

## Injuries caused by body overheating

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### Summary:

Injury and heat stroke are life-threatening states, requiring immediate help and fast treatment. Body overheating caused by physical effort (heat cramps, heat injury and heat stroke) pose a serious problem during military actions.

Body overheating is accompanied by serious biochemical, physiological and haematological disorders - including life-threatening conditions, which required immediate medical treatment

**Key words:** hyperthermia, hyperthermia-favouring factors, heat exhaustion, sunstroke, immediate treatment.

Some time ago, the American researchers published shocking data according to which over 600 people died in Chicago, due to the heatwave between 12 and 20 July 1995. More than 3300 people were admitted to Intensive Care Units and 21% of them died during their hospital stay.

According to publications from other countries, with a climate similar to that of Poland, the first fatalities appear with only 2-3 days of temperature reaching the level of 32°C or more in the shade. This is followed by a sudden increase in mortality and morbidity due to body overheating.

The number of admissions due to heat stroke in such periods has increased tenfold compared to the previous years, i.e. from 0.2/1000 to 2.3/1000 cases and the highest number of patients were admitted after 6-7 days of persistent heat [2].

In Europe, weather forecasts on gradual climate warming are coming true. A heatwave in the south

of France, Spain, and Portugal from mid-June to mid-July 2003 caused not only a series of fires but also a disastrous "epidemic of death" among people, due to hypothermia, i.e. body overheating.

According to other sources, heatwave in 2003 led to over 15000 fatalities in France only and these were only estimates (and only thorough). Although Poland has a moderate climate and the periods of scorching summer heat are usually short, the recent years have witnessed temperatures reaching 32°C or even more (35-36°C in the shade) from mid-May to end-September, normally accompanied by increased air humidity.

In the available statistical data, the fatality rate due to body overheating on hot days in Poland is not given. It is only known that Emergency Medical Services record more sudden illness calls then and a higher number of patients present to emergency rooms at hospitals, for medical help.

Such weather conditions are very tiring and sometimes even dangerous or fatal for many individuals, especially the elderly, the sick and the young children.

Moreover, it should be remembered that weather conditions on such days may be extreme for individuals employed at work places as smelting plants, mines or in other industries, as well as for professional sportsmen and for soldiers serving in other climates than in Poland.

Overheating concerns people of all ages, and especially the ones that travel to countries where the climate (compared to the Polish one) is warmer, with high insolation, considerable air humidity, and temperatures reaching 40°C in the shade, or much more.

Such weather conditions can be found in south Europe or Mediterranean countries already, but also in Israel or Arabian Peninsula: Kuwait, Saudi Arabia, and currently especially Iraq.

Armed Forces stationed in Iraq should therefore be previously adapted to summer weather conditions of that country. This may be necessary, especially for military tasks connected with a significant physical effort.

The level of tolerability of hot weather is influenced not only by the temperature but also by air humidity.

Many hours of work connected with physical effort in hot environment or in insulated places, as well as breathing with hot, humid air results in adverse consequences of overheating.

This is a result of extremely increased body temperature due to:

- No acclimation to the existing conditions or
- Disturbed mechanisms of thermoregulation and
- Heat stored in the body, with no possibility of its exchange with the environment.

## 1. Factors favouring hyperthermia

Hyperthermia is favoured by the following factors:

- Dehydration,
- Hard work or extensive effort – at high environmental temperatures and considerable air humidity,
- Physical exhaustion,
- Cardiovascular diseases,

- Chronic diseases – e.g. diabetes,
- Stress,
- Covering oneself up too warmly,
- Decreased heat radiation from the body caused by medicines disturbing thermoregulation,
- Sedatives and hypnotics,
- Drugs, especially amphetamine,
- Old age or physical disabilities.

## 2. Consequences of a long-term and uncontrolled increase in body temperature

In hot environment, after the period of increased perspiration, the human body stops producing sweat, and there follows uncontrolled increase in body temperature, exceeding 40°C or even reaching 44°C.

The consequences of long-term and uncontrolled increase in body temperature can be as follows:

- **heat cramps,**
- **sun stroke,**
- **heat exhaustion or**
- **heat stroke.**

Body overheating is accompanied by severe biochemical, physiological, and haematological disorders – that may be even life-threatening, and requiring immediate treatment (Table 1).

The activation of defence mechanisms leads to increased heart rate and cardiac output, and then to translocation of blood to skin vessels. This may result in haemodynamic abnormalities and decreased blood pressure, leading to ischemia of muscles and internal organs, and especially brain, kidneys, liver, and heart.

