I, John W Woltz, hereby submit this original work as part of the requirements for the degree of Master of Science in Occupational Medicine.

It is entitled:
Cardiovascular Risk and Left Ventricular Hypertrophy in Firefighters

Student's name: John W Woltz

This work and its defense approved by:

Committee chair: James Locke, MD, MS
Committee member: David Louis, MD
Committee member: Thomas R. Hales, PhD
Committee member: Charles Ralph Buncher, ScD
Cardiovascular Risk and Left Ventricular Hypertrophy in Firefighters

A thesis submitted to the

Graduate School

of the University of Cincinnati

in partial fulfillment of the

requirements for the degree of

Master of Science

In the Department of Environmental Health

Of the College of Medicine

By

John W. Woltz

B.A. Capital University

DO Ohio University College of Osteopathic Medicine

November 2011

Thesis Committee

Chair: James Lockey, MD

David Louis, MD

Thomas Hales, MD

Charles Buncher, ScD
ABSTRACT

Purpose: The National Institute for Occupational Safety and Health (NIOSH) Firefighter Fatality Investigation and Prevention Program (FFFIPP) has investigated hundreds of firefighter deaths since it began in 1998 including 224 non-trauma deaths. This is the first study to collate the medical data NIOSH has collected regarding risk for cardiovascular events and non-trauma death in firefighters.

Methods: There were 110 appropriately detailed non-trauma death cases available from NIOSH, covering 1998 to the present. These cases were compared to generic controls developed from National Health and Nutrition Examination Survey (NHANES) data. Statistical analysis was conducted on cardiovascular risk profiles and cardiac mass at autopsy.

Results: Framingham risk scores in 110 Firefighters were significantly higher than the predicted Framingham risk scores for the average American. Firefighters who succumbed due to cardiac events also had significantly larger cardiac mass (513 gm) compared to expected (387 gm) across all age groups, P <.05.

Conclusions: Elevated Framingham risk and/or Cardiac Hypertrophy may be a significant indicator of increased risk of sudden cardiac death in firefighters.
ABSTRACT

TABLE OF CONTENTS

SECTION I – INTRODUCTION

A. PURPOSE & RATIONALE
B. OBJECTIVES
C. HYPOTHESIS

SECTION II – BACKGROUND

A. FIREFIGHTER AND CV DEATH
B. FRAMINGHAM CV RISK
C. LEFT VENTRICULAR HYPERTROPHY

SECTION III – METHODS

A. STUDY DESIGN
B. STUDY POPULATION – FIREFIGHTER/Generic CONTROLS
C. DATA COLLECTION
D. ANALYTICAL METHODS
SECTION IV – RESULTS

A. FRAMINGHAM CV RISK
B. LEFT VENTRICULAR HYPERTROPHY

SECTION V – DISCUSSIONS

A. FRAMINGHAM CV RISK
B. LEFT VENTRICULAR HYPERTROPHY
C. LIMITATIONS

SECTION VI – CONCLUSION/RECOMMENDATION

A. CONCLUSION
B. RECOMMENDATION

SECTION VII – APPENDICES

A. REFERENCES
B. KALES PROPOSED SCHEME FOR USING BLOOD PRESSURE
C. DISCUSSION OF C-STATISTIC
D. PATHOLOGIST DISCUSSION OF CARDIAC CHANGES FOLLOWING SUDDEN CARDIAC DEATH
E. RECOMMENDED SCHEME FOR USING CARDIOVASCULAR RISK CALCULATOR AND ECHOCARDIOGRAPHY
SECTION I: INTRODUCTION
PURPOSE & RATIONALE

The primary purpose of this study is to determine if firefighters who experience sudden cardiac death (SCD) on duty have elevated, identifiable risk factors that were known prior to the episode of SCD. Secondarily, cardiac mass at autopsy will be identified and compared to expected cardiac mass by body weight to see if this would be a useful adjunct. Currently, recommended screening procedures from the National Fire Protection Agency (NFPA) are limited to blood pressure measurement, physical exam and annual electrocardiogram (ECG) for member firefighters. The investigator’s concern is that these screening measures are not sufficient to correctly identify firefighters at highest risk for SCD.

OBJECTIVES

1) Determine whether firefighters who died at the fire ground had a different CVD (cardiovascular disease) risk profile than that expected of the general population.

2) Determine whether firefighters who died at the fire ground had cardiac mass differences than that expected of the general population.

HYPOTHESIS

Study Hypothesis are stated as assumptions of no difference (null).

