# Cardiovascular (and Thermal) Strain of Firefighting

Denise L. Smith, Ph.D.
Gavin Horn, Ph.D

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# Outline

Section 1 – Firefighter Injury and Fatality Statistics

Section 2 – Conceptualizing SCE in the Fire Service

Section 3 – Research Agenda

- Framework/Approach
- Research Projects

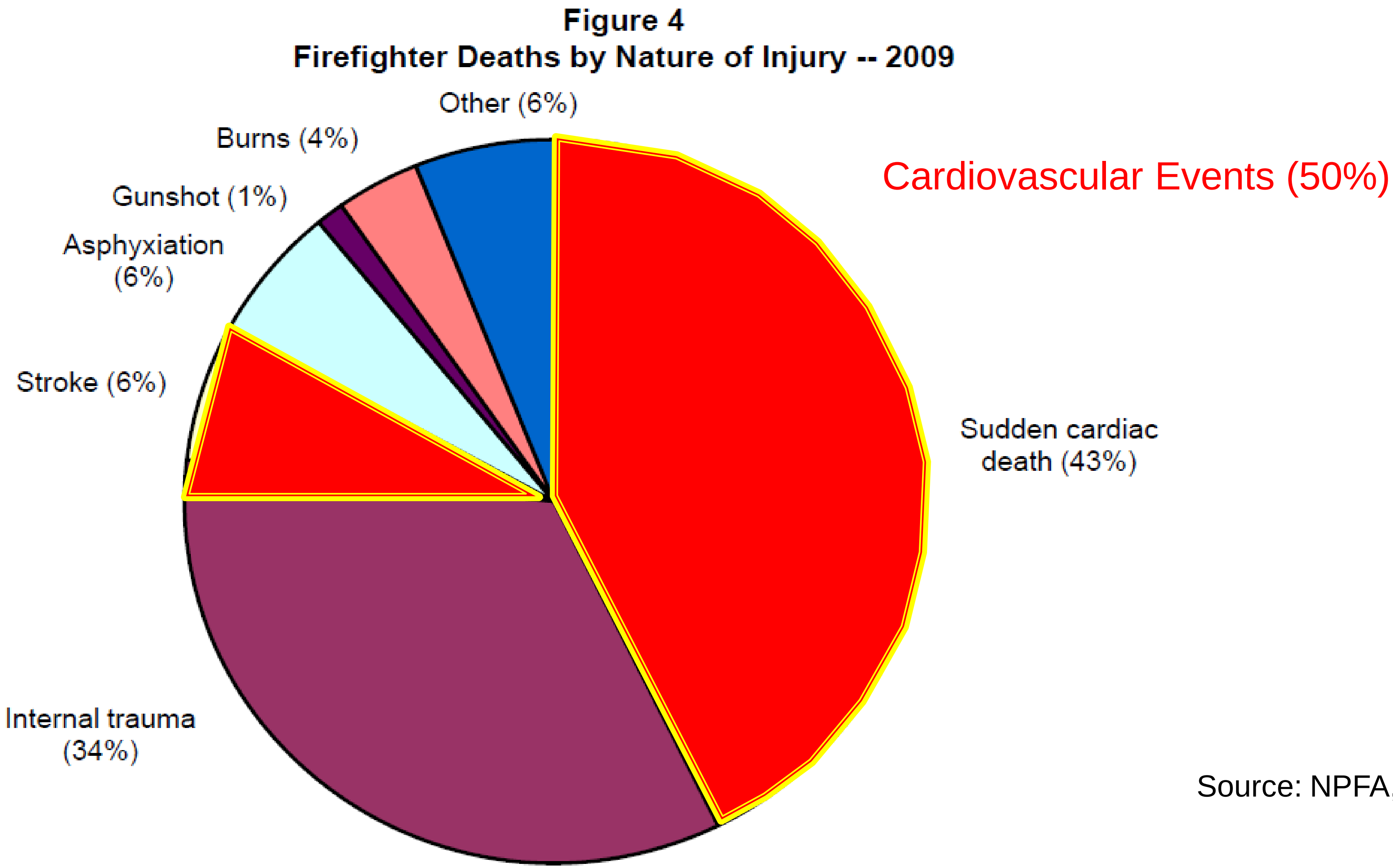
Section 4 – Mitigating Risks in the Fire Service

