Cardiovascular Disease in the US Fire Service:

Past, Present and Future

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Photo: 1911, Library of Congress
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Grant Support / Disclosures

Funding: Grant No. EMW-2006-FP-01493 (PI: Kales, SN)
Grant No. EMW-2009-FP-00835 (PI: Kales, SN)
U.S. Department of Homeland Security

Consultant: Novartis Pharmaceuticals (2009-2010)

Paid expert witness, various entities, medico-legal reports
1860’s: Fireman’s Fund

San Francisco was a “Goldrush Town” whose economic growth was limited by frequent fires in its wooden buildings.

Volunteer firefighters worked without remuneration despite their risks.

Insurance companies wary of offering coverage to San Francisco-based businesses.


Kales et al
1860’s: Fireman’s Fund

In 1863 a ship's captain, William Holdredge, created Fireman's Fund Insurance Company to insure San Franciscans. Success would depend on the ability to protect property from fires.

To motivate firefighters, Holdredge established a retirement fund for the firemen, financed by 10% of his company's profits.


Kales et al
PAST: 1903 William Osler, MD

Angina Pectoris

- Assoc. w/ Arteriosclerosis

- Predominantly Men

- Many DieSuddenly w/o Warning

Photo: 1911, Library of Congress

Kales et al

Principles and Practice of Medicine, by Sir William Osler.
Angina Pectoris

- Tobacco abuse
  - Coronary Spasm
  - Arteriosclerosis

-Precipitants:
  - Exertion
  - Strong Emotions/ Anger
  - Influenza

Principles and Practice of Medicine, by Sir William Osler.

Kales et al
Early Advances in CVD

1915
Mt. Sinai sets up its electrocardiographic (EKG) laboratory under Dr. Bernard Oppenheimer.

1929
Dr. Arthur Master of Mt. Sinai develops "Master Two-Step,“ first standardized cardiac stress test.

http://www.mountsinai.org/patient-care/service-areas/heart/mount-sinai-heart-today/mount-sinai-firsts
Firefighters & Increased Mortality


Kales et al
1934: First Heart & Lung Law

The IAFF assisted locals in Pennsylvania.

Passed the first Heart and Lung Act, Worker's Compensation Act, and the Occupational Disease Law.

http://iaff2498.org/visitors/history-of-iaff.html

Kales et al
“Sufficient evidence…in recent years (for) wider acceptance of firefighting as an occupational factor in the production or aggravation of certain heart diseases…”

Etiologic factors: heat/cold, exertion, stresses, “smokes and gases…to which firemen are repeatedly subjected…”

Dis Chest 1953;24;304-309 (http://chestjournal.chestpubs.org/content/24/3/304)
Recognized:

HTN & Arteriosclerosis as Synergistic

Acceleration of “normal” Atheromatous changes leads to premature CAD

Plaque rupture and MI can follow exertion

Dis Chest 1953;24;304-309 (http://chestjournal.chestpubs.org/content/24/3/304)
1953:

Firefighting and Heart Disease

NATHANIEL E. REICH, M.D., F.C.C.P.*
Brooklyn, New York

Firefighting causes marked change in CV hemodynamics

“Obvious that...underlying heart disease can be markedly affected by this change...”

Dis Chest 1953;24;304-309 (http://chestjournal.chestpubs.org/content/24/3/304)
1957-58: John P. Redmond

Joined Chicago FD in 1912

President of IAFF 1946-1957

Sudden death December 1957, "occupational heart disease"

http://iaff2498.org/visitors/history-of-iaff.html
1957-58: John P. Redmond

John P. Redmond Foundation established 1958

Focused on health & safety of firefighters.

Research used to lobby for statutes & benefits to firefighters with heart and lung disease.

http://iaff2498.org/visitors/history-of-iaff.html
By 1960’s, “Heart Presumption” laws established in most US states. Most of the laws date back to before 1965.

(Melius J. 1995)
1960’s: Modern EMS Begins

http://www.iaff4173.com/History/index.html

Kales et al
1970’s: Barnard & the LA FD

Stress testing and CAD RF’s in the LA FD vs. Insurance Executives (JOM 1975).

FF Less HTN >160/90 (2% vs 25%) &
Chol >260 (12% vs. 18%)

FF more smoking (32% vs 26%)

FF 10% Ischemic ETT vs. 8% of Executives

Kales et al
1970’s: Barnard & the LA FD

Heart rate and ECG Responses of Fire Fighters (JOM 1975).

