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Casualties and Rescue Workers in the Cold

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Foreword

This guidebook is designed for people who attend accidents and are involved in first aid and casualty protection in cold conditions. Its aim is to increase awareness of the effects of cold on casualty victims, on pre-hospital care and on first responders in Northern periphery areas.

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Content

1 CASUALTIES IN THE COLD

This chapter informs you that

- thermal balance depends on ambient temperature, humidity, wind, metabolic heat production, and thermal insulation of the protective materials
- forms of heat loss are convection, conduction, radiation and evaporation which should be counteracted by different means
- cooling can be superficial or deep body cooling - deep body cooling can eventually lead to hypothermia
- injured patients lose heat by contact with the ground and they have a decreased ability to produce heat
- injured patients need to be protected from cold, ground, windy and wet conditions
- additional heaters can be used to warm the injured patients
- intravenous fluids should be warm and IV bag and line thermally insulated
- oxygen administration is safe in cold environments

Reasons and effects of cooling

Heat balance

Human heat balance depends on three basic components: ambient thermal conditions, the thermal insulation of clothing and metabolic heat production. The body heat balance is regulated by heat generation and heat loss.

Metabolic heat production by muscle activity (voluntary movements or involuntary shivering) may be diminished by the injuries and by immobilization of the casualty victim. Children, elderly, medicated or drunk persons may not shiver. Control of the body heat balance is affected by trauma: e.g. hypovolemia, hypohydration and seasickness can impair thermoregulation. Hypovolemia increases the cooling rate of the whole body, particularly the periphery.

Heat loss

Heat is lost from the body through **convection** (movement of air or water), **conduction** (contact with cold surfaces or liquids), **radiation** (minimised with good clothing insulation) and **evaporation** of sweat or water (Figure).

A patient who is lying on the ground and covered will lose 2/3 of his total heat loss by conduction. Good insulation between the patient and the ground decreases conductive heat loss. Wet clothing increases heat loss. Replacement of wet clothes with dry clothing which has good insulation diminishes cooling.

Avenues of heat loss and heat production and prevention of heat loss

Wind

Wind markedly increases the rate of cooling by removing the insulating layer of air surrounding the body and transfers heat away from surfaces. The cooling effect of wind can be expressed by a "wind chill index". It is based on the rate of heat loss from exposed skin caused by the combined effects of wind and cold. A wind chill index of -10 to -24°C is defined as uncomfortably cold, -25 to -34°C as very cold (risk of skin freezing), -35 to -59°C as bitterly cold (exposed skin can freeze in 10 minutes) and -60°C or colder as extremely cold (skin may freeze within 2 minutes).

Wind chill index

Wind speed m/s	Air temperature °C								
	0	-5	-10	-15	-20	-25	-30	-35	-40
1	-1	-7	-12	-18	-23	-29	-34	-40	-45
3	-4	-10	-16	-22	-28	-34	-40	-46	-52
5	-5	-11	-18	-24	-30	-36	-43	-49	-55
7	-6	-12	-19	-25	-32	-38	-45	-51	-58
9	-7	-13	-20	-27	-33	-40	-46	-53	-59
11	-7	-14	-21	-27	-34	-41	-48	-54	-61
13	-8	-15	-25	-28	-35	-42	-49	-55	-62
15	-8	-15	-22	-29	-36	-43	-50	-57	-63
17	-9	-16	-23	-30	-37	-44	-51	-57	-64
19	-9	-16	-23	-30	-37	-44	-51	-58	-65
20	-10	-17	-24	-31	-38	-45	-52	-59	-66

Frostbite time 30 min 10 min 2 min

Water immersion

The thermal conductivity of water is up to 25 times greater than air of the same temperature. This leads to high rates of heat loss even in relatively warm water. Heat loss occurs when water temperature is lower than skin temperature, i.e. water temperatures below 33°C. Cold water triggers a cold shock phenomenon (gasping reflex) which affects the cardiac and respiratory systems. Eventually cold water immersion leads to hypothermia.

Effect of cooling

The cooling of tissues affects almost all physiological systems. Body cooling can be superficial (involving skin and peripheral temperatures) or deep (involving core temperature). Slight cooling causes discomfort as well as skin and peripheral vasoconstriction, more severe cooling may induce shivering and the first sign of it is increased muscle stiffness.

Vasoconstriction in the skin and peripheral body parts (arms and legs) reduces heat loss and decreases skin and peripheral temperatures. There is minimal vasoconstriction in the skin of the head and the rate of heat loss through the bare head increases in a linear manner as ambient temperature decreases. At –4°C, heat loss from a bare head may be 50% of total heat loss.

Hypothermia

Hypothermia is a condition in which core temperature drops below 35°C and is frequently associated with outdoor trauma casualties. Several factors contribute to the development of hypothermia. These can roughly be divided into those that reduce heat production, those that increase heat loss and those that impair thermoregulation. Old age, endocrine diseases (e.g. hypothyroidism) and starvation reduce heat production. Skin disorders, burns and alcohol use are examples of states of increased heat loss. Injuries to the central nervous system, spinal cord, neuropathies, and several medications impair thermoregulation. Injuries to the skin and muscles might impair or eliminate signals from peripheral thermoreceptors, while hypovolaemia and hypotension affect central thermoregulation.

Hypothermia can be classified by core temperature into mild, moderate and severe.

- In mild hypothermia (35-32°C) thermoregulatory mechanisms operate fully but gradually decline with ensuing ataxia, dysarthria, amnesia and coagulopathy.
- In moderate hypothermia (32-28°C) the effectiveness of thermoregulatory mechanisms diminishes until it fails. The level of consciousness progressively decreases, severe coagulopathy develops, and atrial and ventricular dysrhythmias occur.
- In severe hypothermia (<28°C) consciousness is lost, severe dysrythmias arise, and ventricular fibrillation or asystole may develop, either spontaneously or by mechanical stimuli.

