

# **Heat Illness and the Wildland Firefighter Risks, Research, and Recommendations**

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## Introduction

Wildland firefighters often work for extended periods in hot, dry, dusty, and smoky conditions. Fires tend to occur during the summer season, when environmental temperatures are at their peak. Direct exposure to the heat of fire can have an added, unpredictable impact. *"Fire creates its own weather and can change winds over several miles. Wildland fires don't just respond to the weather, they interact with the atmosphere surrounding them"* (Coen, 2009). When firefighters engage wildland fires, all the components of a *complex system* emerge -- diversity, connection, interdependence and adaptation (S. E. Page, 2011). Complex systems are difficult, if not impossible, to predict and control because they are continually changing and emergent.<sup>1</sup>

Recent heat-related incidents during the 2011 wildland fire season highlight the need for education and mitigation strategies on this topic. Heat illnesses may be hard to track, as a person may not understand what they are experiencing, or may ignore developing symptoms. Firefighters are often regarded by society as heroes, and thus, it may be hard for them to vocalize their personal observations, or ask for help. This may increase risk for the entire team. *"One athlete experiencing heat-related symptoms (i.e., the "weak link") often indicates that other exertional heat casualties will soon follow"* (Armstrong, et al., 2007, p. 566).

The risk of experiencing a heat illness is interwoven with many factors. *"The risk of (heat illness) rises substantially when athletes experience multiple stressors such as a sudden increase in physical training, lengthy initial exposure to heat, vapor barrier protective clothing, sleep deprivation, inadequate hydration, and poor nutrition"* (Armstrong, et al., 2007, p. 559). When these and other factors are combined, the result may be one or more acute responses, including heat illness and cardiovascular events.

### 1. Exertional Heat Illnesses: An Overview

Exertional heat illness, also called 'heat stress', can occur during any prolonged, intense physical activity - particularly one that lasts more than an hour. In this case, the term "heat" refers to the human body's ability to release heat and cool itself, so that the core temperature is homeostatically regulated and organ systems are protected (Armstrong, et al., 2007). As temperatures rise into the 80°F range and/or with the addition of high humidity (which reduces the capacity for evaporative cooling), heat stresses are more likely to occur (Cohen, et al., 1996). However, higher temperatures are not a *necessary* factor, as heat stress can occur in much milder conditions (Armstrong, et al., 2007).

The body must dissipate heat, which is usually accomplished by radiation, convection and evaporation (Maughan, Shirreffs, & Watson, 2007). Barriers to effective dissipation may include: Environmental temperatures that are higher than

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<sup>1</sup> "Emergence is when the macro differs from the micro - not just in scale, but in kind... One fascinating thing about emergent phenomena is that they arise from the bottom up, without superimposed formalism" (S. Page, 2009, p. 4).

the skin temperature, humidity, and clothing that prevents a release of heat from the body (Armstrong, et al., 2007; Binkley, Beckett, Casa, Kleiner, & Plummer, 2002). Air movement over the skin is essential for heat dissipation, which explains why even a light wind and breathable clothing can reduce the incidence of heat stress disorders. Disorders most likely to occur with exercise include: Heat cramps, heat syncope, rhabdomyolysis, heat exhaustion, heatstroke, dehydration, and hyponatremia.

### **1.1 Heat Cramps**

Heat cramps, also known as 'exercise-associated muscle cramps', are described by the American College of Sports Medicine as, "*painful spasms of skeletal muscles that are commonly observed following prolonged, strenuous exercise, often in the heat*" (Armstrong, et al., 2007). These cramps can appear rapidly, without warning, and may occur in any muscle group, especially in the arms, legs or abdomen. The affected muscle groups may contract in 'wandering spasms', moving from one muscle group to another. Twitching of muscles may also be noticed. Heat cramps can be induced by one or more of the following conditions: Extreme muscle fatigue, loss of hydration, or by hyponatremia - a low sodium electrolyte imbalance. (Armstrong, et al., 2007).

Firefighters are at significant risk for heat cramps, due to their extended physical activities in extreme environments. Treatment should include hydration with electrolyte beverages and stretching the affected muscles to relieve cramping (Brian Sharkey, 2009). Heat cramps, though not fatal on their own, may be a signal that other heat-related disorders are likely to occur.

### **1.2 Heat Syncope**

Heat syncope is also called 'orthostatic dizziness', due to the common presentation of a person becoming dizzy when standing upright, in hot environmental conditions. Symptoms include light-headedness, dizziness, and fainting. "*Heat syncope usually occurs during the first 5 days of acclimatization, before the blood volume expands, or in persons with heart disease or those taking diuretics*" (Binkley, et al., 2002, p. 330). Treatment includes sitting or lying down in a cool location, and hydration with electrolyte enhanced beverages. Heat syncope is considered a relatively mild disorder and usually responds quickly to treatment. However, it shares symptoms in common with other heat related disorders that have greater consequences ("Heat stress," 2011). Thus, firefighters experiencing heat syncope should not be left alone and should receive medical evaluation.

### **1.3 Rhabdomyolysis**

Rhabdomyolysis can occur during exertional heat stroke (EHS), as the body temperature increases. "*Rhabdomyolysis, the breakdown of muscle fibers, occurs in EHS as muscle tissue exceeds the critical temperature threshold of cell membranes*" (Armstrong, et al., 2007, p. 560). Athletes and military groups have shown a tendency for rhabdomyolysis, especially during their first work or practice sessions of the season ("Rhabdomyolysis," 2009). In addition to extreme exertion scenarios, cholesterol reducing 'Statin drugs' have been definitively linked to rhabdomyolysis. It

is critical for any person taking a Statin to learn about the potential effects of the drug, as well as potential preventative measures.<sup>2</sup>

Symptoms of rhabdomyolysis include aching or stiff muscles, muscle weakness or tenderness, and a change in urine color to a dark red or 'cola' color. A person experiencing these symptoms should stop physical activity, follow hydration protocols and seek medical evaluation, as advanced rhabdomyolysis may result in permanent muscle or kidney damage. Prevention for firefighters should include progressive pre-fire season athletic conditioning and proper hydration while on assignment (Brian Sharkey, 2009).