Section One

# Fatality Statistics

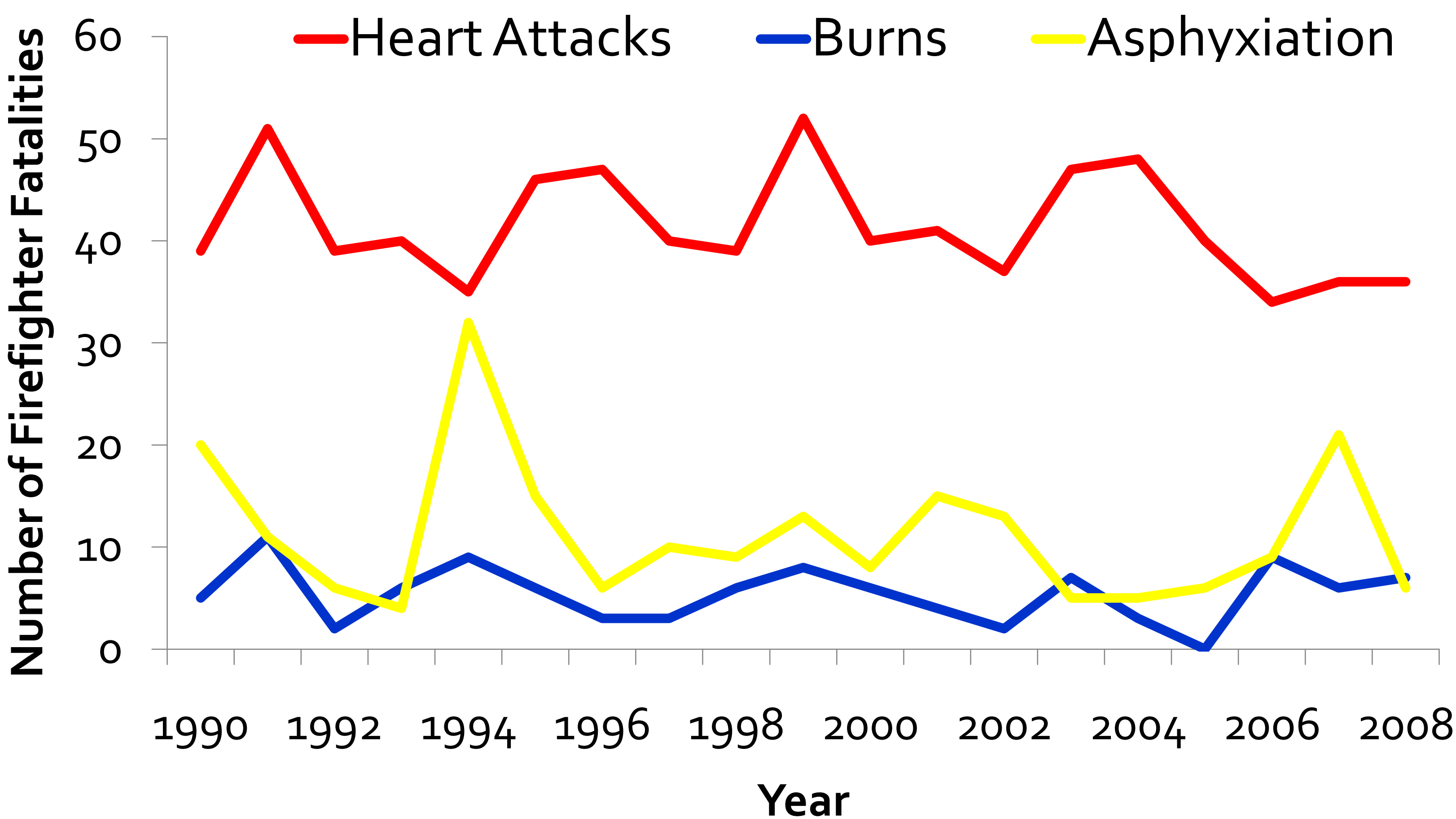
Relative risks

# Firefighter Fatality Statistics (2009)




Source: NPFA, 2010

# Firefighter Fatality Statistics



Section Two

# Conceptualizing Risks

Complex Job of FF

Theoretical Models

# Firefighting Physical Demands

## Strenuous work

Climbing stairs

Forcible entry

Search and rescue

## Heavy PPE

> 22 kg

↑ Metabolic work

↓ Heat dissipation

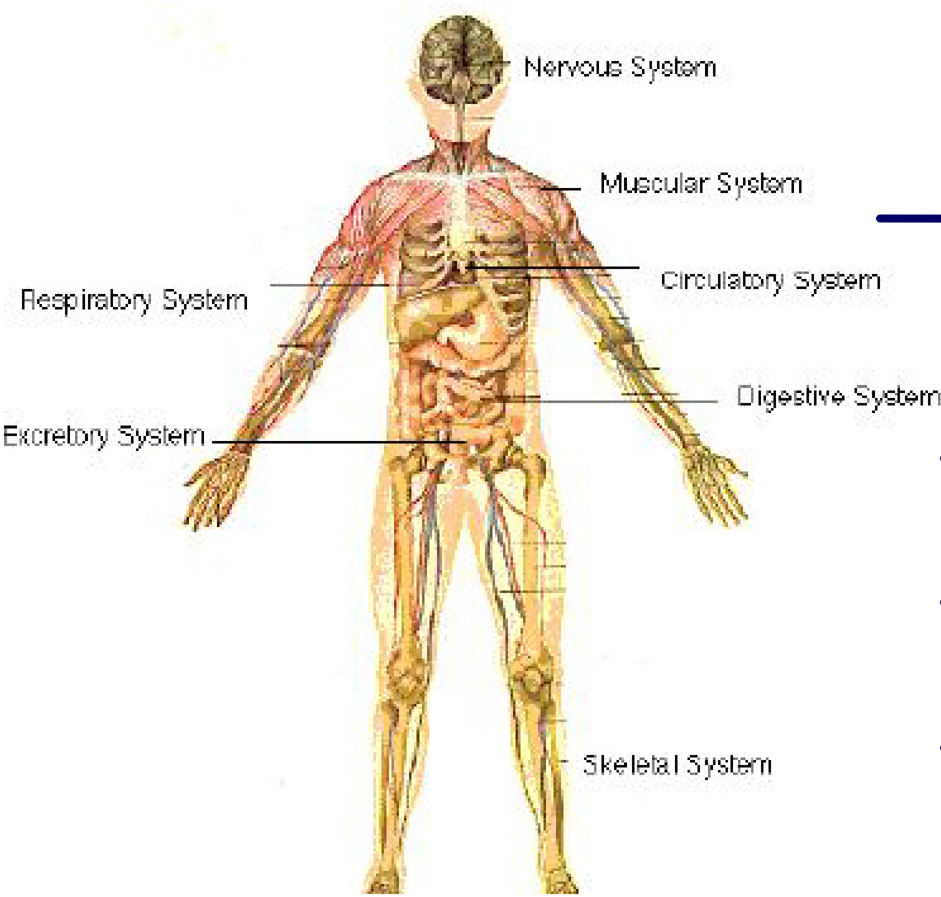
## Hot and Dangerous Environment

Over 100º C routinely

Chaotic

Low visibility

# Characterizing Physiological Responses to Firefighting




**Thermoregulation/Dehydration**
•↑ Tco, ↑ Sweating, ↓ Plasma Volume

Core Temperature

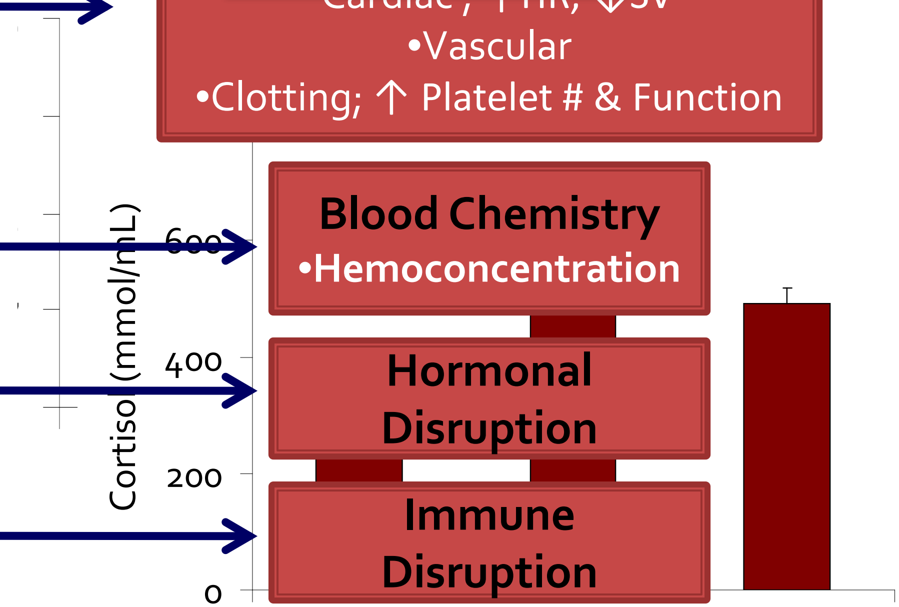
**Cardiovascular**
•Cardiac ; ↑HR, ↓SV
•Vascular
•Clotting; ↑ Platelet # & Function

**Blood Chemistry**
**•Hemoconcentration**

**Hormonal Disruption**

**Immune Disruption**

**Metabolic**
•↑VO2 ↑ Lactate




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

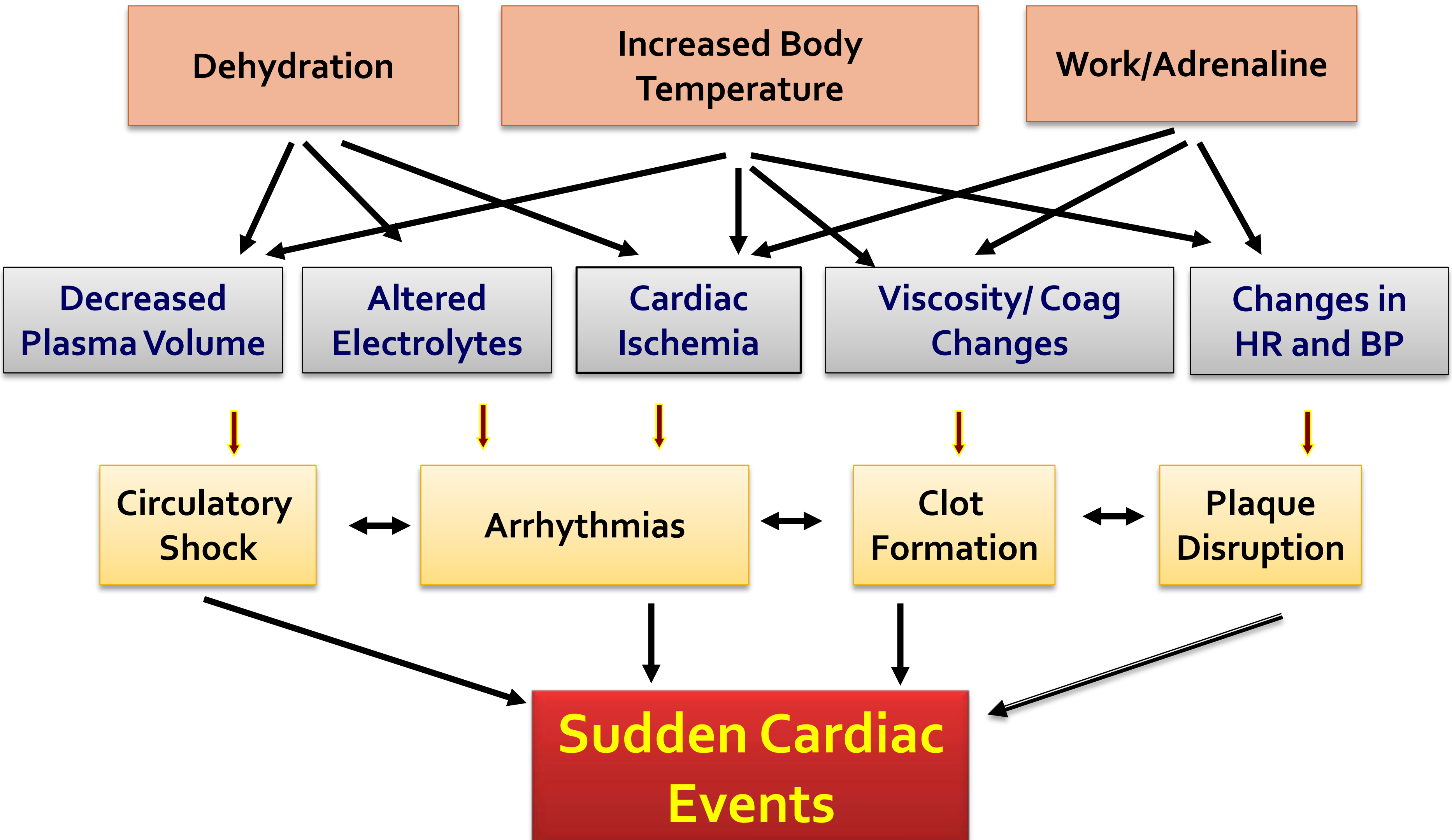
a p<0.05 vs Pre and Post
b p<0.05 vs Pre

Smith *et al.* 2001, *J Thermal Biol*
Smith *et al.* 2005, *Ergonomics*

# Risk Profiles

| | Impairs Performance | Potential Health/Safety Risk | Life Threatening |
|---|---|---|---|
| Cardiovascular | Higher HR<br>Earlier Fatigue | Exhaustion | **Sudden Cardiac Events** |
| Dehydration/ Heat Strain | Heat Stress<br>Hyperthermia<br>Early Fatigue | Heat Exhaustion<br>Impaired Cognitive Function | Heat Stroke |