With a long stay in a hot and humid environment, there appear disturbances of thermoregulatory mechanisms and a significant loss of water and electrolytes: decreased or even stopped perspiration, and then body overheating and disturbances of the central nervous system, leading to life-threatening conditions.

### 2.1. Heat cramps

Hard physical work in conditions of exposure to heat concerns many areas of life. Hot environment activates thermoregulatory mechanisms

that are aimed to protect the body from overheating. This results in increased perspiration; the evaporating sweat absorbs significant amounts of warmth from the body through the skin. This may lead to a loss of 1-3 litres of sweat in one hour, and then to considerable dehydration and increased loss of ions of sodium, potassium and chlorine.

In normal conditions, the 24-hour perspiration involves excretion of sodium, potassium and chlorine in the amounts presented in Table 1.

**Table 1:** \*

Volume and composition of the sweat				
Mean volume (ml/day)	Concentration of electrolytes (mEq/l)			
	Na <sup>+</sup>	K <sup>+</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>
500 - 4000	30 - 80	0 - 5	30 - 70	0

\* After: H.A. Harper: *Terapia plynowa i elektrolitowa*, in: *Chirurgia w zarzysie*, /editor/ J.L. Wilson, PZWL, Warsaw 1973, page 148

### 2.1.1. Symptoms

In individuals performing a hard physical work in hot environment, there usually appear (at the end of the day) painful cramps of muscles involved in the most intense physical effort.

### 2.1.2. Mechanism of action

These disorders are directly connected with a loss of considerable amounts of sweat containing ions of sodium, potassium, and chlorine.

Body temperature, heart rate and blood pressure values remain normal.

### 2.1.3. Treatment

Water and electrolyte deficits should be corrected as fast as possible.

### 2.1.4. Prognosis

After correcting water and electrolyte deficits, the symptoms disappear relatively fast and entirely.

## 2.2. Sunstroke

This is a pathological condition caused by staying long in the open air on a sunny and hot day, bare-headed, that is with the head directly exposed to sun.

### 2.2.1. Symptoms

In young children – after a longer exposure to sun – the fever may be a basis for a diagnosis of sunstroke.

The skin on the face is very red and hot, while the remaining skin surface is pale and cool. Body temperature can be increased. There may appear vomiting, stiff neck and headaches, and the patient can be agitated, with disturbed sense of direction. A temporary loss of consciousness may develop into a more persistent state which can be life-threatening and requiring immediate treatment.

Sunstroke may be accompanied by heat stroke, inhibiting correct diagnosis.

### 2.2.2. Mechanism of action

Due to a direct exposure of the head to sun, the head becomes overheated, giving symptoms of cerebromeningeal irritation.

Children, elderly persons and bald people are at the highest risk of this kind of thermal injury when directly exposed to sun and bareheaded. Thin skin and skull bones (which are not fully fused in young children in the area of fontanelle) are not an effective barrier against heat. The regions of the brain directly adjacent to the skin in these areas easily get overheated.

### 2.2.3. Treatment

The patient should be located in the shade and cold. When body temperature is increased, it should be lowered as fast as possible by removing excessive clothing, and applying cold compresses on the head. The skin of the head should be sprinkled with cold water and ventilated with air from electric fan, causing increased water evaporation with simultaneous cooling of the skin.

In case of lost consciousness, the patient should be placed in a lateral position. Cardiopulmonary resuscitation should be introduced when required.

### 2.2.4. Prognosis

Prognosis concerning survival is usually favourable, although there may appear haemorrhages from the gastrointestinal tract and foci of cerebral malacia.

## 2.3. Heat exhaustion

**It is a life-threatening condition – requiring immediate treatment.**

Heat exhaustion is a result of exhausted thermoregulatory mechanisms of the body due to a

longer stay in high environmental temperatures and air of increased humidity. There occurs a secondary loss of water and ions: chlorine, potassium, and sodium. This condition develops within a few days of heat and usually after a longer stay in a hot microclimate.

### 2.3.1 Symptoms

Disturbed thermoregulation is accompanied by a collapse of peripheral circulation. Many organs become injured at the cellular level, which results in disturbances of the function of:

- heart, liver and kidneys,
- coagulation system,
- thermoregulatory mechanisms and perspiration – manifested by a hot and dry skin,
- central nervous system, manifested by:
  - Confusion,
  - Delirium,
  - Lost consciousness.
- Body temperature raised to over 40.6°C

According to the literature data, mortality ranges from 10% to 80% in such cases and depends on the level of overheating [1].

