stress, exercise, diet, smoking, drinking, health status, height and weight. The survey was completed by firefighters online through Survey Monkey (www.surveymonkey.com); ensuring easy access from work or home. Though the survey covered a wide range of risk factors, the questions were designed to be simple and straightforward. Online completion of the survey was designed to take no more than 10 to 15 minutes and allowed total anonymity. The study protocol, online survey, and outreach materials were all submitted and approved by the University of Cincinnati Institutional Review Board with individual participant consent linked to the survey.

2.2. Participants

Fire Chiefs from every fire department in Hamilton County, Ohio, 40 fire departments in all, were contacted to recruit participants. A recruitment poster was designed to convey information to prospective participants along with how to access the online survey, this information was emailed to the fire chiefs with a request that it be posted in several places at each of the participating fire stations. Each participating fire department was given access to the online survey on their onsite computers as well through email. Information was disseminated through each fire department via the fire chief.

Active, full-time, part-time and volunteer firefighters of both sexes were included in the study. Consent was obtained by each participants reading a one page form at the start of the online survey and providing confirmation that they read it prior to beginning the electronic survey. This allowed consent to be provided while assuring anonymity.

Participation in the study was voluntary. Interaction between the Fire Chiefs and the investigator was limited to questions and clarification via email to avoid the possibility of influence or breach of confidentiality. Confidentiality was maintained throughout data collection and no identifying data was obtained from questionnaires. Further, data obtained from questionnaires was linked to a coded identification number.

2.3. Survey

Participants were asked to identify themselves as full-time, part-time or volunteer and whether they worked at more than one fire department. On the subject of personal protective equipment, firefighters were asked about their use of respiratory and hearing protection. Several questions focused on the after effects of fire response, such as dizziness, vomiting, or skin contamination. Firefighters answered questions about their eating, drinking and smoking habits, and their participation in exercise and video gaming. Specific questions about firefighter health addressed whether they had ever been diagnosed with heart disease, vascular disease, stroke, hypertension, diabetes or high cholesterol. Demographic information collected included age, race, height, weight and gender.

2.4. Data analysis

Survey data were entered into a computer spreadsheet and categorical data analysis was performed using the Statistical Analysis System (SAS) version 9.2 (SAS Institute Inc., Cary, NC). For each categorical (qualitative) variable, a frequency distribution of the individual cases was computed using a bar chart or a frequency table. For each quantitative variable (e.g., weight, height and BMI) the mean and standard deviation were calculated. Logistic regression analysis was performed to model the relationship between the outcome variable (disease outcome) and the potential risk factors. Backward elimination logistic regression procedures were used to remove variables one at a time from the model until all the selected variables remaining were significant ($\alpha = 0.05$). A formal statistical test for the Goodness-of-fit of the logistic regression models was used to measure how well the models fit the data, by using the method of an adjusted generalized coefficient of determination (R-square).

3. Results

Fifteen fire chiefs provided access to their departments and allowed the surveys to be administered to their firefighters. Of the fifteen fire departments, one was rural, eight suburban, five small urban and one large urban. The potential pool of participants (1431) included 1056 full-time, 291 part-time and 84 volunteer firefighters. Two fire chiefs did not respond with the number of firefighters in their departments so the potential number of participants was actually higher. However, the overall response rate was low (11%), as shown in Table 1, with only 117 full-time (11% of possible participants), 16 part-time (5.5% of possible

Table 1
Survey participation rate of full time, part time, and volunteer fire fighters

	Number of responses	Number of firefighters	Firefighter participation rate (%)
Full time	117	1056	11.1
Part time	16	291	5.5
Volunteer	24	84	28.6

Table 2
Number of participant (frequency) responses based on ethnicity

Ethnicity	Number of responses
White/Caucasian American	143 (90.5%)
Black or African American	12 (7.6%)
American Indian or Alaskan Native	1 (0.6%)
Other	2 (1.3%)

participants) and 24 volunteer (28.6% of possible participants) firefighters completing the survey. One participant neglected to specify his status; that data was not included in the subsequent analysis. Of the participants, 40 stated that they worked at more than one fire department; this included 21% of the full-time, 69% of the part-time and 17% of the volunteer firefighters. Data analysis was performed on a total of 157 surveys.