35 FF responding to 189 alarms

HR increases: mean 30 bpm above bsln in 1st minute (max 80 bpm)

During fires high heart rates for extended periods.

One FF, 188 bpm for 15 minutes at a structure fire

Kales et al
Mortality among Boston firefighters, 1915–1975*


From the Departments of Physiology and Epidemiology, Harvard School of Public Health,
665 Huntington Avenue, Boston, MA 02115, USA

ABSTRACT  Although the nature of firefighting involves particular health hazards, previous mortality and morbidity studies of firemen have produced inconsistent evidence for an increased risk of mortality from cardiovascular disease, respiratory disease, cancer and accidents. Mortality experience since 1915 has been examined in 5655 Boston firefighters, comprising all male members of the city fire department with three or more years of service. The observed cause of death as stated on the death certificates of 2470 deceased firefighters has been compared with the numbers expected based on rates for the male population of Massachusetts and of the United States of America. Among all firefighters, deaths from all causes were 91% of expected. The standardised mortality ratio (SMR) was markedly reduced (less than 50) for infectious disease, diabetes, rheumatic heart disease, chronic nephritis, blood diseases and suicide. The SMR was 86 for cardiovascular deaths, 83 for neoplastic deaths, and 93 for respiratory deaths. The SMR for accidents was 135 for active firefighters. The results suggest that the survival experience of firefighters is strongly influenced by strict entry selection procedures, ethnic derivation, and sociocultural attributes of membership. While excessive morbidity has been demonstrated in firefighters, there does not appear to be a strong association between occupation and cause-specific mortality.
Late 1970-1980’s: CVD ~45% all Deaths

Source: NFPA.org
# Heart Deaths by Occupation

<table>
<thead>
<tr>
<th>Occupation</th>
<th>% of On-Duty Deaths caused by CVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firefighters</td>
<td>45%</td>
</tr>
<tr>
<td>Police</td>
<td>22%</td>
</tr>
<tr>
<td>Overall*</td>
<td>15%</td>
</tr>
<tr>
<td>Construction</td>
<td>11.5%</td>
</tr>
<tr>
<td>EMS</td>
<td>11%</td>
</tr>
</tbody>
</table>

*Average % of all Occupational Fatalities, all industries

Kales et al
Prospective study: rate of MI’s lower than in NHANES population of similar age

1.35 vs 2.07 MI’s/ 1000 P-Years (NS)

CHD and MI incidence were largely explained by well-known CVD Risk Factors

Age, smoking, BP, BMI, Lipids

Kales et al
Present
Cohort Studies vs. Presumption Laws

- Definitive evidence of an increased CHD risk in Firefighters lacking.
- Based on $\geq10$ cohort mortality studies, Firefighters’ risk of CHD death, SMR of $\sim0.9$

- High proportion of CHD deaths and recognition of cardiovascular stressors has led to “Heart Presumption” laws in 37 / 50 states and 2 Canadian Provinces

Kales et al
Scope of the Problem

- 1977-2006: CVD ~45% on-Duty Deaths
  (~ 45 / year)

- ~17 Non-fatal CV events for each Fatal Event

- Morbid & Mortal CVD events 800-1000/yr

- Affects 1 in 1000-2000 per year

(If Off-duty included, Many More Affected...)

Kales et al
On-Duty Events, Work-Related or Just happen at Work???

- Smoke & chemical exposure
- Irregular physical exertion
- Handling of heavy equipment
- Heat stress
- Noise
- Psychological stressors
- High prevalence of CV risk factors
- Shift work

Kales et al
Emergencies & Cardiovascular Risk

Long Stretches of relative inactivity

Brief periods of intense, unpredictable, life-threatening action

→ Adrenergic surges and high demands on CV system
**Methods:** Case-control study, 52 male firefighters CHD deaths investigated by NIOSH.

Control population: 51 male firefighters on-duty trauma deaths
Figure One. Circadian Pattern of CHD Deaths in Firefighters versus Emergency Calls and Compared to General Population. From Kales et al, ref.14
CHD Deaths vs. Time Spent in Each Activity

Job Activity:
- Fire suppression
- Alarm response
- EMS or other emergen
- Training
- Returning from alarm
- Fire house

Percent:
- % of CHD Deaths
- Average % of Time Spent per Year

Kales et al
Emergency Duties and Deaths from Heart Disease among Firefighters in the United States

Stefanos N. Kales, M.D., M.P.H., Elpidoforos S. Soteriades, M.D., Sc.D., Costas A. Christophi, Ph.D., and David C. Christiani, M.D., M.P.H.
Table 4. Risk of Death from Coronary Heart Disease among Firefighters Engaged in Emergency Duties and Physical Training as Compared with Firefighters Engaged in Nonemergency Duties.