Hypothermia prolongs bleeding. Dysregulation and cooling of coagulation factors including platelets, activation of fibrinolysis and endothelial injury can contribute to coagulopathy among hypothermic patients. Hypothermia that accompanies severe trauma has a significantly worse prognosis than either trauma or hypothermia alone.

Pre-hospital care in cold environment

The first responder dealing with a casualty victim may be confronted by difficult environmental conditions, such as a blizzard or a storm at sea. This can make it hard to perform even the first task: protecting the patient from further loss of heat and a fall in deep body temperature. The fundamental rules of action must therefore be:

Rescue • Examine • Dry and insulate • Evacuate

In a difficult outdoor situation it is important to remember that rescuers must not put themselves in danger. Another casualty will not help an injured person.

Since it can be very difficult, even for trained medical personnel, to decide on the best course of action, it is crucial to establish early radio or telephone contact with a doctor who can supply instructions and suggest a course of action.

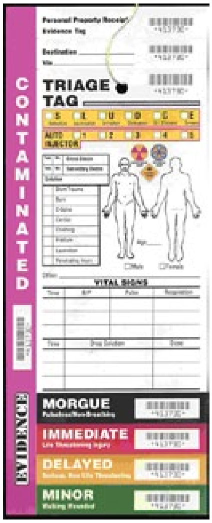
As far as possible, the assessment of the **hypothermic** casualty victim must include a detailed history. Questions about associated illnesses and injuries, drugs and medications, food, and fluid intake and duration of exposure must be asked.

The conscious hypothermic casualty may be given a sweetened, warm drink; increasing calorie intake will fuel shivering heat production. If intravenous fluid is given, it must be warmed to between 37 to 41°C.
If possible, an ECG should be recorded while the conscious patient is in transit. Violent shivering may make it difficult to achieve a readable tracing.

The hypothermic casualty must be handled with care and avoid sudden movements that might stimulate ventricular fibrillation. As the patient warms the risk of hypovolaemia and rewarming shock increase, if there is inadequate fluid replacement.

A **non-hypothermic** casualty in the cold will soon become a hypothermic casualty if counteractive measures are not taken. The key to early recognition of mild hypothermia is awareness of the risk and the speed with which it can develop. Mild insidious hypothermia has been termed the “umbles”: the patient fumbles, grumbles, and later mumbles. Fine motor skills such as zipping up a parka decreases, the patient withdraws and becomes less sociable. Gross motor skills are affected and a stumbling gait develops.

Triage



Triage is the process of sorting patients into priority order for treatment and evacuation. Triage takes many different forms, and operates at a number of different levels, but its overall aim is to provide the right patient with the right level of care at the right time. Triage must be a simple, reliable and reproducible procedure. A common pre-hospital priority system is summarised below.

Description	P	Colour	Evidence
Immediate	1	Red	Life threatening
Delayed	2	Yellow	Serious
Minor	3	Green	Walking wounded
Dead		Black/white	

Environmental conditions, especially dark and cold may make the priority process difficult to perform. Dealing with hypothermic patients adds even further problems as a slow pulse, long capillary refill time and cyanosis are all part of the clinical picture of hypothermic patient and so normal triage systems might not be immediately applicable in the hypothermic situation. The rule of putting the apparently dead in the last category for aid and transportation does not apply in the hypothermic victim as a severely hypothermic may appear dead but is still alive. A patient is not dead until he is warm and dead.

Body temperature measurement

Knowing the body temperature of the casualty victim is important for accurate correct diagnosis. Body temperature measurement should be performed without increasing heat loss from the patient and without compromising vital functions. Therefore the anatomic site of temperature measurement is important. Pulmonary artery temperature is defined as "real" core temperature. The oesophagus has the best correlation with the pulmonary artery temperature. The urinary bladder, rectum and tympanum are also sites that give reliable results. The ear canal temperature is the most practical. Outside hospital, the optional measurement sites are the oesophagus, rectum, mouth, axilla and, ear canal. The following should be considered:

Mid-oesophageal temperature measurement provides the closest indication of pulmonary artery temperature and can be practically measured during pre-hospital transport however, insertion of the probe may cause vomiting.
Rectal temperature measurement is accurate but undressing is required which is not realistic in cold conditions.
Oral temperature measurements are influenced by the consciousness of the patient. Measurements in an unconscious patient who has been lying prone with an open mouth are inaccurate. Measurements of fully conscious patient may give a result that seems accurate, but may be deceptively low. Tachycardia and tachyphnoea (respiratory rate $>$ 20 breaths/min) may affect temperature.
Axillary temperature is almost always inaccurate in cold conditions because the skin temperature is influenced by the ambient temperature.
The ear canal is easily accessible. Both ear canal and tympanic temperature can be measured. When measuring ear canal temperature, the walls of the canal may be cooled by ambient air, giving values that are too low, unless the ear is insulated. Well-insulated ear canal temperature gives values maximally only 0.6°C lower than rectal temperature. When measuring tympanic temperature, it is important that the instrument touches the tympanum.

Infrared radiation readings from the tympanum by infrared emission detection devices are accurate only under limited ambient temperatures. If the ambient temperature is too hot or too cold, the temperatures recorded vary widely. The accuracy of their use in hypothermic patients is unproven, and preference should be given to other methods which give more reliable repeatable readings.

Casualty protection in the cold

Casualty protection is one of the most important elements in the treatment of someone who has sustained an injury, particularly in traumatic circumstances. As well as the physical benefits of maintaining the heat within the casualty's body, the psychological benefits must not be underestimated.