1. Firefighters who died of sudden cardiac death, regardless of type of duty being performed, have the same cardiac risk profile as the general population.
2. Firefighters who died of sudden cardiac death have the same cardiac mass at autopsy as would be expected from the general population.
SECTION II – BACKGROUND

FIREFIGHTERS AND CV DEATH

Cardiovascular events are the major cause of mortality in both career and volunteer firefighters. Myocardial infarction or fatal arrhythmia accounted for 39% of career and 50% of volunteer firefighter deaths from 1994 to 2004.\(^1\) Firefighters over the age of 40 represent 46% of the fire service nationwide and account for 60% of the annual fatalities, representing a disproportionate number of deaths.\(^2\) It is clear that firefighters over 40 are a higher risk group for experiencing a cardiac event. These trends have stayed unchanged since 2004.

Kales et al. have shown that type of duties being conducted has a significant impact on risk of a cardiac event, with fire suppression being 10 to 100 times higher risk than non-emergency duties.\(^3\) Kales et al. also showed that the circadian distribution of cardiac events in firefighters is different than the general population and is correlated to periods of increased emergency calls, with afternoon to evening for firefighters as the period of highest risk. Of those who experienced cardiac death, many had personal risk factors for cardiac disease.\(^4\)

Currently, only blood pressure, physical exam and annual ECG are recommended per National Fire Protection Association (NFPA 1582) standards for member firefighters.\(^5\) NFPA 1582 recommends restriction and further evaluation if cardiac risk is suspected (coronary artery disease, heart failure, uncontrolled hypertension). Although these recommendations include asking the physician to ‘consider’ certain testing procedures, no definitive algorithm is recommended. Kales et al. proposed a management scheme based on blood pressure during
annual physical exams for firefighters (appendix B). Unlike NFPA, this scheme included recommended physical restrictions, interventions and follow-up intervals.\(^{(28)}\)

Many algorithms have been developed that calculate a predictive risk for experiencing a cardiac event including Framingham in the USA, QRISK in Britain, PROCAM in Germany, and others. The algorithm typically use inexpensive and easily obtained values, such as age, blood pressure, cholesterol levels, etc, to determine a risk over a set number of years, i.e. 1.7% over 10 years. It has become generally accepted that these algorithms are useful in identifying those at elevated risk. This study will examine if the use of a cardiovascular risk predictor would identify those firefighters at increased SCD risk.

FRAMINGHAM CV RISK

The Framingham Heart Study began in 1948 as a National Heart, Lung and Blood Institute, NHBLI, (formerly National Heart Institute) project to conduct research on the general causes of heart disease and stroke. Over the last 6 decades, more than 15,000 participants have been enrolled in multiple cohorts. Results from the Framingham Heart Study, now a joint project with Boston University, have been published in more than 1200 articles. In addition, the study has lead to the development of 14 different algorithms to predict various forms of cardiovascular disease.\(^{(32)}\)

Risk factors for heart disease are generally well accepted, such as age, sex, race and family heredity, smoking, diabetes and cholesterol.\(^{(6)}\) The Framingham “General Cardiovascular Disease (10-year risk)” risk score profile utilizes sex, age, high density lipoproteins (HDL-‘good’ cholesterol), total cholesterol, systolic blood pressure (SBP-adjusted for blood pressure
medication), positive smoking and diabetes.\(^{(7)}\) The algorithm was developed using the Framingham Heart Study data and does have some limitations, such as overestimating low-risk populations, but is generally accepted as a reliable predictor of 10 year cardiac risk in the general US population.\(^{(8,9,10)}\) The General Cardiovascular Disease (10-year risk) risk score is limited to 30% over 10 years. This score represents the chance that an individual will have any one of the following cardiovascular events in the next 10 years (coronary death, myocardial infarction, coronary insufficiency, angina, ischemic stroke, hemorrhagic stroke, transient ischemic attack, peripheral artery disease or heart failure).\(^{(7)}\)

For the General Cardiovascular Disease (10-year risk) model, researchers have found C statistics ranging from 0.763 to 0.803 indicating sufficient accuracy for predicting CAD.\(^{(7,11)}\) (see appendix C for a discussion of the C-statistic)

The General Cardiovascular Disease (10-year risk) risk score profile will be referred to as the “FRS” for the remainder of this paper.