The majority of the participants were white (90%) and male (91%) (Tables 2 and 3). The mean height was 178 cm (range 160 to 198 cm), the mean weight was 94 kg (range 61.2 to 158.8 kg), and the mean age was 40.8 years (range 19 to 72 years). Results of the BMI indicated that 0% fell into the underweight category (BMI $<$ 18.5), 13% were in the normal range (18.5 $<$ BMI $<$ 24.9), 53% were overweight (25 $<$ BMI $<$ 29.9) and 33% were obese (BMI $>$ 30).

Use of hearing protection varied and seemed dependent upon the activity, as shown in Table 4. Forty-seven percent of participants stated that they always wore hearing protection on the way to a fire and 23% stated that they never wore hearing protection at this time. In contrast, 95% of respondents stated that they never wore hearing protection during fire suppression and 94% never wore hearing protection during overhaul.

The use of self-contained breathing apparatus (SCBA) varied as shown in Table 5, with usage being much more prevalent during fire suppression than during overhaul.

Nine percent of respondents indicated no soot or ash on the skin beneath protective clothing following a fire response. This indicates that over 90% of the respondents return from fire response with soot under their protective clothing which may indicate that dermal exposure to any toxic chemicals could be present in this ash. Thirty three percent of participants indicated that they had experienced dizziness, vomiting, or fainting on the job (during fire suppression, overhaul or after returning to the firehouse). The reported symptoms may indicate that heat stress may have been a contributing factor.

The survey also included questions regarding the respondent's medically diagnosis (Table 6). The most common personal health issues were high cholesterol and high blood pressure with 55 and 28 positive responses, respectively. Seven participants indicated having issues with high blood sugar and 5 indicated they had been diagnosed with heart disease. Two of the participants with heart disease also indicated that they suffered from high cholesterol. Another participant who reported having heart disease also reported having high blood pressure.

In the category of diet, responses varied as indicated in Table 7. Red meat was most commonly eaten from 1–5 times per week by 83% of participants. Ninety percent of respondents indicated they relied on fast foods 1 to 3 times per week. Fish was eaten less than once per week by 57% of participants. Vegetables were eaten most commonly from 1–5 times per week as indicated by 73% of participants and grains were most commonly consumed anywhere from 1–7 times a week by 92% of participants.

Certain lifestyle activities can be beneficial or detrimental to cardiovascular health. Exercising was engaged in 1–3 times per week by 46% of participants and 16% indicated that they exercised less than once per week (Table 8). There was no opportunity for participants to indicate why they did not exercise and it is possible that some participants did not exercise at all. Twenty-one percent of respondents indicated that they played video games either daily or weekly. Therefore, 79% of participants spend time playing video games less than once a week or never. Of the 152 participants who responded to questions regarding tobacco use, only 7% used tobacco products on a daily basis. Energy drinks most commonly consumed less than once a week by 87% of participants. Alcohol consumption varied with the most common response being less than once per week (54%), but 37% of participants indicated they consumed alcohol 1 to 3 times a week. A small number of respondents (6) chose the response, "prefer not to answer" as indicated in Table 8. Their re-

Table 3
Survey participant average weight, height and body mass index (standard deviation)

Age group	Weight (kg)	Height (cm)	Body mass index (kg/m^2)
50+	91.7 (15.6)	179.6 (9.4)	28.3 (3.9)
40–49	98.7 (16.5)	180.1 (6.4)	30.4 (4.6)
30–39	93.5 (19.0)	179.3 (8.1)	29.1 (4.9)
Younger than 29	89.0 (12.6)	181.9 (9.7)	26.9 (2.7)

Table 4
Use of hearing protection en-route, during fire suppression and overhaul as indicated by survey results

	En-route to a fire ($n = 156$)	During fire suppression ($n = 153$)	During overhaul ($n = 153$)
Never	36 (22.8%)	146 (92.4%)	143 (90.5%)
Sometimes	12 (7.8%)	6 (3.8%)	9 (5.7%)
Most of the time	35 (22.2%)	0 (0%)	0 (0%)
Always	73 (46.2%)	1 (0.6%)	1 (0.6%)

Table 5
Number of firefighters indicating use of self-contained breathing apparatus (SCBA) during fire response