#### **1.4 Exertional Heat Exhaustion**

Exertional heat exhaustion is the inability to continue exercise and occurs most frequently during heavy exertion (Armstrong, et al., 2007). This condition can occur in *all* temperatures, but is more common in the heat. Studies have shown that certain environmental conditions increase the likelihood of heat exhaustion, including an air temperature >91°F, very light or absent winds, and high humidity. Physical factors leading to this disorder include dehydration, and/or a body mass index greater than 27 (Armstrong, et al., 2007; NHLBI, 2011).<sup>3</sup> Dehydration is a very influential factor, as laboratory and field studies have shown. One study suggests, "*Exercise does not induce heat exhaustion unless dehydration is present*" (Armstrong, et al., 2007, p. 562). However, tolerances for dehydration are very personal and, "*Wide variations of heat tolerance exist among athletes*" (Armstrong, et al., 2007, p. 557).<sup>4</sup>

A recent firefighter fatality was attributed to hyperthermia, *without* severe dehydration.<sup>5</sup> Firefighters who maintain hydration may be less likely to experience heat exhaustion or heat stroke, but other factors can lead to these conditions (Brian Sharkey, 2009). If heat production in the body is extremely high (such as with hard labor), adequate hydration may not be able to dissipate the rising core temperature through sweat and other mechanisms (Cuddy & Ruby, 2011).

Common symptoms of heat exhaustion include headache, weakness, dizziness, "heat sensations" on the head or neck, chills or "goose flesh", nausea, vomiting, diarrhea, irritability, low blood pressure, elevated pulse or respiratory rate, and decreased muscle coordination (Armstrong, et al., 2007, p. 563). Immediate measures should be taken to move the firefighter to a cool, shaded location and remove clothing, to encourage airflow over the skin. Rehydrate with electrolyte-enhanced beverages. Heat exhaustion can mimic other disorders, such as hypoglycemia, so it is best to have the person evaluated and treated by a trained medical professional, preferably on-

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<sup>2</sup> Former astronaut and USAF flight surgeon, Duane Graveline, suggests taking coenzyme Q10 with any Statin therapy. His website offers extensive information:  
[http://www.spacedoc.com/statin\\_associated\\_rhabdomyolysis.html](http://www.spacedoc.com/statin_associated_rhabdomyolysis.html)

<sup>3</sup> The body mass index (BMI) is a measure of body fat, based on height and weight. A BMI ranging from 25 - 29.9 indicates 'overweight' status. To calculate BMI easily, go to the following website:  
<http://www.nhlbisupport.com/bmi/>

<sup>4</sup> Blood chemistry 'normal' values are based on wide populations and may not fully reflect individual differences.

<sup>5</sup> BLM firefighter fatality, on the CR 337 fire in Texas, July 7, 2011.

scene. Left untreated, heat exhaustion can progress to heat stroke. (Armstrong, et al., 2007; Domitrovich & Sharkey, 2010)

### **1.5 Exertional Heat Stroke**

Exertional heat stroke occurs when the core body temperature rises above 104°F (hyperthermia). By the time the temperature has progressed to the level of 'heat stroke', cardiac output may no longer be able to deliver oxygen to tissues or mitigate the internal heat buildup. At this extreme, hyperthermia can result in organ damage, coma, and death (Armstrong, et al., 2007; Binkley, et al., 2002).

Signs of heat stroke can initially be similar to heat exhaustion and may also include clumsiness, slurred speech, stumbling, confusion, and rapid breathing (hyperventilation). The skin may be wet or dry at the time of initial collapse, but as it advances, sweaty cool skin is a common sign of heat stroke (Armstrong, et al., 2007; Binkley, et al., 2002).

Heat stroke can progress to a dangerous level in just 10 to 15 minutes ("Heat stress," 2011). "*Aggressive cooling is the most critical factor in the treatment of exertional heat stroke*" (Binkley, et al., 2002, p. 334). Immediate measures must be taken -- an ice water bath may be the quickest way to cool the person down, but perhaps not the most practical in the field. Alternatives would include using ice packs or ice water soaked towels -- at least in the armpits, groin, and neck. "*Although some patients exhibit a misleading "lucid interval" that often delays the diagnosis, observation and cooling therapy should continue*" (Armstrong, et al., 2007, p. 561). It is critical to keep cooling measures going until professional medical attention is attained.

## **2. Dehydration**

Dehydration ('hypohydration') can occur when the body loses a large amount of water, especially during exercise that lasts more than 40 minutes. The average human body contains about 60% water. Athletes in prime fitness can lose 1-2 liters of water per hour, without negative effects, as long as they can effectively replace the lost fluid (Maughan, et al., 2007).<sup>6</sup> Firefighters are similar to professional athletes, in many respects. In fact, "*Studies of energy expenditure during this arduous work indicate that daily energy expenditure approximates that of running a marathon*" (Elliot & Kuehl, 2007, p. 54). Unlike an athlete, who may only perform for minutes or hours and then have the chance for complete recovery, a wildland firefighter may be on assignment for weeks at a time in extreme environmental conditions.

Dehydration can result in impaired thermoregulation, which can trigger other heat illnesses. Dehydration can increase the perception of effort and decrease work performance. Concentration and alertness may be affected, with a noticed impairment of cognitive ability (Maughan, et al., 2007). This may put the firefighter at increased risk of injury, as well as illness. Other symptoms include increased heart rate,

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<sup>6</sup> In addition to water losses, the body may experience loss of electrolytes - particularly sodium, which can lead to hyponatremia (Maughan, et al., 2007).

headache, nausea, and insomnia. Severe dehydration can lead to delirium, coma and death.

An easy way to measure for overall water loss is to step on a scale -- a loss of 2% or more body weight, during exercise, is considered 'dehydration' (Maughan, et al., 2007; Brian Sharkey, 2009). Though individual tolerances to fluid vary, daily weighing might be one tool to help firefighters predict dehydration, so they can take steps to replace lost fluids before heat illness becomes an issue. Another simple indicator of hydration status is urine color -- a pale yellow to straw color indicates a hydrated state, while a darker color may indicate dehydration (Binkley, et al., 2002; Brian Sharkey, 2009). However, urine color may not represent sodium loss.

### **3. Hyponatremia**

Hyponatremia is a precondition for many exercise related heat illnesses. A hyponatremic state (low blood-serum sodium levels) may occur when a person loses large amounts of sodium, usually through sweating, which results in an electrolyte imbalance. This imbalance directly affects muscle contraction. If the firefighter drinks too much *plain water*, without replacing this sodium loss, the result may be hyponatremia, or a worse state called 'water intoxication' (Binkley, et al., 2002; Helmenstine, 2011).<sup>7</sup>

The first signs of hyponatremia may be gastrointestinal discomfort or nausea. An advanced progression may lead to, "*...unusual fatigue, confusion, disorientation, a throbbing headache, vomiting, wheezy breathing, and swollen hands and feet. Seizures, coma, and death are possible if plasma sodium reaches very low levels*" (Brian Sharkey, 2006). This condition may also lead to heat cramps. Treatment of hyponatremia includes ingestion of fluids or foods that contain sodium, rest from labor, and stretching cramping muscles. In extreme cases, intravenous fluids may need to be administered (Armstrong, et al., 2007; O'Connor & Kasatsky, 2008).