LEFT VENTRICULAR HYPERTROPHY

Left Ventricular Hypertrophy (LVH) has also been shown as a significant predictor of sudden cardiac death (SCD).\(^{(12)}\) LVH is common in long term hypertensives and has been associated with “increased risk of sudden death, arrhythmias, stroke, heart failure, and atherosclerosis.\(^{(13)}\) In males the hazard ratio for LVH and risk of sudden death is 2.89, (95% C.I. 1.56-5.38).\(^{(14)}\) Unfortunately, inexpensive and simple diagnosis of LVH has proven to be elusive. Electrocardiography techniques have been developed that have sensitivities ranging
from 7 to 51%. \(^{(15)}\) Echocardiography has much higher sensitivity, approaching 100% in severe LVH, but is more involved and expensive than an ECG. \(^{(16)}\) Regression of LVH during hypertensive treatment has been shown to decrease risk of SCD from 20-43%. \(^{(17,18)}\)
SECTION III – METHODS

STUDY DESIGN

This study is a case-control design. Firefighter fatality data is collected by a NIOSH investigation team within six months of a fatality. NIOSH conducts investigations on both traumatic and non-traumatic (typically cardiovascular suspected) deaths of firefighters. The Cincinnati NIOSH office is the lead for non-traumatic investigations. This office has data available for 224 non-trauma fatalities. While a cohort using new recruits would be ideal, the actual number of average annual deaths (~100 total, ~40 cardiac) and the fact that relatively few cardiac events occur prior to age 35, made a case-control study the only reasonable methodology.

STUDY DESIGN: CARDIOVASCULAR RISK

The first objective was to calculate the FRS risk scores which are the independent variables and compare to generic controls. Selection criteria included those cases with enough data to complete a FRS risk score. The calculator requires sex, age, SBP, total cholesterol and HDL cholesterol. Positive history of diabetes mellitus, blood pressure medication use and smoking status independently affect the total score.

To create a generic control population, data from the Third National Health and Nutrition Examination Survey (NHANES III) was used. NHANES III was conducted in 1988-1994 and collected medical data from over 30,000 Americans age 2 months and older. Using NHANES data, an “average’ American male was created for each age group.\(^{(19,20,21)}\) Firefighter cardiovascular risk profiles have been found to be similar to the general US population.\(^{(22)}\) These controls were then independently adjusted to reflect the prevalence of smoking, diabetes, and/or
blood pressure medicine use in the general population across age groups. When determining Framingham risk, medication adds 2 points, diabetes 3 and smoking 4. These points were multiplied by the percentage of Americans that smoke, have diabetes, or take blood pressure medication. For example, in the 30-39 age group, approximately 10% of the US population has diagnosed or undiagnosed diabetes, an adjustment of 0.10x3 or 0.3 points was added to the control FRS risk score prior to determining risk.

In summary, the average American male, aged 30-39 has a systolic blood pressure of 118 mm/hg, HDL of 45 and total cholesterol of 200. When risk score is calculated, this average American using NHANES III data has a 10 year cardiovascular risk of 2.3%. Adding the prevalence of smoking, diabetes and BP medicine in this age group causes the risk to be increased to 3.3% over 10 years. This creates ONE generic control per age group to compare to each firefighter case in the corresponding age group.

STUDY DESIGN: LEFT VENTRICULAR HYPERTROPHY

Objective two was an additional case-control study to quantify the additional data obtained pertaining to LVH. Cardiac mass (or weight) at autopsy is the independent variable. This was compared to the expected cardiac mass for a person of the same sex and weight (the generic control) using previously published charts from Kitzman et al.. Kitzman et al. used 765 hearts obtained at autopsy to conduct their analysis. They then evaluated the prediction of cardiac weight in relation to body weight, body height and body surface area. They found the most reliable predictor of cardiac mass was body weight. (25)
STUDY POPULATION

Firefighter Cases: The NIOSH Firefighter Fatality Investigation and Prevention Program (FFFIPP) conducts investigations of firefighter line-of-duty deaths to formulate recommendations for preventing future deaths and injuries. Data collected, as mentioned previously, includes death certificates and autopsy when performed (over 90% have autopsy reports). Only those cases with substantial evidence, through autopsy or medical history and medical records, of death due to a cardiac event were used in this study.

Controls: The creation of the generic control as described above served as the control in Objective one. Objective two controls were obtained from previously published charts predicting cardiac mass norms based on gender and body weight and more fully explained under LVH analytical methods.

DATA COLLECTION

There were 224 records of deceased firefighters investigated by the NIOSH Firefighter Fatality Investigation and Prevention Program (NIOSH FFFIPP). These cases were non-traumatic of which 91% (203 cases) were cardiovascular deaths. Collected data was obtained from the records themselves and not from previously extracted data. In the instance of multiple data points, i.e. multiple blood pressures, the most recent value prior to the fatal event was used. Records may include interviews with witnesses and co-workers, training history, personal and departmental medical charts, emergency room records, death certificates and autopsy data. The following data points were collected: Gender, paid vs. volunteer status, race, age, height, weight, systolic blood
pressure (SBP), diastolic blood pressure (DBP), total cholesterol, high density lipoprotein (HDL), smoking status (any history of use), diabetes, previous LVH diagnosis (by echo, ecg, chest xray), duty being performed, cardiac findings at autopsy including cardiac weight, and any further pertinent medical data such as history of chest pain or previous MI. This data was entered into an excel spreadsheet and checked for accuracy.

