FEATURE ARTICLE
Research

Cardiovascular Risks in Firefighters

Implications for Occupational Health Nurse Practice

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Abstract

Limited cardiovascular risk data are available for firefighters. This cross sectional study of data collected during annual physical examinations described the prevalence of cardiovascular risk factors among firefighters (N = 200) and examined relationships between body mass index (BMI) and other cardiovascular risk factors. Evidence based guidelines were used to determine prevalence of cardiovascular risk factors and Framingham risk scoring was used to estimate probability of coronary heart disease (CHD). Firefighters ranged in age from 22 to 64 with a mean of 41. The prevalence of obesity, elevated total cholesterol, and elevated blood pressure in firefighters exceeded Healthy People 2010 targets. In addition, their prevalence of obesity, low high density lipoprotein (HDL), high low density lipoprotein (LDL), and high total cholesterol levels was higher relative to the general population. Elevated body mass index (BMI) values had positive significant ($p \leq .01$) associations with elevated blood pressures, triglycerides, and glucose levels, and a negative significant ($p < .05$) association with lower HDL cholesterol levels. Fire department worksite health and fitness policies and programs should proactively target firefighters' cardiovascular risks. Future firefighter related intervention research will benefit from considering not only the individual determinants of cardiovascular disease, but also the ecological framework that includes the influences of workplace and external environmental factors.

It is estimated that 61.8 million individuals in the general population have cardiovascular disease (American Heart Association [AHA], 2002). Cardiovascular disease continues to be the leading cause of death in the United States population (AHA, 2002) and is also a major cause of disability (National Heart, Lung and Blood Institute [NHLBI], 2000). Additionally, cardiovascular disease significantly contributes to increased health care costs. The total costs of cardiovascular disease and stroke in the U.S. population for 2003 is estimated to be $351.8 billion (AHA, 2002).

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CARDIOVASCULAR RISK FACTORS

Non-modifiable cardiovascular risk factors include age, gender, and familial disease history, and modifiable cardiovascular risk factors include diabetes mellitus, high blood cholesterol, high triglycerides, high blood pressure, and overweight and obesity (AHA, 2000). In general, an individual's risk for cardiovascular disease increases with the presence of multiple risk factors, advancing age, or elevations in risk factor severity (Grundy, 1998).

With multiple cardiovascular risk factors, individuals face an increased risk for morbidity (Brown, 2000; Grundy, 1999) and all cause mortality (Calle, 1999). In light of such an increased risk, the Healthy People 2010 initiative targets the improvement of cardiovascular health by focusing on associations between risk factors (U.S. Department of Health and Human Services [USDHHS], 1998).

Obesity as an Independent Risk Factor

As an independent cardiovascular risk factor, obesity predisposes individuals to coronary heart disease (CHD), increases the risk of mortality from CHD, and increases the burden of other cardiovascular risk factors (Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults, 1998). The increased rates of obesity occurring in the United States may potentially lead to elevated levels of disease, disability, and early death along with concomitant rises in health care costs and lost wages (USDHHS, 2001).

In terms of increasing the burden of other cardiovascular risk factors, obesity is associated with lower high density lipoprotein (HDL) cholesterol levels (Denke, 1993, 1994), and higher blood pressure levels (Krieger, 1988), higher triglycerides and total and low density lipoprotein (LDL) cholesterol levels (Denke, 1993, 1994), and higher plasma glucose levels (Hartz, 1983). Additionally, elevated triglyceride levels in obese individuals further increase cardiovascular risk (Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults, 1998), and act as an independent risk factor for CHD (Austin, 1998). High LDL cholesterol levels and low HDL cholesterol levels are also associated with risk of CHD (AHA, 2002).

Framingham Risk Scoring

Cardiovascular risk in the presence of multiple risk factors can be assessed by estimating an individual's multivariate risk or total risk factor burden. Based on Framingham Heart Study data, multivariate risk algorithms were developed to assess risk for CHD (Anderson, 1991) and subsequently updated (Wilson, 1998). These algorithms provide the ability to estimate an individual's absolute risk or probability of developing CHD within a 10 year period (Wilson, 1998). Estimates of absolute risk for CHD increase with advancing age and reflect the number of risk factors present (Grundy, 1999). Additionally, these algorithms enable the comparison of an individual's estimated total 10 year absolute risk for CHD with that for a person of the same gender and age group having low risk, including (Wilson, 1998):

- Optimal blood pressure.
- A desirable total cholesterol level.
- A medium HDL cholesterol level.
- No diagnosed diabetes.
- No smoking.

Using these algorithms, health care providers can identify individuals at high risk for CHD and have a better understanding of their total cardiovascular risk factor burden (Grundy, 1999).

What Does This Mean for Workplace Application?

