SUDDEN CARDIAC DEATH IN FIREFIGHTERS: CAUSE AND MITIGATION STRATEGIES

Denise L. Smith, Ph.D
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Outline

Section 1 - Fire Service Fatality Statistics

Section 2 - Physiological Strain of Firefighting

Section 3 - Pathology of Sudden Cardiac Events

Section 4 – Lessening Cardiac Events
Section One

Fire Service Statistics

Fatalities: 61-100 deaths per year

Non-fatal CV events: 800-900 per year
Prevalence of Sudden Cardiac Events

<table>
<thead>
<tr>
<th>Cause</th>
<th>Percentage of Deaths (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVA</td>
<td>10</td>
</tr>
<tr>
<td>Trauma</td>
<td>30</td>
</tr>
<tr>
<td>Heart Attack</td>
<td>50</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
</tr>
<tr>
<td>Heat Exhaustion</td>
<td>5</td>
</tr>
<tr>
<td>Violence</td>
<td>0</td>
</tr>
<tr>
<td>Electrocution</td>
<td>0</td>
</tr>
<tr>
<td>Burns</td>
<td>0</td>
</tr>
<tr>
<td>Asphyxiation</td>
<td>0</td>
</tr>
</tbody>
</table>

United States of America
Heart Deaths by Occupation
(\% of On-Duty Deaths Caused by CVD)

- **Firefighters**: 45\%
- **Police**: 22\%
- **Overall\***: 15\%
- **Construction**: 11.5\%
- **EMS**: 11\%

*Average \% of all occupational fatalities, all industries*
Section Two

Physiological Strain of Firefighting

Theoretical Models

Research Findings
Firefighting Physical Demands

Strenuous work
- Climbing stairs
- Forcible entry
- Search and rescue

Hot and Dangerous Environment
- Over 100º C routinely
- Chaotic
- Low visibility

Heavy PPE
- > 22 kg
- ↑ Metabolic work
- ↓ Heat dissipation
Factors That Affect FF Response

- Environmental Factors
- Work Performed
- Gear
- Thermal Environment

Physiological Responses to Firefighting

- Personal Factors
- Health Status
- Fitness
- Hydration Level
Heart rate and temperature responses to repeated firefighting evolutions

Changes During Firefighting

- Drills
- Drills
- Drills

Rehab

$Rc_1$

~ 8 min  ~ 8 min  ~ 8 min

= measurement period
Cardiac Responses – Heart Rate

Heart rate (HR) responses to short-term firefighting

Pre Trial 1 Trial 2 Trial 3

HR (bpm)

a p<0.05 vs Trial 1

Stroke volume (SV) responses to short-term firefighting

Changes During Firefighting

- Drills: ~20 min
- Recovery: 90 min
- Measurement period: ~20 min
Dehydration

Change in Plasma Volume (%)

Pre  Post  Post 90

a Significantly different (p<0.05) than immediately post’

Blood Chemistry Responses

Sodium

- Pre
- Post
- Post 90'

Glucose

- Pre
- Post
- Post 90'

Mean Body Fat % = 18.1
Mean Age = 31.8 yrs
n=11

a p<0.05 vs Pre and Post

b p<0.05 vs Pre

Hormonal Responses to Firefighting Drills

Plasma ACTH

Plasma Cortisol

Smith et al., 2005. *Ergonomics.*
Platelet Data

Platelet Number

Aggregation Time

* p < 0.05

Smith et al., 2005. *Prehospital Emergency Care*
Strenuous work
- Climbing stairs
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Hot and Dangerous Environment
- Over 100° C routinely
- Chaotic
- Low visibility
High Aerobic Capacity

- $\text{Vo}_{2\text{max}} > 44 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ as the minimal acceptable value for FF

Gledhill and Jamnik 1992

High Anaerobic Capacity

- Firefighting activity requires high levels of anaerobic system around 40% of energy expenditure