Wet, cold and windy conditions demand sustained pre-hospital effort to prevent hypothermia in the seriously ill or injured casualty. To prevent body cooling and hypothermia developing during pre-hospital care casualty protection should be simple, providing adequate thermal protection.

Methods for casualty protection

Casualty protection requires adequate thermal insulation, air permeability and resistance to water penetration. A casualty in the cold can be protected with simple blankets, a wind and water proof lightweight reflective aluminised sheet, a padded special rescue bag. Other solutions such as bubble wrap and additional heating methods may be employed. Heat transfer by conduction to the ground can be prevented by using 1) a sledge, 2) a stretcher with a mattress or 3) a mattress inside the covering system or included in the special rescue bag.

Casualty coverings come in a range of shapes, sizes and weights with differing attributes. Some are disposable; some are designed for short timescales, etc. Each has its own merits and careful decisionmaking is needed to decide on the right product for a particular circumstance. Covering gear varies in thermal insulation, wind and water protection, and usability. There are several key factors which need to be taken into account when deciding on the most suitable product. It is important to consider the options based on the expected risk of an incident occurring and the most suitable product for this incident.

Blankets and reflective sheets

In calm weather the casualty can be covered with one or two blankets. The thermal insulation of blankets is greatly reduced by environmental conditions, such as wind and moisture.

Using a reflective sheet, i.e. a wind and water proof covering, underneath the blankets, increases the covering's thermal insulation and prevents heat release by evaporation. Its thermal insulation is approximately 50% higher under the effect of wind and dampness than that of blankets.

Special rescue bags

The purpose of a special rescue bag is to combine proper covering with easy use. It is typically similar to a padded sleeping bag. Rescue bags are well suited not only for preventing cooling of the casualties, but also for warming the casualty. The rescue bags are designed to cover the casualty from all sides. Zippers facilitate the examination and treatment of the casualty without the need to fully expose him/her to the cold. The protective cover may include a pocket designed for a heat package. Wind and water proof materials provide protection not only against cold, damp and wind, but also bacteria. A mattress included in the rescue bag prevents heat conduction to the cold ground. The casualty can be easily transported by using the handles.

Other solutions

Other solutions for casualty protection in pre-hospital care are simple, lightweight and rapidly usable systems. For example bubble wrap has recently been taken into use as casualty cover, because it is cheap, disposable, and contains insulative air. However, bubble wrap used alone can not provide adequate thermal protection in cold ambient temperatures.

Additional heating components are often included in the mattress or covering system. The purpose of the heated mattress is to reduce heat loss by conduction to the ground during pre-hospital care and transportation.

Additional heaters can be pillow like heat packages containing liquid, transferring heat through piping, or they may be permanently installed in the protection. Heaters distributing heat in a large area significantly reduce body heat loss. By warming up large skin areas, such as the back or the chest and arms, total body heat loss may be reduced by up to 30%.

The placement of additional heaters inside the protective covers affects how quickly the casualty will rewarm; the more layers of cloth between the skin and the heater, the more slowly the heat is transferred to the casualty. It is not advisable, however, to place the heater directly against bare skin, to avoid excessive local warming. The heater should not be too close to the exterior surface of the protection system, otherwise heat will be released to the ambient air. The reflective sheet enhances the effect of the heaters due to its aluminised reflective surface. The effect of the heaters starts to steadily decrease in two hours.

When covering a hypothermic casualty, rapid active warming, especially of the limbs, may cause fatal after-cooling of the myocardium. Safe warming takes place slowly and in moderation.

Mattress, stretchers and sledges

The importance of using mattresses is to prevent heat loss by conduction and to provide the sensation of warmth in the back. They can improve thermal insulation in the area of the hands and feet.

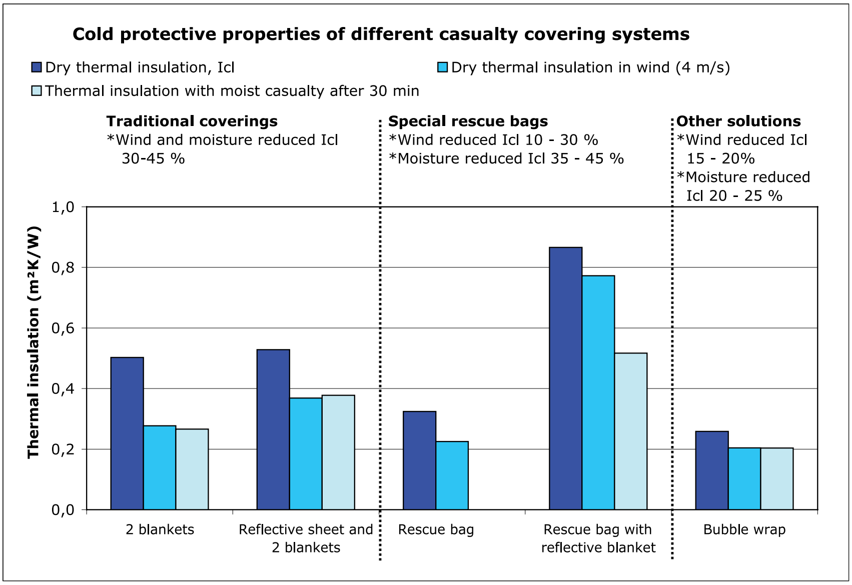
Mattress	Increase in thermal insulation (%)
1 mattress (12 mm)	+ 10
2 mattresses (12 mm)	+ 15
Mattress with welt	+ 15
Air mattress	+ 25

Lightweight stretchers are made from composite materials and designed to provide a secure method for transportation of casualties over rough terrain. The stretcher prevents heat loss by conduction to the ground. The use of a covered sledge in casualty transportation is more efficient than other methods in preventing the effect of wind and conductive heat loss from the casualty.

