

# UNDERSTANDING HEAT STRESS

Firefighters are required to work in temperatures well over the normal body core temperature of 36.5 to 37.5 Deg. C. It is essential that the firefighter understand the processes in how the human body attempts to regulate the body core temperature and what actions and precautions we can take.

## **1. DEFINITIONS**

### **1.1 Heat Exhaustion**

Persons exposed to extreme environmental heat often experience other difficulties. They need large amounts of water and salt to replace those lost in the sweat. Without sufficient water, they suffer from dehydration and may collapse from inadequate circulation. This collapse, whether caused by dehydration or other phenomena, is called heat exhaustion. It can be distinguished readily from heatstroke by the moderate or absent elevation of body temperature and by the persistence of heavy sweating. Salt, or other mineral, and sugar depletion may contribute to heat exhaustion or cause other difficulties, among them heat cramps, which are relieved specifically by supplying added salt, minerals, or sugar to the diet. Although such difficulties may complicate or even precipitate heatstroke, they are complications rather than essential features. Heat exhaustion is treated by lying down in a cool place and drinking water to which salt has been added, though any fluid (such as fruit juice) is helpful.

### **1.2 Heatstroke**

A potentially life threatening condition caused by exposure to high temperature and humidity. The term sunstroke refers to the same disorder when exposure to direct sunlight is the main source of environmental heat. The fundamental feature of heatstroke is an extreme and uncontrolled elevation of body temperature (41 to 43 C, or even higher), which can harm the central nervous system.

There is good evidence that heatstroke in its uncomplicated form is caused by the failure of sweating to cool the body. The average human body produces 70 calories of heat per hour at rest and up to eight times this figure in severe muscular work. In mild climates this heat is eliminated by radiation and convection from the skin and lungs and by evaporation of sweat. As the surroundings become hotter, all methods of heat elimination become

ineffective except the evaporation of sweat. Experiments involving prolonged work in heat demonstrate a slow decline in the rate of sweating. Thus, physiologic mechanisms for control of body temperature seem to become fatigued if exposure to heat is prolonged. When the sweat rate is insufficient, rapid changes may occur, including a further drop in or near cessation of sweating, a rapid rise in temperature, collapse, and coma. If prompt treatment by cooling is not instituted, the victim will die.

In the early stages of heatstroke the victim may experience dizziness, headache, nausea, weakness, restlessness, or mental confusion and has a rapid bounding pulse and hot, dry, flushed skin. As collapse persists, the coma deepens and a weak, thready pulse and a more dusky skin will follow. Cooling of the body is urgent if the victim's life is to be saved. Ice-water baths or packs, with massage to promote circulation, are effective. After this first-aid procedure, expert medical care is necessary to manage the effects of possible circulatory disorder and brain damage. Death from such residual damage is not unusual. The recovered patient may have increased susceptibility to the ill effects of heat.

## **2. THERMOREGULATION**

The human body will only tolerate a drop of 8 degrees C in body core temperature and an increase of only 3 degrees C. Failure to regulate within these limits may cause death. Heat stress is responsible for a large percentage of firefighter deaths. ( FIND OUT THE EXACT FIGURE)

High heat conditions combined with high work loads under stressful conditions can lead to rapid body core temperature increases which can be lethal.

Sustained work load can increase the metabolic rate to 20 -25 times the resting level. This can theoretically increase core temperature by about 1 degrees C every 5 minutes.

The hypothalamus, located at the base of the brain, is the coordinating centre for the various processes of temperature regulation. This is considered the "thermostat" for temperature regulation. The body makes adjustments in response to input from thermal receptors in the skin, and changes in the temperature of blood flowing past the hypothalamic region (back of the head). In Sweden firefighters wear a flash hood and then a second hood, which is built into the coat, is placed over or under the helmet. This is because they believe that it is vital to protect this heat regulating region. The head plays a significant role in the heat regulation process by allowing for up to 35% of the total shedding the body's metabolic heat. However it can also be a major avenue of heat gain by absorbing up to 35% of the body's total heat gain of external heat radiation.

## **2.1 THERMOREGULATION IN TEMPERATURES BELOW 37 DEGREES C.**

### **Mechanisms for Metabolic Heat Loss**

The "Second Law of Thermodynamics" tells us that heat flows from the hotter object or body to the cooler body or object. At ambient temperatures at or below 37 Degrees C the body has a number of means of shedding excess metabolic heat.

#### **2.1.1 Convection And Conduction**

Involves the direct transfer of heat through a liquid, solid, or gas from one molecule to another.

Conduction relies on the body being at a lower temperature than the surrounding environment.

The body conducts heat to the surrounding air. Convection has to do with the exchange of air or water next to the body and the relative temperature of the air or water. The greater the convection, the more heat lost, or gained due to conduction.

#### **2.1.2 Radiation**

The exchange of radiant heat energy through the air to cooler objects in the environment. If the temperature of objects in the environment exceeds skin temperature, radiant heat energy is absorbed from the surrounding.