The prevalence of obesity, elevated total cholesterol, and elevated blood pressure among the firefighters in this sample exceeded Healthy People 2010 targets. In addition, using evidence based guidelines to determine prevalence of cardiovascular risk factors and the Framingham risk scoring method to estimate the probability of coronary heart disease, the prevalence of obesity, low high density lipoproteins, high low density lipoproteins, and high total cholesterol levels was higher in this group relative to the general population.

Occupational health nurses can take a leadership role in helping firefighters lower their cardiovascular risk factors and increase their levels of health and fitness by identifying employees with cardiovascular risk and referring them for prevention, treatment, and follow up. Finally, using an ecological approach, occupational health nurses can promote future research focusing on cardiovascular risk in firefighters by considering not only individual determinants of cardiovascular disease but also the influences of workplace and external environmental factors.

CARDIOVASCULAR DISEASE IN THE FIREFIGHTER POPULATION

The strenuous and hazardous demands of firefighting require a firefighter to possess optimal aerobic fitness (Sothmann, 1992; Swank, 2000), as well as physical strength and agility (Gledhill, 1992). Because a national mandatory fitness standard for firefighters does not exist, variability among firefighter fitness occurs across fire departments. Although regular physical fitness programs for firefighters have been shown to have a beneficial effect (Cady, 1985; Conrad, 2004), many fire departments do not require their firefighters to maintain their initial high levels of physical fitness throughout their careers (Horowitz, 1993). Firefighters need a high level of cardiorespiratory fitness to respond to the high intensity emergency conditions demanded by their jobs (Davis, 1987). Without an optimal level of fitness, firefighters are at increased risk for causing injuries to themselves and others (Lavender, 2000).

Medical Requirements

The National Fire Protection Association (NFPA) 1582 Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians recommends minimum medical requirements for firefighters and firefighter candidates (Technical Committee on Fire Service Occupational Medical and Health, 2000). For example, in terms of cardiovascular disease, firefighters may not perform firefighting operations if they have existing heart conditions, including angina pectoris, acute pericarditis, or endocarditis. Firefighters with coronary artery disease must be evaluated on an individual basis to determine if they may perform firefighting operations.

Occupational Exposures

Line of duty exposures may increase firefighters' risk for cardiovascular disease. The few studies examining the role of line of duty exposures have found that firefighters experienced pronounced cardiovascular stress while fighting fires (Barnard, 1975) and in response to alarms (Kourinka, 1981). Barnard (1975) suggested that repeated exposure to cardiovascular stresses might be associated with cardiovascular disease in firefighters. Further, fireground exposure to high levels of carbon monoxide, which reduces oxygen delivery to the heart, may be related to increased cardiovascular disease in firefighters (Barnard, 1979). Additionally, firefighter uniforms were found to impose a level of physiologic stress on firefighters by significantly increasing heart rates and rates of oxygen consumption and water loss (Malley, 1999). Taken together, these exposures produce extraordinary cardiovascular stresses and may increase the risk of cardiovascular morbidity or mortality in firefighters.

Recent Cardiovascular Mortality Statistics

A review of several studies of the association between firefighting and cardiovascular disease relating to morbidity or mortality from cardiovascular disease among firefighters indicates mixed findings.

In terms of the risk of morbidity from cardiovascular disease, a 10 year longitudinal study of Boston firefighters found their rate for coronary heart disease was 50% of the risk for non-firefighters (Dibbs, 1982). Glueck (1996) found that male firefighters with cardiovascular disease had statistically significant increases in systolic and diastolic blood pressures, LDL cholesterol levels, total cholesterol levels, and triglycerides in comparison to those firefighters without cardiovascular disease. More recently, Soteriades (2002) found statistically significant increases in obesity and triglycerides in a sample of on-duty firefighters during a four-year follow up period. In terms of the risk of mortality from cardiovascular disease, several studies indicated a lower mortality than expected (Beaumont, 1991; Demers, 1992; Eliopulos, 1983; Guidotti, 1992; Heyer, 1990; Musk, 1978; Tornling, 1994), while others indicated a higher mortality than expected (Bates, 1987; Feuer, 1986; Grimes, 1991; Sardinas, 1986).

For the year 2000, cardiovascular diseases accounted for 39% of all deaths in the United States (AHA, 2002). During this same time period, data from the National Fire Protection Association (NFPA) indicated that cardiovascular disease, heart attacks in particular, accounted for 38% of all on duty firefighter deaths (Fahy, 2001), and that stress and over-exertion continued to be the leading causes of death in firefighters. Of 44 stress related deaths in firefighters, 40 were caused by fatal heart attacks (Fahy, 2001).

During 2001, firefighters who died while on duty ranged in age from 18 to 78, with a median age of 45 (Leblanc, 2002). Two of three firefighters who died of heart attacks were older than 50. However, during this same time, two 27 year old firefighters also died of heart attacks (Leblanc, 2002). Similarly, firefighter fatality data from the Federal Emergency Management Agency (FEMA) United States Fire Administration (USFA) for year 2002 indicated that 30% of on duty firefighter deaths were caused by heart attacks (FEMA, 2003). These firefighter fatality data were for on duty fatalities—if off duty firefighter fatalities were also considered, the proportion of fatalities in firefighters caused by cardiovascular disease would be even higher.