Thermal protection of covering systems

A covering's ability to reduce heat transmission to the environment is described by thermal insulation. It is expressed in m^2K/W (SI unit system). Clothing with thermal resistance of $0.16m^2K/W$ provides thermal comfort in indoor conditions. The thermal insulation values of casualty covers, such as blankets and rescue bags, correlate to the thickness of fabric. The thermal insulation of different types of casualty protection ranges from 0.26 to $0.98m^2K/W$. These provide a minimum duration limited exposure (DLE) time from 24 min to over 8 hours in an ambient temperature of -20°C. It is known that the structure (thickness, air content in material), size and model of the rescue bags affect heat loss from the casualty covers. Zippers cause the greatest heat loss from rescue bags. Examples of the thermal insulation values of various coverings are presented in the figure.

Moisture in casualty covers can be a serious problem. Moisture reduces thermal insulation and increases cooling, when the casualty is wet. Also wind reduces the thermal protection of casualty covers.

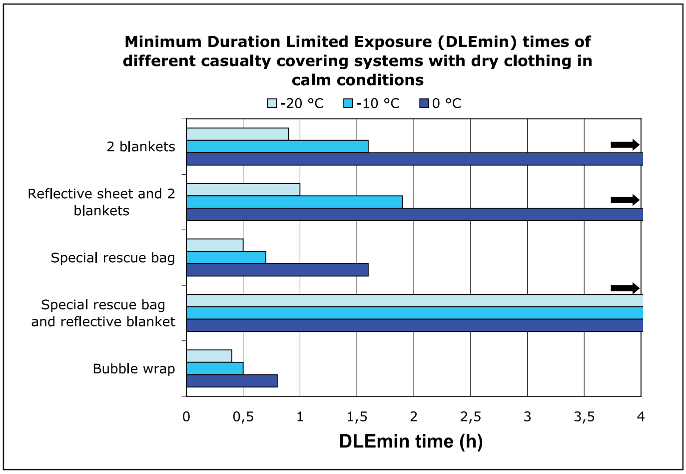


If the casualty is wet:

1. Immediately replace damp or wet clothing with dry clothing.
2. Add extra insulation under and around the casualty. Add a windproof/waterproof layer and place the casualty within shelter from wind and water.
3. Addition of heat via heat packs or hot water bottles increases the rate at which a cold or mildly hypothermic casualty rewarms. These can be applied to armpits, groins or over the thoracic region. This heat should not be applied directly to the skin since heat damage may occur to cold skin.

Duration limited exposure (DLE) time of covering system

Coverings should keep the casualty warm during transportation from the scene of the accident to the vehicle. Therefore, from the covering's usability point of view, it is important to know the duration of the prospective exposure. The usability times of casualty protections are defined by the DLE time, which gives the time of exposure to cold in hours in a given temperature, given a particular thermal insulation for the casualty protection. Cooling will start to impair the person's functional ability when average skin temperature drops to 30ºC. In accordance with the above definition, the enclosed table shows the recommended exposure times for various coverings.



The use of a covered sledge allows several times longer casualty transportation time than other protection systems. In very cold environmental conditions (-25ºC) the casualty may survive as long as five hours if a covered sledge is used, but less than an hour when other coverings are used.

Walking casualties with minor injures

At a casualty collection point at least one paramedic or ambulance driver (more if many casualties) should always be with green casualties in case the casualty victim's state deteriorates and requires treatment.

Cold protection for walking casualties with minor injuries must be provided as soon as possible to prevent cooling. Blankets and thermal wraps are suitable for casualty protection and insulative tarpaulin or other insulation is needed to prevent contact with the cold ground.

Adequate quantities of warm sweet oral fluids can be given to 'green' casualties with minor injuries. Sweetened drinks provide energy to maintain heat production through shivering. Hot food and drink will not add much heat to the body, but may provide comfort.

Emergency tents in disasters

Ideally, the health care area is protected against the rain and wind, is warm, illuminated, spacious and easy accessible to rescue units. Emergency tents are required for pre-hospital care in disasters and are used in major rescue exercises. The emergency tents can be used for:

1. Weather protection
2. Triage and care of injured casualty
3. Casualty collection point
4. Decontamination
5. Mortuary purposes
6. Command and control
7. Space for a break

Emergency tents are made from polyvinyl chloride- (PVC) or Polyurethane (PU) coated polyester fabrics, or neoprene coated nylon with an anodised aluminium expanding frame structure. Their weight varies from 90 to 195 kg. Air heating is the common heating method. The erection of the inflatable tents takes from 2.5 to 15 min. The durability of the tents is estimated at between 5 and 20 years.

Thermal aspects on pre-hospital care

Auscultation

To achieve the best possible care for the casualty victim, the medical equipment must be reliable and easy to use. During the evaluation of breathing, the chest of the casualty victim is conventionally uncovered in order to check the chest and diaphragm movements and synchronisation and to check for chest injuries. If circumstances do not allow the removal of clothing, the alternative is to use an electrical stethoscope, that works through layers of clothing.

Usability tests of the electrical stethoscope show that the reliability of auscultation on the bare skin is equal to an acoustic stethoscope. Although electrical stethoscope allows auscultation through three layers of clothing garments, the outer shell garment on casualty would have to be removed or opened to achieve reliable auscultation. The volume and filter buttons, and the headphone connections should be protected from interference caused by cold, rain or snow.

Methods for keeping intravenous fluids warm

Intravenous (IV) fluids are administered as treatment for hypotension, shock or dehydration in the injured or ill person. The optimal temperature of infused IV fluid is 37 to 41°C, and this temperature should not fall below 25°C. Cold fluid may cause local vasoconstriction and pain. There is a risk of making hypothermia worse if large amounts of cold fluids are infused. Rapid core temperature changes may cause ventricular fibrillation and disturb coagulation. For these reasons, warm IV fluids are recommended in the treatment of trauma patients.