# Potential Mechanism of Sudden Cardiac Events



Section Three

# Research Agenda

Framework/Approach

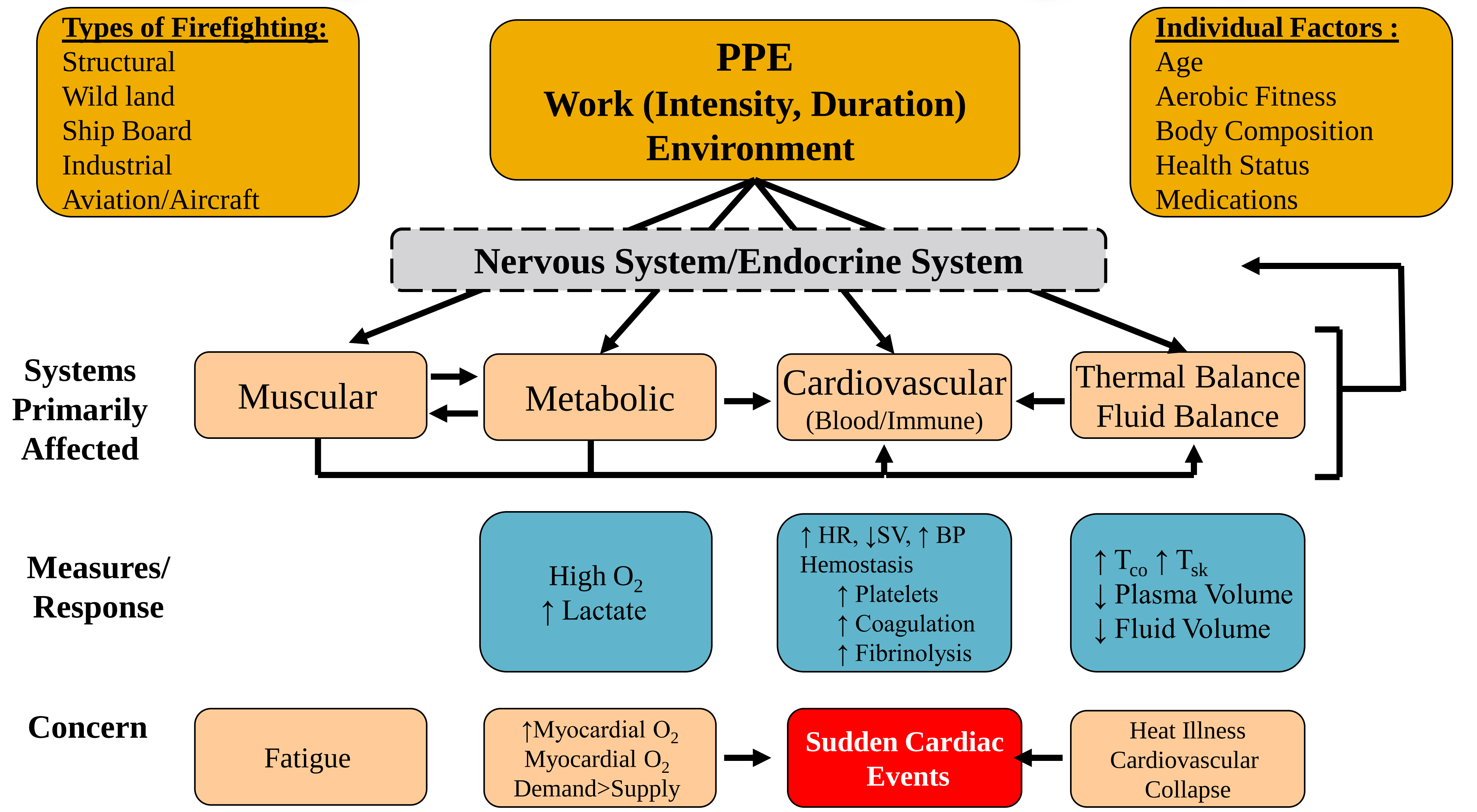
Research Projects

# Research Goals

Quantify the **cardiovascular strain** (cardiac, vascular, blood) associated with firefighting activity

…….and test interventions designed to lessen cardiovascular strain and the risk of injury or fatality, and improve performance

# Theoretical Model: Physiological Stress of Firefighting



# Framing a Research Agenda

**Cardiovascular Effects of FF**

| Firefighting | Cardiac | Vascular | Blood (clotting) |
|---|---|---|---|
| Simulated Firefighting (IFSI)<br>• Short – Term<br>•Long- Term<br>•Other missions | | | |
| | | | |
| Work in PPE (Skidmore) | | | |
| | | | |
| Actual Firefighting (Skidmore) | | | |

↑

**Interventions** (policies, pharmacological, technological)

# Baseline CV health characteristics

| Variable | Body Mass Index (kg/m$^2$) | | |
|---|---|---|---|
| | <25.9 (Group 1) | 25.9-29.5 (Group 2) | ≥29.5 (Group 3) |
| Intima-media thickness | 0.44 (0.01) | 0.46 (0.01) | 0.52(0.01)*† |
| Aortic pulse wave velocity | 5.9(0.1) | 6.4(0.2)* | 6.8(0.1)* |
| β Stiffness | 4.6(0.2) | 5.1(0.2) | 6.2(0.4) |

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

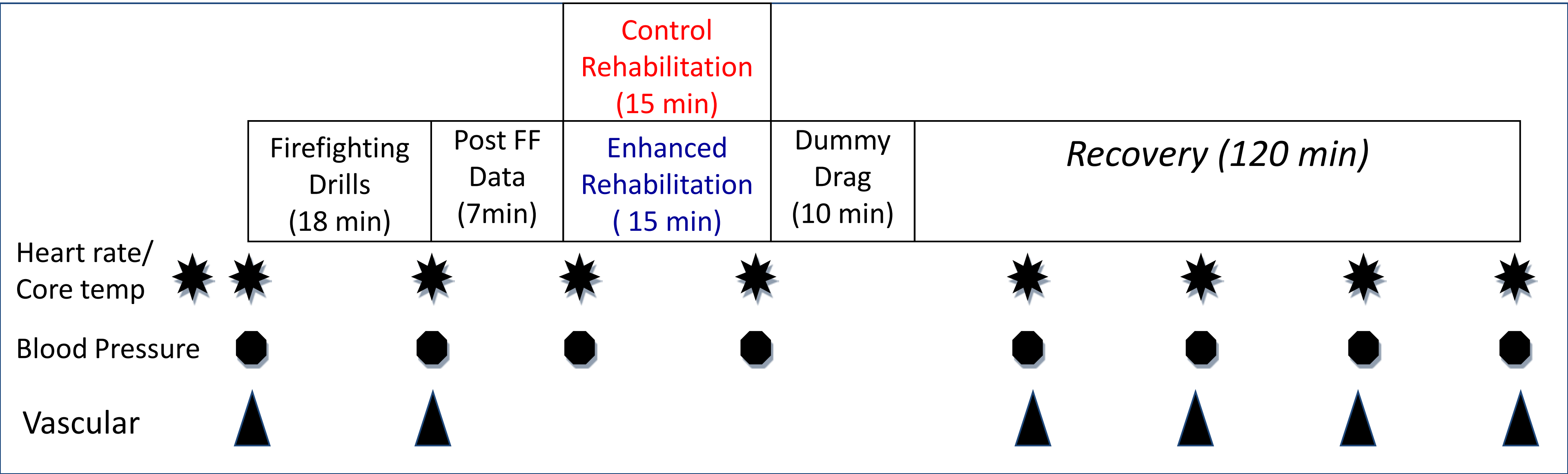
N=110 firefighters
Age= 29.7±8.0 years

Fahs et al., 2009, Am J Cardiol.

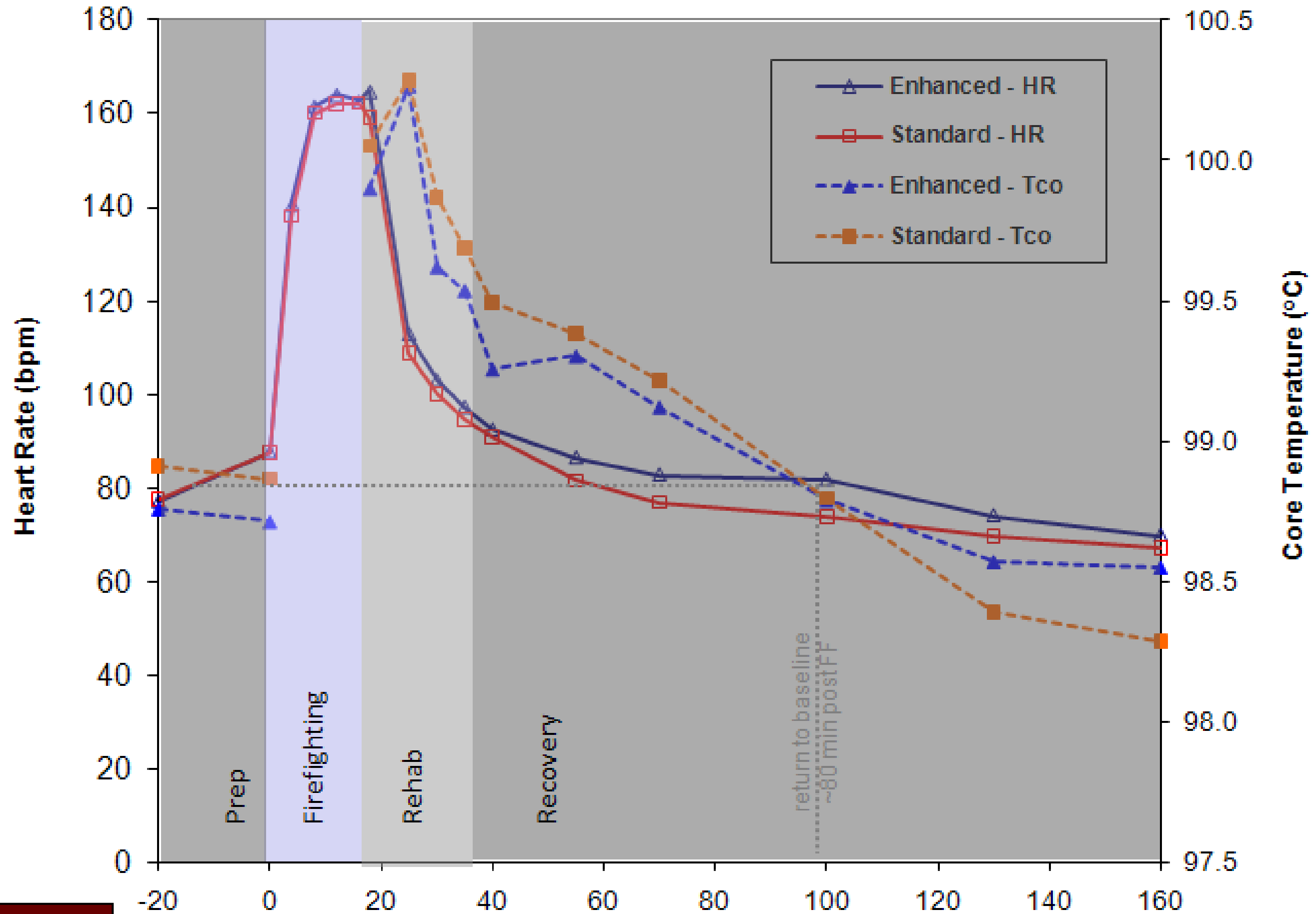
# Simulated Firefighter Activities

# Methods

- **Subjects - 23 firefighters**
- **Design – RM (2 conditions: control rehab vs. enhanced rehab)**
- **Protocol – 18 min FF drills**
  - **–Control or enhanced Rehab**
  - **– 10 minute dummy drag**
  - **– 120 min RECOVERY**



