Heat Related Illness and Rhabdomyolysis in Firefighters and National Park Employees

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What is Rhabdomyolysis (rhabdo)?

- Muscle tissue injury or death results in release of muscle cell contents into the bloodstream

Muscle cell component	Consequence of release
Potassium	Heart arrhythmias Seizures Nausea/Vomiting
Myoglobin	Renal impairment

- Many causes and associations
- Creatine Kinase (CK) is the blood test for rhabdomyolysis

Why is Rhabdo a Serious Occupational Health Issue?

- Jobs in hot environments that are physically demanding ↑ risk rhabdo
  - 8% rhabdo cases fatal*
  - Renal failure → lifelong hemodialysis
  - Permanent functional disability
- Result in unemployment/career change due to inability to meet fitness standards

* Cervellin et al 2010

Overview

- Background
- Definitions
- Health Hazard Evaluations (HHEs):
  - Structural Firefighters
  - National Park Employees
- Conclusions

HHE Background

2010 HHE

- Request prompted by 11 cases of rhabdo in wildland firefighters
- Site visit Jan 2011

2012 HHE (Example #1)

- Request from a structural fire department training academy
- Site visit August 2012

2013 HHE (Example #2)

- Request from Safety director concerning heat stress in national park employees
- Site visit July 2013

<u>Common rhabdo risk factors in these worker populations:</u>

1) ↑ core body temperature (CBT)
2) Prolonged, intense exertion

Heat and Rhabdo "two-fer"

Hot work environment may result in rhabdo via:

- ↑ CBT
- Muscle overwork
  - Physical exertion
  - Seizures from heat stroke

In other words…

<u>If the workplace is hot enough for heat stroke to be a concern, then rhabdomyolysis must be also be considered!</u>

Heat Stress Definition

Heat Stress = Net heat load to which a person may be exposed from the combined contributions of:

- Ambient environmental heat
- Active heat source (i.e., fire)
- Metabolic heat (i.e., exertion)
  - ↑ by carrying extra weight
    - Clothing/personal protective equipment (PPE) requirements
    - Job equipment
    - Victims

PPE may also trap heat

Firefighter Heat Load Contributors

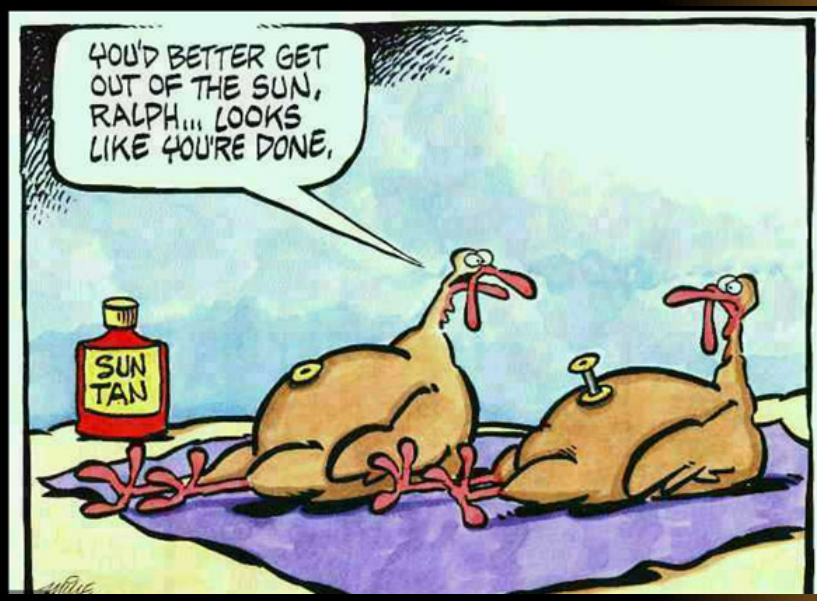
Smokejumper gear 110 lbs.

Chain saw with 4 ft. blade ≈ 20 lbs.

Structural FF turnout gear with SCBA 40-60 lbs. Hoses, ventilation hooks, victim, etc...