### **4. Hydration Strategies**

Preventing heat illnesses requires a multi-faceted approach. Hydration plays a critical role in the body's release of heat. However, high work intensity (internal heat production) and/or extended exposure to external heat can result in heat stress, even if adequate hydration is maintained (Cuddy & Ruby, 2011; Domitrovich & Sharkey, 2010). Wildland firefighters may not have a choice about their work location, or be able to mitigate the dynamic conditions that occur on a fire assignment. However, a firefighter can become educated on the amount and type of beverages that will assist in maintaining hydration.

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<sup>7</sup> Water intoxication is a potentially fatal result of extreme sodium loss. "*From the cell's point of view, water intoxication produces the same effects as would result from drowning in fresh water. Electrolyte imbalance and tissue swelling can cause an irregular heartbeat, allow fluid to enter the lungs, and may cause fluttering eyelids. Swelling puts pressure on the brain and nerves, which can cause behaviors resembling alcohol intoxication*" (Helmenstine, 2011). Water intoxication can lead to seizures, coma, and death.

#### **4.1 Total Fluid Intake**

It is important to drink enough total liquid to maintain hydration during intense exercise or extreme conditions. "*Wildland firefighters should consume a quart (liter) of fluid (water and sports beverages) for each hour of work in the heat*" (Brian Sharkey, 2006, p. 10). Total ingested liquid helps maintain blood volume and supplies water for sweating, which then cools the system. Sipping throughout each hour may be more effective than consuming in large, singular amounts (Brian Sharkey, 2009). Firefighters should pre-hydrate at least an hour before work and continue to drink for 2 - 3 hours after the shift, to replenish lost fluids.

#### **4.2 Water and Electrolytes**

Water is an important component of hydration and should make up 1/2 to 2/3 of the total beverage intake. However, for extended work or high temperature conditions, drinking plain water is not enough - firefighters must replenish lost electrolytes with beverages or foods that contain sodium and potassium. These minerals are important for muscle and nerve function, and also help the body maintain hydration (Brian Sharkey, 2009). Beverages containing electrolytes should make up 1/3 to 1/2 of the fluid intake. Effective drink choices are discussed below. Electrolytes may also be consumed in food and should be eaten in small, frequent amounts, in order to keep electrolyte levels steady (Brian Sharkey, 2006).

#### **4.3 Sports Drinks**

Sports drinks (e.g. Gatorade®, Powerade®, Cytomax®, etc.) are one premixed option for replacing electrolytes. These beverages combine water, carbohydrates (in the form of sugars), sodium, and sometimes potassium. Electrolyte beverages and supplements vary widely, so firefighters should become familiar with the content of their selection. It is suggested that a 1-liter size electrolyte beverage contain 140 - 500 mg sodium, and 80 - 308 mg potassium (B. Sharkey, 2004). Sports drinks should make up 1/3 - 1/2 of the total ingested liquid (Brian Sharkey, 2009). It is important to mention that beverages labeled as 'Energy Drinks', such as Red Bull®, Rockstar®, Monster®, etc., are not sports drinks and are not suitable for hydration purposes. Energy drinks are discussed in detail, later in this paper.

Sodium is more critical to replace than potassium, as it can be lost in large amounts through sweating (Armstrong, et al., 2007). Sodium can have a large impact on hydration levels, by itself. "*It has been previously demonstrated that sodium supplementation reduces urine output and expands plasma volume, thus hastening rehydration*" (Cuddy, Ham, Harger, Slivka, & Ruby, 2008, p. 178). Simply adding 1/4 - 1/2 teaspoon of table salt to a beverage will meet sodium demands for hydration and help prevent water intoxication and heat illnesses. Many sports drinks have added sodium, which will fit the needs of most firefighters.

#### **4.4 Carbohydrates: Positive Effects**

The addition of carbohydrates to beverages has shown positive benefits. Carbohydrates are usually provided in the form of simple sugars, which supply energy demands during periods of hard work. One study with wildland firefighters showed,

"When subjects ingested 200 milliliters of a 20-percent carbohydrate liquid every hour (160 kilocalories), they maintained blood glucose and sustained a significantly higher level of work output" (Cuddy, et al., 2008; S. Gaskill, Ruby, Goodson, McClaughry, & Cuddy, 2005, p. 7). The firefighters showed a 16.6% increase in their work, especially during shift times that were normally less productive, such as before lunch and 4 hours before end of shift. The perception of fatigue was lower with carbohydrates, and alertness and cognitive function were higher. Firefighters were in a better mood and said the beverages tasted good, which encouraged them to drink (S. Gaskill, et al., 2005; Brian Sharkey, 2007).

Several studies have detected a positive link between carbohydrate ingestion and immunity increase, for athletes or workers who engage in arduous activities. A study with wildland firefighters showed that the immune function indicator, sIgA, became depressed after hard labor. This can increase susceptibility to illnesses, such as respiratory infections.<sup>8</sup> Firefighters given a carbohydrate enhanced beverage showed less depression of sIgA and also recovered this immunity factor more quickly, than a group that did not receive carbohydrate beverages.

In addition, added carbohydrates have shown a positive effect on overall hydration. A study with wildland firefighters showed that those given a drink containing carbohydrates consumed 43% less total fluid, but maintained the same hydration levels as those who drank a non-carbohydrate beverage (Cuddy, et al., 2008). Other studies have shown the same results, "*It has been previously demonstrated that sodium supplementation reduces urine output and expands plasma volume, thus hastening rehydration*" (Cuddy, et al., 2008, p. 178). One study showed that, "*Water absorption increases 6-10 fold when 2-6% carbohydrate (CHO) is added to saline*" (O'Connor & Kasatsky, 2008, p. 42). This finding may be useful to firefighters in the field, as they may need to carry less weight volume of fluid in their packs.

