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This article reviews considerations for reducing the risk of cold injury for athletes and recreational participants. Recommendations are presented for precautionary measures which may be taken during training sessions, competition and recreational activities. Because of the journal involved, athletic populations are highlighted. Eight specific considerations are presented. Keywords:

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PREVENTING COLD INJURIES DURING TRAINING, COMPETITION AND
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PREVENTING COLD INJURIES DURING TRAINING. COMPETITION AND RECREATION

Cold injuries involve either whole-body hypothermia or peripheral cold damage, due to cold-dry or cold-wet conditions. Historically, cold injuries have been experienced mostly by soldiers. Campaigns during WW I, WW II, the Korean War, and the Falkland Islands conflict have shown that 10-33 % of all infantrymen suffered from cold injuries (3). In recent years, however, widespread interest in outdoor winter sports, and the need for athletes to train year-round, have resulted in a large number of athletes and sports enthusiasts being exposed to the perils of cold environments. Dr. Cameron Bangs (1), for example, has written:

In the "good old days", folks were content to while the winter doing jigsaw puzzles by the fire. For reasons not totally understood, this contentment to get fat and lazy during cold months has been rejected by many who insist upon continuing with outdoor recreation year round. In addition to the estimated four to six million skiers in the U.S., joggers now don woolen caps and face masks to continue huffing and puffing in the cold; (and) climbers make winter ascents of mountains after a pleasant night in a dripping snow cave.... With an increasing number of people exposing themselves to

the cold. the risk and incidence of cold injuries naturally rises.

Therefore, the purpose of this article is to present cold injury prevention considerations for those individuals who train, compete, or recreate in the cold. This article does not detail the recognition and treatment of cold injuries (Table 1) because there have been several excellent articles published about this topic in recent years (1,3,5,6).

ENVIRONMENTAL FACTORS

Both environmental and human factors interact to produce cold injuries. The primary environmental factors are temperature, precipitation, wind speed, and ground surface conditions.

Obviously, as ambient temperature and humidity decrease, the risk of frostbite increases. Wind combines with low air temperature to greatly accelerate the loss of body heat, because it penetrates loose-fitting clothing or openings in clothing to remove still, warm air layers which insulate the body. In fact, evaporative cooling can cause up to 80% of total body heat loss. The combined effect of moving air and low temperature on the skin has been called "wind chill". A wind chill factor chart may be found in NSCA's Journal of Applied Sport Science Research, volume 2(4), 1988. This chart, initially developed by Antarctic

explorer Paul Seiple, describes three zones of frostbite risk: little danger, increasing danger (flesh may freeze within 60 seconds), and great danger (flesh may freeze within 30 seconds).

Rain, snow, and wet skin/clothing greatly increase the incidence of cold injury. Wet skin may result in cold injury at higher temperatures than those causing frostbite. For example, few people recognize that trenchfoot is possible in temperatures of 32 - 50°F, if feet remain wet and are exposed to cold-wet conditions for periods up to 3 days. Most athletes living and training in the U.S., however, are not exposed to cold-wet conditions for more than a few consecutive hours.

Outdoor exercise during winter months also must take into consideration the increased risk of orthopedic injuries when ground surface conditions are slippery. In addition to falling on ice, ligament/tendon/muscle strains occur (i.e. ankle, knee, hip) on slippery surfaces because footing is poor and biomechanical movements are subtly altered.

HUMAN FACTORS

The list of human factors which predispose to cold injury is extensive. Recognition of these factors is imperative in preventing cold injury in athletes and sports enthusiasts. During recreation, intelligent behavior allows us to add clothing or move to a warm, indoor environment.

However, during training or competition, young, healthy individuals expose themselves to conditions which they would not normally endure, because of strict self-discipline, peer pressure and coaching demands.

A typical training session or competitive effort in the cold involves two significant human factors: skin wettedness and fatigue. Both of these factors clearly contribute to an increased risk of hypothermia and frostbite, and require significant planning efforts. Fatigue developed during prolonged competition (more than four hours) at low exercise intensities also may render an athlete unlikely to perform simple preventative measures, such as changing clothing, drying feet, etc.

The duration, mode and intensity of exercise also alter the risk of cold injury (5). An individual who rides a bobsled produces less internal metabolic heat than a cross country skier, and experiences faster wind movement across exposed skin. From this perspective, the sledder has a greater risk of cold injury. However, this same bobsled team member also produces less sweat and has drier skin/clothing. From this perspective, his risk of cold injury is less than the cross country skier. This example demonstrates that many factors must be considered in planning training and competition.

Youthful athletes and young adults seem to be relatively resistant to frostbite and tend to have fewer

post-freezing complications. In contrast, babies and very young children are highly susceptible to cold injury; this is partly due to a large surface area, in relationship to body mass (5). Older adults are at increased risk of peripheral cold injury to the skin, nerves and surrounding tissue. This probably results from inadequate circulation to the extremities.