Heat Strain

Definition = Physiological response to the heat load to increase heat loss from the body to maintain a stable functional body temperature



Heat Exhaustion = a type of heat strain characterized by muscle weakness, nausea/vomiting, dizziness, and pale clammy skin

Heat Stroke – most severe form of heat strain <u>characterized by a change in mental status.</u> Can be fatal!

HHE Goals

- Comprehensive assessment of heat stress, heat strain and rhabdo and its risk factors during at risk work tasks
- Tailor prevention strategies and educational materials

Rhabdomyolysis (often called rhabdo) is a medical condition resulting from the breakdown of damaged muscle tissue. Due to prolonged physical exertion, wildland firefighters are at increased risk for rhabdomyolysis. If not recognized and treated early, rhabdomyolysis can cause permanent disability and may be fatal.

What can increase your risk for rhabdomyolysis?

- Over-the-counter medications such as decongestants and antihistamines
- Certain antibiotics
- Dietary supplements such as creatine
- Some weight loss products
- Cholesterol lowering drugs known as statins
- Excessive caffeine intake

What are the signs and symptoms of rhabdomyolysis?

- Muscle aches or pains out of proportion for the amount of exercise done
- Muscle cramping
- Tea-colored or cola-colored urine

Rhabdomyolysis is often mistaken for heat stress and dehydration. It can occur in well-conditioned athletes doing their usual workouts, so DO NOT ignore these symptoms.

What wildland firefighters need to know

How do I know if I have rhabdomyolysis?

The only sure way is to seek medical care. A licensed healthcare provider will determine if you need to have a serum creatine phosphokinase (CPK or CK) test to look for muscle proteins in the blood. You cannot tell by symptoms alone if you have rhabdomyolysis.

Severe cases of rhabdomyolysis require hospitalization to monitor the heart and kidneys and to provide emergency treatment for dangerous heart rhythms and loss of kidney function. High rates of intravenous fluids are needed to flush out the muscle proteins and electrolytes without damaging the kidneys. If the kidneys fail immediate dialysis is needed. Sometimes kidney function does not recover, requiring a lifetime of dialysis.

Rhabdomyolysis can be treated without complications if it is recognized early.

What should I do if I have symptoms?

Listen to your body! If your muscles hurt more than expected, if you can't tolerate exertion that you previously could, or if your urine turns unusually dark you should:

- Stop your current activity
- Tell your supervisor or trainer about your symptoms
- Seek immediate care at the nearest medical center
- Ask to be checked for rhabdomyolysis

Reporting your symptoms is not a sign of weakness.

Early detection could save your career and your life!

CDC Workplace Safety and Health | NIOSH | HHE Health Hazard Evaluation Program

Educational documents developed for wildland firefighters

HHE Testing - Rhabdo

- Creatine kinase (CK)
  - Pre and post shift Mon-Thurs
  - Rest days Fri-Sun
    - Firefighters: twice a day
    - Park employees: once a day
  - Endpoint: 2nd declining CK after post shift Thursday
- Basic metabolic panel
- Questionnaire
- Post-shift symptom survey

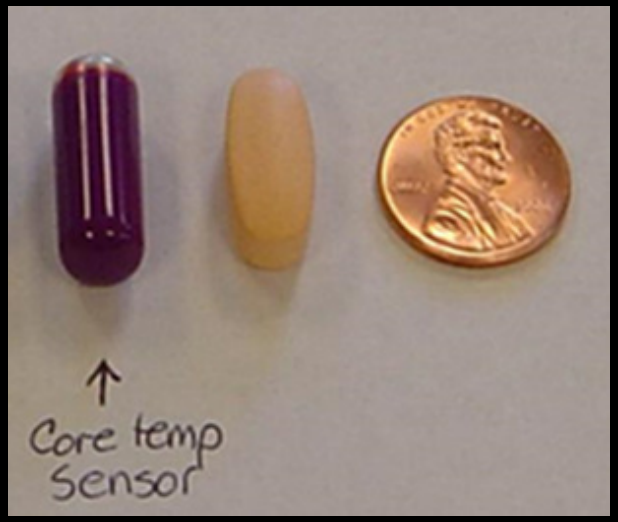
HHE Testing – Heat Stress

- Heat Sources
  - Environment: outdoor temp, fire
  - Exertion
  - Heat trapping by PPE
- Environment Heat Assessment
  - Ambient temperature
  - Relative humidity
  - Solar load
- Exertion
  - One-on-one observation of work tasks
  - Task/effort rated on a standardized scale