<table>
<thead>
<tr>
<th>Duty</th>
<th>Municipal Fire Department</th>
<th>Large Metropolitan Fire Departments</th>
<th>National Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds Ratio (95% CI)</td>
<td>P Value</td>
<td>Odds Ratio (95% CI)</td>
</tr>
<tr>
<td>Fire suppression</td>
<td>53 (40–72)</td>
<td>&lt;0.001</td>
<td>12.1 (9.0–16.4)</td>
</tr>
<tr>
<td>Alarm response</td>
<td>7.4 (5.1–11)</td>
<td>&lt;0.001</td>
<td>2.8 (1.9–4.0)</td>
</tr>
<tr>
<td>Alarm return</td>
<td>5.8 (4.1–8.1)</td>
<td>&lt;0.001</td>
<td>2.2 (1.6–3.1)</td>
</tr>
<tr>
<td>Emergency medical services and other nonfire emergencies</td>
<td>1.3 (0.9–2.0)</td>
<td>0.16</td>
<td>0.5 (0.3–0.8)</td>
</tr>
<tr>
<td>Physical training</td>
<td>5.2 (3.6–7.5)</td>
<td>&lt;0.001</td>
<td>2.9 (2.0–4.2)</td>
</tr>
<tr>
<td>Nonemergency duties (fire station and other)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Type of Duty</td>
<td>Kales et al 2003 (relative risk of CHD death)</td>
<td>Holder et al 2006 (relative risk of heart event leading to retirement)</td>
<td>Kales et al 2007 (relative risk of CHD death)</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>----------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Fire suppression – OR** (95% CI£)</td>
<td>64.1 (7.4-556)</td>
<td>51 (12-223)</td>
<td>53 (40-72)</td>
</tr>
<tr>
<td>Physical training – OR** (95% CI£)</td>
<td>7.6 (1.8-31.3)</td>
<td>0.68 (0.2-2.7)</td>
<td>5.2 (3.6-7.5)</td>
</tr>
<tr>
<td>Alarm response – OR** (95% CI)</td>
<td>5.6 (1.1-28.8)</td>
<td>6.4 (2.5-17)</td>
<td>7.4 (5.1-11)</td>
</tr>
<tr>
<td>Alarm return – OR (95% CI£)</td>
<td>3.4 (0.8-14.7)</td>
<td>0.37 (0.07-1.8)</td>
<td>5.8 (4.1-8.1)</td>
</tr>
<tr>
<td>EMS and other non-fire emergencies – OR** (95% CI£)</td>
<td>1.7 (0.5-5.9)</td>
<td>0.75 (0.3-1.8)</td>
<td>1.3 (0.9-2.0)</td>
</tr>
<tr>
<td>Firehouse and other non-emergency activities – OR** (95% CI£)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Kales et al
Figure 1. Daily Cardiovascular Events in the Study Population from May 1 to July 31 in 2003, 2005, and 2006.

The FIFA World Cup 2006 in Germany started on June 9, 2006, and ended on July 9, 2006. The 2006 World Cup matches with German participation are indicated by numbers 1 through 7: match 1, Germany versus Costa Rica; match 2, Germany versus Poland; match 3, Germany versus Ecuador; match 4, Germany versus Sweden; match 5, Germany versus Argentina; match 6, Germany versus Italy; and match 7, Germany versus Portugal (for third-place standing). Match 8 was the final match, Italy versus France.
SEASONALITY AND CORONARY HEART DISEASE DEATHS IN UNITED STATES FIREFIGHTERS

Ibeawuchi Mbanu,1 Gregory A. Wellenius,2 Murray A. Mittleman,1–3 Lynne Peeples,4 Leonard A. Stallings,5 and Stefanos N. Kales1,5

2007; Vol. 24
Deaths due to Myocardical Infarction and Acute Respiratory Morbidity

Madjid, M et al. European Heart Journal 2007
Reviewed all completed fatality reports on NIOSH website from 1996- December 2002.