#### **2.1.3 Evaporation**

Evaporation is one of the main means of heat dissipation in high ambient temperatures. Distribution of heat is done by blood circulation. Heat goes from each cell to the surrounding liquid and afterwards to the circulated blood. The blood flow is directed to the surface of the skin where it can be conducted or radiated away ( at ambient temperatures below 37 Degrees C). This also stimulates the sweat glands which secrete a weak saline solution. The human body has 2 - 4 million sweat glands distributed throughout the body. The evaporation of the sweat results in a large amount of heat loss due to the amount of energy required in the process. The cooled skin in turn serves to cool the blood that has been shunted to the skin surface.

## **2.2 HEAT LOSS AT HIGH AMBIENT TEMPERATURES**

At high temperatures the firefighter loses the effectiveness of radiation, conduction and convection. When temperatures exceed body temperature, the firefighter gains heat through the above mechanisms

Thus, the only means of heat dissipation is through evaporation of sweat. Small amounts of body heat can be dissipated through the exhaled breath.

There are a number of factors effecting vaporization of sweat from the skin:

- a. Surface exposed to the environment
- b. Temperature and humidity of the ambient air.
- c. Convective air currents about the body.

Relative humidity is by far the greatest factor in determining the effectiveness of evaporative heat loss. When water vapour pressure approaches that of the moist skin and evaporation is greatly reduced. It is important to realise that it is not simply the process of sweating that cools the skin, but the evaporation of the sweat.

It can be seen therefore that a firefighter in the extremely hot environments (50 degrees or higher) encountered during firefighting in compartments, will be unable to shed metabolic heat through any of the mechanisms discussed. The second law of thermodynamics tells us that the flow of heat will be always to the colder body (the firefighter). Heat will be conducted from air to the firefighter, so any air flow or exposure will lead to heat gain. As well as the high radiant energy and air temperatures there could also be a high humidity due to the application of water for firefighting.

So the firefighter not only gains heat from the environment but he is also unable to dissipate the heat being generated within his body. As previously stated the high levels of work load can further increase in metabolic heat generated.

It is vitally important that the firefighter realise that in these extreme environments that no protective clothing will allow him to shed metabolic heat. It is only a matter of time before the body core temperature begins to rise. The insulative properties of the clothing will have a major bearing on how long it takes for the heat to penetrate to the skin of the firefighter. The higher the insulative properties the less heat will be absorbed by the body.

### **3.1 FACTORS AFFECTING THE INDIVIDUALS RESPONSE TO HEAT STRESS?**

People who are overweight, physically unfit, suffer from heart diseases, abuse alcohol or take certain other medications are at greater risk due to reduced ability to deal with extreme heat.

### 3.1 Other factors

#### 3.1.1 Gender: Women

1. Possess more heat-activated sweat glands per unit skin area
2. Less prolific sweaters
3. Begin to sweat at higher temp.
4. Produce less sweat for comparable work load even after acclimatization.
5. Probably depend more on circulatory mechanisms rather than evaporative as men.
6. Large surface area to mass ratio
7. No effect of menstrual cycle found for competition.

#### 3.1.2 Body fat

1. Excessive body fat is a liability when working in the heat.
2. Increases the insulatory capacity and retards conduction of heat to the periphery.
3. Reduces surface area to mass ratio.
4. Adds to metabolic cost of activity
5. Fatal heat stroke 3.5 times more in excessively overweight young adults.

#### 3.1.3 Age

1. No difference found between young and middle-aged men during marathon running
2. Sweating in desert walks was fully adequate for men 58-84 years.
3. More controlled studies need to be made.

#### 3.1.4 Acclimatisation

People who are not acclimatized do not have as efficient sweat- evaporating cooling mechanisms as those who are and should build up gradually to a full workload in hot conditions over a period of about one week. This should again occur after one or two weeks away from hot work as acclimatization is rapidly lost.

It should also be realised that people vary in the efficiency of their cooling mechanisms and hence their ability to tolerate heat stress.

## **HOW CAN THE ADVERSE EFFECTS OF HEAT STRESS BE MINIMISED**

### **GENERAL PRINCIPLES**

#### **1. Hydration.**

Thirst is a very poor indicator of hydration. If you wait until you are thirsty until you drink then you are already dehydrated. Firefighters should ensure that they remain hydrated by drinking small amounts of water regularly. Salt may be added to fluids but is only required in small amounts when sweating is heavy and continuous. Salt tablets are unnecessary and not recommended.

#### **Effects of Dehydration**

Dehydration can impede heat dissipation and severely compromise cardiovascular function and work capacity. Sweating causes reduced blood volume which means that less blood is available to be shunted to peripheral areas for heat dissipation. When the work load is high the muscular system is also competing for blood flow and this places additional stress on the body. Fluid loss can peak of about 3 litres per hour in extreme conditions.