ANALYTICAL METHODS: CARDIOVASCULAR RISK

Cases: Absolute criteria for inclusion in the cardiovascular risk case-control study were sex, age, HDL, total cholesterol and SBP. Use of blood pressure medication, smoking or diabetes was used if present, but lack of this latter information did not exclude these cases. The most recent values, excluding the fatal event records, were used for the risk calculation. Of the original 224 cases, 21 were excluded for non-cardiovascular deaths, 18 for younger than 30 years old, 4 due to female gender and 71 for incomplete data. The remaining 110 cases met inclusion criteria for this arm of the study.

An MS Excel formula was created to calculate FRS risk scores. The study population was divided into 10 year age groups, 30-39, 40-49, 50-59 and 60+.

Cases with a history of previous cardiac event were included as never having had an event because of this limitation in the FRS. Risk of a second cardiovascular event is greatly increased after the first event and is an independent risk factor not included in the FRS. Using myocardial infarction (MI) as an example, the risk of a second MI is greater than 18% over the next 6 years following first MI, this means that on average, 18 out of 100 individuals who have an MI, will have a second MI within 6 years.\(^{(24)}\) Using the earlier 30-39 year old generic
American example, with a FRS risk of 3.3% over ten years, if the same individual had also suffered an MI within the last six years, his risk would be 18% of having a second event, in addition to the 3.3% risk from his FRS score. By including cases as never having a prior cardiac event, the resulting risk scores will be comparable to data used in the FRS calculation for the controls in this study.

Statistics: Following calculation of the case FRS risk scores, the scores were entered into a spreadsheet obtained from the University of Delaware which calculated the mean and upper and lower 95% Confidence limits.\(^{(23)}\) The appropriate age control was then directly compared to the 95% C.I. obtained from the firefighter cases separated into the previously mentioned age groups. If the control score fell outside the upper or lower limits, it is likely that the firefighter scores were significantly different than controls.

ANALYTICAL METHODS: LEFT VENTRICULAR HYPERTROPHY

Cardiac weights were obtained from autopsy reports. Autopsies diagnosing hypertrophic cardiomyopathies or right ventricular hypertrophy were excluded. 145 of the original 224 cases met inclusion criteria for this arm. Calculation of predicted weight used data published by Kitzman et al., with averages and upper and lower 95% C.I. for cardiac weight by body weight. The predicted normal (average) heart weight was used in the comparison.\(^{(25)}\) When using the Kitzman table, cases falling between body weight categories were rounded up to next weight, i.e. after 198 pounds, the next weight value is 203 pounds.
Statistics: Student’s t-test was used to compare autopsy cardiac weight to Kitzman predicted normal values. This was done both by age groups and overall. A two tailed t-test was conducted using Microsoft excel data analysis software. Significance was set at $P<.05$. 
SECTION IV - RESULTS

CARDIOVASCULAR RISK

Of the 110 cases that met criteria for determination of General Cardiovascular Disease risk, there were a total of 18 cases age 30-39, 39 age 40-49, 42 age 50-59 and 11 age 60-69. The average risk score calculated, by age group with 95% Confidence Intervals is shown in Tables 1-4 below. Additionally, individual data points for determining General cardiovascular risk are listed as well as the data points used to determine the generic control scores.

Table 1 CV Risk ages 30-39

<table>
<thead>
<tr>
<th>30-39 Age Group (n=18)</th>
<th>Lo 95% CI</th>
<th>Mean</th>
<th>Hi 95% CI</th>
<th>Control</th>
<th>P&lt;.05 ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framingham Score</td>
<td>3.5%</td>
<td>6.29%</td>
<td>9.08%</td>
<td>3.3%</td>
<td>Y</td>
</tr>
<tr>
<td>Avg SBP (# Stage 1 HTN or greater)*</td>
<td>129 (4)</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDL</td>
<td>42</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Chol</td>
<td>221</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP Med % (#)</td>
<td>33% (6)</td>
<td>27%**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes % (#)</td>
<td>17% (3)</td>
<td>11%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker (ever) % (#)</td>
<td>11% (2)</td>
<td>16%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Stage 1 HTN is systolic BP 140-159 mm/Hg

**BP med % for 30-39 is the overall US prevalence, specific Data for 30-39 age group unavailable
Table 2 CV Risk ages 40-49

