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Module:	**9: Extreme Temperatures in Agriculture – health challenges**

9 Module 9: Extreme Temperatures in Agriculture – health challenges

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9.1 Introduction

The impact of physical hazards such as heat and cold is examined, highlighting the concern regarding climate change, health effects, and adaptation. Given the fact that most agricultural work takes place in hot and frequently humid environments, it is important to orient the practitioner and to raise awareness, because heat exposure and heat prevention measure are not formally regulated in this occupational sector. Useful clinical information on hyper- and hypothermia are given here, as well as physiological considerations and solutions.

The aim is to help occupational physicians to understand the health risks associated with working in extreme heat and cold situations, to learn the basic concept of homeostasis and thermal comfort, and to suggest reasonable solutions for workplaces.

In agriculture, workers spend a great deal of time exposed to excessive outdoor temperatures, often while performing vigorous physical activities. Acclimatization and adaptation are the main factors in preventing heat-related death and non-fatal illness changes, especially in the perspective of a warmer climate. Respiratory and renal problems (e.g., kidney stone) are expected to increase. Any agricultural activity carried out outdoors, especially during the warm seasons and during the day, is likely to produce various severe or less severe effects, such as blood flow imbalance, as well as hydro-electrolyte or thermal imbalance.

By managing thermal comfort employers are likely to improve behavior and productivity as well as improving health and safety. People working in uncomfortably hot and cold environments are more likely to behave unsafely because their ability to make decisions and/or perform manual tasks deteriorates.

Pathological outcomes are identified as follows:

- Hyperthermia (heat syncope, heat stroke, heat cramps, heat exhaustion),
- Hypothermia (localized, and systemic).

Pedagogical Objectives

Knowledge related objectives:
The trainee should be able to:

- explain the basics of thermoregulation,
- nominate the important factors for outdoor workers in agriculture,
- nominate the heat- and cold related illness in outdoor workers,
- give examples of heat stress indices,
- explain the principles of prevention and medical surveillance.

Aquiring skills and changing the attitude:

The trainee should be able to:

- find reliable sources of information on thermal comfort,
- recognize and diagnose heat- and cold-related pathological outcomes,
- apply the rules on communicable and recordable occupational diseases,
- implement reasonable solutions in case of extreme temperatures,
- have a preventive attitude in relationship with workers and employers and to advice them on efficient alert-systems and procedures.

9.1.1 Glossary

Term	Definition
Acclimatization	the physiological changes that occur in response to a succession of days of exposure to environmental heat stress and reduce the strain caused by the heat stress of the environment; and enable a person to work with greater effectiveness and with less chance of heat injury; the process of adaptation which enhances the capability to sweat in hot environments, to preserve body core temperature.
Climate	the composite or generally prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years.
Dehydration	a deficit of total body water, with an accompanying disruption of metabolic processes.
Heat stress	the net heat load to which a worker is exposed from the combined contributions of metabolic heat, environmental factors, and clothing worn which results in an increase in heat storage in the body.
Hyperthermia	a condition where the core temperature of an individual is higher than 37.2°C.
Hypothermia	a condition where the body's core temperature starts to fall, being unable to compensate heat loss.
Physical activity	activity which generates more body heat by increasing metabolism.
Thermal comfort	refers to whether a person feels comfortable – not too hot, nor too cold.
Wet Bulb Globe Temperature (WBGT) Index	is a model for assessing the heat stress on a person in a hot environment using factors such as air temperature, radiant heat, humidity and air speed.
Work	physical efforts performed using energy from the metabolic rate of the body.

9.2 Important factors to be considered for outdoors employees exposed to extreme temperatures

The following are important factors regarding employees' exposure to extreme temperatures:

- → *Air temperature*: is what can be measured with a thermometer, and values between 18-24°C belong to the comfort zone for humans. It is not always an accurate indicator about how hot or cold a person feels.
- → *Radiant heat*: is a source of heat given by direct sunlight, machinery, hot water, heaters or open flames.
- → *Relative humidity*: is the amount of moisture (water) in the air. High humidity makes workers feel hotter or colder.
- → *Air movement*: usually cools.
- → *Hour of day*: the warmer hours of the day are mid-day and early afternoon.
- → *Physical activity*: work intensity and duration generates heat through metabolism.

→ *Clothing*: insulation keeps warm, permeability helps heat loss.
→ *Individual characteristics*: general health, weight, age 45+, level of acclimatization, medical conditions, pathological outcomes such as cardio-vascular diseases.
→ *Other factors*: use of alcohol, use of certain medicines, use of drinking water in summer as a hygienic individual habit.