Carbohydrates may also be consumed as food, but should be eaten in frequent, snack size amounts. Simple carbohydrates, such as sugars, may be metabolized more quickly than complex carbohydrates. Most prepackaged foods already include sugars (*The Science of Sugars*, 2010). Typical fire-line food includes military style 'Meals-Ready-To-Eat' (MRE's), which are designed as large-portion meals. A study with wildland firefighters compared MRE's to another military ration, called 'First Strike Ration' (FSR). First Strike contains a variety of 'snack sized' foods, which can be consumed at any time, over a period of three days. The study found that firefighters ate more of the FSR than the MRE, enjoyed the ability to snack throughout the day, and liked the taste of the food (S. Gaskill, et al., 2005; Montain, et al., 2006). Like endurance athletes, who eat in small amounts throughout an event to keep energy levels high, firefighters may find the same benefit.

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<sup>8</sup> Firefighters are already at greater risk for respiratory infections, due to smoke inhalation (Brian Sharkey, 2009).



## 4.5 Carbohydrate Cautions

While carbohydrates are essential for physical function and have several added benefits, not all people require the additional calorie load. Wildland firefighters actively engaged in physically demanding work may need two or more times the caloric intake of sedentary people, or those performing light physical tasks. Carbohydrates can add up quickly and create caloric excess for those who are not expending the energy, which can lead to weight gain. The Centers for Disease Control and Prevention (CDC) states that 33.8% of adults in the U.S. are in the 'obese' range (BMI >30).

Obese individuals are more likely to experience heat stress events, because the fat layer decreases heat loss from the body (Binkley, et al., 2002). Obesity also increases the risk of numerous diseases, including coronary heart disease, type 2 diabetes, and hypertension ("Overweight and obesity," 2011).<sup>9</sup> Arteriosclerotic vascular disease affects the efficiency of blood flow through the arteries, which can impede the ability to dissipate heat, making the person more prone to heat illness.

Diabetics and pre-diabetics<sup>10</sup> should use caution when selecting sugar-based drinks or foods. A deficiency in insulin makes it harder for a diabetic's body to metabolize sugar, which can build up in the system and lead to potentially fatal consequences. While carbohydrate loading may be useful for the active wildland firefighter population, diabetics should consult with a nutritionist. Some populations, such as Native Americans, have an increased risk of diabetes and should monitor their intake even more cautiously.<sup>11</sup>

All firefighters should learn about nutrition and apply these principles to their fire assignment food and drink choices. In 2004, researchers at the University of Montana studied wildland firefighters and their knowledge of nutrition. *"In the survey, 75 percent of the respondents agreed that a basic class in nutrition should be one of the requirements for wildland firefighter training. This survey showed that fire crew members had numerous misconceptions and lack information concerning the nutritional demands of wildland firefighting"* (Kodeski, Ruby, Gaskill, Brown, & Szalda-Petree, 2004).

## 5. Additional Risk Factors for Heat Illness

### 5.1 Caffeine

Caffeine is frequently used by firefighters to maintain alertness and help with energy demands, especially during long shifts. Athletes have also used caffeine for its alleged performance-enhancing quality. However, a number of negative effects have been associated with this chemical, which could potentially impact firefighters.

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<sup>9</sup> A full list of diseases can be found on the CDC website: <http://www.cdc.gov/obesity/index.html>

<sup>10</sup> Pre-diabetics have glucose levels above normal, but not high enough to be classified as 'diabetes' ("Basics about diabetes," 2011).

<sup>11</sup> American Indians and Alaskan Natives are more than twice as likely to develop diabetes, as non-Hispanic whites of a similar age ("National diabetes education program tailors cardiovascular disease message for American Indians and Alaska natives," 2005)

"As a stimulant, caffeine jazzes up your whole body, increasing blood pressure, heart rate and in some cases, causing heart palpitations and an irregular heartbeat. Caffeine also leads to headaches, jitteriness, agitation, stomach problems and abnormal breathing" ("Why mixing alcohol and caffeine is so deadly," 2010).

Caffeine is not fully regulated by the U.S. Food and Drug Administration (FDA), because it is considered a 'chemical' and not a 'nutrient'. If added to a food or beverage, the ingredients label must state caffeine in the content, but it does not need to list the amount ("Why isn't the amount of caffeine a product contains required on a food label?," 2011).

The amount of caffeine that is contained in products can vary widely. The Mayo Clinic lists amounts found in common food, beverages, and medications, including the following examples:<sup>12</sup>

Coffee (caffeinated)	27 - 200 mg per 8oz
Tea	40 - 120 mg per 8oz
Soft drinks	0 - 71 mg per 12oz
NoDoz® max strength	200 mg (1 tablet)
Monster® energy drink	160 mg per 16oz
Red Bull® energy drink	76 mg per 8.3oz

Caffeine has received wide study, but results are conflicting. Some studies have shown positive affects of caffeine on cognitive performance (Howard & Marcinski, 2010).<sup>13</sup> Other studies show a positive benefit on endurance, in athletes. However, at least one study did not support this -- athletes running a 21-km race, in hot and humid outdoor conditions, showed no benefit on performance from caffeine consumption (Cohen, et al., 1996).

Caffeine has often been considered a diuretic agent, which might cause people to lose hydration. However, a 2006 study did not support this claim. College men were given caffeine at a rate of up to 6mg/kg (a 175# man would receive 477 mg caffeine, at this dose), and then ran for 90 minutes on a treadmill in hot, humid conditions. The study was done consecutively over 6 days and found that, "*Chronic caffeine did not alter fluid-electrolyte parameters at baseline or during exercise and did not negatively impact ability to perform exercise in the heat*" (Roti, et al., 2006). In comparison, other studies have shown that caffeine may have a diuretic effect if more than 300 mg is consumed (O'Connor & Kasatsky, 2008). Research for this paper could not find evidence that the diuretic effect of caffeine had been studied during intense physical activity lasting *more* than 90 minutes. Thus, the effect of this chemical on wildland firefighters, who may work 12 + hour shifts, is unknown.

Caffeine has been reported to have negative or dangerous effects on the cardiac system. Due to its stimulant nature on the sympathetic nervous system, heart rate and blood pressure may be increased, which can place a strain on the heart (O'Connor &

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<sup>12</sup> ("Caffeine content for coffee, tea, soda and more," 2009)

<sup>13</sup> Cognitive performance referenced included attention, reaction time, visual search, psychomotor speed, memory, vigilance, and verbal reasoning.

Kasatsky, 2008). For those with existing heart problems, this strain will increase the risk of heat related illnesses, as the body's thermoregulatory system may not function at full capacity.