Wet bulb globe thermometer (WBGT) placed at each work location

HHE Testing – Heat Strain

- Hyperthermia = elevated core body temperature (CBT)
- Heat Strain assessed by full shift monitoring of:
  - CBT via an ingestible sensor
  - Heart rate via chest strap



Chest strap for heart rate data

Excessive Heat Strain Criteria

- At least one of the following criteria met at any time during testing:
  - CBT > 101.3°F †
  - HR > (180 bpm – employee age) sustained for ≥ 3 minutes
  - Cross shift body weight loss of > 1.5%
  - Any HRI symptoms: sudden, severe fatigue, nausea, headache, dizziness or lightheadedness*

Live fire exercise. Ambient temp 105°F; heat index 120°F

† for acclimatized individuals
* ACGIH ® Threshold limit value criteria

HHE Participant Numbers

- HHE#1→ 32
  - 30 cadets
  - 2 instructors
- HHE#2 → 9
  - 8 Maintenance
  - 1 Archaeologist

Above: Archaeologist in sand dunes
Below: Maintenance crew laying bricks
Ambient Temperature 122°F

Results HHE #1- Rhabdo

- 16/32 (50%) had elevated CK levels
- 1/32 met case definition for rhabdo
  - Peak CBT of 102.4°F was recorded Thursday

Test Day	MON		TUE		WED		THUR		FRI		SAT		SUN
Sample	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM Emergency Department
CK	167	271	230	303	257	320	270	436	430	475	1,349	4,791	**12,665**

Firefighter with Rhabdo

- Notified Saturday PM - Asymptomatic
- Received 8L IV fluids
- CK 7500 IU/L on discharge Monday
- Returned to training Tuesday AM

CK Reference Range:

- Elevated > 380 IU/L
- Rhabdo cutoff CK>1950 IU/L

Results HHE#1 –CBT

- Highest peak CBT ? during live fire exercise
- Using ACGIH TLV CBT > 101.3°F: # exceedances = 67
- Using NIOSH REL* CBT>100.4°F: # of exceedances = 78

Criteria	Number and percent of participants who met criteria at any time during testing
CBT > 101.3°F	
Day 1 (n = 22)	20 (91)
Day 2 (n = 22)	15 (68)
Day 3 (n = 21)†	17 (81)
Day 4 (n = 22)	15 (68)

28/32 (88%) met at least one criteria for excessive heat strain

* Recommended Exposure Limit

Results HHE#1 –Hydration Status

- Blood markers
  - 78% had BUN/Cr>20
  - All were pre-shift samples
- Body weight

Criteria	Number and percent of participants who met criteria at any time during testing
> 1.5% body weight loss	
Day 1 (n = 32)	14 (44)
Day 2 (n = 32)	5 (16)
Day 3 (n = 32)	6 (19)
Day 4 (n = 32)	5 (16)

Results – HHE#2

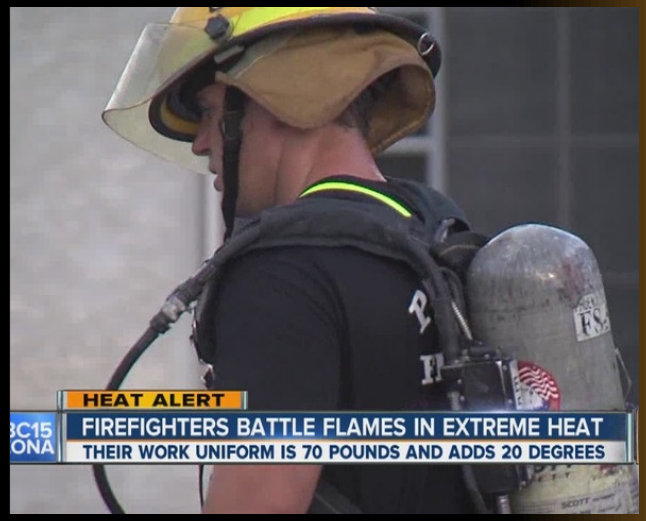
- No cases of rhabdo or dehydration
- One employee had elevated CK level
- 5/9 exceeded ACGIH heat strain criteria:

Criteria	# employees who met criteria at any time during evaluation
HR>180-age in yrs. for 3 or more minutes	5/9
CBT> 101.3°F	1/9
Sudden/severe fatigue, nausea, headache, dizziness, rash, feeling faint or lightheaded	3/9
Weight loss over a shift > 1.5% body weight	1/9

Exceedances mostly occurred at the lower elevation work areas where the WBGT >85°F

Conclusions

- Cannot remove rhabdo/HRI risk factor exposure in specific workers
- Tailor risk reduction strategies
- Rhabdo and HRI occurring despite current risk reduction policies
- Workplace hydration for both structural firefighters and park employees appears to be adequate
  - Firefighters need to increase fluid intake on off-work hours



Phoenix, July 2014: 114°F

HRI/Rhabdo Risk Reduction Strategies

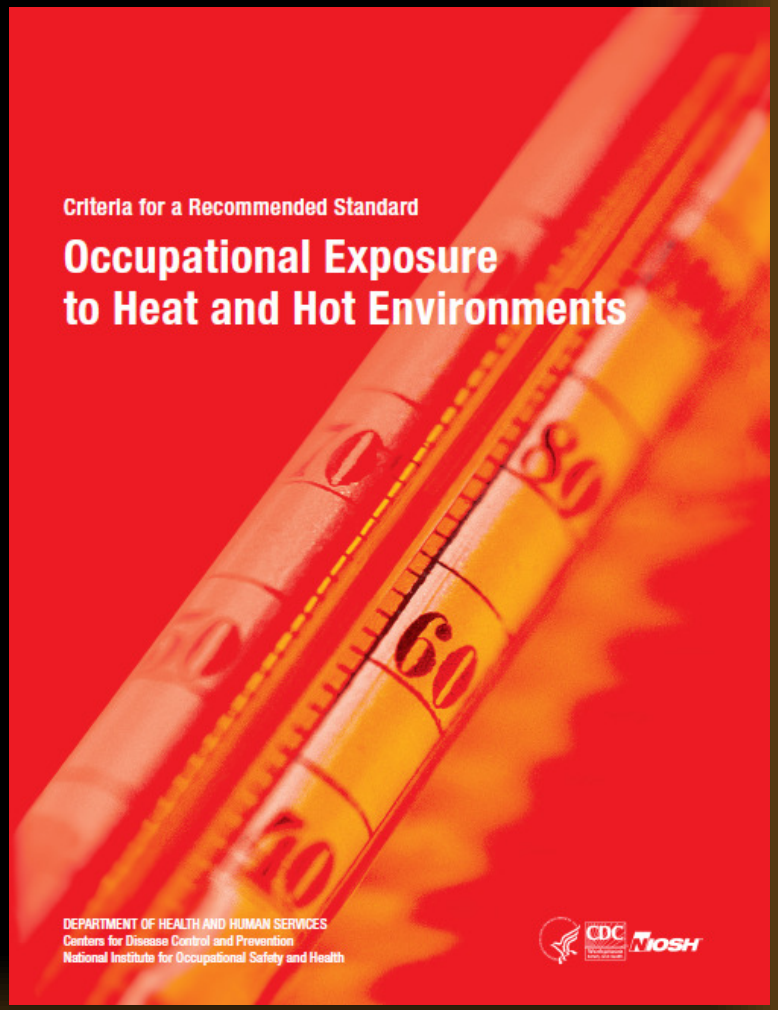
- HRI specific recommendations:
  - Schedule outdoor work/training during cooler months or at night
  - Strict buddy system
  - Rehydration with non-alcoholic and low sugar products
  - Access to cooling stations

- Rhabdo specific recommendations:
  - Increase education/awareness
  - Decrease barriers for seeking care