<table>
<thead>
<tr>
<th>40-49 Age Group (n=39)</th>
<th>Lo 95% CI</th>
<th>Mean</th>
<th>Hi 95% CI</th>
<th>Control</th>
<th>P&lt;.05 ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framingham Score</td>
<td>11.2%</td>
<td>13.81%</td>
<td>16.41%</td>
<td>9.4%</td>
<td>Y</td>
</tr>
<tr>
<td>Avg SBP (# Stage 1 HTN or greater)*</td>
<td>133 (11)</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDL</td>
<td></td>
<td>43</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Chol</td>
<td></td>
<td>218</td>
<td>212</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP Med % (#)</td>
<td></td>
<td>56%</td>
<td>29%**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes % (#)</td>
<td></td>
<td>15%</td>
<td>11%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker (ever) % (#)</td>
<td></td>
<td>36%</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Stage 1 HTN is systolic BP 140-159 mm/Hg

**BP med % for 40-49 and 50-59 is a 40-59 prevalence.

Table 3 CV Risk ages 50-59

<table>
<thead>
<tr>
<th>50-59 Age Group (n=42)</th>
<th>Lo 95% CI</th>
<th>Mean</th>
<th>Hi 95% CI</th>
<th>Control</th>
<th>P&lt;.05 ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framingham Score</td>
<td>18.8%</td>
<td>21.08%</td>
<td>23.37%</td>
<td>18.4%</td>
<td>Y</td>
</tr>
<tr>
<td>Avg SBP (# Stage 1 HTN or greater)*</td>
<td>136 (17)</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDL</td>
<td></td>
<td>41</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Chol</td>
<td></td>
<td>204</td>
<td>215</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP Med % (#)</td>
<td></td>
<td>67%</td>
<td>29%**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes % (#)</td>
<td></td>
<td>17%</td>
<td>11%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker (ever) % (#)</td>
<td></td>
<td>24%</td>
<td>24%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Stage 1 HTN is systolic BP 140-159 mm/Hg

**BP med % for 40-49 and 50-59 is a 40-59 prevalence.
Table 4 CV Risk ages 60+

<table>
<thead>
<tr>
<th>60+ Age Group (n=11)</th>
<th>Lo 95% CI</th>
<th>Mean</th>
<th>Hi 95% CI</th>
<th>Control</th>
<th>P&lt;.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framingham Score</td>
<td>24.36%</td>
<td>26.81%</td>
<td>29.26%</td>
<td>29.4%</td>
<td>N</td>
</tr>
<tr>
<td>Avg SBP (# Stage 1 HTN or greater)*</td>
<td>148 (8)</td>
<td>135</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDL</td>
<td>41</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Chol</td>
<td>193</td>
<td>207</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP Med % (#)</td>
<td>82% (9)</td>
<td>46%</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes % (#)</td>
<td>9% (1)</td>
<td>23%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker (ever) % (#)</td>
<td>27% (3)</td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Stage 1 HTN is systolic BP 140-159 mm/Hg

**BP med % for 60+ is reported as a over 60 prevalence.

P-values of less than 0.05 were obtained for firefighters in the 30-59 year age groups. In these groups the average calculated firefighter risk was significantly higher than the generic control.

LEFT VENTRICULAR HYPERTROPHY

145 cases were documented with cardiac weight by autopsy. By age group, average cardiac weights were as follows: <30, 480g; 30-39, 484g; 40-49, 525g; 50-59, 522g; and 60+ 532g. The overall average was 513g. In all age groups the average of the actual weights exceeded those predicted by Kitzman. Student’s T-test showed statistically significant (p <.05) elevated cardiac weights in all age groups. Table 5 shows the average mean weights, by age
group, for actual cardiac weight vs Kitzman predicted normal (adjusted for body weight) and the T-Test p-values by age group and overall for actual vs. Kitzman.

Table 5: Cardiac Weight T-Test Results

<table>
<thead>
<tr>
<th>Age Groups (by decade)</th>
<th>Firefighters Cardiac Weight (mean in grams)</th>
<th>Firefighters predicted based on weight, (Kitzman Predicted Normal**, mean in grams)</th>
<th>Actual vs Kitzman Predicted Normal** P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30</td>
<td>479.82</td>
<td>386.5</td>
<td>0.014</td>
</tr>
<tr>
<td>30-39</td>
<td>483.76</td>
<td>394.45</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>40-49</td>
<td>524.52</td>
<td>387.47</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>50-59</td>
<td>522.03</td>
<td>389.08</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>60+</td>
<td>532.14</td>
<td>358.46</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Total</td>
<td>513.17</td>
<td>387.05</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

*Statistical significance, P < .05

**Kitzman table predicts normal heart weight for 30 to 150kg males or females (66 to 331 lbs)
SECTION V – DISCUSSION

FRAMINGHAM CV RISK

Firefighters who succumbed to cardiovascular deaths have significantly different FRS risk scores than that expected from the general population in the 30 to 59 age groups, as presented in tables 1 to 4. This is not surprising considering the cases were derived from individuals who experienced a fatal cardiac event. More importantly is whether or not these firefighters could have been identified as high risk prior to their cardiac event. When comparing the individual data points used to calculate the risk scores, the firefighters have higher Systolic Blood pressures and lower HDLs than the NHANEs average. Both of these lead to higher calculated scores (lower is better with blood pressure and higher is better with HDL (the ‘good’ cholesterol). Total cholesterol is split with the 30-39 and 40-49 having higher total cholesterol, and the older age groups having lower total cholesterol.