IM-Medico *with two heat packs (bag and tip).*

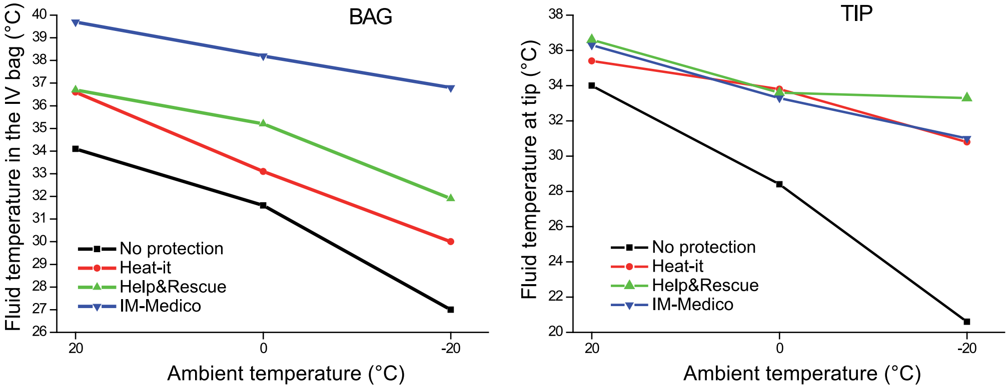
Help&®Rescue *insulative.*

Heat-it *with one heat pack and a pressure pouch.*

Most ambulances and emergency helicopters have equipment to heat IV fluids. However, warmed fluid exposed to cold ambient temperature rapidly cools down during infusion if the infusion bag and the IV line are not thermally insulated. Infusion line covers are available, which consist of either thermal insulation only or additional active heating systems such as reactivated heat packs.

An initial IV fluid temperature of 37°C decreases by 6 to 10°C in the IV bag and by 9 to 17°C in the cannula during a 10 min infusion when no thermal protection is available (graphs). With protection, the decrease is only 3 to 5°C in the cannula. In addition to the protection of the IV line, the cannulated hand should be covered.

Fluid temperature in the IV bag and in the cannula (tip) at the end of a 10- min infusion at full speed. The IV fluid bag was initially warmed to 37 °C.



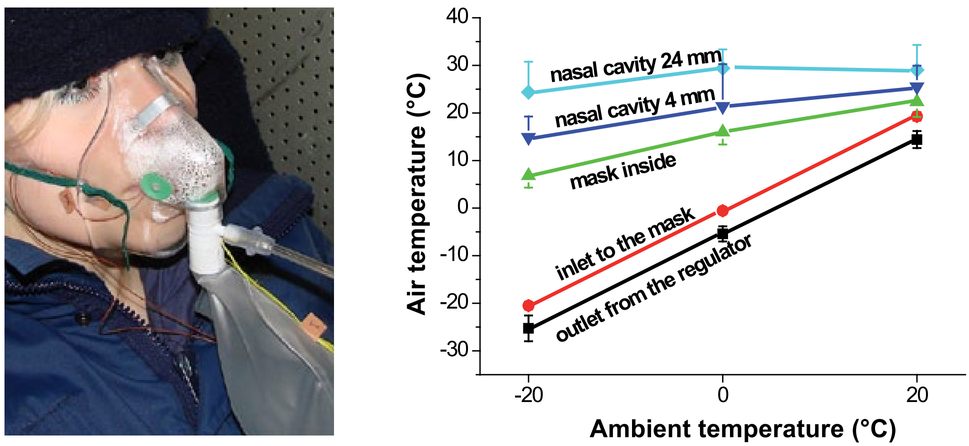
According to tests in cold environments, medicated plasters with a warming component are **not** effective enough to warm hand skin temperature and thus to increase vasodilatation of veins.

Oxygen administration

Supplemental oxygen is of great benefit to a patient with severe trauma and/or hypothermia. Oxygen gives a cooled heart a better chance of survival and lessens the risk of arrhythmias.

Figure shows that it is safe to administer oxygen through mask even when the oxygen bottle is stored in the cold environment. The temperature of the oxygen bottle (cold or warm) does not affect the temperature of the upper respiratory tract. The air temperature inside the nasal cavity at a depth of 24 mm is about 25°C even in an ambient temperature of -20°C. Likewise, the heat capacity of the gas is too low to cause any decrease in the body heat content. The mask works as a heat and moisture exchanger and the air temperature inside the mask increases to a safe level regardless of the oxygen bottle temperature.

Air temperature at the end of a 9-min exposure to three different ambient temperatures.



Oxygen administration is safe in cold environments even though the oxygen bottle is stored in cold.

2 RESCUE WORKERS IN THE COLD

This chapter informs you that

- thermal balance depends on ambient thermal conditions, metabolic heat production, heat loss and thermal insulation of the clothing
- cooling causes vasoconstriction in skin and extremities decreasing their temperature
- extremities, especially fingers are vulnerable to cooling
- wind increases heat loss in bare hands
- handling of cold objects and possible snow contact decrease hand temperatures
- selection of cold protective clothing depends on ambient conditions, level of physical activity and the terrain at accident sites

In much of Northern of Europe, and particularly in remote and rural locations, responders must be able to tolerate conditions such as rain, cold, wind and snow for long durations without the possibility of getting shelter for rewarming and rest.

Changing weather conditions and extremes of weather mean that responders should be clothed in a way that is easily adaptable (suits for different types of weather), is comfortable and allows ease of movement. All of these features are covered by different aspects of European legislation (through the EN classification and the CE marking system for Personal Protective Equipment).