The following workplaces are considered at risk for extreme temperatures exposure: agriculture, fishing, ranching, forestry, horticulture, road paving, construction, and power line and pipeline maintenance.

9.3 Climate conditions and climate change

Romania's climate is a temperate-continental transition, marked by some oceanic, continental, Scandinavian-Baltic, submediterranean and pontic climatic influences. In Banat and Oltenia, the Mediterranean influence is characterized by mild winters and a richer rainfall regime especially in autumn. In regions in the eastern part of the country, the continental character is more pronounced. In the northern part of the country (Maramures and Bucovina) the effects of the Scandinavian-Baltic nuance are manifested, causing a cooler climate with cold winters. (1).

Climate change is heating the earth's surface, with world-average temperatures conservatively forecasted to increase within the range of 1.1°C to 4.8°C by 2100. In the past years, particular attention has been paid to this issue, along with raising concern for the phenomena triggered by global warming and the subsequent climate changes, as the waves of heat hitting the temperate areas have grown in frequency and intensity. Means of evaluating thermal stress have been analyzed and revised against this background, in an attempt to improve the prediction capacity of these indicators. (2). Economic effects of these climate changes are difficult to predict in terms of the drop in productivity caused by the effects on people's health (3), but the number of people at risk for hunger could double by mid-century. (4). Recent studies have shown there is an obvious connection between the occurrence of heat waves and the increase (4 to 7 times) in the incidence of diseases caused by such heat waves in those who carry out outdoor activities. (5). For example, excess mortality from the 2003 heat wave in Europe (August only) resulted in 44,878 cases. (4). Climate change can threaten health more directly through heat-related morbidity and mortality; flooding and storms with associated trauma and mental health concerns; air pollution, especially from ground-level ozone and potentially from aeroallergens (pollen and molds); and infectious diseases, particularly those that are water- or vector-borne. In a warmer world the reduction of extreme cold could reduce the number of deaths caused by low temperatures which might offset the expected lives lost from more frequent heat waves. (4).

In Romania, climate models forecast serious droughts during the summer, especially in the South and the Southeast, up to 4°C; increase of winter precipitation in the Western and the North-Western part of 30-40 mm; annual average precipitation decreases from West to East (lower in Baragan Plain and Dobrogea); temperature extremes (minimum and maximum daily temperature) show significant increasing trends for all seasons, except for autumn, and the strongest increase was detected for hot-related extremes (no. of summer days and tropical nights) in extra - Carpathians areas of Romania. (1). In the Carpathian region encompassing Croatia, Hungary, Slovakia, Czech Republic, Poland, Ukraine, Romania and Serbia heat wave events have become more frequent, longer, more severe and intense over the period 1961-2010. (1). In 2007 Southern Europe - especially Italy - was experiencing an unusually warm and dry summer, with high risk for mosquito-borne diseases. (4). The August 2003 Heat Wave in Europe affected countries like France, Italy, Spain, Germany and Portugal in terms of excess deaths. (4). Heat waves are defined by the World Meteorological Organization as periods of five or more days when temperatures exceed the average maximum (in the years from 1961 to 1990) by 5°C.

9.4 Advances in thermoregulation

Maintaining a constant body temperature (36.5-37°C) is the result of a full balance between thermogenesis (heat production) and thermolysis (heat loss) processes. The main sources of thermogenesis are basal metabolism, to which the energy produced by physical effort is added - the higher the effort, the higher the production of heat. In respect to thermolysis, teguments play a major role. At ambient temperatures within comfort limit, the heat transfer between body and the external environment is mainly achieved through a passive transfer of heat, in the form of caloric radiation, from the warmer environment (the worker's body) to the colder one (the surrounding environment). The problem is that this process can turn ineffective if the ambient temperature is higher than 37.2°C, situation in which sweating and evaporation become the most important heat loss mechanisms. In turn, evaporation becomes ineffective along with a rise in air humidity. At 100% relative humidity, evaporation is completely ineffective. A major adjustment mechanism that can help prevent the bad effects of exposure to high temperatures, associated with sustained physical effort, is acclimatization. (6).

Acclimatization is achieved by progressive exposure to growing temperatures (few hours daily, during 7-9 days), through which we allow the body to put in motion a number of mechanisms (sweating at lower temperatures, an increase in the production of sweat and the drop in the salt and electrolyte content, an increase in the plasma volume of the heart flow and a subsequent heart rate drop), which would subsequently protect the body from the damaging effects of extreme temperatures.