Lemon and Hermiston 1977, Barr et al 2010

High Muscular Strength/Endurance

- Needed for forcible entry, hoisting of hose, chopping tasks, and victim rescue

Sothmann et al 1990, Clark 2002
Generally do not have CV risk profile that differs from general population (Drew-Nord, 2009)

Recruits – 35 ml/kg/min (Roberts et al, 2002)

High Prevalence of obesity
- 87% - BMI > 25
- 77% - BMI > 25
- 75% - BMI > 25

34% > 30 (Kales et al, 1999)
33% > 30 (Tsismenakis et al, 2009)
25% > 30 (Fahs et al, 2009)
## Effect of Obesity on CV Health

<table>
<thead>
<tr>
<th>Variable</th>
<th>Body Mass Index (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;25.9</td>
</tr>
<tr>
<td></td>
<td>(Group 1)</td>
</tr>
<tr>
<td>Intima-media thickness</td>
<td>0.44(0.01)</td>
</tr>
<tr>
<td>Aortic pulse wave velocity</td>
<td>5.9(0.1)</td>
</tr>
<tr>
<td>β Stiffness</td>
<td>4.6(0.2)</td>
</tr>
</tbody>
</table>

* Different from group 1 (p<0.05)
† Different from group 2 (p<0.05)

N=110 firefighters
Age= 29.7±8.0 years

Fahs et al., 2009, Am J Cardiol.
Section Three

Pathology of Sudden Cardiac Events

Theoretical Models
CV Disease Progression
Sudden Cardiac Events
Mismatch with Bad Outcome

Physical Demands of Firefighting

Lack of Fitness or Poor Health

• Impaired Performance
• Increased Risk of Injury
• Increased Risk of Fatality
Figure 1.4. (a) Normal healthy artery; (b) plaque accumulation in an artery; (c) plaque rupture and clot formation.
Mechanism of Sudden Cardiac Death

- Dehydration
- Increased Body Temperature
- Adrenaline

- Decreased Plasma Volume
- Altered Electrolytes
- Increased Viscosity
- Changes in HR and BP

- Circulatory Shock
- Arrhythmias
- Clot Formation
- Plaque Disruption

Cardiac Event
<table>
<thead>
<tr>
<th>Activity</th>
<th>Time Spent (%)</th>
<th>Fatalities (%)</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Suppression</td>
<td>1%</td>
<td>32.10%</td>
<td>136</td>
</tr>
<tr>
<td>Response to Alarm</td>
<td>4%</td>
<td>13.40%</td>
<td>14.1</td>
</tr>
<tr>
<td>Return from Alarm</td>
<td>7%</td>
<td>17.40%</td>
<td>10.5</td>
</tr>
<tr>
<td>Physical Training</td>
<td>8%</td>
<td>12.50%</td>
<td>6.6</td>
</tr>
<tr>
<td>Nonfire emergencies</td>
<td>15%</td>
<td>9.40%</td>
<td>2.6</td>
</tr>
<tr>
<td>Nonemergency duties</td>
<td>65%</td>
<td>15.40%</td>
<td>1</td>
</tr>
</tbody>
</table>

Kales, et al., NEJM, 2007

Line of Duty Deaths - CHD related
N=449, 1994-2004
Model of CVE in Fire Service Cardiac

Soteriades, Smith, Tsismenakis, Baur and Kales, CIR 2011

**Progression of Atherosclerosis**

- CHD, coronary heart disease
- LVH, left ventricular hypertrophy
- CVD, cardiovascular disease

**A)** Genetics, Baseline Habits, Initial Body Composition, Regular Exercise, Physical Activity, Healthy Diet, Adequate Sleep, Moderate Alcohol, Hypertension, Dyslipidemia, Diabetes, Obesity, Tobacco, Sedentary Behavior, Poor Diet, Smoke (gases & particulates), Noise, Stress, Shift work / sleep deprivation