Rescue workers include all the personnel that are involved at the accident site: fire fighters, physicians, nurses, ambulance drivers, mountain rescuers, police and volunteers.

Body heat balance and work capacity in different rescue tasks

Rescue workers' tasks vary widely depending on the accident type and phase of the tasks (**see Page 19**). Duration of the task can vary from a few minutes to hours and, the physical strain of the task from very light (traffic control) to very heavy work (rescue action or carrying casualties by stretchers).

Cooling

Body heat balance depends on ambient thermal conditions (especially air temperature and velocity), thermal insulation of clothing and metabolic heat production by muscles. The first signs of cold strain appear in an adequately clothed worker at 10°C during light work, where finger dexterity may be impaired. Skin cooling stimulates the cold receptors causing thermal sensations and stimulation of the sympathetic nervous system. Sympathetic stimulation constricts the small veins and arteries in skin, arms and legs which diminishes skin and extremity blood flow and allows them to cool more, and increases the thermal insulation of superficial tissues by more than 300%. With the help of thermoregulatory vasoconstriction/vasodilatation, body heat balance can be maintained when ambient temperature changes less than ca. 4°C.

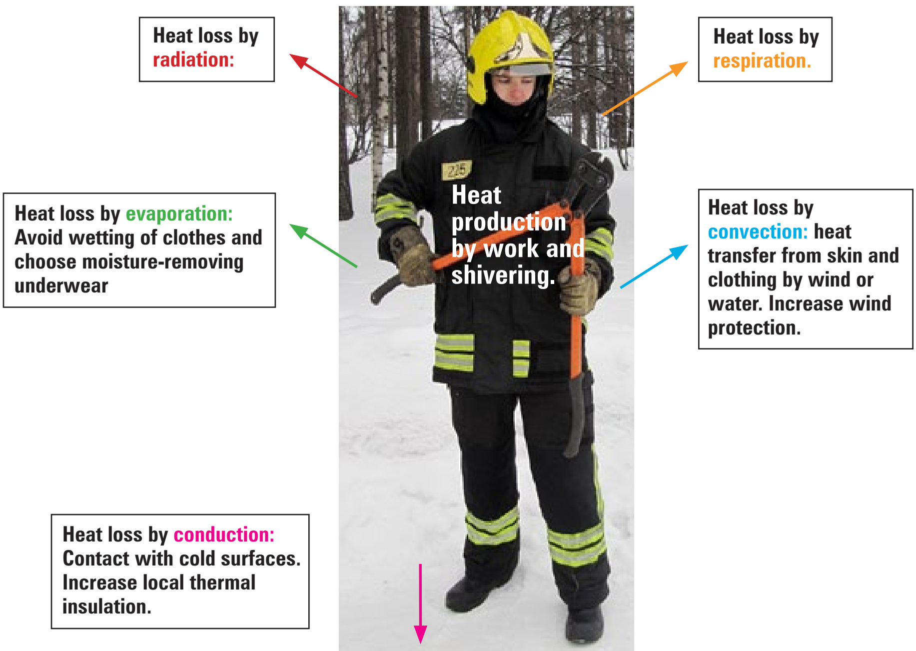
The consequences of body cooling are seen in cardiovascular, respiratory, neuromuscular and endocrinological functions. Working capacity is usually decreased by cold. Especially manual performance is sensitive to cooling. Whole body cooling impairs physical and/or cognitive working capacity and increases the physical strain of the work. Heavy exercise associated with increased ventilation and consequent respiratory tract cooling and drying may cause constriction in upper respiratory tracts.

Adaptation to cold takes about 2 weeks: in cold-adapted subjects the physiological responses to cold are usually attenuated and cold exposure is less stressful. However, in some cases cold adaptation may result in an increase in metabolic heat production.

Moisture

The wetting of clothing due to sweating or a moist environment decreases the thermal insulation of the clothing and increases heat loss (see Figure). During rest or light work, increased heat loss results in the body cooling.

Avenues of heat loss and heat production and prevention of heat loss.



Wind

Wind increases the cooling rate by removing the insulating layer of warmed air surrounding the body and by transferring heat from the surfaces. Such conditions may cause local cold injuries to exposed parts of the body, such as the face or hands, if uncovered. Prolonged exposure to wind can lead to general whole body cooling.

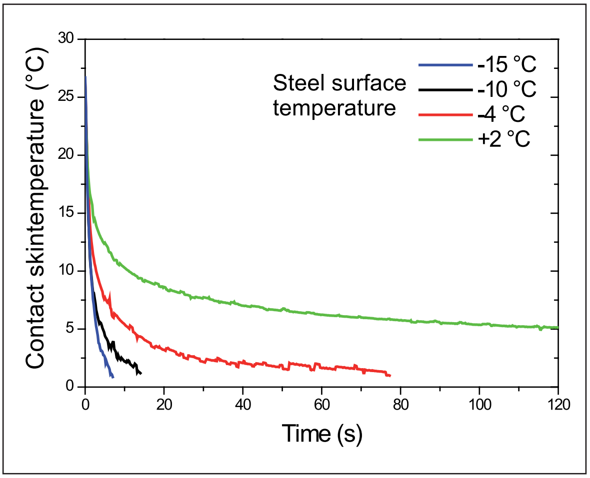
Working with bare hands or wearing only thin latex gloves cools down hands and fingers. Wind also increases cooling of fingers and the risk of freezing cold injuries.

Predicted times to finger freezing (in minutes) in different ambient temperatures and wind speed.