	During fire suppression ($n = 155$)	During fire overhaul ($n = 154$)
Never	3 (1.9%)	12 (7.6%)
Sometimes	6 (3.8%)	63 (39.9%)
Most of the time	25 (15.8%)	64 (40.5%)
Always	121 (76.6%)	15 (9.5%)

Table 6
Survey responses indicating frequency of personal health issues that could contribute to CVD

	Yes	Prefer not to answer	No
Heart disease	5 (3.2%)	0 (0%)	151 (96.8%)
Poor circulation	0 (0%)	0 (0%)	157 (100%)
Stroke	0 (0%)	0 (0%)	157 (100%)
High blood pressure	28 (17.8%)	0 (0%)	129 (82.2%)
High blood sugar	7 (4.5%)	2 (1.3%)	148 (94.3%)
High cholesterol	55 (35.0%)	2 (1.3%)	100 (63.7%)

sponses were not included in the percentages reported above.

Logistic regression analysis was performed to model the relationship between the health outcomes, such as high cholesterol, high blood pressure, etc. and the risk variables, such as occupational exposures and lifestyle factors. Regression analysis indicated that the occupational exposure factors, such as use of hearing protection, respirators, skin exposure to soot, or job stress, were not significant predictors of health outcomes.

In predicting an increased risk for high blood sugar ($n = 7$) and high blood pressure ($n = 28$), age was determined to be the only significant contributing factor. The odds ratio for high blood sugar with increasing age was 1.24 ± 0.17. The odds ratio for high blood pressure with increasing age was 1.06 ± 0.05. With respect to heart disease ($n = 5$), eating whole grains was the only factor measured that significantly reduced the risk. The odds ratio for heart disease with increasing whole grain consumption was 0.27 ± 0.59.

Many more participants reported high cholesterol ($n = 55$) than other health issues. Three factors significantly contributed to a risk of having high cholesterol: age, BMI, and alcohol consumption. Participants with a higher BMI and increasing age had an increased risk of high cholesterol. The odds ratio for high cholesterol with increasing BMI was 1.09 ± 0.08. The odds ratio for high cholesterol with increasing age was 1.08 ± 0.04. Increased alcohol consumption was associated with a decreased risk of high cholesterol (Table 9). The odds ratio for high cholesterol with increasing frequency of alcohol consumption was 0.52 ± 0.41.

4. Discussion

Cardiovascular disease (CVD) was a very significant issue when it came to the health and safety of participating firefighters. These individuals perform physically, mentally, and environmentally stressful activities that benefit society without regard for their own per-

Table 7
Survey responses indicating consumption frequency of red meat, fast food, fish, green vegetables, and grains

Frequency of eating	Less than 1 time a week	1–3 times per week	4–5 times per week	Daily	Prefer not to answer
Red meat	18 (11.4%)	81 (51.3%)	50 (31.6%)	8 (5.1%)	0 (0%)
Fast food	64 (40.5%)	78 (49.4%)	15 (9.5%)	0 (0%)	0 (0%)
Fish	91 (57.6%)	55 (34.8%)	11 (7.0%)	0 (0%)	2 (1.3%)
Green vegetables	10 (6.3%)	52 (32.9%)	62 (39.2%)	33 (20.9%)	0 (0%)
Whole grains	13 (7.6%)	46 (29.1%)	52 (32.9%)	46 (29.1%)	0 (0%)

Table 8
Survey responses indicating frequency of individual lifestyle choices (exercise and video games) and use of tobacco, energy drinks, and alcoholic beverages

Frequency of activity	Less than 1 time a week	1–3 times per week	4–5 times per week	Daily	Prefer not to answer
Exercise	25 (15.8%)	72 (45.9%)	46 (29.3%)	14 (9.0%)	0 (0%)
Play video games	121 (77.1%)	22 (14.0%)	7 (4.4%)	4 (2.5%)	3 (1.9%)
Use tobacco	132 (84.0%)	2 (1.3%)	8 (5.1%)	10 (6.3%)	5 (3.2%)
Drink energy drinks	133 (84.6%)	7 (4.4%)	8 (5.1%)	5 (3.2%)	4 (2.5%)
Drink more than two alcoholic beverages	83 (52.8%)	57 (36.3%)	14 (9.0%)	1 (0.6%)	2 (1.3%)