Healthy Worker Effect

When viewing the statistics of mortality caused by cardiovascular disease in firefighters, it is necessary to keep in mind the operation of the healthy worker effect (HWE). The basis of a HWE is that workers are likely to be healthier than the population at large and subsequently have a lower mortality rate, thereby influencing the interpretation of morbidity and mortality. Guidotti (1995) proposed that two types of HWE exist in the firefighter population. One occurs at the time of hire when new firefighters must meet extraordinary fitness requirements. The other occurs when firefighters who become ill or unfit for employment are reassigned to other duties or removed from employment. In reference to mortality, given the lack of a universally accepted method for controlling for this effect, Mielus (1995) suggested it is difficult to determine cardiovascular disease mortality among firefighters relative to the population at large.

Accounting for the HWE, Choi (2000) reassessed the previously noted studies along with several others and concluded that firefighters have an overall increased risk of mortality from cardiovascular disease. However, he noted it is unclear whether the increase in mortality risk from cardiovascular disease is caused by the firefighting occupation itself, non-occupational risk factors, or perhaps a combination of both.

PURPOSE

Although cardiovascular risk is well documented for the population at large, the existing research related to cardiovascular risk in firefighters is limited, often conflicting, and focused mainly on cardiovascular disease mortality rather than morbidity or risk factors. In general, a lack of research focusing on the extent of car-

Variables and Measures of Cardiovascular Risk in Firefighters

Variable	*Scoring of Measure*	*Variable*	*Scoring of Measure*
Blood Pressure–Systolic[*] (mmHg)	Systolic blood pressure 1 (< 120) Optimal 2 (120 to 129) Normal 3 (130 to 139) High normal 4 (140 to 159) Stage 1 5 (160 to 179) Stage 2 6 (≥ 180) Stage 3	Low Density Lipoprotein (LDL) Cholesterol[†] (mg/dL)	LDL cholesterol value 1 (< 100) Optimal 2 (100 to 129) Near optimal 3 (130 to 159) Borderline high 4 (160 to 189) High 5 (≥ 190) Very high
Blood Pressure–Diastolic[*] (mmHg)	Diastolic blood pressure 1 (< 80) Optimal 2 (80 to 84) Normal 3 (85 to 89) High normal 4 (90 to 99) Stage 1 5 (100 to 109) Stage 2 6 (≥ 110) Stage 3	Triglycerides[†] (mg/dL)	Triglyceride value 1 (< 150) Normal 2 (150 to 199) Borderline high 3 (200 to 499) High 4 (≥ 500) Very high
Total Cholesterol[†] (mg/dL)	Total cholesterol value 1 (< 200) Desirable 2 (200 to 239) Borderline high 3 (≥ 240) High	Body mass index (BMI)[‡] (kg/m^2)	BMI value 1 (< 18.5) Underweight 2 (18.5 to 24.9) Normal 3 (25.0 to 29.9) Overweight 4 (30.0 to 34.9) Obesity I 5 (35.0 to 39.9) Obesity II 6 (≥ 40) Extreme obesity
High Density Lipoprotein (HDL) Cholesterol[†] (mg/dL)	HDL cholesterol value 1 (< 40) Low 2 (40 to 59) Medium 3 (≥ 60) High	Fasting Plasma Glucose[§] (mg/dL)	Fasting plasma glucose value 1 (< 110) Normoglycemia 2 (110 to 125) Impaired fasting glucose 3 (≥ 126) Diabetes diagnosis

[*]Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *(1997).*
[†]*Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. (2001).*
[‡]*Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults. (1998).*
[§]*Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. (2000).*

diovascular risk among firefighters or of the associations of cardiovascular risk factors exists. Thus, the purpose of this cross-sectional study was to describe the prevalence of cardiovascular risk in a sample of firefighters and to examine relationships among the cardiovascular risk factors in this population. Evaluating cardiovascular risks of firefighters can provide insight into the cardiovascular health of firefighters and direct the implementation of health promotion activities that will improve and maintain the cardiovascular health of firefighters.

The research questions addressed in this study are as follows:

- What is the prevalence of cardiovascular risk factors (i.e., high blood pressure, dyslipidemia, high triglycerides, increased BMI, increased fasting plasma glucose) in a sample of firefighters?
- What relationships exist between BMI and other cardiovascular risk factors in a sample of firefighters?

METHODS

Research Design

This cross-sectional study is an analysis of cardiovascular related data from a larger study assessing firefighters' occupational injuries (Walton, 2000).

