It's a Dry Cold! Hypothermia and the Athlete

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Many athletic endeavors subject the participant to significant cold stress. This exposure can be either short term (cross country skiing, biathlon, downhill skiing etc.), medium term (adventure racing) or long term (such as mountaineering, polar or other adventures).

RESPONSES TO COLD

The human response to cold stress is both behavioral and physiological. Upon feeling cold, athletes may either change their macroclimate by changing locations to a warmer setting, or change their microclimate by adding layers or pieces of clothing. The body responds physiologically to cold through vasomotion (peripheral vasoconstriction which decreases blood flow and heat loss from the extremities) and shivering (involuntary oscillating muscle contractions which produce heat). The athlete will also create heat through the heat produced by voluntary exercise. Paradoxically, at higher work intensities, sweating may also occur.

In summary, behavioral and blood flow responses tend to decrease heat loss, while shivering and exercise increase heat production; both types of response focus on attenuating, stopping or reversing a decrease in body core temperature (hypothermia). One other concern for the athlete is the paradoxical effects of vasoconstriction. Although this response decreases heat loss (therefore minimizing core hypothermia), it also eliminates heat delivery to the extremities (therefore exposing the athlete to the risk of local frostbite).

PREVENTION OF COLD INJURY

The major health threats during cold weather exercise are frostbite, hypothermia, cold-induced asthma and musculoskeletal injury. The following factors are important for preventing these problems.

Hydration

The body tends to dehydrate during exercise. In the cold, dehydration increases through extra respiratory water loss to cold air. This leads to decreased plasma volume, thickening of the blood and decreased blood flow (and heat delivery) to peripheral tissues, especially in the hands and feet. This increases the risk of frostbite. Also, efficiency of metabolic and enzymatic reactions are reduced. Thus, a conscious effort must be made to hydrate more than during warm weather exercise (i.e., up to 2-6 litres/day) because the thirst mechanism is kicks in only after dehydration has started.

Energy substrate depletion

An adequate supply of substrate is required for fueling exercise and shivering if necessary. Both processes are important for the production of heat. If an athlete (i.e., a cross-country skier) becomes fatigued and is no longer able to exercise or shiver, hypothermia becomes a very real risk. Energy stores should be replenished by ingesting complex carbohydrates and fats (i.e., nuts) at regular intervals of 15-60 minutes to support continuous activity in the cold.

Maintaining heat balance

Hypothermia occurs when heat loss significantly exceeds heat production. As described above, heat production depends on exercise and/or shivering. Heat loss occurs through respiration, evaporation, conduction, convection and radiation. Respiratory heat loss can be decreased by wearing a mask or scarf. Although this avenue of heat loss is a small fraction of total heat loss, minimizing the heat (and water) loss from the airways may help alleviate symptoms of exercise- and cold-induced asthma. Whereas water intake within the body is encouraged above, all efforts should be made to prevent accumulation of water either on the body or within clothing. If too much clothing is worn, sweating will occur causing two problems. First, evaporative heat loss will increase. Second, water will greatly reduce the insulation capacity of clothing and increase convective heat loss (more details below).

GENERAL SAFETY

Exercise in the cold is different than in heat. Cold weather training should build up gradually, improving fitness and expertise with clothing protection. Smooth non-slippery surfaces should be chosen to prevent injuries from slipping or twisting of lower limbs. In the cold, there may be a tendency to avoid pre-exercise stretching. Stretching is even more important in the cold so special emphasis should be considered. It is best to predict changes in heat balance rather than respond to them. Just prior to exercise, clothing should be reduced to what will be needed during the exercise bout. Thus, the athlete may feel cool during the first part of exercise but sweat accumulation will be minimized. When a rest stop is taken, extra clothing should be added to prevent chilling.

In conclusion there are few contraindications to full physical activity in environments as cold as even -25 to -30°C. Proper preparation and knowledge will enable safe and productive training and competition.

Clothing and equipment must be chosen, maintained and used properly to maximize effectiveness in preventing frostbite and hypothermia. If the body is adequately protected from cold stress, this will tend to attenuate central thermoregulatory vasoconstriction and subsequent extremity cooling and frostbite. However, it is important to balance the need for adequate insulation and avoid the tendency to over-insulate.

CLOTHING

THERE IS NO SUCH THING AS BAD WEATHER … ONLY BAD CLOTHING.