The end result is:

Blood volume drops

Impairment in stroke volume

Impairment in cardiac output

Impairment in skin blood flow

Higher heart rate

Higher perception of effort

Higher core temperature

Decreases sweat rate

Decreases max oxygen uptake

Decreases work capacity

This also means that there is less blood flow to the brain. This can lead to fatigue, disorientation, confusion, reduced decision making ability, higher perception of effort and possibly loss of consciousness. Definitely not the sort of symptoms that you would like to experience inside a burning building.

Clearly, dehydration reduces the capability of the circulatory and temperature regulating systems to meet the metabolic and thermal and psychological stress of firefighting.

It is therefore vital to maintain hydration and therefore blood volume so that circulation and sweating can progress at optimal levels. Hydration is the most effective defence against heat stress.

## **2. Electrolyte Replacement**

For a fluid loss of less than 3 l in adults, electrolytes are readily replenished by adding a slight

amount of salt to the food. Sodium-conservation mechanisms of the kidney activated during exercise are usually sufficient for endurance exercise sodium replacement.

## **3. Fitness**

Physical fitness plays a major role in the body's ability to handle the stresses of working in hot and humid environments. Enormous stress is placed on the heart, lungs and other internal organs during firefighting operations. Any weakness in the cardiovascular could prove life threatening in times of high work demands in very hot environments.

Relative workload (percentage of one's capacity) determines the change in core temperature with exercise. It is essential that firefighters maintain a reasonable level of physical fitness and have regular medical check ups

## **4. Heat Acclimatisation**

Repeated exposure to hot environments during exercise results in improved capacity for exercise and less discomfort upon heat exposure. It takes about 10 days to acclimatise. This can be lost within 2- 3 weeks.

### **Physiologic factors in acclimatisation**

The body adapts by shunting larger quantities of blood to the blood vessels to facilitate heat transfer from body core to the skin. Adaptations allow blood pressure to be more stable due to more effective distribution of cardiac output. The sweat produced becomes more dilute ( conserving salt), temperature at which sweating begins is reduced and there can be as much as twice the volume produced. Sweat is more evenly distributed on the skin surface.

Hormonal adjustments allow for the reabsorption of water from the kidneys which causes the urine to become concentrated. Thus, more water is available for sweat. Sodium is reabsorbed which allows more sodium for sweat production.

The result is that the individual is able to work harder and longer with lower skin temperature, body core temperature, and heart rate. This is provided that hydration is maintained.

### **Summary**

In the Swedish Fire Service fitness training is compulsory. They must undergo an annual fitness test in order to ensure that they are in the physical condition to wear BA. There is a one hour fitness training requirement for each shift, and often if time permits they will do two fitness sessions per day. The stations are all very well equipped with an indoor sports hall, gymnasium, and sauna. They take the saunas very seriously citing tests that reveal that the body can be conditioned to the heat stress experienced during firefighting. This conditioning takes about 2 to 3 weeks to develop and can be lost in about the same time frame. They are regularly exposed to high heat conditions during training. The sauna has two main functions. They are used after physical training to help to maintain the heat stress conditioning effect and also after hot fire training or fires to cleanse the skin of the contaminants from the smoke. They start by washing with soap in a warm shower and then entering the sauna. After the sauna the skin is cleansed again and finished off with a warm rinse down to keep the pores open.

It is recognised across the world that the tasks required of a firefighter can be very arduous. This is particularly evident when Firefighters are wearing BA in very hot and hostile environments. Fitness training and heat conditioning can have a major effect on the ability to perform these tasks.

## **RECOGNISE THE SYMPTOMS AND KNOW HOW TO DEAL WITH**

# **THEM EFFECTIVELY.**

## **SYMPTOMS OF HEAT EXHAUSTION**

1. Profuse perspiration
2. Fatigue
3. Headache
4. Dizziness
5. Nausea and vomiting
6. Body cramps

## **Treatment**

Emergency medical treatment is needed for heat exhaustion due to the risk of heat stroke. Until

emergency help arrives, the person should be moved to a cool location, if possible. If the person

is conscious and liquids can be tolerated, sips of cool water - with half a teaspoon of salt added per litre- may help restore fluid balance.

The symptoms often begin suddenly and may resemble shock. Heat exhaustion can lead to heat stroke. Immediate medical attention is needed.

## **SYMPTOMS OF HEAT STROKE**

- \* Reduction or cessation of perspiration
- \* Confusion
- \* Delirium
- \* Body temperature higher than 41 degrees C
- \* Loss of consciousness

## Treatmnet

Heat stroke is a medical emergency that can be life threatening and requires immediate medical assistance.

First aid consists of cooling the body as quickly as possible by soaking the victim's clothing in cold water and increasing air movement by fanning the victim.

### Effects Protective of Clothing on Thermoregulation

2. Thus, several layers of light clothing is more effective than a single thick layer of winter clothing for insulation from cold since several layers provides a relatively thick zone of trapped air against the skin.
3. The clothing layer against the skin must be effective in transporting moisture away from the body's surface to the next clothing layer.
4. 90% of the clothing's insulating properties are lost when it is wet. Thus heat is lost to the environment rather than conserved.



The views expressed here are my own and do not necessarily reflect those of the QFRS