Sample and Setting

Data for this analysis were collected during periodic health maintenance physical examinations for firefighters at an occupational medicine clinic during 1999. The selected sample includes 200 firefighters across five suburban fire departments. In all, 194 firefighters (97%) were men. Female firefighters comprise a larger portion of the study sample (3%) than in the U.S. firefighter population (< 1%) (Karter, 2002). The mean age of the sample was 41 years (± 9.28, range 22 to 64 years). Male firefighters' ages ranged from 22 to 64 years (mean = 41 years, ± 9.31), and female firefighters' ages ranged from

31 to 51 years (mean = 39 years, ± 8.45). The data set did not indicate ethnicity, smoking status, personal or family history of cardiovascular disease, or previous or existing risk reduction therapies. Although racial data were not available for the firefighter sample, the firefighters served by the occupational medicine clinic used in this study are predominately White, as is true of the U.S. firefighter population (Karter, 2002).

The data for this study were available only at the level of the individual firefighter. As such, this study is focused on cardiovascular risk factors at an individual level, and is not guided by an ecological model in which the interplay of the individual with the environment is considered. Institutional Review Board approval was obtained from the university.

Measures

Evidence based guidelines were selected as criteria for classifying the following:

- Systolic and diastolic blood pressures.
- Cholesterol (i.e., total, HDL, LDL) and triglyceride levels.
- Body mass index values.
- Fasting plasma glucose levels.

Measures of the cardiovascular risk factors focused on in this analysis were assigned numerical values. These values correspond to the clinical classifications for particular levels of cardiovascular risk as presented in the evidence based guidelines. The Sidebar on page 69 shows the cardiovascular risk variables and the scoring of each measure (i.e., operational definition). Similar to the multivariate risk analysis of firefighters performed by Kales (1999), firefighters were assessed for absolute risk for CHD using Framingham multivariate risk algorithms (Wilson, 1998).

Blood Pressure. The firefighters' systolic and diastolic blood pressures were taken in a seated position. Evidence based guidelines focused on high blood pressure were used to classify systolic and diastolic blood pressures (Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure, 1997).

Cholesterol and Triglycerides. Per the clinic's protocols, a 12 hour fasting blood test was used to determine the cholesterol and triglyceride levels. Standard protocols for the blood draws and analyses were followed. Evidence based guidelines for cholesterol treatment were used to classify levels of total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides into risk categories (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001).

Body Mass Index. Body mass index was measured in pounds and inches and calculated as follows: [weight (pounds)/height (inches)^2] $\times$ 703 (Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults, 1998). Weights were gathered using a calibrated weight scale on a hard, flat surface. Firefighters wore minimal clothing and no shoes, and their heights were determined with the weight scale ruler while they stood straight facing forward with their feet together. Evidence based guidelines for identification, evaluation, and treatment of overweight and obesity were used to classify BMI values (Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults, 1998).

Fasting Plasma Glucose. A 12 hour fasting blood test was used to determine the plasma glucose levels. Standard protocols for the blood draws and analyses were followed. Evidence based guidelines for diagnosis and classification of diabetes were used to classify levels of fasting plasma glucose into risk categories (Expert Committee on the Diagnosis and Classification of Diabetes Mellitus, 2000).

Multivariate Risk. Gender specific multivariate risk scoring algorithms (Wilson, 1998) were used to assess the total 10 year absolute risk for CHD in the sample of firefighters. These algorithms are based on risk factor categorical classifications presented in evidenced based guidelines, and are not valid for adults younger than 30 or for individuals with diagnosed CHD (Kannel, 1996). Cardiovascular risk factors assessed include age, total cholesterol level, HDL cholesterol level, blood pressure, diabetes status, and smoker status (Wilson, 1998). The scoring protocol allocates points per the categorical classifications of each risk factor and is based on the availability of a person's fasting total or LDL cholesterol level (Wilson, 1998). In addition to gender differences, the algorithms also account for severity gradations in each of the risk factors. After points are allocated and totaled, the total point value is used to determine an individual's estimated total 10 year absolute risk for CHD (Grundy, 1999; Wilson, 1998). This estimated risk for CHD can be compared with that of individuals of the same gender and age range with low risk for CHD.

Although no firefighters in the sample were known to have CHD, only firefighters in the sample ages 30 to 64 were assessed. Because smoking status data were unavailable, all firefighters were assigned a value of zero for the smoker status risk factor. Thus, absolute risk values will represent a lower bound.

Data Source

Data for this analysis were provided by an occupational medicine clinic contracted to provide health services to fire departments (Walton, 2000). The data were provided electronically in ASCII text format, converted into a spreadsheet using Microsoft Excel 2000 (Redmond, WA) and reviewed for accuracy, then input for analysis into the Statistical Package for the Social Sciences Release 10 (SPSS Inc., Chicago, IL). Measures of central tendency and frequency distributions were used to describe the study variables. Pearson correlations were used to determine associations for continuous variables.