Norwegian Proverb

Since humans are tropical animals and poorly designed to withstand a cold environment, they are reliant on external protection from the cold in order to survive. This is primarily accomplished through clothing. There are three main principles involved in choosing cold weather clothing.

1) Clothing should be assembled as a complete ensemble. **The clothing ensemble should be designed for the specific conditions to be encountered.** This can be done by keeping in mind the following:

a) The physical work regime that will be done (i.e., continuous or intermittent, long or short periods, low or high work rate etc.), and

b) The environmental conditions that will be encountered (i.e., temperature, humidity, rain or snow fall expected, prevailing wind conditions etc.)

2) The principles of how clothing works should be understood completely and every effort should be made to maintain the clothing and to use it properly. If this is done, **one can widen the window of conditions in which a specific clothing ensemble can be used, even though they are outside the parameters that the ensemble was originally designed for**.

3) The most important factor, which can be controlled by the first two principles, is to minimize moisture accumulation in clothing. The cold weather enthusiast should religiously do everything possible to…

…KEEP WATER MOLECULES OUT OF THE CLOTHING ENSEMBLE !!!

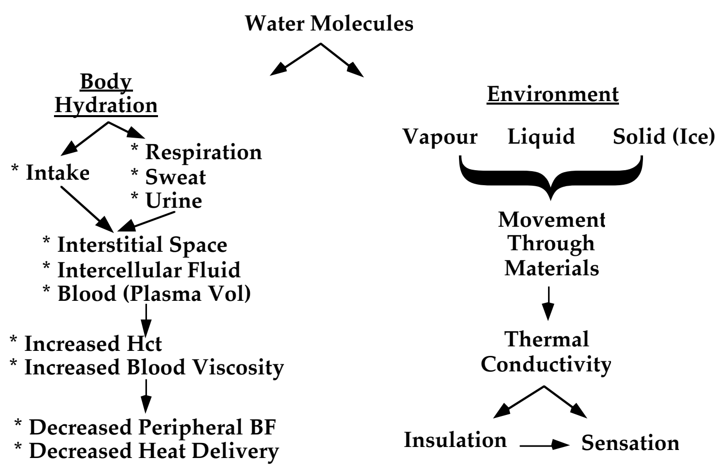

Figure 1. While water ingestion is vital for body hydration and function, however, water molecules greatly decrease clothing insulation and personal comfort.

Specific Considerations Of The Clothing Itself

1) Material properties. The following properties are important when considering clothing adequacy:

a) Insulation – Generally referred to in Clo units, indicates the resistance to heat transfer. One Clo unit provides the insulation of a business suit, and the usual undergarments, and can be defined as:

1 Clo = 0.18 °C/(kcal/m^2/hr)

Don't worry, no more equations. Insulative value of a garment is mainly dependant on: 1) material thickness; 2) the ability of the garment to trap air, which itself acts as an insulator; and 3) how dry the material is (as you will see later).

b) Permeability and moisture transfer – Moisture is produced at the skin through sweating and insensible water loss. In the heat, liquid sweat evaporates releasing heat of evaporation, thus increasing heat loss from the skin surface. This heat loss is not always advantageous in the cold. However, it is important to transfer as much water as possible from the skin through the clothing, either in vapor or liquid form. Permeability indicates the ability to allow vaporized moisture to pass through the material. Condensed (liquid) moisture transfer is also important as liquid can pass along material fibers to the clothing surface where it can evaporate. Moisture that remains within the material can decrease thermal insulation by as much as 30-50% because conductive heat loss is increased through wet clothing.

c) Water resistance – This indicates the ability of the material surface to repel liquid moisture from entering the material (normally the outside surface). Of course, minimizing water entry into the material will help maintain the insulation value of the material and thus the comfort level of the garment.

d) Wind resistance – The resistance to airflow (wind) through the material. This is very important as air flow carries heat away from the skin surface via convection.

2) Comfort. This will affect one's perception of clothing effectiveness. The fit of the clothing is important. If several layers are going to be included in an ensemble, each layer must be large enough to fit loosely over the layer beneath.

3) Design. Many design factors will affect not only the physical comfort/fit of the garment, but will also affect the thermal protection from the cold as well as practical usability of the garments.

a) Hoods, collars, sleeve ends and cuffs. It is important to have a high collar that zips up to the end of the collar, thus providing a 'high turtleneck' effect. This provides great comfort as the neck is especially sensitive to cold air currents. The high collar can also provide frostbite protection to much of the face.