These deceased firefighters also had an increased prevalence of diabetes (age groups 30-59) and use of Blood pressure medication (all ages). Smoking rates were split with 30-39 and 50-59 having lower prevalence and 40-49 and 60+ age groups having a higher prevalence.\(^{(26)}\)

The most striking finding is the increased use of blood pressure medication in firefighters over the age of 40. The national average of BP medication use is 27% among those with pre-hypertension or hypertension. National use of blood pressure medication by age group is 29.1% ages 40-59 and 46.4% aged 60+.\(^{(27)}\) The firefighters in this study had the following BP medication usage rates by age group: 11% age 30-39, 56% age 40-49, 67% age 50-59 and 82% age 60+. (see table 6)
Table 6: Average Rates of blood pressure medication use, Cases and National US avg.

<table>
<thead>
<tr>
<th>Age</th>
<th>Firefighter Fatality Cases</th>
<th>Average US usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-39</td>
<td>33%</td>
<td>-</td>
</tr>
<tr>
<td>40-49 and 50-59</td>
<td>62%</td>
<td>29.1%</td>
</tr>
<tr>
<td>60+</td>
<td>82%</td>
<td>46.4%</td>
</tr>
<tr>
<td>Overall</td>
<td>59%</td>
<td>27%</td>
</tr>
</tbody>
</table>

Average SBP for firefighters taking BP medication was 137 mm/Hg vs 133 mm/hg for those not on BP medication (not statistically significant difference with p > .05)

This use of blood pressure medication is the most consistent additional risk factor that the firefighters have with increasing age. In the two older age groups, the addition of these 2 raw points for medication raises the resulting risk score 3-4 percentage points.

While it was not unexpected that a group of individuals who died from SCD would have elevated risk for cardiac events, it is important that many of these cases were identifiable as high risk prior to their cardiac event.

As mentioned previously, the NFPA only recommends office blood pressure and electrocardiogram in annual physical screening exam. While office blood pressure is an important screening tool, its use as a sole screening method for cardiovascular (cv) disease risk is limited. Kales et al. proposed a ‘blood pressure management scheme for emergency
responder” in 2009. This proposal bases fitness determination, recommended interventions and medical follow up on office blood pressure measurements. The proposal does not address other risk factors that also contribute to cardiovascular risk, such as those found in the Framingham risk calculators. Additionally, while office blood pressure measurements are a staple of the medical community, many investigators have questioned the prognostic value of isolated measurements, versus repeated home and/or ambulatory blood pressure measurements.\(^\text{(29,30)}\)

In reviewing the 110 cases, the average systolic blood pressure reading was increased in comparison to controls but below 140mm/hg (except the 60+ age group). This would place them in the pre-hypertensive category and would not call for restriction of duties using Kale’s et al. scheme.\(^\text{(28)}\) When other cardiac risk factors are taken into account, as in the utilization of the FRS, identification of a larger number of those at increased risk is possible. Using the criteria developed by the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure, Seventh Report (JNC-7), only 11 of the 39 firefighters aged 40-49 in this study would have been identified as hypertensives (systolic 140 or greater). The 50-59 age group would have identified only 17 of 42 cases. Using the FRS scores and a 10% risk cutoff, an additional 12 firefighters aged 40-49 (23 of 49) and 22 firefighters aged 50-59 (39 of 42) would have been identified as having a high cardiovascular risk.

LEFT VENTRICULAR HYPERTROPHY

It is not unexpected that a group of individuals who perished due to SCD would have cardiac hypertrophy. The T-Test shows that the deceased firefighters from the age of 30 and
older, had statistically larger hearts than predicted by Kitzman et al., based on their own body weight. Left ventricular hypertrophy is a significant, independent predictor of cardiac mortality. Total heart weight at autopsy reflects left ventricular hypertrophy.\textsuperscript{(31)} Of the 145 cases available by autopsy, 17\% were described as fresh thrombus or having a cardiac vessel blockage, suggesting that a significant number of cases may be due to a fatal arrhythmia which is highly correlated with left ventricular hypertrophy and dysfunction.\textsuperscript{(12)} As mentioned previously, inexpensive diagnosis of LVH is difficult. Relying on ECG analysis is not sensitive enough as a screen for LVH and echocardiography is not as accessible and more cost prohibitive. For those individuals with an increased FRS risk score, screening echocardiography, however, may be beneficial and cost effective in identifying those individuals with LVH and therefore at higher risk for SCD.