Table 9
Logistic regression results for response variables of high cholesterol, high blood sugar, high blood pressure, and heart disease, respectively, using various independent variables*

	BMI		Alcohol		Age		fWhole Grains	
	p-value	Odds ratio with 95% CI	p-value	Odds ratio with 95% CI	p-value	Odds ratio with 95% CI	p-value	Odds ratio with 95% CI
High cholesterol	0.03*	1.09 ± 0.08	0.04*	0.52 ± 0.41	< 0.01*	1.08 ± 0.04	–	
High blood sugar	–		–		< 0.01*	1.24 ± 0.17	–	
High blood pressure	–		–		< 0.01*	1.06 ± 0.05	–	
Heart disease	–		–		–		0.03*	0.27 ± 0.59

*Results indicated are the p-value (Pr $>$ Wald ChiSq) for the Wald Chi-square statistic with 1 df. A value below 0.05 indicates a significant effect. Values indicating "–" were not significant. A total of 17 independent variables were initially included in the logistic regression, and only four (BMI, Alcohol, Age, and Whole Grains) remained following backward elimination.

sonal health and safety. Society has a responsibility to protect the health of these important public servants. This starts by understanding the number one killer of firefighters, cardiovascular disease, which is responsible for 45% of on-duty firefighter deaths [27].

Despite the inherent risks of firefighting, these public servants are also susceptible to the same lifestyle risk factors as the rest of the population. BMI data for the participants supported the results of a study by Baur et al. [6] which determined that 12.4% of firefighters were of normal weight, 50.8% overweight and 36.8% were obese [6]. Results of the present study indicated that 13% of participants were of normal weight, 53% were overweight and 33% were obese. Some study participants expressed concern that, like some athletes, their high BMI scores may reflect a higher proportion of muscle mass than fat, and that this result may not reflect obesity. However, in a study of firefighters by Poston et al. [34], 97.1% of participants with a BMI in the obese range were also obese according to their percent body fat [34]. In fact, these researchers concluded that, consistent with earlier studies, rates of overweight and obesity for career and volunteer firefighters ($N = 677$) in their study were higher than those for the general adult American population.

In the current study, it was not surprising to find that those in the youngest age group had the lowest BMIs. However, the average BMI was still in the "overweight" range. It is noteworthy that the next-best BMI belonged to the age group, 50+. The age group with the worst BMI scores was Age 40–49. The average BMI of this group placed them in the "obese" range. These results may indicate a generational difference where those in 50+ age group were more health conscious (e.g., with regard to their food choices or exercise regimes) than the youngest generation. Another possibility is that, by the time they have reached the age of 50, those with the highest BMI may have left the fire service. If the youngest group begins with a higher than normal BMI, it follows that continuation of current habits may contribute to falling into an extremely high BMI after the age of 40. Weker [43] found that obesity, and therefore a higher BMI, in children is connected to family and environmental factors [43].

As children eat what the family provides, this would indicate that diet and healthy habits are learned at an early age which may make it difficult for a young adult to change their habits later in life, thus leading to a potential continual increase in BMI and at added risk of CVD.

High BMI was associated with increased risk of higher cholesterol levels. As determined by Gul et al., increased BMI in the general population is positively correlated with an increase in blood sugar and cholesterol [22]. Factors such as age, sex, exercise, and existing medical issues may reduce the correlation; suggesting that increasing exercise and addressing current medical issues can decrease BMI and positively affect health factors that can contribute to CVD.

It was not surprising to find in the present study that an increase in age was a risk factor for several adverse outcomes which followed the pattern seen in the general population. The present survey did not include a question about years of service as a firefighter. Increased age could possibly be confounded with increased years of occupational exposure. This could be an area for future study.

Eating whole grains is known to be healthy for the heart, but in this study, eating whole grains was found to be the only significant variable in predicting a reduced risk of heart disease. Diet is a modifiable risk factor that in recent studies has been associated with reduction of the risks of CVD [7,26]. Harris and Kris-Etherton [23] have determined that different types of grains can affect different risk factors [23]. Oats and barley can lower both total cholesterol and low-density lipoproteins (LDL) [2,30] and wheat has been associated with an improvement in blood sugar control and decrease in blood pressure [19,25]. The number of participants reporting heart disease ($n = 5$) in the present survey was very low, and the results may not be significant, but the amount of overlap between the risk factors reported and heart disease remains unknown. It is entirely possible that the individuals with other contributing risk factors, such as high blood sugar, smoking, or high cholesterol, may not yet have been diagnosed with CVD. Because no medical examinations were performed, it is also possible that false reporting occurred.