RESULTS

Results are presented in relation to the research questions posed for this study. For the sample of firefighters (N = 200), Table 1 presents data characteristics in terms of measures of central tendency and variability. Table 2 presents the total 10 year absolute risks for CHD found in the sample of firefighters as compared to estimated low CHD risk in men.

Table 1

Cardiovascular Risk Measures for 200* Suburban Firefighters

Variable	*Range*	*Mean*	*Median*	*Modes*	SD
Blood pressure–systolic (mmHg)	98.00 to 170.00	126.30	126.00	128.00	11.23
Blood pressure–diastolic (mmHg)	52.00 to 110.00	79.94	80.00	80.00	8.39
Total cholesterol (mg/dL)	118.00 to 347.00	209.72	206.00	178.00†	43.57
High density lipoprotein (HDL) Cholesterol (mg/dL) (*n* = 162)	22.00 to 105.00	47.50	46.00	37.00	13.86
Low density lipoprotein (LDL) Cholesterol (mg/dL) (*n* = 155)	60.00 to 262.00	129.29	119.00	117.00	39.06
Triglycerides (mg/dL)	25.00 to 1,341.00	160.48	124.00	131.00	137.50
Body mass index (kg/m^2)	19.50 to 54.30	29.14	28.55	24.30†	4.51
Fasting plasma glucose (mg/dL)	59.00 to 279.00	95.58	92.00	93.00	22.43

**N = 200 except where indicated.*
†Multiple modes exist. The smallest value is shown.

Research Question 1

"What is the prevalence of cardiovascular risk factors (i.e., high blood pressure, dyslipidemia, high triglycerides, increased BMI, increased fasting plasma glucose) in a sample of firefighters?"

High blood pressure. The mean systolic blood pressure of the sample of firefighters was 126 mmHg (± 11.23) ranging from 98 to 170 mmHg. Twenty-three percent of the firefighters had a systolic blood pressure categorized as high normal, and 14% had a systolic blood pressure categorized as Stage 1 or Stage 2 hypertension. Of the six female members of the sample of 200 firefighters, one was categorized with Stage 1 hypertension.

The mean diastolic blood pressure of the sample was 80 mmHg (± 8.39) ranging from a low of 52 mmHg to a high of 110 mmHg. Fourteen percent of the firefighters, all men, had a diastolic blood pressure indicating Stage 1, Stage 2, or Stage 3 hypertension.

Overall, 20% of the firefighters had a systolic blood pressure, a diastolic blood pressure, or both that could be

Table 2

Comparison of Estimated 10 Year Absolute Risk of Coronary Heart Disease (CHD) in Male Firefighters (*n* = 133) to Estimated Low 10 Year Absolute Risk of CHD in Men

Age Group	n	*Low* CHD Risk in Men*	*Range of CHD Risk in Firefighters*	*Firefighters Exceeding Low CHD Risk*
30 to 34	23	2%	2% to 8%	74%
35 to 39	30	3%	2% to 20%	40%
40 to 44	35	4%	2% to 20%	51%
45 to 49	19	4%	3% to 16%	79%
50 to 54	9	6%	3% to 31%	67%
55 to 59	9	7%	5% to 16%	67%
60 to 64	8	9%	8% to 25%	87%
Missing data: 61†				

**Risk estimates were calculated for a man having the same age, optimal blood pressure, a total cholesterol level of 160 to 199 mg/dL, an HDL cholesterol level of 45 mg/dL, no diagnosed diabetes, and being a nonsmoker (Wilson, 1998).*
†Missing data include male firefighters ages 22 to 29 (n = 23) and male firefighters for whom HDL cholesterol levels were not available (n = 38).