LIMITATIONS

There are limitations to this study. While the data used was formally obtained during official NIOSH FFFIPP investigations, the data points were collected by a myriad of clinicians throughout the United States and can be expected to have variability secondary to the lack of a standardized data collection protocol.

Depending on the timing of the firefighters death to his last provider visit, a study member may have data within weeks of his death or the last data points may have been multiple years prior to SCD. The long lag between available clinical data and SCD occurred more commonly prior to 2005.
Another limitation is that while all of the firefighter cases succumbed to cardiovascular
death, the controls obtained from the published Kitzman data included non-cardiac fatalities.
This may have contributed to the difference in cardiac mass seen during analysis. Additionally,
while it is unknown whether there are significant changes to cardiac mass (edema) during a
cardiac event, it is assumed, at least in the cases of sudden cardiac death, no meaningful changes
in mass will occur. (see appendix D for pathologist discussion reference acute changes)

Demographically, this study population is not representative of minority populations. At
best, 13% of the samples were non-white, and females consisted of 2% of the sample.
Interestingly, career firefighters outnumbered volunteers 2 to 1, most likely due to increased time
engaged in fire service duties.
SECTION VI – CONCLUSION/RECOMMENDATION

CONCLUSION

Data, from this study demonstrates that many firefighters who succumbed to SCD had identifiable risk factors either in the form of an elevated FRS score and/or LVH.

As mentioned in the discussion, the firefighter groups blood pressures were higher than the national average, but not high enough to be considered hypertensive by JNC-7 standards. These individuals would not trigger further evaluation or restriction as recommended by either the NFPA or the proposed Kales scheme. Also mentioned in the discussion is the elevated use of BP medication firefighters, suggesting at least part of the reason for fewer hypertensives. The addition of BP medication as a risk factor, as is done in the FRS, allows more firefighters to be identified as at increased risk of a cardiac event and therefore restrictions and interventions can be recommended to help prevent or reduce this risk of cardiac death. This is also supported by the fact that SBP was statistically no different between those who did take blood pressure medicine and those who did not. The use of BP medication may in fact be hiding those at increased risk when only using BP measurement as a screening tool versus a risk algorithm such as FRS.

Utilization of a FRS type calculator would identify more firefighters at increased risk for SCD. Use of echocardiograms in those individuals with elevated FRS scores would further identify those at increased risk for SCD and provide opportunities for more aggressive medical intervention strategies.
RECOMMENDATION

What these results suggest is that a new algorithm or screening tool be implemented by the NFPA. An algorithm developed by this author and Dr Thomas Hales, MD, MPH, Senior Medical Epidemiologist, National Institute for Occupational Safety and Health, was presented at the Firefighter/public service update presentation during the 2010 American Occupational Health Conference. In addition to providing a risk calculator to the screening tools, it also provides a guide to occupational examiners and departments as to when to do further studies/referrals and when strenuous duty restrictions are warranted. This algorithm is similar to one developed at Robins Air Force Base, Georgia in 2006 in support of the USAF Cardiovascular Risk Assessment. While no test or tool will stop occurrences of sudden cardiac death, a multi-pronged approach that helps identify those at greatest risk will help those in greatest need of treatment and duty restrictions, and hopefully reduce the number one killer of firefighters. (Appendix E)

A follow-up cohort study of a broad spectrum of firefighters is recommended to confirm both the results and the utility of the recommendations for assessing firefighter CV risk.
Appendix A: REFERENCES


15. "Journal of Human Hypertension - Table 2 for Article: The Prognostic Value of the ECG in Hypertension: Where Are We Now?" Nature Publishing Group : Science Journals, Jobs, and
Information. Web. 01 Nov. 2011.
<http://www.nature.com/jhh/journal/v22/n7/fig_tab/jhh200824t2.html>.