The hypothalamus is the central integration center for thermoregulation, while peripheral control mechanisms include myriad of vasoactive neurotransmitters, brown adipose tissue, and the recently discovered transient receptor potential channels involved in temperature transduction. Physiological responses to heat and cold stress include vasodilatation and vasoconstriction, sweating, nonshivering thermogenesis (brown adipose tissue), piloerection, shivering and altered behavior. (7).

Thermal comfort refers to whether a person feels comfortable - not too hot nor too cold. Achieving thermal comfort is challenging because of the six factors (air temperature, radiant heat, relative humidity, moving air, physical exertion and clothing) described in Chapter 2, but also because of the variability between people (different metabolic rates, levels of physical fitness, medical conditions, medication, acclimatization, level of hydration, age, smoking, etc). Heat loss also depends on:

- *Quality of clothing:* good quality clothing with high insulating properties will trap air creating a thicker boundary layer, while wet items lose their insulating value and cause heat loss nearly equal to that of exposed skin;
- *Body type:* people with a tall slim build tend to become cold much faster than those that are shorter and heavier;
- *Metabolism:* physical activity increases body's metabolism and generates more body heat;
- *Exposure to the sun:* bright sunshine may reduce the effect of wind chill (make it feel warmer) by 6 to 10 units;
- *Age and physical condition:* elderly people and children have less muscle mass, so they generate less body heat;
- *Adaptation:* people who live in a cold climate are often able to withstand cold better than those from warmer climates;
- *Wind chill*: contributes to evaporation of moisture from the skin or from damp clothing against the skin, which makes someone feel colder by drawing more heat away from the body. (8, 9).

Apparently, women's capacity to adapt to extreme heat is lower than men's. (10).

The physiologic effect of heat on the body depends largely on the combination of temperature and humidity (heat index). *Heat index* (apparent temperature) is a measure of how hot it feels when relative humidity is added to the actual air temperature. For example, high humidity (>50%) & temperature of 30°C = Heat Index of 32°C-40°C which disrupts the thermal balance by limiting body heat loss through evaporation (risk for sunstroke, cramps and exhaustion), as shown in figure 1.

HEAT INDEX °F (°C)													
	RELATIVE HUMIDITY (%)												
Temp.	40	45	50	55	60	65	70	75	80	85	90	95	100
110 (47)	136 (58)												
108 (43)	130 (54)	137 (58)											
106 (41)	124 (51)	130 (54)	137 (58)										
104 (40)	119 (48)	124 (51)	131 (55)	137 (58)									
102 (39)	114 (46)	119 (48)	124 (51)	130 (54)	137 (58)								
100 (38)	109 (43)	114 (46)	118 (48)	124 (51)	129 (54)	136 (58)							
98 (37)	105 (41)	109 (43)	113 (45)	117 (47)	123 (51)	128 (53)	134 (57)						
96 (36)	101 (38)	104 (40)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	132 (56)					
94 (34)	97 (36)	100 (38)	103 (39)	106 (41)	110 (43)	114 (46)	119 (48)	124 (51)	129 (54)	135 (57)			
92 (33)	94 (34)	96 (36)	99 (37)	101 (38)	105 (41)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	131 (55)		
90 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	103 (39)	106 (41)	109 (43)	113 (45)	117 (47)	122 (50)	127 (53)	132 (56)
88 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	98 (37)	100 (38)	103 (39)	106 (41)	110 (43)	113 (45)	117 (47)	121 (49)
86 (30)	85 (29)	87 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	102 (39)	105 (41)	108 (42)	112 (44)
84 (29)	83 (28)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	92 (33)	94 (34)	96 (36)	98 (37)	100 (38)	103 (39)
82 (28)	81 (27)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	91 (33)	93 (34)	95 (35)
80 (27)	80 (27)	80 (27)	81 (27)	81 (27)	82 (28)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	86 (30)	87 (31)

Category	Heat Index	Possible heat disorders for people in high risk groups
Extreme Danger	130°F or higher (54°C or higher)	Heat stroke or sunstroke likely.
Danger	105 - 129°F (41 - 54°C)	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	90 - 105°F (32 - 41°C)	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	80 - 90°F (27 - 32°C)	Fatigue possible with prolonged exposure and/or physical activity.

Figure 9-1 Heat Index (US National Oceanic and Atmospheric Administration)

9.5 Heat stress: effects and prevention

9.5.1 Heat syncope

The patient suddenly loses conscience, for a few minutes, usually after resuming physical work (for approx 2 hours) in an excessively hot environment. It is based on the disturbed blood distribution due to insufficient control of the blood pressure mechanisms - skin vasodilatation accompanied by cerebral hypotension. (11).