It was a surprise to find a decreased risk of high cholesterol with increased alcohol consumption in this survey. It was noted that chronic alcohol abuse can be detrimental to individual health, but studies have shown that consumption of moderate amounts of alcohol or wine may provide protection against high blood pressure, atherosclerosis, and heart attack [1,42]. Resveratrol is found in wine and is thought to be responsible for the protective heart effects reported [11]. In addition, it has been determined that the benefits of moderate wine intake may affect interactions with fatty acid metabolism in a positive manner that proves cardio-protective benefits, whereas no positive association has been found between fatty acid metabolism and ingestion of beer or liquor [12]. Results of the current study cannot address what types of alcohol was consumed by participants as that question was not included.

For the adverse health outcomes surveyed, none of the occupational risk factors were found to be statistically significant predictors. This supports the results presented by Glueck et al. [18], who determined that many of the risk factors for heart disease faced by firefighters are the same factors affecting members of the general population [18]. Smoke inhalation alone was not a predictor of future heart disease. However, the combination of occupational exposure to physical exertion, smoke inhalation and heat stress may be important in precipitating on-duty cardiac death. Although participants in other studies spent only 1 to 5% of their on-duty time in active fire suppression, the exertion required for active fire suppression activities accounted for 32 to 43% of on-duty cardiovascular events [6].

It has been determined that firefighters may not continue to wear respirators after the fire has been extinguished due to comfort issues [9]. Therefore, during the overhaul process, firefighters may be exposed to, and therefore inhale, toxic particulate and soot. Crouse et al. [10] in a Canadian cohort study, examined the effect of long-term exposure to fine particulate matter ($PM_{2.5}$) on cardiovascular mortality [10]. In this 10-year longitudinal study, researchers found a hazard ratio of 1.31 to death from ischemic heart disease for each 10 microgram per cubic meter increase in $PM_{2.5}$ concentration. Wearing respiratory protection during overhaul could help reduce exposure to inhaled particulate. Contaminants in soot may also be absorbed through the skin. Therefore, providing appropriate dermal protection could decrease dermal exposure. Decreasing the potential amount of time for either inhalation or dermal exposure are important factors in reducing risk of detrimental health effects.

5. Limitations and future directions

In the current study, there was no distinction made between full-time and part-time firefighters, or be-

tween professional and volunteer firefighters. Future studies could focus on differentiating between the risks associated with membership in each of these groups. In addition, it would be beneficial to determine if there are differences in the cardiovascular risk factors between rural, suburban, and urban firefighters as we expect the general mixtures of toxicants firefighters are exposed to in each of these settings to be different. In the present study the focus was on a mix of fire departments with no differentiation between the designation of rural, urban, and suburban fire departments.

The participation rate in this survey was lower than anticipated. Future studies should increase the rate of participation by increased interaction between researchers and firefighters or providing an incentive for participation. Also, despite the wide range of topics covered in the current survey, the questions may not include all of the factors that contribute to determining the firefighters' cardiovascular risk. Future studies would benefit from inclusion of subjective measures, perceptions (e.g., what firefighters view as a risk), and direct measures (e.g., air monitoring, bio-monitoring), verification of activities via actual observations or interviews, recruitment across a larger area, obtaining information from female firefighters, and longitudinal studies.

Future studies might also include methods of education and interventions that could help firefighters to maintain healthy BMI levels.

The present study has several limitations. The survey participants are all employed in the same Midwestern County, and they may not be representative of American firefighters nationwide. The participation rates in the study were low, and those participating are likely not representative of the region. To preserve anonymity, there was no direct interaction between researchers and participants, but increased interaction could have led to better participation rates.

Study participants were largely white males, so the present results may not be applicable to female or minority firefighters. However, the current sample reflects demographics similar to other firefighter populations that have been studied [13,34].