Ambient temperature °C	Wind speed, m/s					
	0.0	2.5	5.0	7.5	10	15
-5	∞	∞	∞	∞	∞	6.2
-10	∞	∞	7.2	5.1	4.0	3.0
-15	∞	8.3	4.6	3.4	2.8	2.0
-20	∞	6.0	3.5	2.6	2.1	1.5
-25	7.1	4.8	2.8	2.1	1.7	1.5
-30	5.6	4.0	2.3	1.7	1.4	1.0

Contact cooling

Contact with cold surfaces, such as metal hand tools or devices, rapidly decreases hand and finger temperatures (graph). Moreover, contact with loose snow decreases hand and finger temperatures by 8°C.



Heat production

When the body is excessively cooling, metabolic heat production by shivering is activated, if there is no possibility to increase voluntary muscular exercise. Heat generating brown adipose tissue has recently been shown to be active in some adults. Cold-induced vasoconstriction increases blood pressure (a typical increase is 20 (young) to 60 mmHg (elderly), this can be counteracted by light exercise. Heavier exercise, however, increases blood pressure.

The risk of the rescue worker cooling is minor if the tasks are associated with high physical activity and thus with high heat production. Work in the cold is more strenuous than in a thermoneutral environment because of decreased neuromuscular performance and the weight, multilayer and friction (between layers) of cold protective clothing. Each additional kg in clothing weight increases energy costs by approximately 3% and each additional layer by 4%. Daily energy expenditure is increased by ca. 100-150 kJ when ambient temperature decreases by 1°C. Forest terrain and snow increase energy expenditure by 2.6 to 3.6 fold compared to walking on the road.

Typical tasks and their cold-related risks at an accident site.

Task	Special risk factor	Effect			Prevention of cooling				
		Hand cooling	Skin cooling	Core cooling	Clothing according to work load	Gloves & contact gloves	Wind proof	Water proof	Additional clothes at rest
Search, isolation and traffic control									
Search of the accident site	variable work level				•				
Searching of casualtiesat the accident site	variable work level				•				•
Isolation of the accident site	variable work level				•				
Traffic control	low heat production		•	•	•		•	•	
Action at the accident site									
Transportation of casualties by a stretcher	variable work level				•				•
Transportation of casualties by snowmobile	wind		•		•		•		
Transportation of casualties by ATV	wind, wetting				•		•	•	
Rescue unit driver (use of machines, pumps)	wetting, contact cool	•	•		•	•		•	•
Diagnosis of the casualties	bare hands	•	•		•	•			•
Treatment of the casualties	bare hands	•	•		•	•			•
Covering the casualties	low heat production		•		•				•
Erecting the emergency tent	variable work level				•				
Communication (tetra, phone)	bare hands	•			•	•			
Management at the accident site	low heat production	•	•		•	•	•	•	
Investigation of the cause of the accident	low heat production		•		•	•	•	•	
Maintenance	contact cooling	•	•		•	•			•
Action in the cold and water									
Fire fighting in the cold	wetting	•	•		•	•		•	•
Rescue from water	wetting		•	•	•			•	•
Driving a boat	wind, wetting		•	•	•	•	•	•	•

Cold protection

To prevent cooling during rescue work:

- Be aware of the effects of cooling
- Wear sufficient protective clothing
- Increase physical activity
- Limit exposure time in the cold
- Take breaks in warm spaces or wear additional clothing during breaks

Cold protective clothing

Insufficient thermal insulation will lead to cooling of the body, whereas excessive thermal insulation will result in sweating during physically demanding rescue tasks. Sweating reduces thermal insulation and increases cooling when moisture is absorbed from the skin before it evaporates. The fabric properties of cold protective clothing systems can significantly affect humidity, temperature distributions and comfort. The significance of air permeability is most pronounced at higher wind speeds and higher levels of physical activity, where heat loss needs to be increased. Air movements cause ventilation inside the clothing, which can be used to remove excess heat and water vapour. Optimum choice of clothing, taking into account the user, the tasks to be performed and environmental conditions, guarantees comfort and efficient performance during cold weather exposure.

Cold protective clothing increases physical workload and energy expenditure. The weight of the clothing has the greatest effect, but the clothes stiffness is the second most important factor. Friction between the clothing layers and the effect of thick clothing in hindering movement of the extremities can add to physical workload.

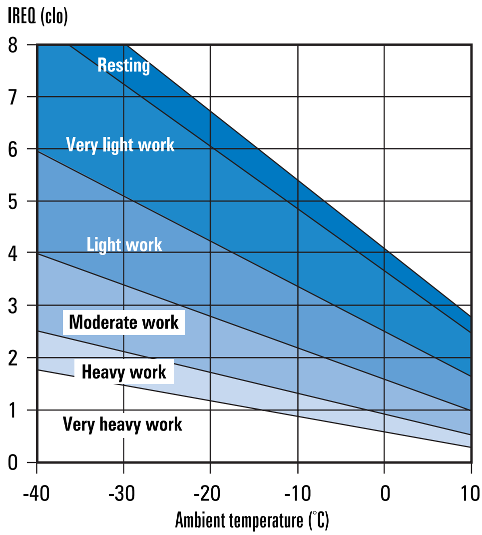
When deciding upon the type of clothing required, the following factors should be considered:

1. Expected weather conditions
2. Type of activity involved
3. The nature of the work
4. Options for shelter
5. Expected/anticipated duration of the incident

Multilayer clothing is a suitable method for protection against the cold. The purpose of the multilayer method is to wear 3 to 5 clothing layers including a base layer, 1 to 3 middle-layers, and an outer layer.
The base layer is a lightweight set of clothing worn next to the skin which is meant to keep the skin dry. If there is a risk of contact with open fire, hot surfaces or radiant heat, suitable base layer materials are wool (WO), silk (SE) and fire retardant materials, such as Nomex. If fire or hot surfaces are not a risk, suitable materials for cold weather underwear are also polypropylene (PP) and polyester (PES).
The middle-layers are an insulating layer designed to trap air and provide an insulating barrier against the external temperature. Adjustment of the thermal insulation can be provided if 1 to 3 middle-layers are used according to the weather and physical activity.
The outermost layer protects against wind, rain, snow, sleet and fire.