Clinical manifestations start with prodromal symptoms (dizziness and fatigue), followed by cephalea, asthenia, nausea and eventually loss of consciousness. Signs show pale and moist teguments (sweating is still effective), accelerated pulse, low blood pressure.

Treatment consists in placing the victim into an environment which has a comfortable temperature or even a lower temperature, and positioning in a recumbent position. Also, cold liquids must be administered to the patient orally. In order to correct the loss of water, physiological serum or glucose solution 5% can be administered intravenous.

9.5.2 Heat stroke

This is the severest clinical manifestation of exposure to heat and must be reported in Romania as occupational disease. Fortunately, the incidence is low, but the mortality rate is extremely high (15-20%), that is why workers in agriculture have been identified as one of the categories most exposed to this threat. (12). Specialized literature has identified two types of heat stroke: the classical one, which occurs in people with a reduced capacity of thermolysis (elderly, chronic patients, etc.) and the exertional one, which usually affects agricultural workers which have not passed through an acclimatization process. Body's core temperature increases to 41-42°C.

Clinical manifestations: the onset is often sudden and associated with confusion, agitation, delirium, and visual and speech impairment, confusion, coma. These signs are the expression of the thermal homeostasis mechanism losing its balance. Blood pressure goes down and the skin is hot and dry.

Treatment is a matter of medical emergency, and its main goal is the immediate reduction in body's core temperature to 39°C by immersing the body in cool water while waiting for transportation to a hospital. (11). Even if the patient fully recovers, exposure to extreme heat and strenuous physical activities will be avoided for at least four weeks.

9.5.3 Heat cramps

Heat cramps are some of the effects of massive hydro electrolytic loss through hyper-sweating, along with the exposure to excessively high temperatures and a large consumption of water without salts. Low levels of sodium alter muscle reaction, resulting in weakness and muscle spasms. (11).

Drinking natural mineral water or a mild salt solution (6g NaCl / liter of water) up to 1 liter per hour is the first choice of treatment for heat cramps, but also the most important preventive measure when working in hot environment.

9.5.4 Heat exhaustion

Heat exhaustion is a more serious condition than heat cramps, due to prolonged exposure to heat combined with inadequate intake of water and salt. Body's core temperature exceeds 38°C, the skin is moist, and the pulse rate is increased. (11). Unfortunately, thirst is not an adequate symptom of dehydration, so the risk must be controlled by continuous fluid replacement.

Chronic heat-related illness is controversial, but some authors mention nephrolithiasis, eye damage, sleep disturbances, and chronic heat exhaustion. (8).

9.5.5 Prevention

Heat stress indices included in ISO standards have been developed to predict the physiological strain: *Wet Bulb Globe Temperature (WBGT)*, created in the USA; Universal Thermal Climate Index (UTCI), established by the European Union in 2009. ISO 7243 provides WBGT reference values for a variety of environmental

and personal conditions (e.g., clothing and workload). *WBGT of +33°C* is the maximum safe work temperature for an acclimatized person. (8).

In the short-term, *appropriate work conditions and interventions* to alleviate heat strain could significantly improve workers health, e.g., easy safe access to water and toilet facilities, regimented rest / drink breaks (work-rest schedule); appropriate clothing; personal cooling techniques and equipment (cooling station); hydration; medical assessment; training; appropriate acclimatization program for new workers; avoid working alone; payment per hour versus payment per output. (8, 9, 13).

9.6 Cold stress: effects and prevention

9.6.1 Localized hypothermia

Chilblains, frostbite and *immersion foot* are local manifestations, usually at the level of the extremities and parts of the body that are not covered or are covered superficially, caused by direct exposure to cold (body temperature at the skin level bellow 15°C).
Chilblain is a superficial skin lesion due to inflammation, while frostbite is a result of ischemia, and the affected areas turn cold, pale, and hyposensitive. In this stage, if exposure to cold ceases, within a certain time-frame, of up to a few hours, the phenomena can be reversed. If, however, exposure continues, the next stage, necrosis, is irreversible. Necrosis may result in self-amputation or may lead to infection and gangrene solved only by amputation surgery.
Immersion foot is an extensive frostbite involving the whole foot and characterized by chronic complications. (11). That is why recognizing the first signs of the disease and promptly adjusting local temperature by placing the subject into an environment which has a comfortable temperature and immersing the affected segments into warm water is extremely important.

9.6.2 Systemic hypothermia

Systemic hypothermia is the result of a serious imbalance between thermogenesis and severe losses of body heat, if body's core temperature is reduced to below 35°C. Such losses may exceed significantly the production of body heat, which is why the body gets gradually colder, starting from the central parts and advancing towards the extremities. A critical threshold in this process is the body's core temperature of 30°C, under which adaptation mechanisms cannot act furthermore. Circumstances of the illness are usually unintended (e.g., falling in cold water), or unexpected weather conditions.