### 2.3.2. Immediate care

The patient should be undressed and placed in a cool place. His/her body temperature should be lowered as fast as possible, down to 38.0°C – within 30 minutes by [2]:

- bathing in cool water,
- wrapping in wet, cool sheets or blankets,
- sprinkling the body with cool water in the form of aerosol,
- lavaging the stomach or colon with cool saline,
- directing the air from an electric fan onto the patient's skin – thus increasing the process of transferring the heat from water evaporating from skin surface to air.

When cooling the body of the patient, the temperature should be continuously monitored with electronic thermometer placed in the rectum, in order to avoid extreme cooling and hypothermia.

It is also required to:

- monitor ECG and central venous pressure.
- administer oxygen and, when necessary, intubate the patient and introduce assisted breathing,
- in case of cardiopulmonary arrest, cardiopulmonary resuscitation should be started,

- start intravenous infusion of fluids – in order to correct water and electrolyte deficits, which should improve blood circulation,
- the fluids should be infused slowly, taking into consideration the fact that the heart muscle might have been injured and the renal function might have been disturbed.

If this is required by patient's general condition, he/she should be transferred to Intensive Care Unit to undergo appropriate adjunctive treatment.

## 2.4. Heat stroke

Heat stroke is a result of a prolonged stay at high environmental temperatures and considerable air humidity. This condition develops within a few days of heat and usually after a longer stay in a hot microclimate, when thermoregulatory mechanisms become exhausted and the body temperature reaches 42.2-43.3°C. Heat stroke is a life-threatening condition requiring immediate care.

It should be remembered that *early diagnosis* and immediately introduced *treatment of heat exhaustion inhibits the development of heat stroke*, and the faster the body temperature is lowered to 38.0°C, the lower the mortality among the victims of this form of body overheating.

Patients with a diagnosed heat stroke, e.g. in Saudi Arabia, are admitted to field, air-conditioned "Departments of Heat Stroke Treatment" where after being undressed, placed in horizontal position, and wrapped in wet gauze or sheet, they undergo cooling by having the body surface sprinkled with water in the form of aerosol, at a temperature of around 15°C and dried with a flow of air of room temperature, from electric fan. That is how the temperature on the skin surface can be lowered to 30-32°C, at a rate of 0.3°C every 5 minutes.

### 2.4.1. Diagnosis

Heat stroke may occur in individuals of all ages, but it usually concerns very young or elderly people.

The diagnosis is mostly based on symptoms and results of laboratory tests.

There follows a peripheral circulatory collapse and a secondary loss of water and ions of sodium, chlorine, and potassium.

Immediate care provided to the patient, a fast transport to hospital, and introduction of appropriate treatment allow for detecting and diagnosing a heat stroke in its early stage and on subjecting the patient to appropriate treatment, which may prevent from fatal consequences of the heat stroke.

However, very often the heat exhaustion and the heat stroke are misdiagnosed in their early stage, which may result in a coma, even at a few hours before the planned hospital discharge.

#### 2.4.2. Differential diagnosis

The diagnosis should be differentiated with:

- pulmonary embolism,
- acute cardiological conditions,
- anaphylactic shock, and
- heat exhaustion.

#### 2.4.3. Symptoms

Heat stroke may be manifested by the following symptoms:

- disturbed consciousness,
- body temperature raised to 42.2-43.3°C,
- dry, hot, and red skin,
- fast, irregular, and weak pulse, tachycardia,
- paroxysmal excessive sweating,
- asthenia, headache, vertigo, and vision disturbances,
- nausea and vomiting,
- stupor,
- muscle weakness,
- oliguria.

#### 2.4.4. Immediate care

The patient should be:

- placed in horizontal position, with his lower limbs above the level of the trunk,
- undressed and placed in a cool and shaded room,
- cooled as fast as possible to achieve body temperature of 38.0°C within 30 minutes by:
  - bathing in cool water,
  - wrapping in wet, cool sheets or blankets,
  - sprinkling the body with cold water in the form of aerosol,
  - lavaging the stomach or colon with cool saline,
  - directing the air from an electric fan onto the patient's skin – thus increasing the process of transferring the heat from water evaporating from skin surface to air.

When cooling the body of the patient, the temperature should be continuously monitored with electronic thermometer placed in the rectum, in order to avoid extreme cooling and hypothermia.

*If this is required by patient's general condition, he/she should be transferred to Intensive Care Unit to undergo appropriate adjunctive treatment.*

### 3. Discussion

Heat exhaustion and stroke are life-threatening conditions requiring immediate care and fast introduction of treatment. Body overheating caused by physical effort (heat cramps, heat exhaustion, and heat stroke) is a serious problem during military actions.