   <http://www.baptisteast.com/Services/Specialty+Areas/Heart+services/Getting+your+life+back/Taking+care+after+a+heart+attack>


### Table 6: Proposed blood pressure management scheme for emergency responders

<table>
<thead>
<tr>
<th>Blood pressure</th>
<th>Fitness determination</th>
<th>Recommended intervention(s)</th>
<th>Occupational follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Unrestricted duty</td>
<td>- Population-based wellness programs</td>
<td>12-24 months based on overall CVD risk factor profile¹</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>Unrestricted duty</td>
<td>- Population-based wellness programs</td>
<td>6-12 months based on overall CVD risk factor profile¹</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>Time-limited clearance for duty</td>
<td>- Population-based wellness programs, Individual education⁸, Hypertension treatment and evaluation</td>
<td>Time-limited clearance 6-12 months based on overall CVD risk factor profile¹</td>
</tr>
<tr>
<td>Stage 2 hypertension</td>
<td>Restricted to modified duty (including physical exertion-related duties) and blood pressure reaches stage 1 or lower</td>
<td>- Population-based wellness programs, Individual education⁸, Clinical management of Hypertension</td>
<td>Time-limited clearance after adequate blood pressure control, Follow steps for stage 1, as above</td>
</tr>
</tbody>
</table>

Assumptions of conditions potentially affecting fitness for duty, programs, and remuneration decisions.

CVD: Cardiovascular disease.

¹ CVD risk factor profile includes total cholesterol level, HDL, LDL, smoking history, diabetes status, hypertension status, and other risk factors.

⁸ Individual education includes lifestyle interventions, diet, and exercise programs.
Appendix C: C-STATISTIC

The Concordance or "C" statistic is a more robust method (less sensitive to the data distribution) to characterize the accuracy of the predictive model (in this case, using Framingham model to predict CAD risk). The C statistic is a measure of concordance with 0.5 providing no information and 1.0 providing perfect correlation.

Appendix D: DISCUSSION OF CARDIAC CHANGES

The following is an email response to the question: “If one suffers from cardiac death, does the heart increase suddenly in weight because of consequences of sudden cardiac event?”

Dr Grinkmeyer was formerly the deputy of the Armed Forces Institute of Pathology and a staff Medical Examiner. He currently Works for the USAF School of Aerospace Medicine.

Dr Huddleston is a staff pathologist at the Wright-Patterson AFB, Wright-Patterson Medical Center.

-----Original Message-----
From: Grinkemeyer, Michael D Col USAF AFMC USAFSAM/FH
Sent: Friday, July 20, 2012 10:13 AM
To: Louis, David J CTR USAF AFMC USAFSAM/FEEE; Woltz, John W LtCol USAF AFMC 88 AMDS/SGPO
Cc: Huddleston, Brent J Maj USAF AFMC 88 DTS/SGQC
Subject: RE: Question for pathologist

I'll let Dr Huddleston add his thoughts to this but here are my own thoughts:

Obviously the heart arrests (stops) in anyone who dies. When we do autopsies we routinely weigh the heart and there are charts of what is considered a normal weight at autopsy. When the heart is above or below those weights then we consider various conditions but we also look at ventricular wall thickness, etc.

I suspect that if someone has a rapid cardiac death then there is likely little change in heart weight but if there is cardiac injury followed by delayed death then the myocytes have time to develop edema, hypertrophy, etc. that would change heart weight.

I don't know if there is a method to obtain a heart weight prior to autopsy (?radiographic) but at autopsy we can always look at microscopic sections of heart muscle to see if there are any microscopic changes that might cause the heart to weigh more.

I think that in cases of sudden fatal arrhythmia we often don't see anything wrong with the heart at autopsy (ie weight or microscopic changes)

I hope that helps

Col Michael Grinkemeyer, USAF, MC
Molecular Genetic Pathologist, Rm W308H Chairman, Department of Aeromedical Research (FH) United States Air Force School of Aerospace Medicine (USAFSAM/FH) Wright Patterson AFB

I entirely agree with Dr. Grinkemeyer's comments. Chronic heart disease will likely increase the weight of the heart. An acute event would likely not. In sudden fatal arrhythmias we would not likely see any microscopic changes either.

Brent J. Huddleston, M.D., Maj, USAF, MC Laboratory Medical Director/Staff Pathologist
88 DTS/SGQC, Department of Pathology
4881 Sugar Maple Dr.
Wright-Patterson AFB, OH 45433
## Potential Options for NFPA 1582

<table>
<thead>
<tr>
<th>JNC-7</th>
<th>SBP/DBP</th>
<th>Current</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;120/80</td>
<td>Annual BP</td>
<td>Annual BP FRS (Framingham Risk Score)</td>
</tr>
<tr>
<td>Pre-HTN</td>
<td>120-139/80-89</td>
<td>Annual BP</td>
<td>BP q 6-12 m FRS Education (Lifestyle Mod)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>≥ 140/90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage I</td>
<td>140-159/90-99</td>
<td>Annual BP</td>
<td>Eval q 3 m until no HTN If FRS &gt;10% - restrict LVH screen based on BP severity and duration. If LVH + --- restrict Education and Rx</td>
</tr>
<tr>
<td>Stage II</td>
<td>&gt;160/100</td>
<td>Annual BP Restrict if &gt;180/100</td>
<td>Same as above</td>
</tr>
</tbody>
</table>