## 5.2 *Energy Drinks*

While many people enjoy coffee or soda on a daily basis, few use caffeinated beverages in such extreme conditions as wildland firefighters. The recent exponential sales and aggressive marketing of 'energy drinks' have changed the amount and conditions under which these beverages are consumed. 'Sports drinks', like Gatorade®, are designed for hydration and are appropriate for physical activities. Energy drinks claim to provide mental alertness and physical 'energy'. This claim, however, comes from ingredients like concentrated carbohydrates (sugars), moderate to large amounts of stimulating caffeine, a few vitamins, and added herbal supplements (which may not be listed on the label by name).

Earlier in this paper it was mentioned that carbohydrates might provide a positive effect for firefighter hydration. Energy drinks, however, often contain more than 10% carbohydrates, in the form of sugars. *"Most of the beverages sold as energy drinks contain more carbohydrates (80 to 120 grams per liter) than are needed during work (30 - 50 grams per liter)"* (Brian Sharkey, 2002, p. 5). This high sugar load may decrease hydration, *"High carbohydrate concentrations will delay gastric emptying, thus reducing the amount of fluid that is available for absorption; very high concentrations will also result in secretion of water into the intestine and thus temporarily increase the danger of dehydration"* (O'Connor & Kasatsky, 2008, p. 42). The extra carbohydrates may also lead to gastrointestinal problems.

The amount of caffeine found in energy drinks and 'energy shots' (highly concentrated energy drinks), can range from 50 mg per serving, to over 500 mg. An average cup of coffee has approximately 100 mg. *"At least 130 energy drinks now exceed 0.02% caffeine (Energyfiend website, 2008), including one that contains 505 mg in a 24 oz can (the equivalent of 14 cans of a typical cola or several cups of coffee)"* (Reissig, Strain, & Griffiths, 2009). Though several sources agree that 300mg of caffeine is 'safe' for most people, this chemical does not create the same response in all individuals. The effect on firefighters may be different, especially when other work stresses are added.

Some energy drinks contain herbal additives that include caffeine, or have stimulant effects that are more potent. The FDA does not directly regulate herbal supplements, so their effects are not tracked and may not be understood. Energy drinks emerged 50 years ago in the Far East and contained herbs that were associated with health benefits. This area of the world has a familiarity with herbal remedies that is thousands of years old. These areas still use herbs as medicine - an understanding that has not passed to most Western countries. Energy drinks often make claims that their ingredients will provide 'enhanced energy' or 'mental stimulation'. Research on herbal supplementation is lacking in Western countries, including knowledge of the safety and/or benefits (Ehrlich, 2009; Herbal supplements: What to know before you buy," 2009; Reissig, et al., 2009; 2009).

Potential negative effects associated with energy drinks have led several countries to impose regulations. Canada advises its citizens, "*Excessive drinking of energy drinks or mixing them with alcohol can have serious health effects*" (Canada, 2010). The European Union requires a high-caffeine label on energy drinks. "*Norway restricts the sale of Red Bull to pharmacies, while France (until recently) and Denmark have prohibited the sale of Red Bull altogether*" (Reissig, et al., 2009, p. 2). In the United States, energy drink labels are not regulated - they must state that caffeine is present in the beverage, but they do not have to list the amount. Energy drink labels are frequently non-descriptive, hiding ingredients under a comprehensive category, such as 'Energy Blend'. Consumers may not know what they are drinking.

Energy drinks have been recently addressed in major league baseball, where several teams have stopped providing these beverages, discouraged their use, or completely banned their use with players. "*The Astros took precautions in 2009 when reliever Wesley Wright was treated for dehydration at a hospital after drinking several cans of Red Bull before pitching*" (Nightengale, 2011).

The clinical term, 'caffeine intoxication', has been used by the World Health Organization to describe a range of symptoms that can occur when a large amount of caffeine is ingested. "*Common features of caffeine intoxication include nervousness, anxiety, restlessness, insomnia, gastrointestinal upset, tremors, tachycardia, psychomotor agitation... and in rare cases, death*" (Reissig, et al., 2009, p. 4). An example from the Journal of Medical Case Reports discusses two cases of atrial fibrillation in adolescent boys, "*who presented with palpitations or vague chest discomfort or both after a recent history of excessive caffeine consumption*" (Rocco, During, Morelli, Heyden, & Biancianiello, 2011). Another case of caffeine intoxication occurred in a 28-year old man, who was admitted to the hospital for sudden tonic clonic seizures (grand-mal), after drinking several (~6) cans of Red Bull® (Trabulo, Marques, & Pedroso, 2011).

In 2009, the American Association of Poison Control Centers' National Poison Data System received reports from sixty of the nation's U.S. poison centers. The category 'Caffeine Exposures' was listed in 4,535 of the reports. Outcomes were listed as: None (570); Minor (629); Moderate (393); Major (7). No deaths were reported in relation to caffeine exposure, at least from these poison control centers in 2009 ("AAPCC Annual Data Reports," 2009). There is no poison control category for 'Energy Drink Exposure' in the U.S. However, deaths have been reported from energy drink consumption in Australia, Ireland, and Sweden (Reissig, et al., 2009).

The combined effects of energy drinks and alcohol have also raised serious concerns. The stimulants in energy drinks may delay the sedative effects of alcohol, leading to higher alcohol consumption. However, the stimulant and sedative effects of each will not cancel each other out. Some energy drinks contain alcohol, sometimes in large amounts that can be dangerous.<sup>14</sup> The combined consumption of energy drinks and alcohol was also found to stimulate 'risky' behavior in college students (Reissig, et al., 2009).

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<sup>14</sup> The popular energy drink Four Loko® is one example, with a 12% stated alcohol volume, in a 23.5 oz can. This drink is sometimes referred to as "Black-out in a can" ("Why mixing alcohol and caffeine is so deadly," 2010).

Energy drink manufacturers repeatedly suggest that 'moderate consumption' of their beverages is safe. However, a study presented at the American Heart Association's Scientific Sessions in 2007 showed that heart rate and blood pressure were affected by *moderate* energy drink consumption. The study mentioned that the ingredients caffeine and taurine (an amino acid that is considered a stimulant) had previously been shown to affect these cardiac indicators, so the study was set up to test this theory. Participants drank two cans of a popular energy drink, which contained 80 mg of caffeine and 1000 mg of taurine, per can. Heart rate and blood pressure were measured frequently, over a 7-day period. The participants did not engage in any physical activity. The results of this study showed the following, as compared with baseline measurements.