A rapid diagnosis of these conditions and immediate cooling of the patient's body are the basic management. Critical cases must be quickly cooled to a temperature of 38°C (in rectum). Their intensive treatment and medical supervision are required.

A heat stroke is typically accompanied by multiorgan disorders. Overheating of milder degree may be managed with hydration, removal from hot environment, and placing the patient in a cool room.

During resuscitation, a 5% glucose solution or saline in glucose should be infused intravenously in order to stabilise the patient's general condition.

To prevent overheating in individuals from the risk group, the following should be introduced:

- their appropriate hydration, that is drinking of fluids in the amount appropriate to the body mass (volume of at least 2000-2500 ml daily),
- staying in cool rooms and
- adapting to the environment.

The drinks should contain mineral salts. Elderly persons should avoid staying in hot environment which should reduce the risk of overheating in hot weather.

Blue-collar workers, sportsmen, and soldiers should be gradually adapted to the hot environment, as well as have more fluids to drink at their disposal. Their clothes should be light and they

should be provided with a possibility to rest in cool rooms frequently.

The following preventive measures should be introduced: drinking more fluids before, during and after physical effort, gradually increasing the time of work spent in hot environment and avoiding physical effort in the hottest part of the day.

Weather forecasts presented in mass media in summer should warn about the forthcoming heatwaves and the health services should inform how to prepare for such hot days and encourage the residents to:

- avoid staying in suntraps,
- stay in cool or air-conditioned rooms,
- avoid attending to important business in the afternoon hours and
- avoid exhausting effort.

In order to reduce the morbidity and fatality rate caused by heatwaves, all residents should be informed about the health-related benefits of installation of electric fans at their homes or – depending on financial capabilities – air conditioners, and use them always when the room temperature starts to be uncomfortable.

#### 4. Conclusions

- 1) Pathological conditions caused by high temperature, such as: heat cramps, sunstroke, heat exhaustion, or heat stroke are frequent in individuals working or staying in adverse environmental conditions – in hot environment – and cause many deaths every year.

#### References:

15. Kurnatowski W: *Urazy spowodowane przegrzaniem organizmu: „Skurcze ciepłe” i „Porażenie Słoneczne”*. Magazyn Lekarza Rodzinnego, 2004;1(7-8):4-10
16. Kurnatowski W: *Urazy spowodowane przegrzaniem organizmu: „Porażenie ciepłe” i „Udar ciepły”*. Magazyn Lekarza Rodzinnego, 2004;1(9):10-6
17. Strużyna J: *Oparzenia w katastrofach i masowych zdarzeniach*, PZWL, 2004
18. Kurnatowski W: *Oparzenia: Pierwsze 48 godzin – Plan postępowania*. Plakat. MEDICUS – Katowice, 2001
19. Kurnatowski W: *Oparzenia. Pierwsze 48 godzin – Plan postępowania. Postępowanie z oparzoną bezpośrednio po wypadku*. Materiały Ogólnopolskiej Konferencji Naukowo-Szkoleniowej: Medycyna Ratunkowa i Medycyna Katastrof, 2001:167-77
20. Kurnatowski W: *Oparzenia - pierwsza pomoc*. Twój Magazyn Medyczny – Lekarz Rodziny, 2002;7:1(60):54-7
21. Kurnatowski W: *Leczenie oparzonego – Plan postępowania. Pierwsze 48 godzin po wypadku*. Twój Magazyn Medyczny, 2005;10(4):45-56

- 2) The risk factors include: age, general health state, chronic diseases, excessive physical effort, high temperature of the environment.
- 3) Most of the fatal cases are recorded after first 2-3 days of intense heat. Individuals at risks of overheating include: sportsmen, soldiers, and people working in the open air or in rooms without proper ventilation.
- 4) Body overheating related to physical effort (heat cramps, heat exhaustion, and heat stroke) are an important problem during military actions.
- 5) The pathological conditions being a result of body overheating usually concern: elderly people, individuals with thermoregulatory abnormalities, with schizophrenia, people taking different medicines – including sedatives, hypnotics - and especially those abusing drugs and alcohol.
- 6) Factors increasing sensitivity to heat are as follows: cardiovascular diseases, diabetes, chronic diseases, multiple sclerosis, abusing drugs and alcohol.
- 7) These groups of individuals are especially exposed to risk of overheating and should take precautions in summer months.
- 8) Body overheating is manifested by many symptoms: from asthenia, vertigo and fatigue (in case of heat exhaustion), through syncope, loss of consciousness, neurological complications, stupor, and coma, to multiorgan complications, convulsions, or even death.

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