52 male firefighters who died of CHD

310 firefighters examined in 1996 and documented as professionally active in firefighting in 1998
Firefighter Heart Presumption Retirements in Massachusetts 1997–2004

Jonathan D. Holder, DO, MPH
Leonard A. Stallings
Lynne Peeples, MS
John W. Burress, MD, MPH
Stefanos N. Kales, MD, MPH

362 Heart presumption retirements

278 CHD retirements (77%) 84 Non-CHD retirements

HTN 30 (36%)
AFIB, Flutter or SVT 19 (23%)
Cardiomyopathy 11 (13%)
CVA 11 (13%)
Syncope 5 (6%)
Aortic Aneurysm 4 (5%)
Other 4 (5%)
Predictors of On-Duty Coronary Events in U.S. Male Firefighters

JR Geibe, J Holder, L Peeples, AM Kinney, JW Burress, SN Kales


Case-Fatality Study

87 Acute On-Duty CHD Fatalities

compared with

113 Non-Fatal, On-Duty CHD Events
## Hypertension & CV DZ Outcomes

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Hypertension Criteria</th>
<th>Adjusted OR (95% CI)</th>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incident CHD</strong></td>
<td>SBP &gt; 140</td>
<td>6.1 (2.6-14.2)</td>
<td>Prospective Cohort (Glueck et al)</td>
</tr>
<tr>
<td></td>
<td>DBP &gt; 90</td>
<td>4.9 (2.1-11.4)</td>
<td></td>
</tr>
<tr>
<td><strong>CHD Retirement</strong></td>
<td>&gt;/=140/90, Dx of HTN, or Anti-HTN Medication</td>
<td>1.2 (0.6–2.4)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td><strong>Non-CHD CVD Retirement</strong></td>
<td></td>
<td>4.8 (1.3-17.9)</td>
<td></td>
</tr>
</tbody>
</table>

Kales et al
## Hypertension & CV DZ Outcomes

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Hypertension Criteria</th>
<th>Adjusted OR (95% CI)</th>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Duty CHD Death</td>
<td>$\geq 140/90$, Diagnosis of Hypertension, or Anti-Hypertensive Medication</td>
<td>4.7 (2.0-11.1)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td>Case-Fatality for On-Duty CHD Events</td>
<td></td>
<td>4.2 (1.8-9.4)</td>
<td>Cross-Sect. Case-Fatality</td>
</tr>
</tbody>
</table>

Kales et al
Left Ventricular Hypertrophy

- Independent risk factor for CVD.
- Increased Risk of Ventricular Arrhythmia
- Independent Predictor of Death
- 57% of On-Duty CHD FF Fatalities had LVH at Autopsy!!

Kales et al
## Table 4: Baseline blood pressures for firefighters and police with and without later incident cardiovascular events

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Event (mm Hg)</th>
<th>No event (mm Hg)</th>
<th>$P$ value</th>
<th>Study design/population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident CHD$^{62}$</td>
<td>140 Mean SBP</td>
<td>125 Mean SBP</td>
<td>&lt;0.0001$^a$</td>
<td>Prospective cohort/firefighters</td>
</tr>
<tr>
<td></td>
<td>92 Mean DBP</td>
<td>82 Mean DBP</td>
<td>&lt;0.0001$^a$</td>
<td></td>
</tr>
<tr>
<td>Incident CHD$^{79}$</td>
<td>141 Mean SBP</td>
<td>134 Mean SBP</td>
<td>&lt;0.01$^\dagger$</td>
<td>Prospective cohort/police</td>
</tr>
<tr>
<td></td>
<td>88 Mean DBP</td>
<td>84 Mean DBP</td>
<td>&lt;0.001$^\dagger$</td>
<td></td>
</tr>
<tr>
<td>Incident stroke$^{79}$</td>
<td>146 Mean SBP</td>
<td>134 Mean SBP</td>
<td>&lt;0.01$^\dagger$</td>
<td>Prospective cohort/police</td>
</tr>
<tr>
<td></td>
<td>91 Mean DBP</td>
<td>84 Mean DBP</td>
<td>&lt;0.01$^\dagger$</td>
<td></td>
</tr>
</tbody>
</table>

CHD, coronary heart disease; DBP, diastolic blood pressure; SBP, systolic blood pressure.

$^a$Adjusted for age, race and BMI. $^\dagger$Adjusted for age.