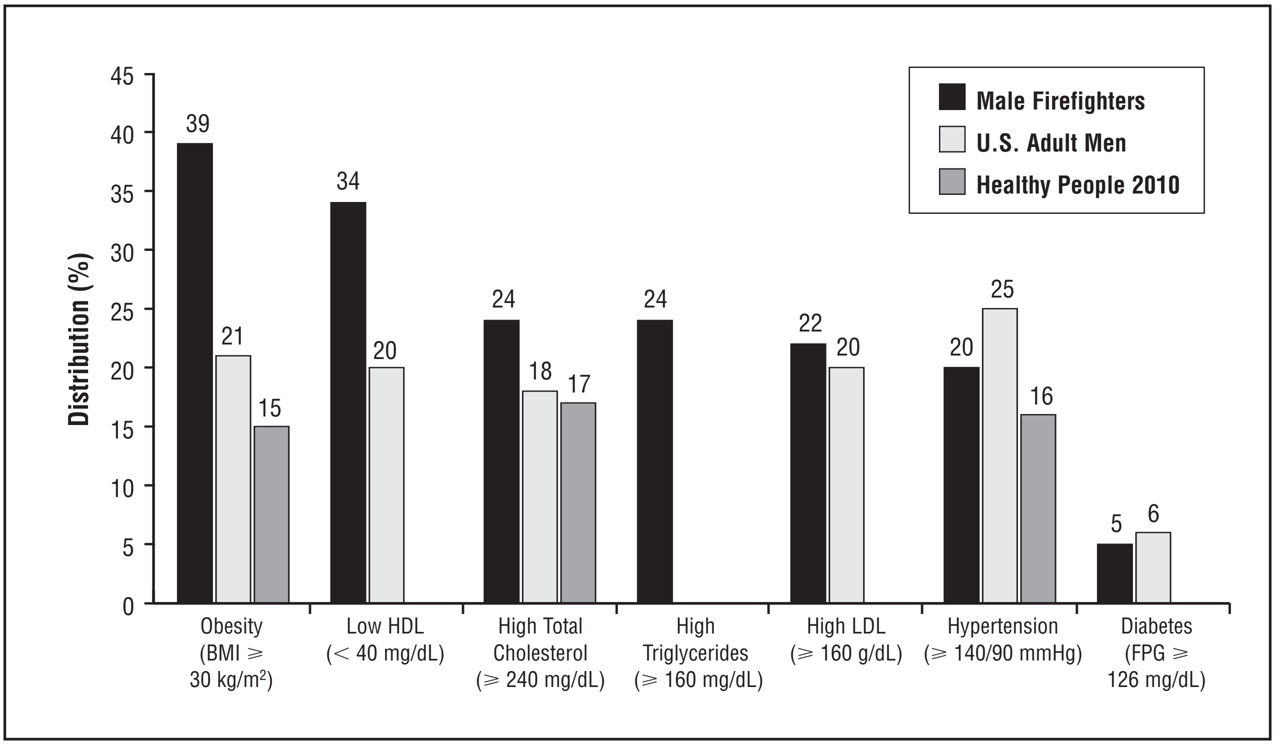

Figure. Comparison of Prevalence (%) of Cardiovascular Risk Factors Between Male Firefighters* and U.S. Adult Men† with Healthy People 2010 Targets.
***For obesity, total cholesterol, triglycerides, hypertension, and fasting plasma glucose (FPG) levels in male firefighters, *n* = 196; for high density lipoprotein (HDL) cholesterol levels, *n* = 156; and for low density lipoprotein (LDL) cholesterol levels, *n* = 148.**
†Based on age adjusted standards for year 2000 as reported by the American Heart Association using National Health and Nutrition Examination Survey III (NHANES III [1988 to 1994]) data for nonHispanic men. These data are not specifically for workers.

classified between high normal blood pressure and Stage 3 hypertension; one of these firefighters was a woman.

Dyslipidemia. The mean total cholesterol level of the sample was 210 mg/dL (± 43.57), which is categorized as a borderline high level. Total cholesterol levels ranged from 118 to 347 mg/dL. Twenty four percent of the firefighters, all men, were found to have total cholesterol levels categorized as high.

Of the 162 HDL cholesterol test results available, the mean HDL cholesterol level of the sample was 48 mg/dL (± 13.86), which is categorized as medium. The HDL cholesterol levels in the sample ranged from 22 to 105 mg/dL. Thirty-three percent of the firefighters had low HDL cholesterol levels.

Of the 155 LDL cholesterol test results available, the mean LDL cholesterol level of the sample was 129 mg/dL (± 39.06), which is categorized as near optimal. LDL cholesterol levels in the sample ranged from 60 to 262 mg/dL with 21% of the sample having high or very high levels.

Hypertriglyceridemia. The mean level of triglycerides in the sample was 160 mg/dL (± 137.50), which is categorized as borderline high. Triglyceride levels ranged from 25 to 1,341 mg/dL. Twenty one percent of the firefighters, all men, had high triglyceride levels, and 2% had very high levels.

Three firefighters had very high triglyceride levels (i.e., 626 mg/dL, 849 mg/dL, and 1,341 mg/dL) and increased the mean level of triglycerides for the sample. If these cases were removed from analysis, triglyceride levels would range from 25 to 505 mg/dL, and the mean level of triglycerides in the sample would drop to 149 mg/dL (± 91.80), which is categorized as normal.

Body Mass Index. The mean BMI of the sample was 29 kg/m^2 (± 4.51), which is categorized as overweight. The BMI values ranged from 19.50 to 54.30 kg/m^2, with 82% of the firefighters categorized as either overweight or obese. Specifically, 44% of the firefighters were categorized as overweight and 38% were categorized as obese. These prevalence data include two female firefighters who were found to be overweight and one who was found to be obese.

Fasting Plasma Glucose. The mean level of fasting plasma glucose in the sample was 96 mg/dL (± 22.43), which is categorized as normoglycemia. Fasting plasma glucose values ranged from 59 to 279 mg/dL. Although an overwhelming majority of the firefighters had a normal fasting plasma glucose level, 6% had an impaired fasting glucose level, and 5% had a fasting glucose level indicating a diagnosis of diabetes. All female firefighters in the sample were found to have fasting plasma glucose levels within the normal range.