*"Within four hours of energy drink consumption, maximum systolic blood pressure (the top number that represents pressure while the heart contracts to pump blood to the body) increased by 7.9 percent on day one and 9.6 percent on day seven; diastolic blood pressure (the bottom number that represents the pressure when the heart relaxes between beats) increased by 7 percent and 7.8 percent, respectively, within two hours of energy drink consumption. Heart rate increased by 7.8 percent on day one and 11 percent on day seven"*  
("Energy drinks may pose risks for people with high blood pressure, heart disease," 2007).

It is difficult to make a direct link between a single 'cause' and its 'effect'. Studies on caffeine and energy drinks have shown ambiguous data. Some studies have received funding from beverage manufacturers, which may bias the results. However, some findings raise a specific concern for firefighters, who are already at increased risk of cardiac events and heat illness.

### **5.3 Medical Conditions and Medication**

Certain medical conditions are known to increase risk of heat illnesses, particularly when combined with strenuous exercise. Coronary heart disease (CHD) is frequently listed in literature for increasing this risk. A heart that does not function adequately may not be able to cool the system, especially when exposed to extreme heat (internal or external). A study done on religious pilgrims in the Saudi Arabian desert, took echocardiogram images of those suffering from heat exhaustion, "*These images showed that heat exhaustion involved tachycardia and high cardiac output with peripheral vasodilatation, characteristic of high output heart failure*" (Armstrong, et al., 2007, p. 562). A narrowing or hardening of the arteries (atherosclerosis, arteriosclerosis), will also affect the body's ability to dissipate heat and can compromise cardiac output and blood flow through the vascular system (Binkley, et al., 2002).

A study of wildland firefighting incident managers evaluated their health status and risk for coronary artery disease (S. Gaskill, Sharkey, & Lieberg, 2007). Self-reported data from incident managers showed the following:<sup>15</sup>

- 41 % had high cholesterol values or took cholesterol medications
- 39 % had high blood pressure or used medications for blood pressure
- 39 % were sedentary during extended periods
- 35 % were overweight
- 17 % had a family history of coronary artery disease
- 3 % were diabetic

Incident team members who held physically active positions, such as division supervisors, were found to have lower risk factors than those who held sedentary positions. Research for this paper could not find a similar study done for 'line firefighters'. However, the data above reflects the need to consider cardiac disease risk factors - for the sake of cardiac events, as well as for potential heat stress risks.

According to '*Circulation*', the Journal of the American Heart Association, cardiovascular disease has been the number one cause of death in the United States in every year since 1900, except for 1918. In 2005, there were 2,448,017 deaths reported in the United States. Of these, coronary vascular disease (CVD) was attributed to 35.3% of total U.S. deaths. Only 6.2% of the CVD deaths were for the population younger than age 65 ("Heart disease and stroke statistics -- 2009 Update," 2008, p. e12). Firefighters, in general, have shown an elevated risk for cardiac events, as compared with this national number. The Federal Emergency Management Agency (FEMA) tracks both structure and wildland firefighter fatalities in the U.S. In 2010, 56.4% of firefighter fatalities were attributed to 'heart attack', a number that is far above the national average of 6.2%, under age 65 (most firefighters are younger than 65). This data includes events occurring up to 24 hours post work shift.

The DOI/USDA reported that from 2000 - 2010 there were 6 heart attack fatalities in wildland firefighters, which represents ~7% of the total fatalities ("DOI/USDA Wildland firefighter fatalities and trend analysis," 2011). This number appears to be very close to the national average. However, there are limitations to the reported data. Fatalities are only tracked if the employee is on duty and belongs to a specific agency. "*For contractors, fatalities are only reported if they are in pay status and under the operational control of one of the Federal agencies at the time of an accident. Therefore, this report does not include wildland firefighter fatalities occurring under other Federal, state, or local agency jurisdiction*" (*Wildland Firefighter Safety CY 2010 Report to the Congress*, 2010). Firefighters who become ill, but do not die during the duty cycle, may not be tracked. In addition, firefighters who die while travelling to or from an assignment may not be tracked. While national numbers reflect the 'end state' of the fatality - no matter how it occurred, statistics used for firefighters may not be comparable, as they require certain parameters in order to be tracked as fatalities. In addition, this paper could not find a reliable system in place, for tracking non-fatalities.

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<sup>15</sup> Self-reported data has been determined to reflect a lower-than-actual estimate of health risks (Newell, Girgis, Sanson-Fisher, & Savolainen, 1999).

Other medical conditions that elevate the risk of heat illnesses include pulmonary, renal, neurologic, and psychiatric diseases. Diabetics may be particularly vulnerable to heat risks, as they may have cardiovascular, renal, and/or neurologic disease progressions. They may also have difficulty concentrating urine, if their glucose is not effectively managed. *"This can lead to a state of chronic dehydration, and acute illness or heat stress can precipitate a severe dehydration leading to ketoacidosis or hyperosmolar hyperglycaemic coma"* (O'Connor & Kasatsky, 2008, p. 33).

Certain medications may raise the risk of heat illness. Diuretics and ACE inhibitors, such as those taken for high blood pressure, can lead to dehydration. Some cardiovascular medications can interfere with heart contractility and/or heart rate. Antihistamines can cause vasoconstriction (even those taken for allergies). Firefighters with medical conditions, or who are on medication for any purpose, should consult with a doctor to assess their level of risk (O'Connor & Kasatsky, 2008).

## **6. Protective Strategies**

Wildland firefighters may be under more physical stress than almost any other class of worker or athlete. What other population performs on demand for long shifts, at high altitude, in the smoke and dust, and in temperatures that can reach high extremes? The firefighter should commit to a progressive fitness regime, eat healthy foods, get adequate sleep and have the chance to fully recover from work fatigue. Support should be available to firefighters, to assure success in both the mission and in maintaining their personal health. The following elements may offer some protection from heat illnesses, as well as from other health risks.

### **6.1 Preconditioning**

There are physical factors that can help maintain hydration and reduce risk of heat stress events. Preconditioning is vital to a firefighter, who should begin a fitness program at least 4-6 weeks before fire season, or before taking a Work Capacity Test (such as the 'pack test'). Brian Sharkey, a former exercise physiologist specializing in wildland firefighters, states that inactive individuals are *50 times more likely* to suffer an exercise-related cardiac event, as those who have been active (Brian Sharkey, 2009, p. 36). A large percentage of firefighter heart attacks occur while taking the pre-season Work Capacity Test, which can indicate a lack of fitness ("Wildland Firefighter Fatalities by Cause 1999-2009," 2010).