Systemic hypothermia has two clinical stages, as follows:

a) The initial *fighting stage*: shivering, tachycardia and tachypnea, a slight increase in blood pressure and in glycaemia.
b) The *exhaustion stage*: breathing rate and blood pressure decline; other heart disorders may occur (atrial fibrillation, even ventricular fibrillation) when the body's core temperature declines below 29°C. These alterations are followed by cognitive impairment and cardio-respiratory arrest.

Emergency transportation to hospital is required if the patient is unconscious. If the person is alert, physical activity may be stimulated; wet clothes should be changed; the person should be transported to a dry environment. (11).

9.6.3 Prevention

Reasonable solutions: protect the hands, face, and feet from frostbite with an on-site source of heat; provide a heated shelter for workers; use thermal insulating material on equipment; use a work / warm-up schedule; work outside during the warmer hours of the day (mid-day / early afternoon); minimize activities that reduce blood circulation such as sitting or standing for long periods of time; avoid working alone in

very cold weather; wear multiple thin layers of clothing (at least three); use insulated footwear; keep energy levels up and prevent dehydration by consuming warm, sweet, caffeine-free, non-alcoholic drinks and soup; always be prepared to adjust the work plan because weather conditions can change throughout the day, and even hour-by-hour. (9, 13).

9.7 Physical performance in extremes temperatures

Heat, if intense, may greatly reduce endurance because of the need for more of the circulating blood volume to be devoted to the transportation of heat rather than to the transportation of oxygen, and because of the effect of dehydration often accompanying heat exposure as a result of loss of body fluids (sweating). Ambient temperatures of *30°C and above* have been shown to reduce mental and physical performance in workplaces. (14). It was shown that physically fit individuals have a reduced incidence of heat injury or illness during exposure to hot environments. The capability to sweat varies among people and can be developed by acclimatization and physical conditioning. Individual variations are seen not only between individuals but also, to some extent, in the same individual exposed to high environmental stress on different occasions, but such variations are not totally understood. (14). Cold weather, if severe, may in itself reduce physical performance because of numbness of the hands or lowered body temperature. (15).

The ideal way to perform physical work is to perform it dynamically, with brief work periods interrupted by brief pauses, so the worker may avoid fatigue and exhaustion. Implementing a buddy system in which workers are responsible for observing fellow workers for early signs and symptoms is recommended, as well as job rotation. (16).

9.8 Conclusions & Recommendations

Health consequences in exposure to extremes of temperature may vary from reversible symptoms and signs to multiple disorders, invalidity and decease. Moreover, behavioral and physiological changes due to hot environment may cause work-related accidents and work-inability. Age 45+, smoking and alcohol consumption are additional risk factors frequently occurring in agricultural workers, therefore workplace health promotion programs, as well as health education in early childhood are welcome.

Due to the fact that agriculture is an occupational sector where exposure to extreme of temperatures, as well as prevention measures, are not formally regulated, more regulations, facilities and control measures are required and expected in the occupational health and safety field, including workplace health promotion guides in rural areas. In this respect, agricultural employers should develop, implement, and enforce a comprehensive safety and health program that includes standard operating procedures.

The occupational physician is recommended to give specialized support to workers and employers to learn and implement procedures and prevention programs to better face climate conditions and climate change.

The occupational physician will better manage the risk of exposure to extreme temperatures towards the medical and physical condition of each employee. In this respect, collaboration with family physician is of great importance.

The occupational physician will take into account that weather conditions of concern may significantly influence other occupational risk factors, because heat, irritated skin, and sweat are all factors common in agricultural work that promote absorption of chemical substances through the unprotected skin. In this respect, a holistic approach is recommended in risk assessment and risk management, as well as following the European Policy for a sustainable use of pesticides (EU Directives and guidelines), and the Romanian case study about adequate managerial approach in a medium sized agricultural exploitation – S.C. ITC SRL Popesti-Leordeni (available on the EU-OSHA website, #extremetemperature).

The occupational physician should also consider the issue of foreign workers from non - European countries who come to agriculture sector and might not be prepared to cope with hot or cold environment; check-up for/or giving advice to develop individual hygienic habits are welcome; culturally and linguistically appropriate and translated materials are needed.

The daily outdoor, ambient temperature (°C), dew point temperature (°C), and relative humidity (%) can be obtained from the Local or National Weather Service Station.

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