An insulated hood is essential for cold weather (insulation may also be accomplished with a toque underneath a thin hood). Although the proportion of heat lost through the head is ***greatly overemphasized***, a good hood will indeed minimize head heat loss, stop uncomfortable cold air currents through the neck of the jacket, and protect against frostbite of the face and ears.

Although it is a matter of preference, sleeve cuffs (elastic cuffs inside the sleeve that close around the wrist) are very helpful in reducing convective air-cooling of the arms. It is very important to consider the interface between mitts and the sleeve end itself. Unless the mitt fits easily and fully inside or over the sleeve end, the bunching of the mitt against the sleeve end will create a weakness in the insulative armor; cold wrists are common with poorly integrated jacket/mitt combinations.

b) Pockets and zippers. Pockets in an outer jacket should be large enough to carry everything intended (i.e., winter mitts etc.), easy to open with mitts on, and must close easily and securely to prevent loss of pocket contents. Unfortunately, style often takes priority over function when clothing is designed. Thus, pockets are often small and openings are slanted (even vertical) to give a more 'sexy' look. Pockets should be large with the opening as close to horizontal as possible. This will increase the amount that can be put into the pocket and minimize the possibility of contents falling out respectively.

Zippers must be able to be OPERATED WITH MITTS ON. This can be greatly assisted by attachment of 5-8 cm (2-3") tabs to EACH zipper on a garment. Again, fashion concerns dictate that zippers be small and inconspicuous. Unfortunately, all things being equal, small zippers 'catch' or 'snag' more often and are more prone to breaking. They are also considerably more difficult to operate, even with the tabs.

c) Length and overall coverage. One major weakness in a clothing ensemble is often the decreased thermal insulation at the waist. It is important that upper and lower body garments either are continuous (one piece or attached) or overlapping. It is important to forgo the fashionable short jacket for a longer model that will overlap your pants and protect your seat while you are sitting. Extra protection can also be gained by switching from a normal pant to a bib design for the outer layer.

d) Ventilation. It is EXTREMELY important to be able to ventilate a clothing ensemble while it is being used. Two main functions of clothing ventilation are: 1) removal of water vapor from inside the ensemble; and 2) to allow convective, conductive, evaporative and even radiative heat loss from the skin surface. Ventilation may be facilitated by opening sleeve ends, 'pit zips' and the front zipper (which is a reason not to use a solid front pullover design). The 'pit zips' should be long enough to actually allow the arms to be placed through them, if the need to increase radiative and convective heat loss from the arms occurs.

Strategies For Using Clothing

1) Layering design. The clothing ensemble should have several layers instead of one large thick layer. This provides the obvious advantage of fine-tuning or adjusting the thermal insulation value in order to adjust to warmer or colder conditions. In addition, each layer should also be chosen to perform specific tasks.

a) Inner layer. It is common knowledge that the inner layer (usually polyester) should be highly vapor permeable so that moisture is transferred or 'wicked' away from the skin through to the next layers of clothing. Having dry skin greatly increases one's comfort level.

b) Middle layer(s). The middle layer(s) are mainly for insulation and can be fleece, pile, wool or even thicker polyester. It should be reemphasized that this middle zone should comprise multiple insulative layers rather than one thicker layer.

c) Outer layer. The main function of this layer is to provide wind and/or moisture protection, depending on the prevailing conditions. Various materials can be used including Gortex, 60/40 cloth, cordura, windstopper (PTFE laminate), nylon, and others.

2) Layering Strategy. As stated above, it is important that a clothing ensemble have several layers, AND that the appropriate layers be designed for plenty of ventilation. Therefore, heat loss can be finely tuned and moisture removal should be optimized. These characteristics are useless unless the layers and ventilation openings are used properly.

The VISCOUS CYCLE. One common problem is that one gets cold while preparing or waiting to start working in the cold, therefore several layers are worn. Travel then begins and eventually (sometimes very quickly) the person gets very warm and moisture begins to accumulate in the clothing. The traveler is hesitant to stop to adjust the clothing and 'puts up' with the discomfort. Finally a rest stop is made and layers are taken off to allow some cooling. However, no work is being done and heat production is lower. The remaining layers are now wet and uncomfortable and rapid cooling occurs causing significant discomfort. By the time the traveler is ready to start again, he/she has put on the outer layers to get warm again. Thus, travel starts with all of the clothing on and more heating and moisture accumulation will occur during travel. The traveler will be colder during the next break when outer layers are taken off again. This cycle continues and gradually gets worse.