# HR and Core Temp during FF and Recovery




NIOSH - 1R03OH009111

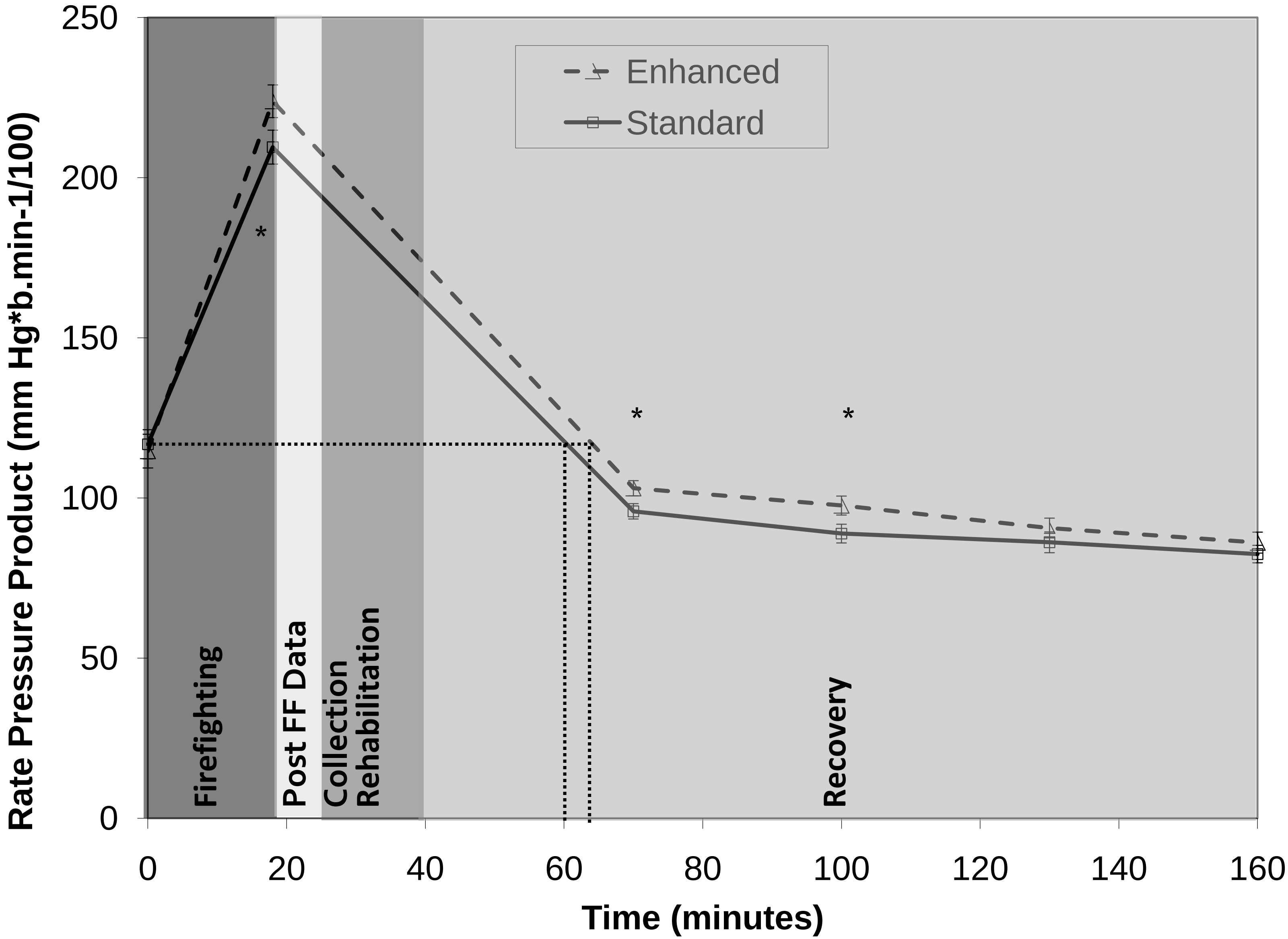



*Figure 6. Changes in Rate Pressure Product (RPP) throughout the test protocol. Data from complete sets only (n=20). All timepoints are significantly different from the prefirefighting condition, dropping below this level before the 30 minute recovery time period in both conditions. (* indicates significant condition affect at these time points)*

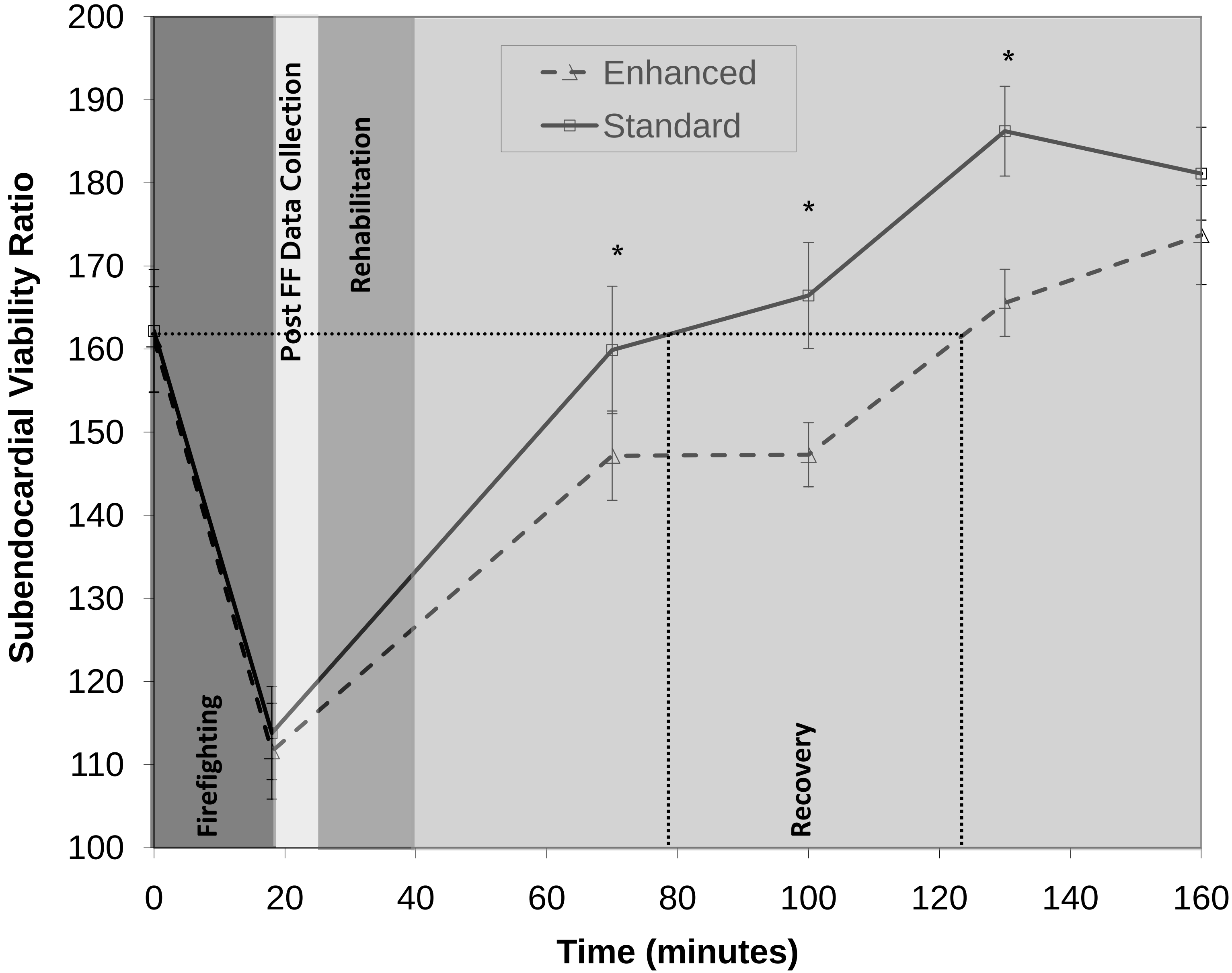
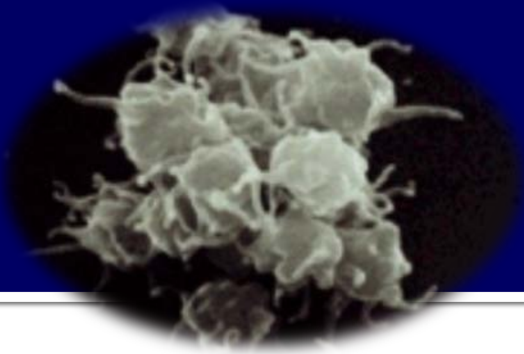
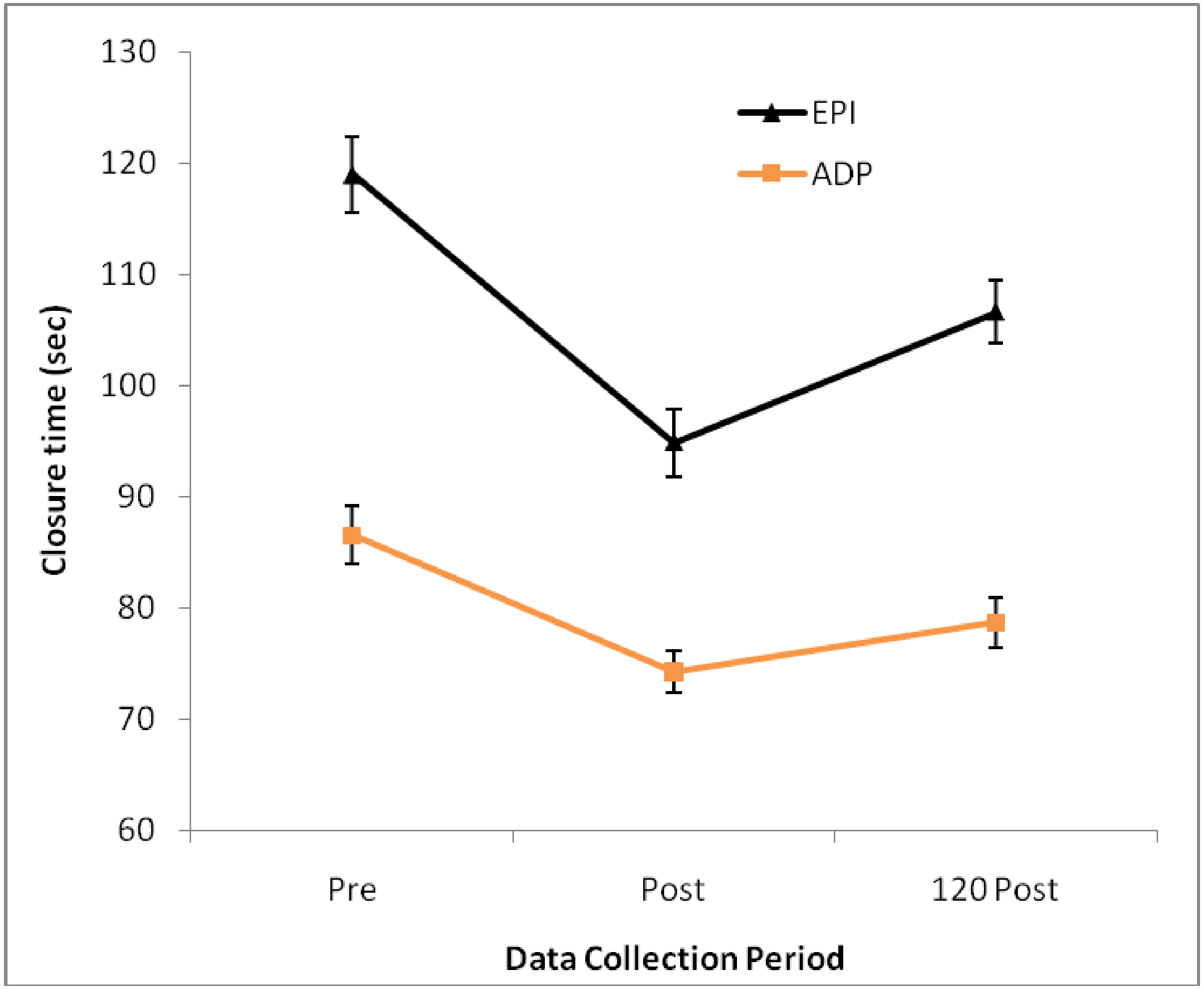