Comparison of Cardiovascular Risk Factors. Because of the small number of female firefighters in the sample (n = 6), data indicating prevalence of cardiovascular risk factors only in male firefighters (n = 196) were considered in comparisons. As such, these data were compared with those for U.S. adult men and to Healthy People 2010 targets available for selected risk factors. As shown in the Figure on page 72, the prevalence for obesity, high total cholesterol, and hypertension in male firefighters was higher than the Healthy People 2010 targets for those risk factors (USDHHS, 1998) and higher than the prevalence of those risk factors found in U.S. adult men (AHA, 2000). The prevalence of obesity in the firefighters (39%) was two and a half times the Healthy People 2010 obesity target (15%) and almost twice the prevalence found in U.S. adult men (21%). The prevalence of high total cholesterol levels in the firefighters was approximately 25% higher than that of both the Healthy People 2010 target (17%) and the levels in U.S. adult men (18%). For hypertension, the Healthy People 2010 target (16%) is less than the firefighter sample (20%). In comparison, the prevalence of hypertension in the U.S. adult population is estimated to be 25% in men.

In a comparison with U.S. adult men (20% for both), the prevalence of low HDL cholesterol (n = 156, 34%) and high LDL cholesterol (n = 148, 22%) levels in the firefighters were higher. For fasting plasma glucose levels indicating a diabetes diagnosis, the firefighters and the U.S. adult population had a similar prevalence of 5%.

Multivariate Risk. The ranges of 10 year absolute risks for CHD are presented per 5 year age group for male firefighters ages 30 years or older and having available HDL cholesterol test results (n = 133). Percentages of firefighters exceeding estimated low CHD risks in men are also presented. Forty percent or more of the male firefighters in each age range had CHD risks exceeding the estimated low risks for CHD in men. One female firefighter in the 35 to 39 age group had a risk for CHD (1%) that exceeded the estimated low risk for CHD in women ($<$ 1%).

Research Question 2

"What relationships exist between BMI and other cardiovascular risk factors in a sample of firefighters?"

All statistically significant associations ($p \leq .01$) were low to moderate in magnitude. Higher BMI values were significantly associated with elevated systolic (r = .39) and diastolic (r = .33) blood pressures, elevated fasting plasma glucose (r = .31), and increased triglycerides (r = .22). The BMI was inversely associated with HDL cholesterol (r = -.21). Non-significant associations were found between BMI and total cholesterol (r = .01) and LDL cholesterol (r = -.07).

DISCUSSION

Prevalence of Cardiovascular Risk Factors

The sample of firefighters tended to be overweight as measured by BMI. A BMI value does not distinguish between an individual's muscle mass or fat mass. As such, an individual having a high BMI value may either have increased muscle or increased fat. Although it is not a foolproof measurement, the BMI measure significantly correlates to body fat and is commonly used to assess overweight and obesity (Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults, 1998). Nonetheless, the sample of firefighters was found to have a prevalence of obesity higher than that in the population at large.

This result is a cause of concern because mortality from CHD increases with increased BMI values and firefighters generally face extraordinary cardiovascular stresses in the workplace. Thus, firefighters have a likely increased risk of cardiovascular morbidity or mortality. In addition, the firefighters in the sample had an elevated prevalence of high triglyceride levels, low HDL cholesterol levels, and high LDL cholesterol levels—each of which is associated with increased risk for CHD. To help reduce the overall risk for CHD, weight reduction is recommended as an initial means to increase HDL cholesterol levels and to decrease triglyceride levels, LDL and total cholesterol levels, blood pressures, and high fasting plasma glucose levels (Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults, 1998).

Although the data in this study were available only at an individual level, occupational health nurses working with firefighters could apply an ecological approach that considers not only firefighters' individual risk factors but also work environment exposures. For example, occupational health nurses could examine firefighter's cardiovascular health risks in the context of occupational stress (Salazar, 2000), musculoskeletal injuries (Conrad, 1994), carbon monoxide exposure (Barnard, 1979), shiftwork, heavy physical work demands, noise, vibrations, and heat (Kristensen, 1995). In turn, they could use their collective information as the bases for developing focused interventions.

Multivariate Risk

Consistent with the literature (Grundy, 1998), the estimates for absolute risk of CHD in the sample of firefighters were found to increase with advancing age and with elevations in risk factor severity. Because of the presence of cardiovascular risk in the firefighters, their estimated absolute risks of CHD were, for the most part, greater than those estimated for individuals having optimal risk factor values. In light of this, 75% of the male firefighters ages 30 to 34 years had an estimated absolute risk of CHD greater than men of the same age having optimal risk factor values.