The best strategy is to BE PROACTIVE IN LAYER ADJUSTMENT. Just before starting out, realize that you will soon get warm. Therefore, take a layer or two off just before starting. Even though it will feel cold initially, you will warm up once you are moving. Now when you stop for a break, you can put extra layers on for added insulation when your heat production is lower. Your inside layers will not be as moisture laden and you will be more comfortable. Again, just before starting out again, shed the extra layers in anticipation of increased heat AND moisture production.

One main principle to remember in the cold is that…

IT IS PREFERABLE TO OPERATE WITH A COOL SKIN SURFACE,

especially while working.

Under normal conditions, sweating is mainly determined by skin temperature, thus cooler skin will result in less sweat production and consequent moisture accumulation in clothing layers.

3) Moisture removal at the end of the day. It is best to avoid the "weekend adventurer syndrome" where many mistakes are made, not corrected, and merely tolerated because one can put up with almost anything for a few days. One should always act as if clothing and equipment will be used on a continual daily basis. Thus, at the end of the day it is important to extract as much moisture out of the clothing ensemble as possible in order to restore maximum insulation and comfort for the next day's activities.

Considerable time and effort may be necessary to dry clothing over a stove or fire, but it will be worth it! Studies have shown that over the period of a week or two, insulative ability of clothing can decrease considerably even when efforts are made to remove moisture each day. You will get very cold if your clothing looses 30-50% of its insulation value.

4) Maintenance. It is also important to take care of any physical problems or damage to any element of the clothing ensemble. Clothing cannot be expected to perform properly if its physical integrity is compromised. Therefore, have adequate sewing equipment and repair kits and know how to use them. It is also important to care for clothing according to manufacturer's instructions. For instance, Gortex garments should be washed (remember to follow instructions) periodically in order to remove dirt particles from the pores in the material. Otherwise the moisture transfer characteristics may be greatly compromised.

In conclusion, remember the following points and you will go a long way to ensuring comfortable safe clothing use in the harsh cold climate:

1) THERE IS NO SUCH THING AS BAD WEATHER… ONLY BAD CLOTHING.

2) As much as possible, the clothing ensemble should be designed for the specific conditions to be encountered.

3) You can widen the window of conditions in which a specific clothing ensemble can be used, even though they are outside the parameters that the ensemble was originally designed for.

4) KEEP WATER MOLECULES OUT OF THE CLOTHING ENSEMBLE !!!!!

This requires commitment to:

a) Proactive layering changes,

b) Aggressive clothing ventilation to expel moisture during the day,

c) Continued efforts to remove moisture at the end of the day.

CARE OF COLD INJURIES

The onset of both hypothermia and frostbite can be insidious, therefore, it is important that athletes are aware of the signs and symptoms to detect cold stress problems in either themselves or their partners. Frostbite can be prevented by adopting the following principle…

NEVER ACCEPT NUMBNESS!

Nerve impulses are absent once nerve temperature decreases below ~7 °C. Therefore, if you feel numb, this is a sign that tissue is already very cold and potentially about to freeze. Once numbness is felt, all efforts must be made to increase insulation, add heat and/or exit the cold environment. If exposed skin is "frostnipped" (superficially frozen), the area should be thawed immediately by placing a warm hand over the area. Care will then be required to prevent recurrence. If actual frostbite does occur, (i.e., a digit or limb part is frozen solid), the frozen part should not be warmed unless it can be guaranteed that refreezing will not occur. Treatment should be done by immediate immersion of the affected part in water at 37-42 °C. This will be painful and proper analgesia should be maintained.

Hypothermia should be rare in athletics and can be diagnosed by noting diminished physical and mental ability, unconsciousness unexplained by drugs or trauma, week or absent shivering in an obviously cold person and inability to locomote. Patients should be treated gently, removed from the cold, kept horizontal and dried. They should then be insulated and transported to medical facilities. In almost all cases, external warming is recommended during pre-hospital care and transport that last longer than ~30 minutes. This is especially important in a severely hypothermic patient who is no longer shivering as heart temperature will continue to cool for a long time and remain low unless external warming is commenced.