Figure 7. Changes in Subendocardial Viability Ratio (SEVR) throughout the test protocol. Data from complete sets only (n=18) (* indicates significant condition affect at these time points, dotted lines indicate the times where SEVR returns to pre-firefighting levels)

# Platelet Data

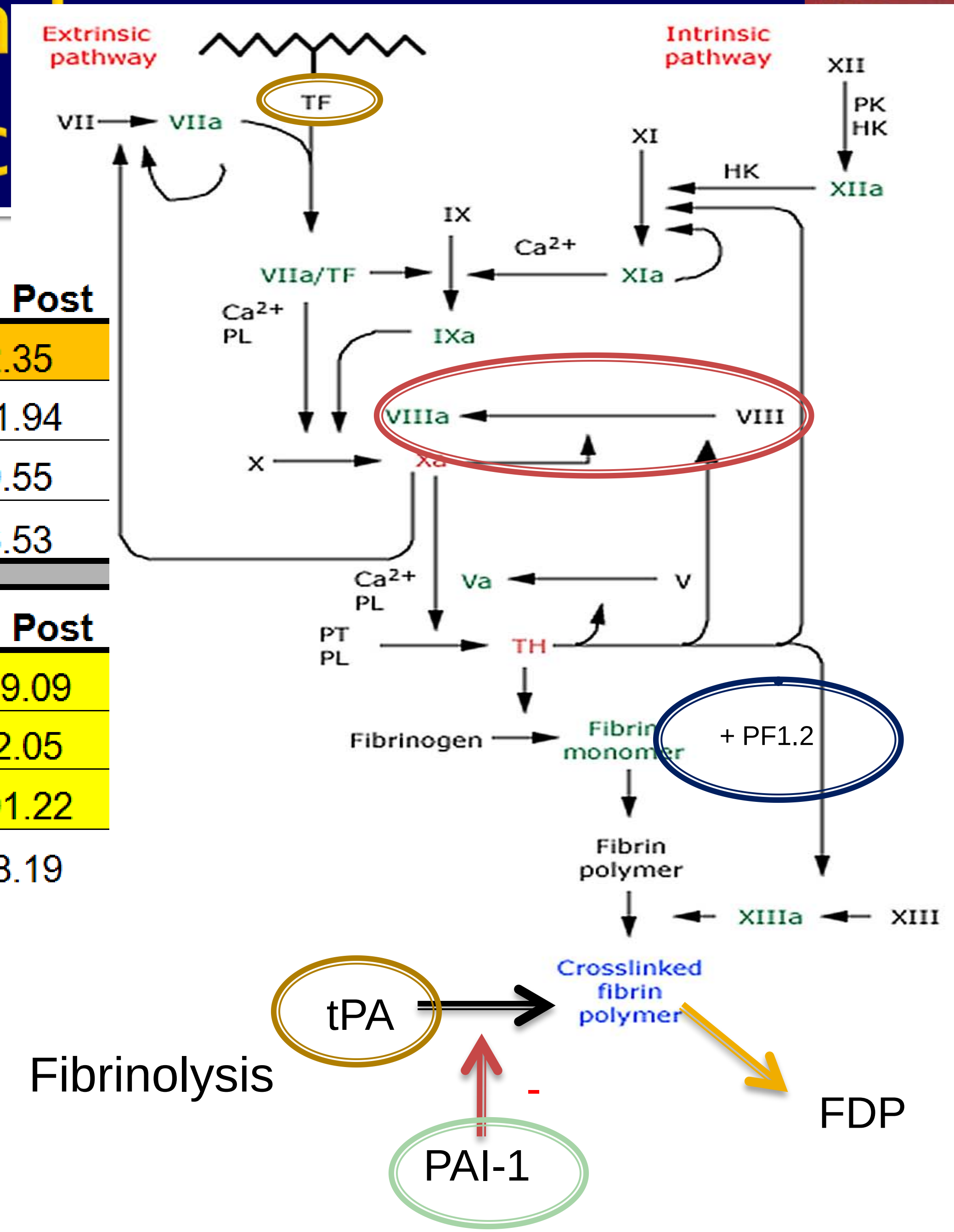




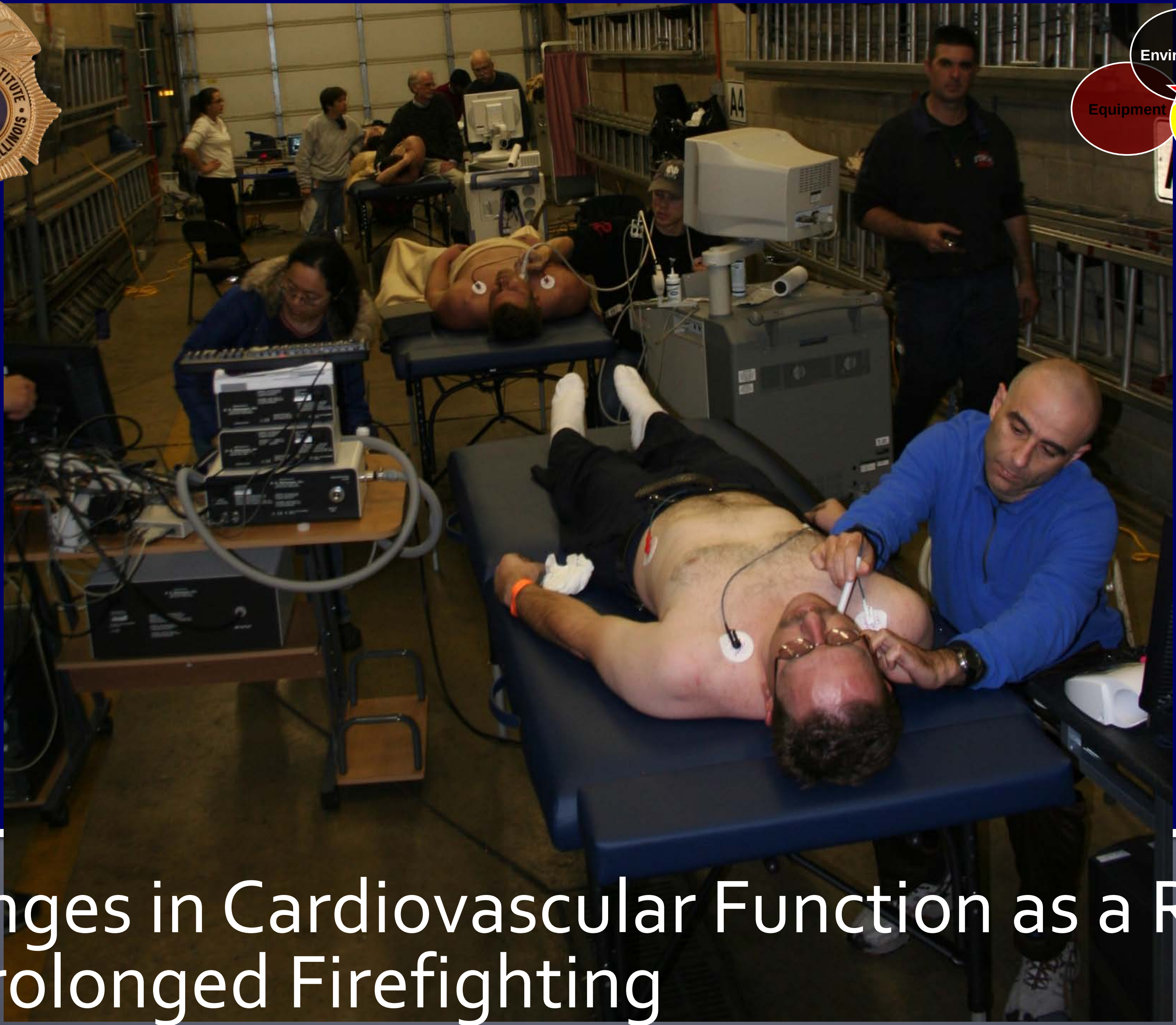
# Coagulatory an
# Fibrinolytic Fac

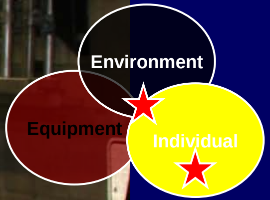

| Fibrinolysis | Pre | Post | 120 Post |
|---|---|---|---|
| Pai-1 act | 2.94 | 2.38 | 2.35 |
| Pai-1 agn | 24.17 | 26.23 | 21.94 |
| Tpa act | 0.53 | 1.90 | 0.55 |
| Tpa agn | 6.21 | 11.69 | 6.53 |