Extremities should be protected by using multilayer hand and feet protection. Work should be possible to perform with gloves, such as thin contact gloves and thick gloves. At least two socks should be used in winter shoes. Thick soles and thermal insoles prevent heat loss by conduction. An undercap should be used under a helmet to protect the head and face.

The selection of the thermal insulation value should be based on the ambient temperature and metabolic rate of the work activity. The IREQ index (required clothing insulation) takes into account a person's metabolic heat production, ambient conditions, and the thermal insulation of the clothing. The IREQ value, in units of Clo (Clo is a relative unit of insulation - 1 clo = 0.155m²K/W) is selected from the chart based upon metabolic rate and ambient temperature. Once the IREQ is determined, clothing ensembles offering the same value of insulation should be selected. Examples of basic insulation values and weights for different clothing ensembles are listed in the following table.



Ensemble	Thermal insulation		Weight (kg)
	Clo	m²K/W	
Firefighter's protective gear, trousers and shirt used in station, short legged underpants	2.2	0.340	5.9
Firefighter's protective gear, trousers and shirt used in station, long sleeved and legged underwear	3.5	0.540	6.3
First responder's clothing, trousers and shirt used in station, long sleeved and legged underwear	3.1	0.480	4.0
Winter clothing, fleece jacket, middle shirt and trousers, long sleeved and legged underwear	3.7	0.580	3.7

External heating

Special attention must be given to clothing when physical activity is low and the ambient temperature is very cold. In these cases additional heating is needed.

A heat vest has thin padding between the outermost and lining fabrics and can be worn either under a jacket or without a jacket. It has three embedded infra red heat panels; one on the back and two panels on the chest. In the cold, the battery lasts a minimum of nine hours.

Additional heating systems can be integrated into shoes or their insoles, or gloves. Separate heat packages can also be placed in the pockets.

Sustaining rescue workers and appliances

Cold protection and recovery during breaks

Tasks involving varying physical activity may expose the body to repeated fluctuations of warming and cooling. Maintaining thermal balance is challenging in this kind of work. Bouts of heavy physical activity create a high heat load resulting in sweating and the wetting of underwear clothing. Clothes may also get wet from rain or water splashes. Wet clothes decrease the thermal insulation of clothing and decreased heat production results in chilling during the breaks.

An ideal solution is to adjust the insulation and ventilation of clothing according to the physical activity in order to minimise sweating during the periods of heavy exercise. At the accident site a shelter or a tent should be set-up in which dry clothes or additional layers of clothes are available and, can be changed.

Energy requirements increase in the cold. Good nutrition and hydration are essential to maintain work capacity in cold weather.

Dry clothes, food and water should be always available for personnel at the accident site.

Appliances

Cold conditions also affect appliances and their maintenance. They especially set limitations and demands on outdoor maintenance, fuels, and materials such as plastic and steel.

A protective mask should be kept unfrozen, if possible, so that it will shape according to the face immediately after placement. Water used for pre-cleaning the protective mask must be protected from freezing. After use, moisture on the face mask caused by breathing and sweating must be dried, so that it does not freeze and render the mask unusable.

When working in winter time, a driver needs to know techniques for cold protection of vehicles, and methods for starting an engine in the cold. Incorrect methods may prevent driving or cause damage to the vehicle engine.

Winter time maintenance of vehicles:

- Maintenance of cold starting devices
- Maintenance and checking of the condition of batteries
- Protection of components and connectors of electrical systems against moisture
- Exchange of engine and transmission gear oils to winter quality fluidity
- Inspection of durability of the coolants in the cold in the autumn
- Draining of water from the fuel system and refuelling of vehicles with winter quality fuel in the autumn before the first frost
- Removal of water from air-pressure brakes on a regular basis

A diesel engine must not be forced to start by towing, because the lack of fuel injection can lead to failure. Similarly, a catalytic converter-equipped vehicle must not be started by towing, because the fuel in the catalyst damages it when ignited.

Use of communication devices in the cold

The TETRA digital radio communication system, based on the Terrestrial Trucked Radio standard, is widely used in emergency and public service in Europe and in many other countries throughout the world. The main idea is to offer an extensive and effective radio network for national security authorities at the site of accidents in all environmental conditions.

It is not only radios that are sensitive under extreme cold conditions; the manual dexterity of rescue workers must also be maintained in cold exposure. Short periods of bare hand working in cold conditions may be possible, but a decrease in finger and hand temperatures causes discomfort and deterioration of performance. Effective communication in a disaster requires accurate functioning of both communication devices and rescue workers.

Usability tests in cold conditions showed that (Figure)

- The use of the hands-free system and an external tangent enables a more user-friendly and efficient way to communicate compared with holding a phone in one's hands. Keeping the TETRA phone warm, e.g. below the outer shell garment, preserves the running time of the battery.
- Firefighter's leather gloves provide better dexterity in the use of TETRA phones compared with textile gloves.

This booklet provides information concerning cold-related effects on both casualty victims and rescue personnel and is a practical guidance.

The first part of the booklet contains information on the factors that casualties face in cold environments. It provides information regarding the diagnosis of the casualty, the pre-hospital care of casualty victims, and protection methods against cold, wind and moisture.

The second part of the booklet offers information regarding rescue workers' work capacity and protection methods against the cold, wind, and moisture in different rescue tasks. It provides information on how to use communication devices and how to maintain equipment in cold conditions.

This booklet provides valuable information on the effects of the cold on pre-hospital care for firefighters, volunteers, border guards, nurses, mountain rescuers, and police.

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