Active aerobic conditioning strengthens the heart and increases the body's ability to maintain homeostasis and cool itself, even in hotter temperatures.<sup>16</sup> High levels of aerobic fitness can result in lower heart rates, which may help prevent life-threatening cardiac events (Brian Sharkey, 2009). Fit individuals recover from fatigue more quickly and are able to produce more work (Domitrovich & Sharkey, 2010). Active fitness conditioning throughout the season is necessary, with firefighting's cyclic work demands.

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<sup>16</sup> A PDF guide created specifically for firefighter fitness can be found online in Brian Sharkey's "Fitness and Work Capacity 2009", [www.fs.fed.us/fire/safety/wct/pdf03512805dpi300.pdf](http://www.fs.fed.us/fire/safety/wct/pdf03512805dpi300.pdf)

## 6.2 Obesity

Fitness conditioning can also help prevent obesity. *"Obese individuals are at an increased risk for heat illness because the fat layer decreases heat loss"* (Binkley, et al., 2002, p. 335). The Center for Disease Control and Prevention (CDC) says that *"Workers at greater risk of heat stress include those who are 65 years of age or older, are overweight, have heart disease or high blood pressure, or take medications that may be affected by extreme heat"* ("Heat stress," 2011). Obesity is linked to an increase in heart disease, high blood pressure, and diabetes. Each of these factors puts a person at a higher risk of exercise-induced heat related illnesses.

## 6.3 Heat Acclimatization

Heat acclimatization is also critical for heat illness prevention. Athletes are encouraged to acclimate to heat and altitude conditions 10 - 14 days before engaging in athletic events (Binkley, et al., 2002). Brian Sharkey relays an event of firefighter heat stress that was influenced by altitude and lack of heat acclimatization,

*"In May of 2005, at the end of a 7-mile training run, a female hotshot crewmember became disoriented and began to show signs of heat-related stress... After 6 miles of running with the crew, the female crewmember "began to sprint ahead of the group." When she returned to the base, she began to suffer from "tunnel vision," and couldn't find the barracks. An emergency medical technician trainee and another employee saw the crewmember in distress and went to her aid. They found her to be extremely disoriented and acting irrationally, trying to climb a fence to get to a creek"* (Brian Sharkey, 2006, p. 8).

Heat extremes cannot always be anticipated and planned for, particularly with fire line work. Gradual exposure to heat has been shown to improve the body's ability to tolerate heat (O'Connor & Kasatsky, 2008). *"Acclimation to heat includes increased sweating at a lower temperature, sweat that is not as salty (saving electrolytes), and an increase in blood volume"* (Domitrovich & Sharkey, 2010). While full acclimation may take two weeks, some benefits may be felt after 4 - 5 days (Domitrovich & Sharkey, 2010). One measure that may be relatively easy to implement is to abstain from using air conditioning in trucks or accommodations, while on assignment. Becoming habituated to air conditioning may impair a person's ability to heat adapt (O'Connor & Kasatsky, 2008).<sup>17</sup>

## 6.4 Sleep

Sleep is important for the firefighter, especially when engaged in long-term work. Sleep deprivation (usually defined as less than 7 hours per night) has been shown to affect cognitive performance, motor function, and mood (S. Gaskill, et al., 2007; Palmer, Miller, & Gaskill). Even on a short-term basis, sleep loss can have negative effects, including an increased risk for heat stress. *"Sleep loss has been linked to some loss of heat tolerance, possibly because less blood flows to your extremities and your body produces less sweat"* (Domitrovich & Sharkey, 2010).

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<sup>17</sup> Air conditioning should be available for suspected heat stress sufferers.



Short-term sleep deprivation can have consequences on mental clarity and physical performance that rival alcohol intoxication. "*Studies show that being awake for 18 hours produces impairment equal to a blood alcohol concentration (BAC) of 0.05, and deficits reach a BAC equivalent of 0.10 after 24 hours of wakefulness*" (Elliot & Kuehl, 2007, p. 7). A blood alcohol concentration of 0.10 is illegal in every U.S. state.

Chronic sleep loss (more than one night) can lead to a variety of issues. It is, "*...associated with a general increase in health complaints and musculoskeletal problems, higher body weights, a greater risk of obstructive sleep apnea and heightened levels of cardiovascular disease and cancer*" (Elliot & Kuehl, 2007, p. iii). Chronic sleep loss can lead to the inability to think clearly, solve mental problems, or make new memories. It can lead to depression, irritability and other mood changes.

In addition, a recent study conducted on gamblers showed that sleep deprivation biases an individual toward positive outcomes. Sleep deprivation, "*Appears to create an optimism bias; for example, participants behave as if positive consequences are more likely (or more valuable) and as if negative consequences are less likely (or less harmful)*" (Venkatraman, Huettel, Chuah, Payne, & Chee, 2011, p. 3717). Though firefighters are not gambling with money, they are making constant decisions that have far reaching consequences.

In several studies, sleep loss has been linked to an increase in cardiovascular events. One study of subjects with no history of coronary risk factors, linked sleep deprivation to weakened coronary circulation. The researchers concluded, "*Our findings are assumed to strongly support the relationship between sleeping disorders and cardiovascular diseases*" (Sekine, Daimon, Hasegawa, Toyoda, & Kawata, 2010). One theory about this data is that sleep deprivation can increase inflammatory processes in all systems, including the cardiovascular (Elliot & Kuehl, 2007).

## **6.5 Recovery from Labor**

Recovery from labor is a critical element in preventing fatigue. The standard guide for work/rest cycles in firefighters is a 2:1, work to rest ratio. Thus, in a 24-hour day, a firefighter could work for 16 hours and be given 8 hours to rest and recuperate. If the firefighter was able to sleep for the entire 8 hours, perhaps recovery could be reached. However, it takes time to mentally and physically relax after working in a stressful, high-tempo situation, where adrenaline is a necessary component of success. Humans are not machines - they cannot simply press a button to turn off racing thoughts from experiences they had earlier in the day. The firefighter must also take time to eat and rehydrate (recall the earlier suggested 2-3 hour post-work rehydration strategy). All of these factors reduce the amount of time that the firefighter can sleep and recover. (Elliot & Kuehl, 2007; Brian Sharkey, 2009)

Researchers at the University of Montana studied fatigue and immunity in firefighters, during a typical 14-day duty cycle. The immune factor, IgA, was measured to determine if immunity was affected by work/rest cycles. Immediately following a 14-hour shift, firefighters had significantly depressed IgA. They recovered their immunity to baseline levels, following a full night's rest. In comparison, firefighters who completed a single 21-hour shift did not recover to baseline levels, even after rest. This immune response failed to recover for the

following 5 shift days, even though the firefighters were now back to 14-hour shifts (Ruby, et al., 2002). A second indicator of fatigue/immunity, the step test, was also used and gave similar results to the IgA test. These results led researchers to suggest, *"The energy expended during a work shift in combination with the shift's duration may impair recovery and increase the risk for upper respiratory infection during extended operations"* (2002).