| Coagulation | Pre | Post | 120 Post |
|---|---|---|---|
| FVIII | 88.33 | 126.83 | 119.09 |
| PTT | 33.71 | 32.80 | 32.05 |
| AT-III | 97.32 | 100.15 | 101.22 |
| TF | 71.52 | 77.66 | 68.19 |



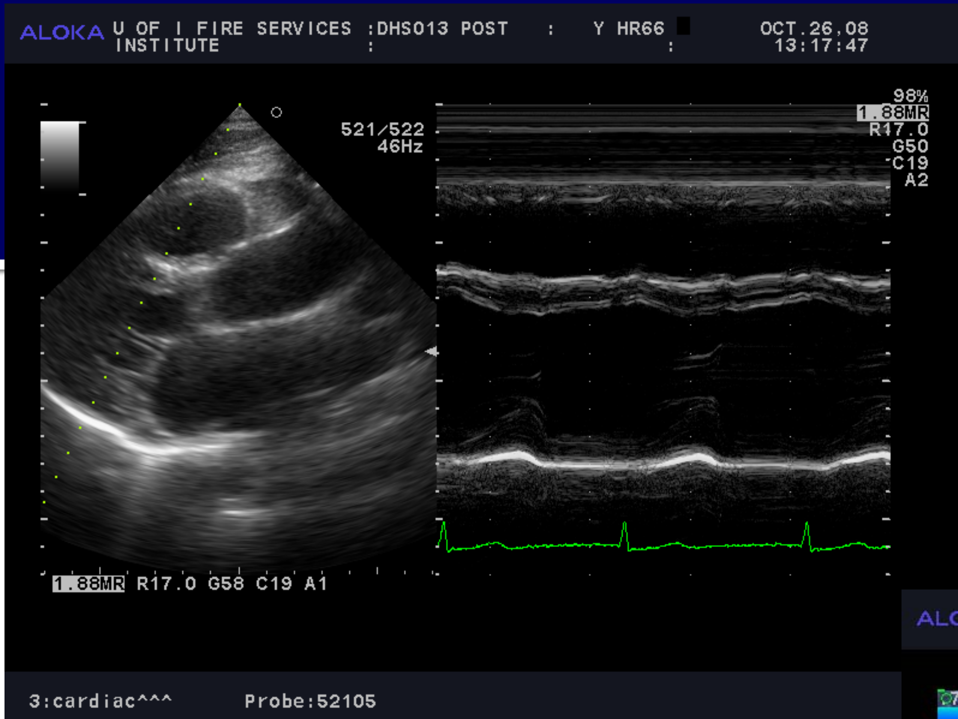

DHS AFG EMW-2006-FP-02459

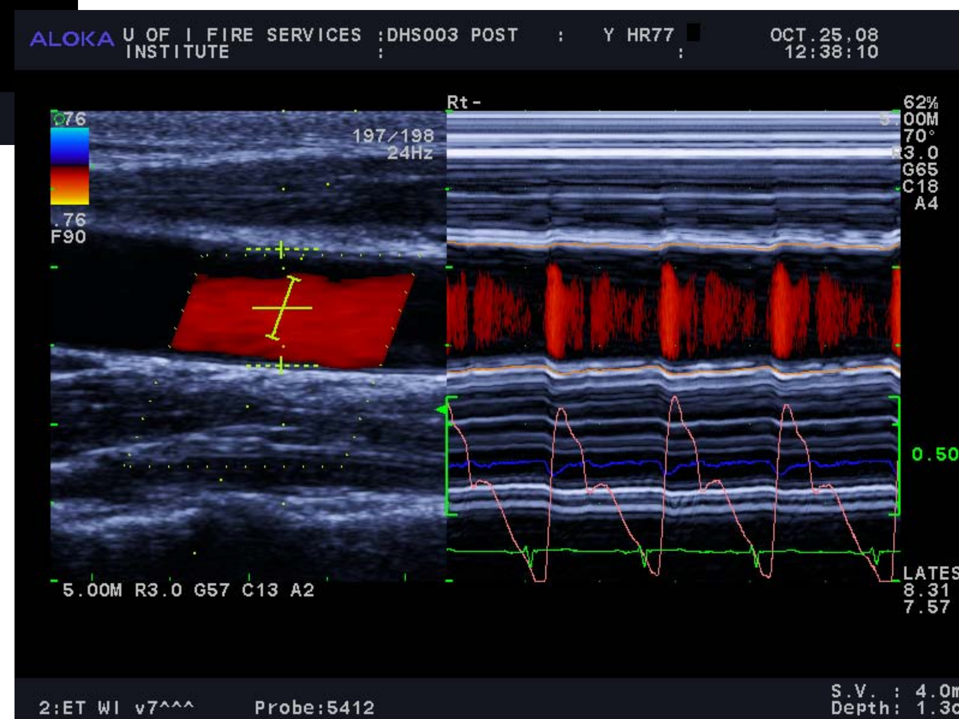





# Changes in Cardiovascular Function as a Result of Prolonged Firefighting

U.S. Department of Homeland Security - Assistance to Firefighters Grants Program (AFG)




DHS AFG EMW-2007-FP-02328

# Echocardiographic variables (systolic function)

| | Before | After |
|---|---|---|
| LVEDD (mm) | 53.0(6.1) | 51.9(6.7)* |
| LVESD (mm) | 35.6(6.3) | 37.2(6.2) |
| LV SF(%) | 33.0(6.3) | 28.6(6.0)* |
| LVEDV ($cm^3$) | 138(37) | 132(38)* |
| LVESV ($cm^3$) | 55(25) | 61(25) |
| Ejection fraction (%) | 60.3(9.2) | 54.3(9.5) |
| Stroke volume (ml) | 82(20) | 71(22)* |

# Echocardiographic variables (diastolic function)

| | Before | After |
|---|---|---|
| Mitral E (cm $s^{-1}$) | 81(14) | 71(14)* |
| Mitral A (cm $s^{-1}$) | 45(9) | 45(14) |
| Mitral E/A | 1.9(0.4) | 1.7(0.6) |
| TDI E′ lateral (cm $s^{-1}$) | 7.8(3.1) | 6.3(2.7)* |
| TDI E′ septal (cm $s^{-1}$) | 4.5(2.0) | 4.2(1.8) |