Although the multivariate risk algorithms assess only major independent cardiovascular risk factors (Wilson, 1998), not all CHD risk can be explained by major independent risk factors. The algorithms do not capture the presence of any life habit risk factors such as obesity, abdominal obesity, or physical inactivity, or of any emerging risk factors such as elevated blood triglyceride levels, small LDL cholesterol particles, or elevated blood homocysteine (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001). As such, it has been suggested that the multivariate risk algorithms be revised to include other types of risk factors. One suggestion is to include obesity (Grundy, 1999)—especially given its growing prevalence in the general population (USDHHS, 2001). Assessing triglyceride levels as part of the algorithms is insightful as well because of the positive relationship found between level of triglycerides and incidence of CHD (Austin, 1998).

If life habit and emerging risk factors were integrated into the multivariate risk estimations for CHD, the estimations could provide a more complete and accurate view of an individual's total risk factor burden (Grundy, 1999). For example, if the risk algorithms accounted for obesity and triglyceride levels, they may indicate increased risks for CHD for the sample of firefighters given the elevated prevalence of obesity and high triglycerides in the sample.

Associations among Cardiovascular Risk Factors

Consistent with the literature, significant positive associations were found between elevated BMI values and elevated blood pressures (Krieger, 1988), triglyceride levels (Denke, 1993, 1994), and plasma glucose levels (Hartz, 1983). Significant negative associations were found between elevated BMI values and low HDL cholesterol levels (Denke, 1993, 1994). In contrast, BMI values did not have any associations with either total or LDL cholesterol levels. These findings differ from other studies in which higher BMI values were generally associated with higher total cholesterol levels and higher LDL cholesterol levels (Denke, 1993, 1994). The strongest associations in the sample were found between BMI values and systolic blood pressures. In general, the low to moderate strengths of associations between cardiovascular risk variables in this study indicate other factors may account for the associations as well.

Study Limitations and Strengths

Because this study uses cross-sectional data, it is not possible to determine any temporal relationships between the risk factors. Because a convenience sample of firefighters whose fire departments contracted for occupational medicine services from a single occupational medicine clinic was used, the study results may not be generalizable. Additionally, the data for this study were available only at an individual level, and, as such, any effects of the work environment were not considered. Data related to risk reduction therapies or smoking status were unavailable. As such, the estimated CHD risks for firefighters are conservative estimates. Strengths of this study include the relatively large sample size, the use of established standardized protocols in collecting measures, and the process followed to ensure data integrity during data transfer.

IMPLICATIONS FOR POLICY, PRACTICE, AND RESEARCH

Firefighters are exposed to cardiovascular stresses in the line of duty. Therefore, public health professionals and agencies should place increased focus and attention on firefighter worker health and safety concerns. Occupational health nurses can lead the effort in affecting firefighter worksite health and fitness policies, promoting health programming at fire departments, and promoting future firefighter health related research.

Affecting Worksite Health and Fitness Policy

Occupational health nurses can act as change agents in the workplace and serve as health promotion consultants to firefighters, fire department personnel, legislators, and other interested individuals. They can promote the use of collaboration and interdisciplinary teams in developing and implementing firefighter health and fitness related policies. Health and fitness policies should be directed at helping firefighters maintain health in light of work shifts of sedentary periods intermixed with periods of high cardiovascular stress. To protect against firefighter injuries, illnesses, and absenteeism and to help reduce and contain overall health care costs, fire department policies should also be aimed at motivating and supporting firefighters to maintain good health and high levels of physical fitness.

Promoting Health Programming in the Workplace

Occupational health nurses can take a leadership role in helping firefighters lower their risk factor burdens and increase their levels of health and fitness. They can identify firefighters with cardiovascular risk and refer them for prevention, treatment, and follow up. Although firefighters must have high levels of health and fitness to join the fire service, the results of this study indicate that many of the firefighters have increased health risks. Enhanced fitness levels in firefighters have enhance job performance (Williford, 1999), lower both injury rates and associated health care costs for the firefighters and their departments (Cady, 1985), and should be considered in efforts to reduce musculoskeletal injury (Reichelt, 1995). Thus, goals for worksite physical activity and fitness programs targeting firefighters should strive to encompass Healthy People 2010 objectives for reducing the prevalence of overweight and obesity, high levels of total cholesterol, and high blood pressure.

Promoting Research

Occupational health nurses can promote future research focusing on cardiovascular risk in firefighters using longitudinal data. Such studies could explore whether the associations found in this study hold true, and would be beneficial in contributing to an increased understanding of the challenges to firefighter health and fitness. Future firefighter related research would benefit from considering not only the individual determinants of cardiovascular disease, but also from an ecological framework that includes the influences of workplace and external environmental factors. Research focusing on the efficacy of worksite health promotion programs in reducing cardiovascular risk factors in firefighters also is needed (Conrad, 2004). To help provide a more solid financial basis for program justification, studies should address the direct health care and associated cost savings in relation to firefighter health and fitness programs.

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