2016 Update to NIOSH Heat Stress Criteria Document

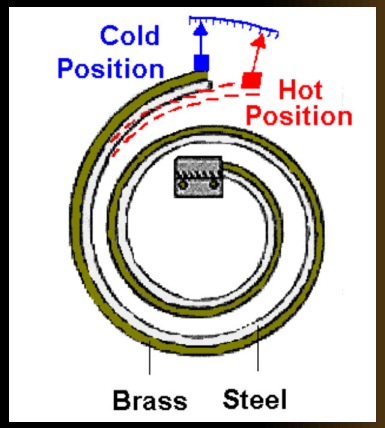
- First update since 1986
- Can be accessed online at: http://www.cdc.gov/niosh/docs/2016-106/default.html
- Citation:

NIOSH [2016]. NIOSH criteria for a recommended standard: occupational exposure to heat and hot environments. By Jacklitsch B, Williams WJ, Musolin K, Coca A, Kim J-H, Turner N. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 2016-106.



What's new?

- More recent data on biological effects of heat
  - Ceiling REL* and RAL† removed!
- Directly addresses heat as rhabdo risk factor
- Training materials
- Psychometric charts - assess indoor thermal environment. Show relationship between:
  - Dry & wet bulb temp
  - Relative humidity
  - Vapor pressure
  - Dew point temp
- Info on bimetallic thermometers



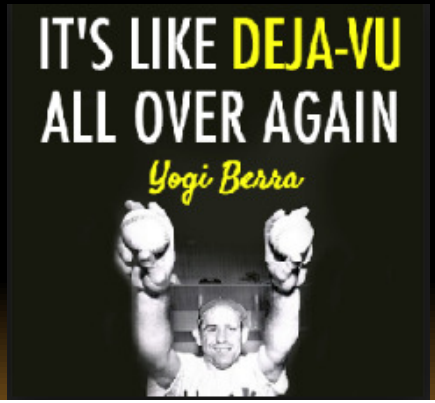
Bimetallic thermometers

No power source needed

* Recommended exposure limit for acclimatized workers
† Recommended alert limit for unacclimatized workers

What wasn't changed?

- RALs and RELs still protective
- Prevention of HRI by:
  - Education
  - ↓ modifiable risk factors
  - Acclimatization plans
  - Hydration
  - Work practices (i.e. work-rest cycles, buddy system, cooling stations, etc.)
  - Sound familiar?