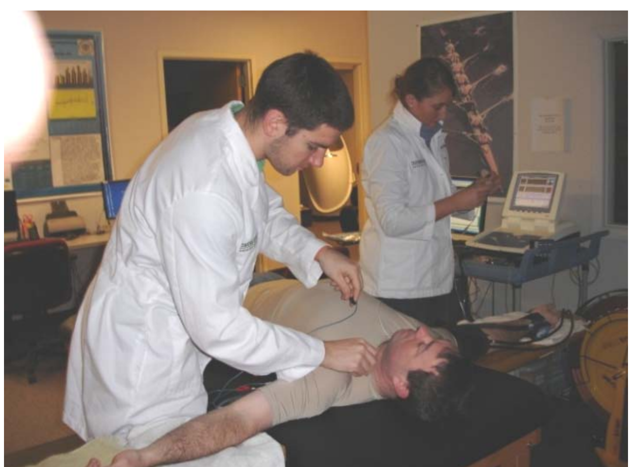
# Laboratory Studies

# Laboratory Study

## Study Purpose

**Investigate the physiological *recovery* from exercise in gear.**

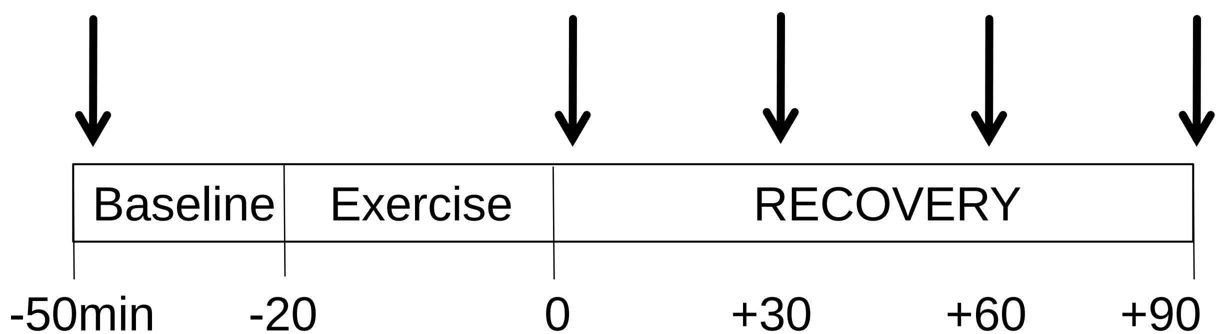
# Methods



**Subjects – 14 moderately trained FF**

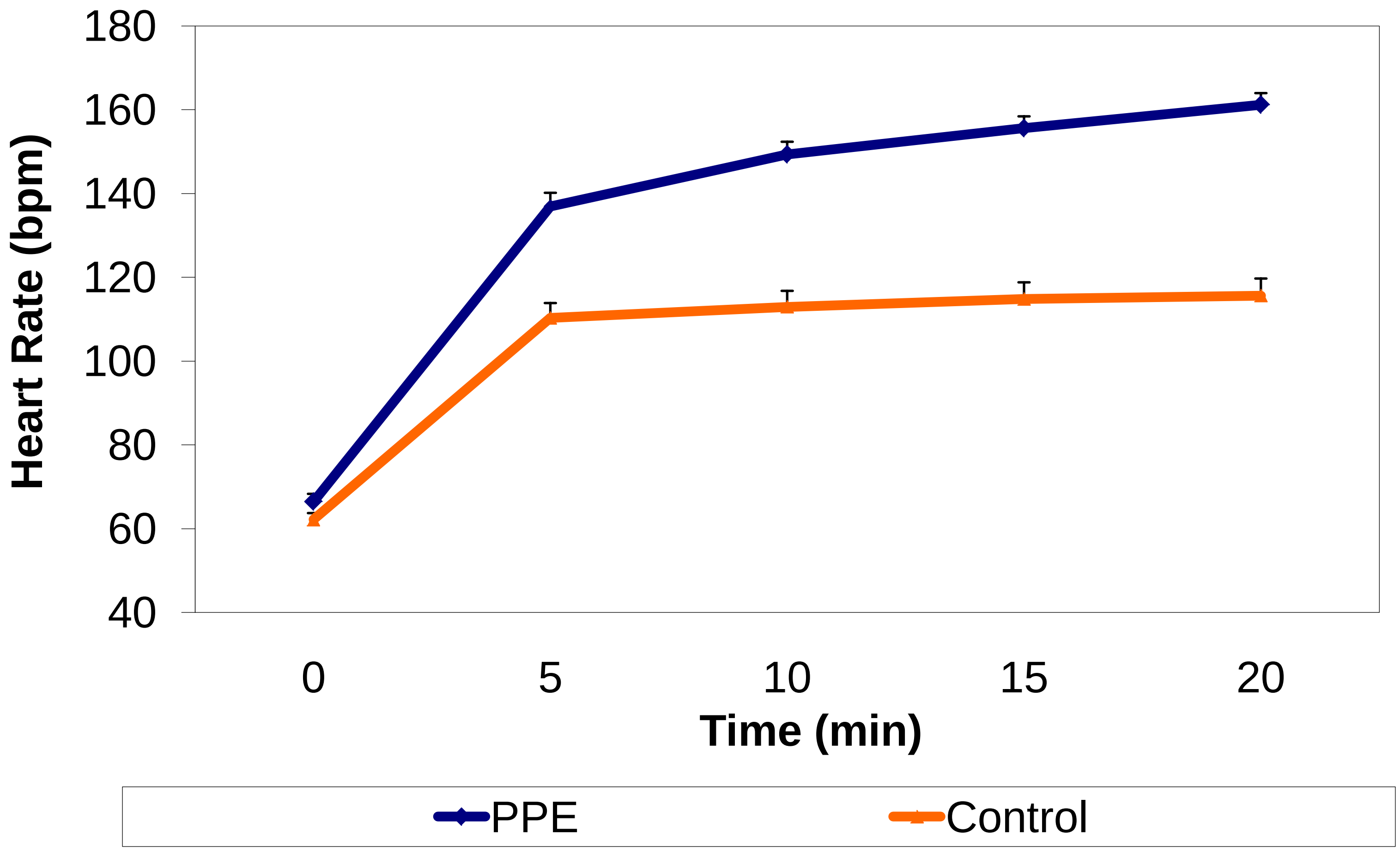
**Design – RM (2 conditions: PPE vs shorts/Tshirt)**