**B)** Known CHD or Equivalent, Subclinical Disease +/- LVH, Death, Disease, Disability

**C)** Triggers / Strenuous Duties, Acute CVD Events

Soteriades, Smith, Tsismenakis, Baur and Kales, CIR 2011
Cardiovascular Strain of Firefighting

- Sympathetic Nervous System Activation
  - Danger/Alarm
  - Chaotic Scene

- Physical Work
  - PPE
  - Work Tasks

- Heat Stress/Dehydration
  - PPE
  - Environment
  - Metabolic Work

- Environmental Conditions
  - Smoke Exposure
  - Asphyxiants
  - Particulates

- Individual Characteristics
  - Health Status
  - Fitness Profile
Cardiovascular Strain of Firefighting

A) Increased Shear Stress | Decreased Plasma Volume | Altered Electrolytes | Viscosity/Coagulatory Changes

Substrate of Cardiomegaly/LVH, and/or Underlying CHD

B) Plaque Rupture and Thrombus Formation | Arrhythmia

SCD or Other CVD Event
Section Four

Lessening Sudden Cardiac Events
Decreasing Physiological & Cardiovascular Strain in the Fire Service

Pre-Event

On-Scene

Post Incident
Decreasing Physiological & Cardiovascular Strain in the Fire Service

Pre-Event

On-Scene

Post Incident
Preventing Cardiac Events

Firefighter

Medical Exam
- Identify CV Risk Factors
- Treat CV Risks

Fitness

Firefighting

Trigger

Plaque Accumulation

Heart Attack

Age (years)

0  20  ………
Physical Fitness

Aerobic Fitness:
1. ↑Thermal Tolerance
2. ↑Plasma Volume
3. ↑Cardiac Efficiency
4. ↑Work Capacity
5. Improve Clotting Profile

Appropriate Body Size:
1. ↑Thermal Tolerance
2. ↓Thermal Strain
3. ↑Cardiac Efficiency
4. ↑Work Efficiency
5. Improve Clotting Profile
Benefits of Fit Firefighters

Improved Public Safety
- ↑ mobility, energy, endurance
- ↑ ability to perform job duty efficiently & safely

Improved Firefighter Health and Safety
- ↓ risk of sudden cardiac event
- ↓ risk of injuries
Physiological Responses:
- Muscular/Metabolic Fatigue
- Dehydration
- Heat Stress

Benefits of Physical Fitness:
- ↑ Strength/Endurance  
  ↓ Fatigue
- ↑ Plasma Volume
- • Improved Thermoregulation  
  • Tolerance for higher temperature
- ↑ Cardiovascular capacity  
  ↓ Risk of Clot Formation

Cardiovascular Strain:
- • HR, BP
- • Blood Clotting
Current Standards

- There are standards that recommend that FF participate in a fitness program (NFPA 1582, IAFF/IAFC WFI)
- It is up to each department to decide if it will have fitness programs
- Approx. 70% of departments have no formal fitness program
- Health and Wellness Guide (for volunteer fire departments) – nvfc.org
Medical Readiness

Single most important step that can be taken in the fire service to decrease fatalities
Medical Readiness

- What risk factors are associated with increased risk of suffering a cardiac event on the job?
- What is the risk factor that is associated with the greatest risk of suffering a cardiac event?
## Relative Risk of Cardiovascular Outcome by Risk Factor

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>On-duty CHD Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age $\geq 45$ years old</td>
<td>18 (8.5–40)</td>
</tr>
<tr>
<td>Current Smoking</td>
<td>8.6 (4.2–17)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>12 (5.8–25)</td>
</tr>
<tr>
<td>Obesity, BMI $\geq 30$ kg·m$^{-2}$</td>
<td>3.1 (1.5–6.6)</td>
</tr>
<tr>
<td>Cholesterol $\geq 5.18$ mmol·L$^{-1}$</td>
<td>4.4 (1.5–13)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>10.2 (3.7–28)</td>
</tr>
<tr>
<td>Prior diagnosis of CHD</td>
<td>35 (9.5–128)</td>
</tr>
</tbody>
</table>