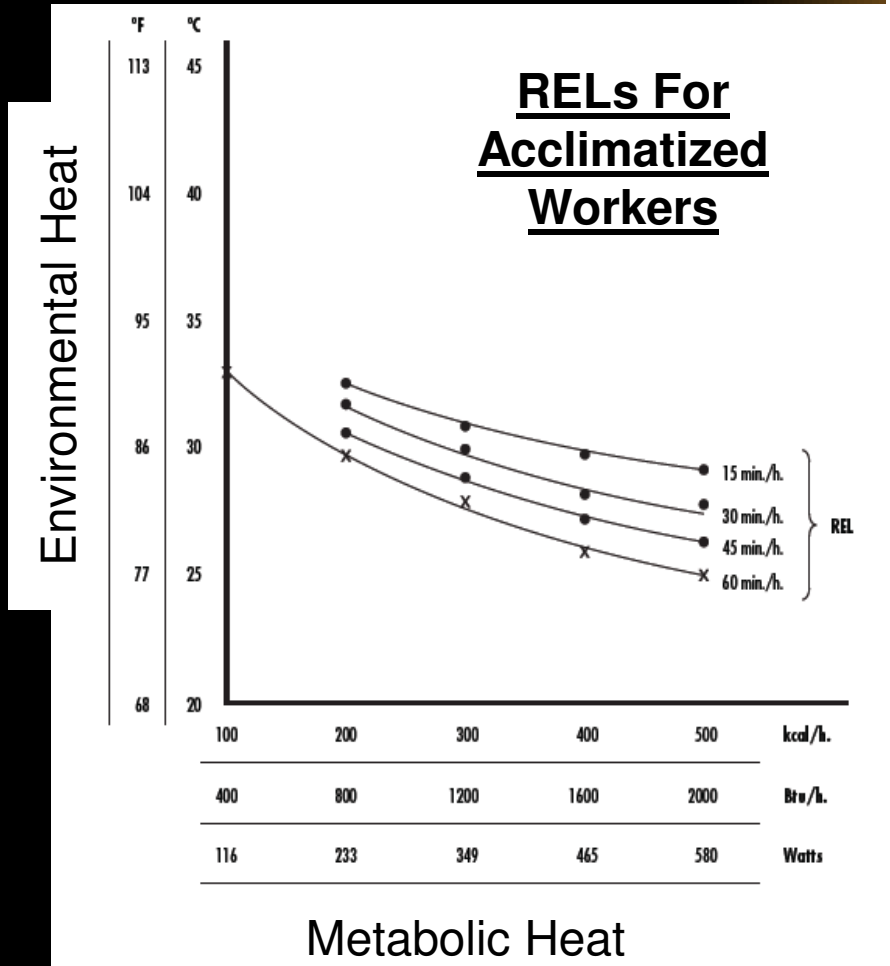


Figure 8-2. Recommended heat stress exposure limits (RELs) for acclimatized workers

Summary

- Many workers have jobs that have unavoidable risk factors for HRI/rhabdo
- Education should include:
  - Signs/symptoms
  - Importance of early recognition/prompt treatment
  - Consequences of delayed medical care
- Tailor risk reduction strategies and educational messages
  - May require a change in work culture

"Time is tissue" – vital principle for rhabdo just like heart attacks and strokes…

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Questions?

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"The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health."

HHE Final Reports

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Addendum Slides

HHE#1 Results Table

Table 2. Participants exceeding heat strain criteria for weight loss, CBT, or heart rate

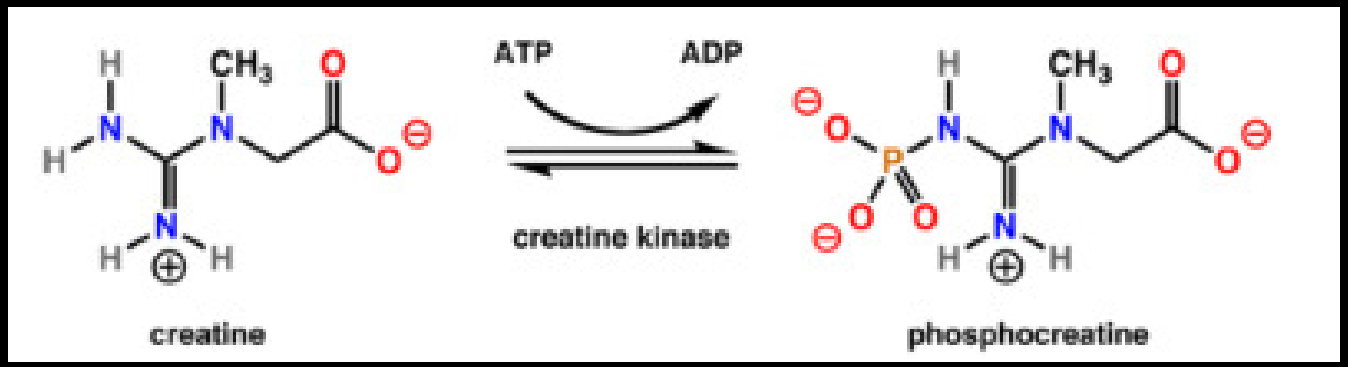
Criteria	Number and percent of participants who met criteria at any time during testing
> 1.5% body weight loss	
Day 1 (n = 32)	14 (44)
Day 2 (n = 32)	5 (16)
Day 3 (n = 32)	6 (19)
Day 4 (n = 32)	5 (16)
CBT > 101.3°F	
Day 1 (n = 22)	20 (91)
Day 2 (n = 22)	15 (68)
Day 3 (n = 21)†	17 (81)
Day 4 (n = 22)	15 (68)
Heart rate > 180 minus age in years*	
Day 1 (n = 22)	13 (59)
Day 2 (n = 21)†	13 (62)
Day 3 (n = 21)†	14 (67)
Day 4 (n = 18)†	13 (72)

*Heart rate sustained for 3 or more minutes with measures a maximum of 15 seconds apart

†Equipment failed to transmit or store data for some participants

What is CK?