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Kales et al

**AMERICAN JOURNAL OF HYPERTENSION**
<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Smoking Criteria</th>
<th>Unadjusted Odds Ratio or Hazard Ratio (95% CI)</th>
<th>Multivariable-Adjusted Odds Ratio or Hazard Ratio (95% CI)</th>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident CHD</td>
<td></td>
<td>5.7 (2.4 – 13.1)</td>
<td><strong>P=0.001</strong></td>
<td>Prospective Cohort</td>
</tr>
<tr>
<td>CHD Retirement</td>
<td></td>
<td>3.9 (2.5 - 6.2)</td>
<td>2.9 (1.3 – 6.3)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td>Non-CHD Cardiovascular</td>
<td>Current Smoking (Last 12 months)</td>
<td>2.5 (1.2 – 5.1)</td>
<td>2.9 (0.6 – 13.6)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td>Cardiovascular Retirement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Duty CHD Death</td>
<td></td>
<td>8.6 (4.2-17.4)</td>
<td>7.0 (2.8-17.4)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td>Case-Fatality for On-Duty</td>
<td></td>
<td>2.1 (1.2-3.9)</td>
<td>3.7 (1.6-8.4)</td>
<td>Retrospective Case-Fatality</td>
</tr>
<tr>
<td>CHD Events</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Kales et al
## Previously Diagnosed CHD & CV DZ Outcomes

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>CHD Definition</th>
<th>Unadjusted Odds Ratio or Hazard Ratio (95% CI)</th>
<th>Multivariable-Adjusted Odds Ratio or Hazard Ratio (95% CI)</th>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHD Retirement</td>
<td>Prior MI, Angioplasty/ Stent, CABG, +ETT or CATH, CVA or Carotid Dz, PAD</td>
<td>29.6 (9.1 – 96)</td>
<td>8.8 (1.9 – 41.3)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td>On-Duty CHD Death</td>
<td>35.0 (9.5 -128)</td>
<td>15.6 (3.5-69)</td>
<td>Retrospective Case-Control</td>
<td></td>
</tr>
<tr>
<td>Case-Fatality for On-Duty CHD Events</td>
<td>2.1 (1.1-4.1)</td>
<td>4.1 (1.6, 10.6)</td>
<td>Retrospective Case-Fatality</td>
<td></td>
</tr>
</tbody>
</table>

Kales et al
Cases with Prior CHD

Median Time: initial diagnosis to final event for fatalities & survivors: 40 vs 43 months

Fatalities: 74% evidence of myocardial damage 35% of survivors (p 0.007).

Often secondary CHD events between initial and final events.

Kales et al
### Lipids and Incident CHD (Glueck et al)

<table>
<thead>
<tr>
<th>Lipid</th>
<th>22 Men Developing CHD</th>
<th>784 Men Free of CHD</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC</td>
<td>227 +/- 40</td>
<td>198 +/- 39</td>
<td>0.014</td>
</tr>
<tr>
<td>HDL</td>
<td>46 +/- 14</td>
<td>48 +/- 11</td>
<td>NS</td>
</tr>
<tr>
<td>LDL</td>
<td>148 +/- 38</td>
<td>127 +/- 35</td>
<td>0.04</td>
</tr>
<tr>
<td>TG</td>
<td>203 +/- 162</td>
<td>124 +/- 130</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Kales et al
<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Obesity Criteria</th>
<th>OR (95% CI)</th>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident CHD</td>
<td>BMI No CHD</td>
<td>P = 0.08</td>
<td>Prospective Cohort (Glueck et al)</td>
</tr>
<tr>
<td></td>
<td>BMI CHD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHD Retirement</td>
<td>BMI &gt;/= 30</td>
<td>1.4 (1.0 – 1.9)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td>Non-CHD CVD Retirement</td>
<td>BMI &gt;/= 30</td>
<td>3.6 (2.0 – 6.4)</td>
<td>Retrospective Case-Control</td>
</tr>
</tbody>
</table>

Kales et al
### Obesity and CV DZ Events

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Obesity Criteria</th>
<th>OR (95% CI)</th>
<th>Study Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-Duty CHD Death</strong></td>
<td>BMI &gt;/= 30</td>
<td>3.1 (1.5- 6.6)</td>
<td>Retrospective Case-Control</td>
</tr>
<tr>
<td><strong>Case-Fatality for On-Duty CHD Events</strong></td>
<td>BMI &gt;/= 30</td>
<td>2.3 (1.0-5.4)</td>
<td>Retrospective Case-Control</td>
</tr>
</tbody>
</table>
Historical BMI changes in U.S. firefighters: 1981-2005
CHD Death Risk by Age and Duty