The present study relied upon self-report with no independent verification. Some participants in the study may have health conditions that are as-yet undiagnosed. Some participants may have felt the need to give the "right" answer to certain questions, such as eating and exercising habits. All of these factors could bias these results toward the null. Providing medical exams for the participants might possibly have revealed previously-undiagnosed medical conditions, but eating and exercising habits could only have been verified by observing each participant over an extended period of time. Such measures were not within the capacity of this investigation.

6. Conclusions

The number of on-duty deaths of American firefighters was at the lowest level ever recorded in 2011. The fraction of those deaths due to sudden cardiac death was 51% [14]. To reduce the on-duty deaths of firefighters even further, it will be necessary to address the causes of cardiovascular disease (CVD).

Lifestyle factors, as shown in this study, are the most significant contributors to the risk of high cholesterol and heart disease; these factors can be altered via education and lifestyle changes. Although age was not controlled in this study, BMI is a modifiable risk factor that could have a significant impact on firefighters' health and therefore lower the risk for CVD. Focusing on the key modifiable cardiovascular risk factors, such as exercise and diet, could help prevent potential future cardiovascular problems in firefighters.

Acknowledgements

This study benefits from the ongoing relationship between researchers at The University of Cincinnati Department of Environmental Health (UC-DEH) and fire departments in the Cincinnati area. Thanks are due to the chiefs of the fifteen fire departments participating in this survey.

Special thanks should be given to Chief William Jetter, of Sycamore Township Fire Department, for his great contributions to firefighter-related research at The University of Cincinnati. Thanks also to participants in the development and execution of this study, including Eric Glassford, Matthew Jackson, Alvin Lim, Tasha Turner-Bicknell, Willard Vaughan, Robin Saxon, and Brian Kim. Mentors for this study were L. Sue Davis, Ph.D., RN and James R. Donovan, Jr., MD.

Ethical approval

University of Cincinnati Institutional Review Board.

Funding

This research was partially supported by the National Institute for Occupational Safety and Health through the University of Cincinnati Education and Research Center. Grant number: T42/OH008432-06.

Conflict of interest

None declared.

References

[1] Aguilar, D., Skali, H., Moyé, L. A., Lewis, E. F., Gaziano, J. M., Rutherford, J. D., Lamas, G. A. (2004). Alcohol consumption and prognosis in patients with left ventricular systolic dysfunction after a myocardial infarction. *Journal of the American College of Cardiology, 43*(11), 2015-2021.

[2] Alminger, M., Eklund-Jonsson, C. (2008). Whole-grain cereal products based on a high-fibre barley or oat genotype lower post-prandial glucose and insulin responses in healthy humans. *European Journal of Nutrition, 47*(6), 294-300.

[3] Angerer, P., Kadlez-Gebhardt, S., Delius, M., Raluca, P., Nowak, D. (2008). Comparison of cardiocirculatory and thermal strain of male firefighters during fire suppression to exercise stress test and aerobic exercise testing. *The American Journal of Cardiology, 102*(11), 1551-1556.

[4] Association, N. F. P. (2002). Standard on fire department occupational safety and health program (NFPA 1500). *Quincy, MA: Author*.

[5] Baris, D., Garrity, T. J., Telles, J. L., Heineman, E. F., Olshan, A., Zahm, S. H. (2001). Cohort mortality study of Philadelphia firefighters. *American Journal of Industrial Medicine, 39*(5), 463-476.

[6] Baur, D. M., Christophi, C. A., Tsismenakis, A. J., Cook, E. F., Kales, S. N. (2011). Cardiorespiratory fitness predicts cardiovascular risk profiles in career firefighters. *Journal of Occupational and Environmental Medicine, 53*(10), 1155-1160.

[7] Bhupathiraju, S. N., Tucker, K. L. (2011). Coronary heart disease prevention: nutrients, foods, and dietary patterns. *Clinica Chimica Acta, 412*(17), 1493-1514.

[8] Burgess, J. L., Brodkin, C. A., Daniell, W. E., Pappas, G. P., Keifer, M. C., Stover, B. D., Barnhart, S. (1999). Longitudinal decline in measured firefighter single-breath diffusing capacity of carbon monoxide values: A respiratory surveillance dilemma. *American Journal of Respiratory and Critical Care Medicine, 159*(1), 119-124.