- Creatine kinase (also known as creatine phosphokinase or CPK) is an enzyme that catalyzes the chemical reaction cells require to utilize the energy stored in ATP (adenine triphosphate or ATP) molecules



- CK is located in cells that require rapid energy consumption including:
  - Skeletal muscle – the heart is a specialized type of muscle → CK-MB
  - Brain
  - Photoreceptor cells in retina
  - Inner ear hair cells
  - Spermatozoa
  - Smooth muscle

Rhabdo Cardiac Effects

- 8% rhabdo cases are fatal†
- Hyperkalemia (abnormally high level of potassium in the blood)
  - Arrhythmias
  - Seizures
  - Nausea/vomiting

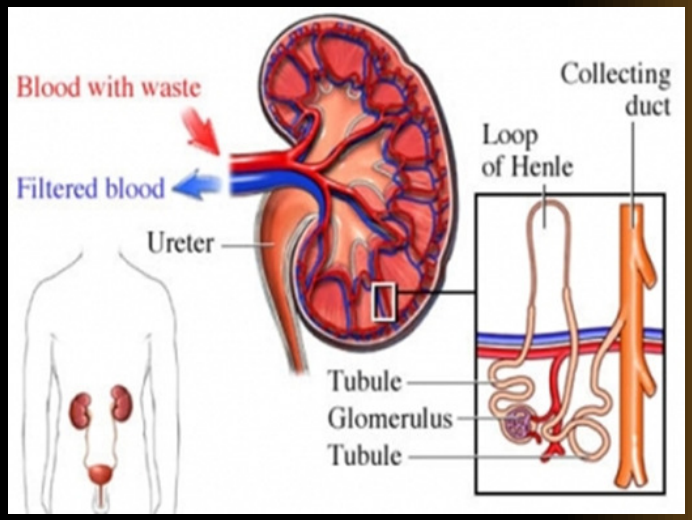
Serum potassium	Typical ECG appearance	Possible ECG abnormalities
Mild (5.5-6.5 mEq/L)		Peaked T waves Prolonged PR segment
Moderate (6.5-8.0 mEq/L)		Loss of P wave Prolonged QRS complex ST-segment elevation Ectopic beats and escape rhythms
Severe (>8.0 mEq/L)		Progressive widening of QRS complex Sine wave Ventricular fibrillation Asystole Axis deviations Bundle branch blocks Fascicular blocks

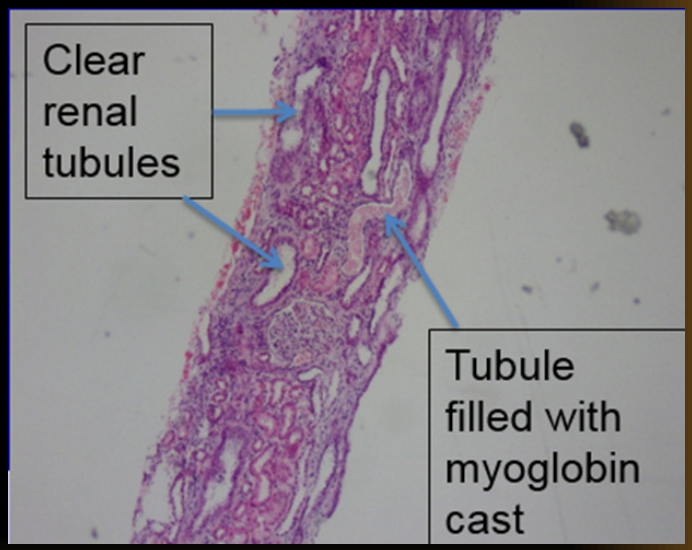
Hyperkalemia effect on EKG [Sood 2007]

†[Cervellin et al 2010]

Rhabdo Renal Effects

- Rhabdo due to exertional heat stroke associated with acute renal failure*
  - Renal function may not return
  - ↑ risk CK>20,000 IU/L
- Dehydration does not cause rhabdo, it just worsens the impact