Kales et al
### Table 3. Relative risk of Cardiovascular Outcome by risk factor

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>On-Duty CHD Fatalities</th>
<th>Non-CHD Cardiovascular Retirements OR (95% CI)</th>
<th>CHD Retirements OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ≥ 45 years old</td>
<td>18 (8.5- 40)</td>
<td>26 (13 – 51)</td>
<td>63 (35 – 111)</td>
</tr>
<tr>
<td>Current Smoking</td>
<td>8.6 (4.2-17)</td>
<td>2.5 (1.2 – 5.1)</td>
<td>3.9 (2.5 - 6.2)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>12 (5.8 – 25)</td>
<td>11 (6.1 – 20)</td>
<td>5.4 (3.7 - 7.9)</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>10.2 (3.7 – 28)</td>
<td>7.7 (2.9 – 20)</td>
<td>13 (6.1 - 28)</td>
</tr>
<tr>
<td>Cholesterol $\geq 5.18$ mmol/L (200 mg/dl)</td>
<td>4.4 (1.5 – 13)</td>
<td>1.1 (0.51 – 2.24)</td>
<td>2.4 (1.6 – 3.6)</td>
</tr>
<tr>
<td>Prior Diagnosis of CHD</td>
<td>35 (9.5 -128)</td>
<td>NA</td>
<td>30 (9.1 – 96)</td>
</tr>
<tr>
<td>Obesity, BMI $\geq$30</td>
<td>3.1 (1.5- 6.6)</td>
<td>3.6 (2.0 – 6.4)</td>
<td>1.4 (0.96 – 1.93)</td>
</tr>
</tbody>
</table>
Kales et al

Genetics
Baseline habits
Initial Body Composition

Regular Exercise
Physical Activity
Healthy Diet
Adequate Sleep
Moderate EtOH

Tobacco
Sedentary Behavior
Poor Diet
Smoke (gases & particulates)
Noise
Stress
Shift work / Sleep Deprivation

Hypertension
Dyslipidemia
Diabetes
Obesity

Known CHD or Equivalent
Subclinical Disease +/- LVH

Death Disease Disability

Acute CVD Events

Progression of Atherosclerosis

Triggers / Strenuous Duties
Type of Firefighter Fatalities by Year
1977 - 2004

- All other deaths
- Sudden cardiac deaths

*Excluding the 340 firefighter deaths at the World Trade Center

Source: NFPA.org
On-Duty Firefighter Deaths - 1977-2009

Year
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09

Number of Deaths

* excluding the 340 firefighter deaths at the World Trade Center

Source: NFPA.org
Physical Fitness, Activity and CHD Risk.
(Williams, 2001)

Persons in the
>=75%ile of Fitness

>=60% Lower Risk

Physical demand

- Wearing 60lb PPE
- Carrying 40lb tools
- Climbing ladders
- Advancing water-filled hose lines
- Dragging victims

Maximal Oxygen Consumption

44 ml/kg/min
OR
12.5 METS

NFPA sets the minimum fit capacity at 12 METS

Thomas Hales MD MPH at NECOEM/OEMAC conference "How to reduce CV Mortality in your Fire Department", Fall 2008
ETT/CRF and Outcomes
Study Populations

Prospective – White
Goal N ≥1200
Consented: 1072
Data Entry: >1000
Prelim Anal: >900

Retrospective – Orange
N ~ 4500
Completed bsln ETT
1998-2005

Kales et al
## Physical Activity Components

### FREQUENCY
Most weeks, I exercise... (include home/work/gym & elsewhere).

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day or less</td>
<td>94</td>
<td>17.6%</td>
</tr>
<tr>
<td>2 - 4 days</td>
<td>321</td>
<td>60.1%</td>
</tr>
<tr>
<td>5 or more days</td>
<td>119</td>
<td>22.3%</td>
</tr>
</tbody>
</table>

### DURATION
Most times that I do cardio or aerobic exercise (e.g., jogging, brisk walking, bike, treadmill, etc.), I do an average of... each session.

<table>
<thead>
<tr>
<th>Duration</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15 min</td>
<td>72</td>
<td>13.5%</td>
</tr>
<tr>
<td>15 – 30 min</td>
<td>228</td>
<td>42.8%</td>
</tr>
<tr>
<td>30 – 45 min</td>
<td>158</td>
<td>29.6%</td>
</tr>
<tr>
<td>&gt; 45 min</td>
<td>75</td>
<td>14.1%</td>
</tr>
</tbody>
</table>

### INTENSITY
Most times that I exercise, I sweat... on average each session.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't exercise too often</td>
<td>21</td>
<td>3.9%</td>
</tr>
<tr>
<td>Light sweat</td>
<td>95</td>
<td>17.9%</td>
</tr>
<tr>
<td>Moderate sweat</td>
<td>300</td>
<td>56.4%</td>
</tr>
<tr>
<td>Heavy sweat</td>
<td>21.6</td>
<td>21.8%</td>
</tr>
</tbody>
</table>
Exercise Tolerance Test Time as a $f(x)$ of PA & BMI