[9] Burgess, J. L., Nanson, C. J., Bolstad-Johnson, D. M., Gerkin, R., Hysong, T. A., Lantz, R. C., Bernard, A. M. (2001). Adverse respiratory effects following overhaul in firefighters. *Journal of Occupational and Environmental Medicine, 43*(5), 467-473.

[10] Crouse, D. L., Peters, P. A., van Donkelaar, A., Goldberg, M. S., Villeneuve, P. J., Brion, O., Pope III, C. A. (2012). Risk of nonaccidental and cardiovascular mortality in relation to long-term exposure to low concentrations of fine particulate matter: A Canadian national-level cohort study. *Environmental Health Perspectives, 120*(5), 708.

[11] Das, S., Falchi, M., Bertelli, A., Maulik, N., Das, D. K. (2011). Attenuation of ischemia/reperfusion injury in rats by the anti-inflammatory action of resveratrol. *Arzneimittelforschung, 56*(10), 700-706.

[12] Di Giuseppe, R., de Lorgeril, M., Salen, P., Laporte, F., Di Castelnuovo, A., Krogh, V., Van Dongen, M. (2009). Alcohol consumption and n–3 polyunsaturated fatty acids in healthy men and women from 3 European populations. *The American Journal of Clinical Nutrition, 89*(1), 354-362.

[13] Donovan, R., Nelson, T., Peel, J., Lipsey, T., Voyles, W., Israel, R. G. (2009). Cardiorespiratory fitness and the metabolic syndrome in firefighters. *Occupational Medicine, 59*(7), 487-492.

[14] Fahy, R. F., Leblanc, P. R., Molis, J. L. (2012). NFPA REPORTS-Firefighter Fatalities in the United States, 2011. *NFPA Journal-National Fire Protection Association, 106*(4), 74.

[15] Fatalities, F. Fatalities Among Volunteer and Career Firefighters – United States, 1994–2004.

[16] Gan, W. Q., Davies, H. W., Koehoorn, M., Brauer, M. (2012). Association of long-term exposure to community noise and traffic-related air pollution with coronary heart disease mortality. *American Journal of Epidemiology, 175*(9), 898-906.

[17] Geibe, J. R., Holder, J., Peeples, L., Kinney, A. M., Burress, J. W., Kales, S. N. (2008). Predictors of on-duty coronary events in male firefighters in the United States. *American Journal of Cardiology, 101*(5), 585-589.

[18] Glueck, C. J., Kelley, W., Wang, P., Gartside, P. S., Black, D., Tracy, T. (1996). Risk factors for coronary heart disease among firefighters in Cincinnati. *American Journal of Industrial Medicine, 30*(3), 331-340.

[19] Good, C. K., Holschuh, N., Albertson, A. M., Eldridge, A. L. (2008). Whole grain consumption and body mass index in adult women: An analysis of NHANES 1999-2000 and the USDA pyramid servings database. *Journal of the American College of Nutrition, 27*(1), 80-87.

[20] Guidotti, T. L. (1992). Human factors in firefighting: ergonomic-, cardiopulmonary-, and psychogenic stress-related issues. *International Archives of Occupational and Environmental Health, 64*(1), 1-12.

[21] Guidotti, T. L. (1993). Mortality of urban firefighters in Alberta, 1927–1987. *American Journal of Industrial Medicine, 23*(6), 921-940.

[22] Gul, A. M., Hafizullah, M. (2010). Does BMI affect cholesterol, sugar, and blood pressure in general population? *J Ayub Med Coll Abbottabad, 22*(4).

[23] Harris, K. A., Kris-Etherton, P. M. (2010). Effects of whole grains on coronary heart disease risk. *Current Atherosclerosis Reports, 12*(6), 368-376.

[24] Huss, A., Spoerri, A., Egger, M., Röösli, M. (2010). Aircraft noise, air pollution, and mortality from myocardial infarction. *Epidemiology, 21*(6), 829-836.

[25] Jenkins, D., Wesson, V., Wolever, T., Jenkins, A. L., Kalmusky, J., Guidici, S., Wong, G. S. (1988). Wholemeal versus wholegrain breads: proportion of whole or cracked grain and the glycaemic response. *BMJ: British Medical Journal, 297*(6654), 958.