In another study, loss of sleep - even over one or two nights, was shown to negatively affect the reported mood of firefighters. Sleep loss also affected the risk for upper respiratory tract infection (URTI) and overall physical fatigue. Heavy workload was also linked to all three of these factors. Particularly, as the intensity of work increased, the firefighters exhibited more physical fatigue and risk for URTI. The researchers concluded that sleep, alone, was not enough to help firefighters fully recuperate from arduous labor. *"The practical solution to reducing accumulated fatigue appears to be periods of 2-3 days of hard work followed by at least one day of lower intensity work to allow for recovery from fatigue"* (S. E. Gaskill & Ruby, 2002). Fitter firefighters were shown to recover from fatigue more quickly, even when their energy expenditure was high.

Increasingly long work hours have been linked to the development of medical conditions, as detailed in the extensive report, 'The Effects of Sleep Deprivation on Fire Fighters and EMS Responders'. Longer work hours were associated with an increased incidence of high blood pressure and heart attacks. *"Studies have found a direct relationship between the risk of myocardial infarction and longer working hours, with a two-fold increase in risk associated with working more than 40 hours each week"* (Elliot & Kuehl, 2007, p. 9). One study of Japanese men indicated that working more than 9 hours per day led to a threefold increase in heart attack risk (Sokejima & Kagaminmori, 1998).

## **6.6 Personal Protective Equipment**

Firefighter personal protective equipment (PPE) plays an important role in heat stress. If attire is made of heat retaining or non-breathable fibers, it can quickly become a barrier to the release of heat from the body and the evaporation of sweat. *"Exercise-related metabolic heat production raises core body temperature without a plateau and readily induces an "uncompensable" heat stress situation"* (Armstrong, et al., 2007, p. 567). In addition to clothing, other equipment like backpacks and helmets can reduce airflow over the skin and lead to increased heat production. *"Participants who wear equipment that does not allow for heat dissipation are at an increased risk for heat illness"* (Binkley, et al., 2002, p. 335).

During exercise, a firefighter's internal temperature will rise and blood flow will increase to the skin, allowing heat release through radiation, convection and evaporation. Once the environmental temperature exceeds that of the skin, heat can only be released through the evaporation of sweat. *"Effective heat loss by evaporation of sweat demands adequate rates of sweat secretion onto the skin surface to maintain a wet skin and a high skin temperature to allow for evaporation before the sweat drips from the skin surface"* (Maughan, et al., 2007, p. 605).

Some athletic sports have developed protocols that help players adjust to increases in heat. Gradually introducing more equipment, like padding and heavier uniforms, helps reduce the risk of heat illnesses during the critical acclimatization time. *"In American football, EHS usually occurs during the initial 4 d of preseason practice, which for most players takes place during the hottest and most humid time of the summer when athletes are the least fit"* (Maughan, et al., 2007, p. 605). Wildland firefighters may benefit from a similar strategy, where heat stress is anticipated during the first days of an assignment and extra precautions, education, and a 'buddy watch' are encouraged.

Currently, wildland firefighters are required to cover as much exposed skin as possible with heat resistant fabrics, like Nomex® and Kevlar®, to prevent burns. Covering the skin reduces the ability of sweat to evaporate and also reduces or eliminates the cooling effect of airflow over the skin. In a study of flame-resistant fabrics, referenced by Du Pont, little difference was seen between the heat release characteristics of several fabrics.<sup>18</sup> The study showed that the weight of the material was a more critical factor, *"...a garment of flame-retardant-treated (FRT) cotton or a polyester/cotton blend that weighs eight to nine ounces per square yard would cause heat stress sooner than a NOMEX® III garment that weighs only 5.9 ounces per square yard"* ("Protective Clothing of Dupont Nomex and Heat Stress,").

PPE must offer a balance between protection from fire, durability, cost, and mitigation of heat stress. The USFS reviews PPE approximately every 7-8 years, for design and material. New models of PPE are 'wear tested' by firefighters, who give their opinions about the pieces (T. Petrilli, personal communication, October 19, 2011).<sup>19</sup> The lightest weight PPE may be the best option to help prevent heat illnesses. In addition, firefighters are encouraged to wear lightweight, loose fitting undergarments to encourage the evaporation of moisture. Natural fibers should be chosen, as these have been shown to be less likely to burn (Domitrovich & Sharkey, 2010).

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<sup>18</sup> Du Pont is the maker of Nomex® and Kevlar®, so bias may be present in this report.

<sup>19</sup> PPE ratings include categories such as: Fit, wear ability, satisfaction with design, feel of material, performance in heat, comfort, etc.

## **Conclusions**

Preventing heat illness requires a multi-faceted approach. There is a wide variation of heat tolerance in firefighters; thus, 'normal' protocols may not work for every person, in every situation. The organizational hierarchy should be educated about the risks, signs, preventions, and treatments of heat illnesses -- from the line firefighter engaged in the physical work, to the leadership and policy makers who are responsible for decisions that will impact the people, schedules, and assignments.

Firefighters who are adequately rested, hydrated, nourished, and heat acclimated will be less at risk of heat stress events. An emphasis on physical conditioning, both prior to and during fire season, can have added benefits for mission success and heat illness avoidance. Understanding the interconnected nature of the environment, workload, and the individual firefighter is necessary to reduce the incidence of fatalities -- both from heat illnesses and cardiac events. When multiple stressors are compounded, the risk for firefighters increases exponentially.

The symptoms of heat illnesses can be similar to one another and can escalate to critical levels within minutes. Firefighters should be trained to recognize these symptoms in themselves and each other. They should not rely on their crewmates to *tell* them that something is wrong -- by the time the symptoms are verbalized by the sufferer, it may be too late. Medical assistance should be close at hand, in order to help diagnose and treat potential heat illnesses.

### **About the Researcher:**

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