**Frequency**

- **Source**: Weekly Exercise
  - **Sig.**: <0.001
- **BMI**: <0.001
- **Age**: <0.001

**Duration**

- **Source**: Session duration
  - **Sig.**: <0.001
- **BMI**: <0.001
- **Age**: <0.001

**Intensity**

- **Source**: Sweat
  - **Sig.**: 0.001
- **BMI**: <0.001
- **Age**: <0.001
TC/HDL Ratio as a f(x) of PA & BMI

**Frequency**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly Exercise</td>
<td>0.006</td>
</tr>
<tr>
<td>BMI</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**Duration**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session duration</td>
<td>0.11</td>
</tr>
<tr>
<td>BMI</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>0.24</td>
</tr>
</tbody>
</table>

**Intensity**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweat</td>
<td>0.12</td>
</tr>
<tr>
<td>BMI</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Decline of CRF with Age-Protection by PA

Mean Total exercise tolerance test time (sec.)

Weekly Exercise Frequency
- 1 or Less
- 2-4
- 5 or More

Age Category

12 METS
Decline of Cardio-Respiratory Fitness as a Function of Age and BMI

Kales et al

12 METS
NFPA Minimum
10 METS
CRF and CV Events / Mortality

2009 Meta-Analysis of 33 Studies

>100,000 gen. population middle-aged subjects

Each 1 additional MET conveyed
- 13% decrease in all-cause mortality
- 15% decrease in CV events

Kodama et al
The future of aerobic exercise testing in clinical practice: is it the ultimate vital sign?

Ross Arena†, Jonathan Myers¹ & Marco Guazzi²
VA Palo Alto Health Care System, Cardiology Division, Palo Alto, CA, USA
University of Milano, San Paolo Hospital, Cardiology Division, Milano, Italy
Author for correspondence: Departments of Physical Therapy, Internal Medicine & Physiology, Virginia Commonwealth University, Richmond, VA, USA † Tel.: +1 804 628 3633 † Fax: +1 804 828 811
Risk Stratification by CRF

Very Low Fitness $\leq$ 10 METS  Highest Risk

Low Fitness $>$ 10-12 Mets  Higher Risk

Medium Fitness $>$ 12-14 METS  Intermediate Risk

High Fitness $>$ 14 METS  Low Risk

Kales et al
<table>
<thead>
<tr>
<th></th>
<th>METS &gt;14</th>
<th>METS &gt;12-14</th>
<th>METS &gt;10-12</th>
<th>METS &lt;=10</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>96</td>
<td>327</td>
<td>414</td>
<td>130</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>34.6 (8.0)</td>
<td>36.7 (8.1)</td>
<td>40.2 (7.4)</td>
<td>47.6 (7.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI</td>
<td>26.0 (2.4)</td>
<td>28.1 (3.3)</td>
<td>30.0 (4.0)</td>
<td>32.8 (5.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>% Fat</td>
<td>16.4 (4.2)</td>
<td>20.4 (5.5)</td>
<td>20.6 (5.5)</td>
<td>24.7 (4.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SBP</td>
<td>121 (12)</td>
<td>121 (12)</td>
<td>123 (12)</td>
<td>127 (13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tot Chol</td>
<td>183 (33)</td>
<td>191 (33)</td>
<td>196 (39)</td>
<td>190 (45)</td>
<td>0.019</td>
</tr>
<tr>
<td>Tot Chol / HDL</td>
<td>3.6 (1.5)</td>
<td>4.3 (1.2)</td>
<td>5.1 (1.6)</td>
<td>5.2 (1.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LDL</td>
<td>111 (33)</td>
<td>119 (29)</td>
<td>126 (33)</td>
<td>125 (37)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HDL</td>
<td>54 (12)</td>
<td>47 (11)</td>
<td>41 (11)</td>
<td>38 (9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TGL</td>
<td>90 (51)</td>
<td>130 (96)</td>
<td>151 (146)</td>
<td>159 (119)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Blood Glucose</td>
<td>89 (13)</td>
<td>92 (14)</td>
<td>95 (12)</td>
<td>102 (22)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>hs-CRP</td>
<td>1.1 (2.0)</td>
<td>2.1 (4.8)</td>
<td>3.5 (2.8)</td>
<td>Insuff data</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>METS &gt;14</td>
<td>METS &gt;12-14</td>
<td>METS &gt;10-12</td>
<td>METS &lt;=10</td>
<td>p-value</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------</td>
<td>-------------</td>
<td>-------------</td>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>N</td>
<td>96</td>
<td>327</td>
<td>414</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Total Treadmill Time</td>
<td>804 (72)</td>
<td>672 (54)</td>
<td>584 (50)</td>
<td>512 (61)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart Rate Recovery</td>
<td>15.0 (0.8)</td>
<td>13.4 (0.4)</td>
<td>11.1 (0.6)</td>
<td>9.0 (1.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Autonomic Index</td>
<td>2.0 (0.9)</td>
<td>2.6 (2.3)</td>
<td>2.8 (1.4)</td>
<td>3.4 (3.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chronotropic Insufficiency</td>
<td>5.2 %</td>
<td>5.2 %</td>
<td>16.4 %</td>
<td>24.6%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Exaggerated BP</td>
<td>17%</td>
<td>23%</td>
<td>19%</td>
<td>32%</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**Notes:**
- METS: Metabolic Equivalent of Task
- N: Number of participants
- Total Treadmill Time: Total time spent on the treadmill (seconds)
- Max METS: Maximum METS achieved
- Heart Rate Recovery: Heart rate recovery at 1 min
- Autonomic Index: Ratio of resting HR to HRR at 1 min (Lower is better)
- Chronotropic Insufficiency: Peak HR less than or equal to 90%
- Exaggerated BP: Peak blood pressure greater than or equal to 220/90
## Low CRF Predicts Abnormal Exercise Testing in Firefighters