[26] Jonnalagadda, S. S., Harnack, L., Liu, R. H., McKeown, N., Seal, C., Liu, S., Fahey, G. C. (2011). Putting the whole grain puzzle together: health benefits associated with whole grains – Summary of American Society for Nutrition 2010 satellite symposium. *The Journal of Nutrition, 141*(5), 1011S-1022S.

[27] Kales, S. N., Soteriades, E. S., Christophi, C. A., & Christiani, D. C. (2007). Emergency duties and deaths from heart disease

among firefighters in the United States. *New England Journal of Medicine, 356*(12), 1207-1215.

[28] Kales, S. N., Soteriades, E. S., Christoudias, S. G., & Christiani, D. C. (2003). Firefighters and on-duty deaths from coronary heart disease: A case control study. *Environmental Health, 2*(1), 14.

[29] Karter, M. J., Stein, G. P. (2011). *US fire department profile through 2010*: National Fire Protection Association Quincy.

[30] Keenan, J. M., Pins, J. J., Frazel, C., Moran, A., Turnquist, L. (2002). Oat ingestion reduces systolic and diastolic blood pressure in patients with mild or borderline hypertension: A pilot trial. *J Fam Pract, 51*(4), 369.

[31] Leigh, J. P., Miller, T. R. (1998). Job-related diseases and occupations within a large workers' compensation data set. *American Journal of Industrial Medicine, 33*(3), 197-211.

[32] Malley, K., Goldstein, A., Aldrich, T., Kelly, K., Weiden, M., Coplan, N., Prezant, D. (1999). Effects of fire fighting uniform (modern, modified modern, and traditional) design changes on exercise duration in New York City Firefighters. *Journal of Occupational and Environmental Medicine, 41*(12), 1104-1115.

[33] Oginska-Bulik, N. (2005). The role of personal and social resources in preventing adverse health outcomes in employees of uniformed professions. *International Journal of Occupational Medicine and Environmental Health, 18*(3), 233-240.

[34] Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., Tuley, B. C., Kales, S. N. (2011). The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *Journal of Occupational and Environmental Medicine, 53*(3), 266-273.

[35] Prezant, D. J., Kelly, K. J., Malley, K. S., Karwa, M. L., McLaughlin, M. T., Hirschorn, R., Brown, A. (1999). Impact of a modern firefighting protective uniform on the incidence and severity of burn injuries in New York City firefighters. *Journal of Occupational and Environmental Medicine, 41*(6), 469-479.

[36] Safety, N. I. f. O. (2007). *Preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events*: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

[37] Saijo, Y., Ueno, T., Hashimoto, Y. (2007). Job stress and depressive symptoms among Japanese fire fighters. *American Journal of Industrial Medicine, 50*(6), 470-480.

[38] Scanlon, P., Ablah, E. (2008). Self-reported cardiac risks and interest in risk modification among volunteer firefighters: A survey-based study. *JAOA: Journal of the American Osteopathic Association, 108*(12), 694-698.

[39] Sørensen, M., Andersen, Z. J., Nordsborg, R. B., Jensen, S. S., Lillelund, K. G., Beelen, R., Raaschou-Nielsen, O. (2012). Road traffic noise and incident myocardial infarction: A prospective cohort study. *PloS one, 7*(6), e39283.

[40] Soteriades, E. S., Targino, M. C., Talias, M. A., Hauser, R., Kawachi, I., Christiani, D. C., Kales, S. N. (2011). Obesity and Risk of LVH and ECG Abnormalities in US Firefighters. *Journal of Occupational and Environmental Medicine, 53*(8), 867-871.

[41] Steenland, K., Johnson, J., Nowlin, S. (1997). A follow-up study of job strain and heart disease among males in the NHANES 1 population. *American Journal of Industrial Medicine, 31*(2), 256-259.

[42] Vasanthi, H., Parameswari, R., DeLeiris, J., Das, D. (2012). Health benefits of wine and alcohol from neuroprotection to heart health. *Frontiers in Bioscience (Elite edition), 4*, 1505.

[43] Weker, H. (2006). [Simple obesity in children. A study on the role of nutritional factors]. *Medycyna Wieku Rozwojowego, 10*(1), 3.

[44] Yoo, H. L., Franke, W. D. (2009). Prevalence of cardiovascular disease risk factors in volunteer firefighters. *Journal of Occupational and Environmental Medicine, 51*(8), 958-962.