**Protocol – 20 min exercise**
**– 90 min RECOVERY**




DHS AFG EMW-2007-FP-02581

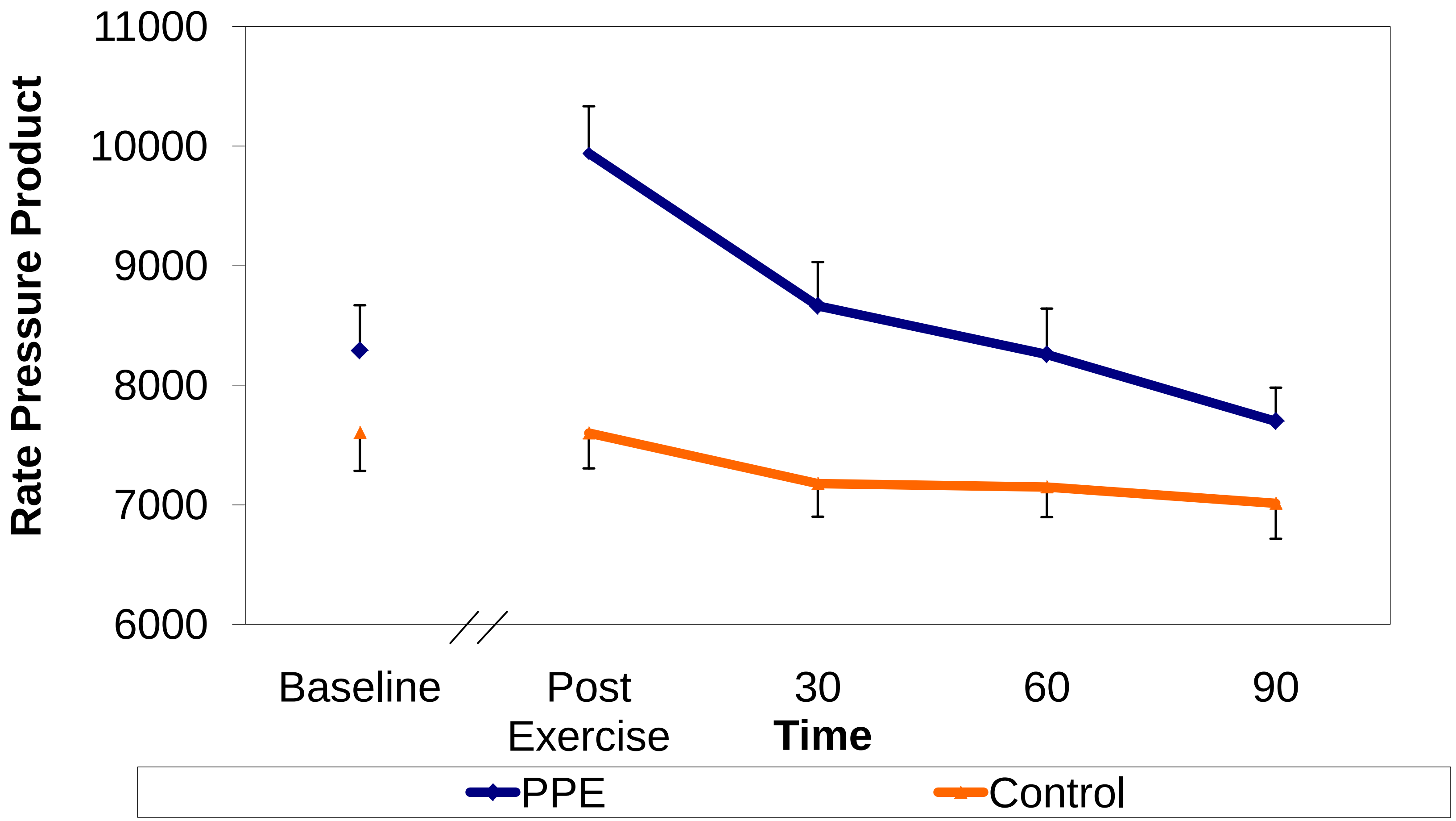
# Heart Rate during Exercise




N=14
Age= 37.9±8.1
BMI= 28.4±3.0

DHS AFG EMW-2007-FP-02581

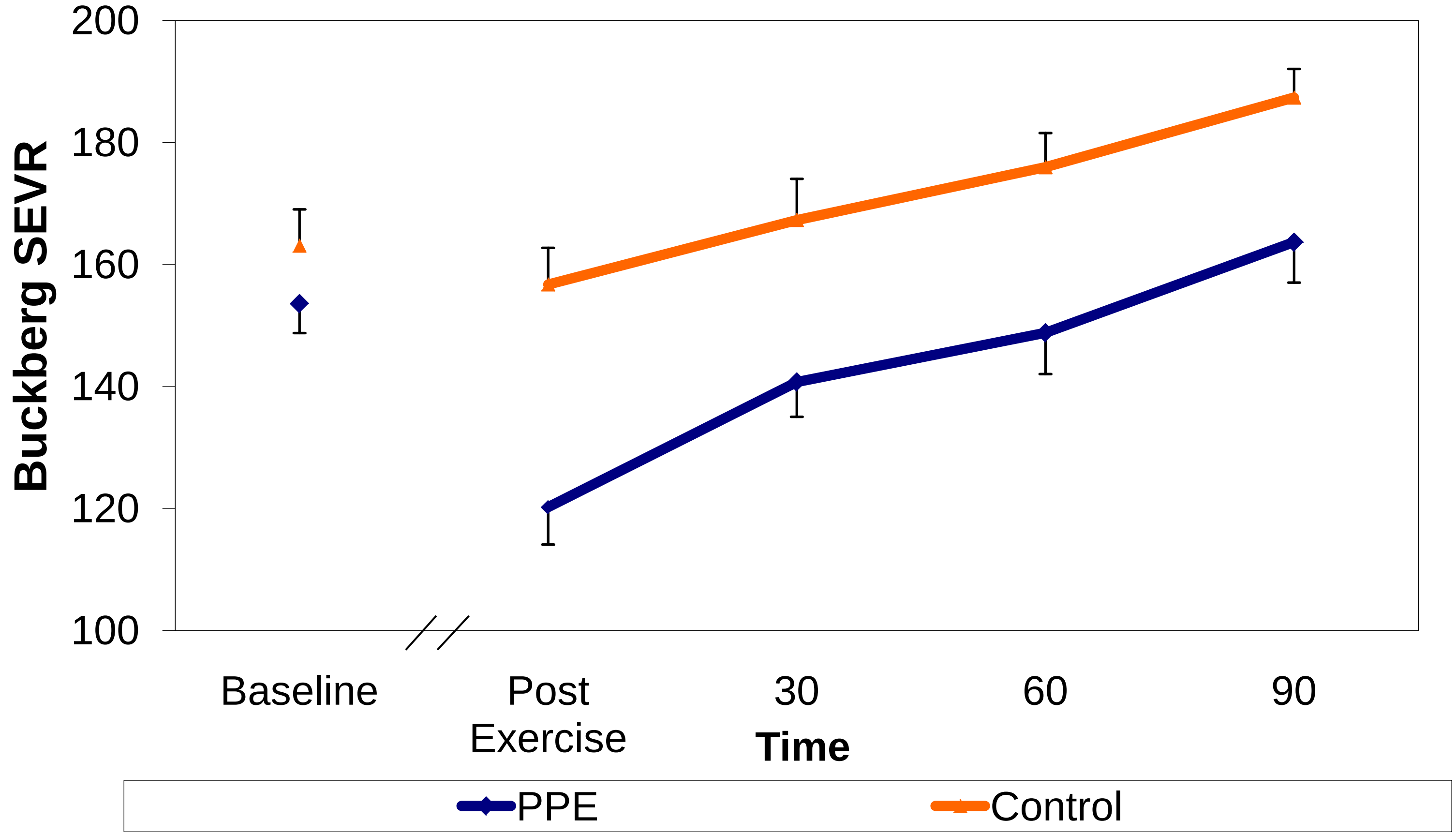
# Rate Pressure Product During Recovery (Myocardial oxygen consumption)




N=14
Age= 37.9±8.1
BMI= 28.4±3.0

2009 AFG Grant

# Myocardial Oxygen Supply (SEVR)




N=14
Age= 37.9±8.1
BMI= 28.4±3.0

# Actual Firefighting Activities



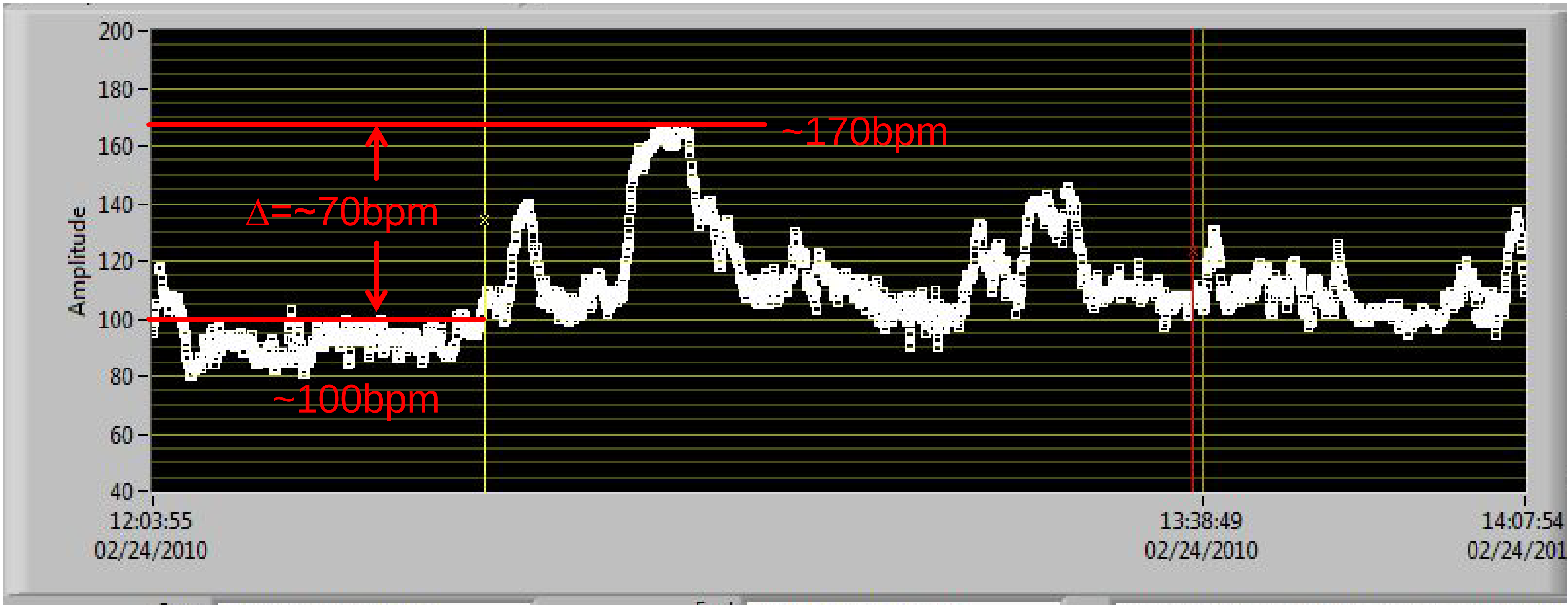
# Protocol

Oxnard and Boston FDs
24 hours of monitoring – PSM
CV strain/Autonomic function

**Alarm response**
During FF activities
Recovery

DHS AFG EMW-2007-FP-02581

# Heart Rate Response while On Scene a Fire Call




Example of raw data from single subject

# Summary

- Firefighting activity places significant strain on the CV system, affecting the heart, vessels and blood
- Firefighters must be physically fit and medically healthy to undertake such strenuous work

Section Four

# Mitigating Risk

Risk Identification

Design Strategies to Modify Risks

- Lessen Individual Risk Factors
- Lessen Risks Associated with Job

Test Strategies (Scientific Hypothesis Testing)

# Mitigating Risk

Preparing Firefighters to Meet the Unique Stresses of Firefighting

- Medically qualified
- Physically fit
- Well hydrated
- Properly trained

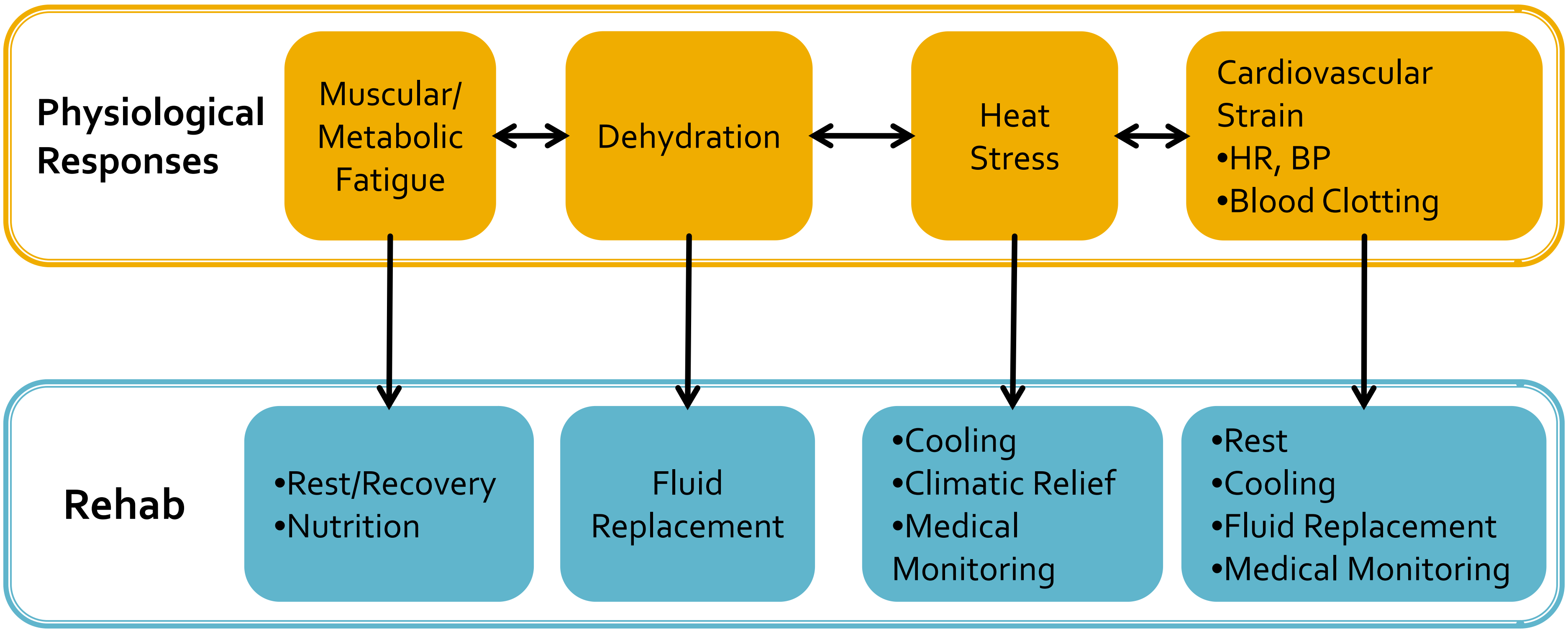
# Mitigating Risk

Decreasing the Stress/Strain of Firefighting

- Staffing
- Approach to fire suppression (aggressive, defensive)
- Rehab (and recovery)

# Discussion

# Example: Decrease Strain of Firefighting



# Example: Decrease Risks to Firefighter