<table>
<thead>
<tr>
<th></th>
<th>METS &gt;14</th>
<th>METS &gt;12-14</th>
<th>METS &gt;10-12</th>
<th>METS &lt;=10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>96</td>
<td>327</td>
<td>414</td>
<td>130</td>
</tr>
<tr>
<td>Stress EKG Abnormality</td>
<td>1.0</td>
<td>1.8 (0.2-15)</td>
<td>7.9 (1.1-58)</td>
<td>20 (2.7-152)</td>
</tr>
<tr>
<td>Abnormal HRR &lt;=12 BPM @ 1 min</td>
<td>1.0</td>
<td>3.3 (0.4-26)</td>
<td>4.0 (0.5-31)</td>
<td>8.8 (1.1-69)</td>
</tr>
<tr>
<td>ETT Abnl any Criteria</td>
<td>1.0</td>
<td>1.4 (0.5-4.2)</td>
<td>3.2 (1.1-9.1)</td>
<td>8.4 (2.9-24)</td>
</tr>
</tbody>
</table>

Kales et al
Characteristics of Low CRF
METS $\leq 12$

- 56% of Cohort
- 37% < 40 years
- 61% < 45 years
- 64% Exercised
- $\leq 3x/WK$
- 75% of Obese FF’s
- 47% of Overweight FF’s
## Prevalence of Trigger-Preventing Behaviors

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Recommendation</th>
<th>Compliant Firefighters (%)</th>
<th>Intervention Gap (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspirin</td>
<td>Daily male over 45 years</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>Physical exercise</td>
<td>30 min most days / week</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>Fish intake</td>
<td>2 servings per week</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>Flu vaccination</td>
<td>Every year</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Smoking / Tobacco</td>
<td>Cessation</td>
<td>61</td>
<td>39</td>
</tr>
</tbody>
</table>
Take Home Messages

Strenuous Duties can Precipitate CV Events

CV Event victims have clinical CHD, subclinical disease & excess RF’s

Many potential victims could be identified

Risk Profiles could be modified before Clinical Events manifest

Kales et al
Prevention

Known CHD and Emergencies Duties do NOT mix

Smoking should be prohibited

HTN & other RF’s should be actively reduced
## Proposed Management Scheme for Emergency Responders

<table>
<thead>
<tr>
<th>BP</th>
<th>Action</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Unrestricted Population-Based</td>
<td>Annual</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>Unrestricted Individual Education</td>
<td>6-12 mos per other RF’s</td>
</tr>
<tr>
<td>Stage 1 Hypertension</td>
<td>Time-limited Clearance Rx &amp; Evaluation</td>
<td>6-12 months</td>
</tr>
<tr>
<td>Stage 2 Hypertension</td>
<td>Restricted Rx &amp; Evaluation</td>
<td>Time-limited Clearance after Adequate BP Control</td>
</tr>
</tbody>
</table>
Prevention

Maximal Exercise Tests to assist Risk Stratification

Sleep Hygiene

? Flu Shots

? ASA
Discussion / Questions