Source: Soteraides et al, Cardiovascular Disease in US Firefighters, *Cardiology in Review*, 2011
Medical Readiness

1. Every Firefighter should have a medical exam and fitness evaluation (IAFC Position Statement)
2. Medical Exam should focus on cardiovascular risk
3. Medical Evaluations should be performed by physicians familiar with the physiological demands of firefighting (including essential job tasks)
Medical Evaluations for FF

- Every FF should have a baseline physical
- Every FF should have an annual medical evaluation
Are you aware of 1582 Standard?

How familiar are you with the 1582 Standard?

Do you think the 1582 Standard is appropriate for your department?
Medical Exam

- What needs to be in a medical evaluation?

- The medical evaluation for a candidate shall include a medical history, examination, and any laboratory tests required to detect physical or medical conditions that could adversely affect his/her ability to safely perform essential job tasks.
Essential job tasks

- So, what are the essential job tasks?
So, what are the medical conditions that affect the ability to safely perform essential job tasks?

- Head
- Neck
- Eyes and vision
- Ears and hearing
- Dental
- Nose, trachea, esophagus
- Lungs
- Heart and vascular system
- Abdominal and GI system
- Urinary
- Spine and extremities
- Neurological
- Skin
- Blood
- Endocrine and metabolic
- Systemic diseases
- Tumors and malignant diseases
- Psychiatric conditions
- Chemicals, drugs and medications
Components of Annual Medical Evals

- Medical history
- Physical examination
- Blood tests
  - CBC with differential
  - Electrolytes
  - Renal function
  - Glucose
  - Liver function
  - Total cholesterol, HDL, LDL, TG
  - PSA after age 40 or after age 50, depending on given criteria, for male members
- Urine
- Audiology
- Spirometry/Pulmonary function
- Chest radiographs
- Electrocardiograms
- Mammography
- Immunizations & infectious disease screening
- Post-exposure bloodborne pathogen testing
- HIV testing
- Heavy metal testing
- Colon cancer screening
Components of Annual Medical Evals

- Medical history
- Physical examination
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Adopt Aggressive Incident Rehabilitation Policies

1. Cool- “Aggressively”
2. Rehydrate
3. Provide rest and recovery
4. Medical Monitoring
Model of Sudden Cardiac Event

Firefighter

Firefighting

Trigger

Lessen Cardiovascular Strain of FF

Plaque Accumulation

Age (years)

Heart Attack
Physiological Responses

- Muscular/Metabolic Fatigue
- Dehydration
- Heat Stress

Cardiovascular Strain
- HR, BP
- Blood Clotting

Rehab

- Rest/Recovery
- Nutrition
- Fluid Replacement
- Cooling
- Climatic Relief
- Medical Monitoring
- Medical Monitoring
- Rest
- Cooling
- Fluid Replacement
- Medical Monitoring
Challenges

- Funds
- Time
- Administration
- Union
- City
- Culture
- Leadership
- Lack of awareness/clarity
Strategies for Implementing/Improving Medical Evals

- Best practices
- Experiences
- Current strategies
- Ideas
Thank You

Skidmore

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Jacquelyn Liebig
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Peggy Wharton

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Logan Arena
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Dr. Gavin Horn
Lt. Brad Bone
Chief Craig Haigh
Eric Goldstein
Dr. Steven Petruzzello

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Dr. Recai Yucel (statistical)
Dr. Tom Rowland (cardiologist)
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Thank You

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Covenant Medical Center  
Pro Ambulance  
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**Participants**

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Chicago Fire Department  
Champaign Fire Department  
Urbana Fire Department  
Over 40 FD’s in Illinois and Wisconsin
Thank You