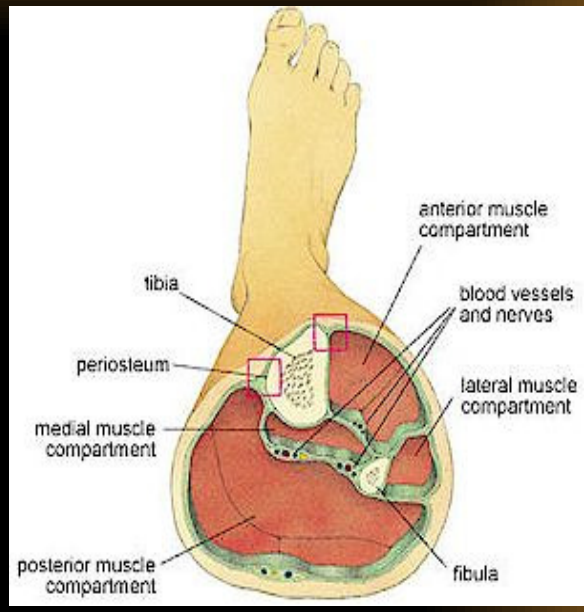




*[Bontempo and Kaji 2010]

Compartment Syndrome

- Compartment: muscles grouped together inside fibrous sheath
- Injured muscle swells; pressure ↑
- Blood supply ↓ to compartment
- <u>Localized</u> muscle pain
- Asymmetric swelling
- Immediate surgery
- Permanent disability risk



Four compartments of the lower leg

- Wildland FF Rhabdo/compartment syndrome
- 3 mile run carrying 45 lbs. in under 45 min

[U.S. Forest Service 2011]

Rhabdo Diagnostic Challenges

- Highly variable presentation
  - Symptoms: none → muscle pain → exercise intolerance → seizures → coma
  - Signs: none → tea/cola colored urine → asymmetric extremity swelling
  - Latency period variable
- Work/recreational activity history not obtained
- Avoiding known risk factors not 100% protective

Tea or cola colored urine characteristic of rhabdomyolysis

Rhabdo - Making the Diagnosis

- Serum creatine kinase (CK) level
  - >5000 International Units/ Liter (IU/L) OR
  - >5x upper limit of normal range for gender*
    - Males > 1,950 IU/L
    - Females > 950 IU/L
- Serial vs. single CK levels
- Most often misdiagnosed as heat stress and/or dehydration if no CK checked

Piccolo Blood Analyzer

*Piccolo Metlyte 8 cartridge information sheet

Rhabdo – Why Inpatient Treatment is Advised

- Aggressive IV fluids
  - Flushes potassium, myoglobin
  - Protects kidney function
- Cardiac monitoring
  - Treat arrhythmias
  - Other potassium ↓ interventions
  - Seizure monitoring
- Nephrology consult
- Compartment syndrome
  - Surgical intervention

✖2

✚

HHE Testing – Hydration Status

- Volume depletion
  - Exacerbate HR response due to heat stress
  - Contribute to responses on symptom surveys
- Pre and post shift
  - Body weight measured
  - Dehydration criteria:
    - BUN/Cr ratio > 20:1 OR
    - Calculated serum osmolarity > 290 mosm/L
- Post-shift symptom survey included estimated total fluid intake during shift

Hydration station for firefighters

Recommendations

- Employees: seek care promptly for HRI/rhabdo symptoms
- Employers need to increase:
  - Pre-employment and periodic medical clearance
  - Training on HRI/rhabdo & possible consequences of delayed treatment
  - Implement <u>and enforce</u> heat stress management policies

www.firegroundrehab.com

Recommendations (cont)

Healthcare providers need to:

- Be aware of inherent risks of HRI/rhabdo in certain worker populations
- Ask about patient's occupation
- Have low threshold to check serial CKs

Occupational medicine personnel may help prevent HRI/rhabdo by:

- Educating management and employees about work-related risk factors & risk reduction methods
- Emphasizing need for prompt medical evaluation in symptomatic employees