Cardiovascular fitness, especially as measured by maximal cardiac output, plays an important role in the development of cold injuries. Those humans who possess high levels of physical fitness (and high cardiac output) tend to deal with cold environments more successfully than unfit individuals (3). Two hypothetical examples may explain this observation. First, a large cardiac output during exercise may allow more blood flow to be shunted to cold-constricted blood vessels in the nose, fingers, toes and ears. Second, a high maximal oxygen consumption ($\text{VO}_{2\text{max}}$) allows an athlete to maintain an exercise intensity which is higher than that of an individual who possesses a low $\text{VO}_{2\text{max}}$; this allows the former athlete to produce more internal metabolic heat.

Alcohol intoxication increases the risk of cold injury, in three ways (5). First, alcohol is a blood vessel dilator that increases heat loss by promoting blood flow to the surface. This increased blood flow may also give a sense of "warmth" and well-being, as the skin becomes heated at the expense of the body's core. Second, alcohol inhibits the

sensations of cold and pain, thus blocking normal behavioral responses (e.g. adding clothing, moving indoors). Third, alcohol is thought to directly interfere with shivering, thus preventing effective heat production; shivering can increase basal metabolic rate 4 - 5 times. Drugs also interfere with thermoregulation. Mechanisms of drug action include: depression of brain control, interference with blood vessel constriction, inhibition of shivering, impairment of judgement, reduction of coordination, and decreased mobility (5).

Differences in racial susceptibility to cold injury have been described primarily in black and white military units (3). The results of several studies do not allow a definitive answer to this question, but one's home of origin may play a role in one's hand rewarming response. Cold weather experience and knowledge of preventative measures are probably more important than racial differences.

Previous cold injury no doubt predisposes humans to further trauma from the cold. Several authors of review articles unequivocally state that even minor prior cold injury predisposes one to a subsequent injury (3). For example, recurrent first degree frostnip clearly decreases peripheral blood flow and increases cold sensitivity. Prior trenchfoot injuries, even though mild, render the individual (a) highly susceptible to reinjury in a cold-wet environment and (b) intolerant of intense marching even in warm weather.

Metabolic abnormalities also may increase the risk of cold injury. Depressed function of the thyroid or adrenal glands (which regulate cell metabolism and heat production), result in hypothermia. In addition, diabetics and alcoholics commonly experience low blood sugar (hypoglycemia). Up to 50 percent of patients with hypoglycemia also experience hypothermia.

It is not widely recognized that dehydration is often observed in cold environments. Cold weather dehydration affects cardiovascular performance in essentially the same way that a hot environment does. Dehydration increases the likelihood of peripheral cold injury, due to decreased circulation to the extremities. Increased urine production in cold weather (known as cold-induced diuresis) adds to this problem.

Anxiety and fear may play a role in peripheral cold injury (7). If an athlete is extremely anxious or fearful of competition or other factors, sympathetic nervous system activity is heightened; this results in blood vessel constriction and sweating. Both reduced blood flow to the skin and sweating contribute to a decrease in skin temperature.

REDUCING THE RISK OF COLD INJURY

Considering these environmental and human factors, the following recommendations are offered to aid athletes and

coaches in planning for winter training and competition:

1. Consider the air temperature, wind speed, and precipitation at the time of cold exposure. Consult a wind chill factor chart and determine a safe exposure time for training or competition.
2. Utilize information about weather conditions to select the proper layers of clothing. The inner layer ought to consist of a non-wetable fiber that transports sweat away from the skin surface. The outer layer should be wind-proof and water-proof, yet allow sweat to evaporate. When immobilized, or during low intensity exercise, a middle layer of clothing may be necessary for insulation. During high intensity exercise, the outer layer (or head covering) may be loosened or removed for brief periods, to prevent excessive heat storage. It is important to keep clothing dry. Tight fitting clothing or shoes reduce blood flow to skin and increase the potential for peripheral cold injury.
3. Plan the outdoor training course by considering slippery ground surfaces, wind direction, and the impact of fatigue.
4. When designing training schedules, consider the age, cardiovascular physical fitness, cold weather experience, previous cold injuries, and current medications of the athletes involved.
5. Teach athletes about the wind chill factor chart, use of proper clothing, first aid for cold injuries, slippery ground surfaces, and alcohol/drug effects on temperature

regulation.

6. Design a plan for evacuation of cold injured athletes.
7. Consider differences in metabolic heat production, especially during team competition. The varsity squad may produce large amounts of internal heat, while reserve units may suffer from hypothermia because they are inactive. Avoid situations in which athletes stand outdoors in wet clothing or footwear. Provide shelter from the wind and precipitation, whenever possible.
8. Supply athletes with liquids, to avoid dehydration, just as you would in a hot environment.

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TABLE 1 - TYPES OF COLD INJURIES

Hypothermia - core body temperature drops to 94°F or below.

Frostnip - freezing of superficial layers of the skin with no subsequent damage or tissue loss (cold-dry environments).

Frostbite - freezing (crystallization) of tissue fluids in the skin, due to cold-dry conditions, which results in damage or tissue death. Occurs when skin or tissue temperature drops to -2°F.

Chilblain - Superficial injury to the hands and/or feet, due to exposure to cold and damp conditions.

Trenchfoot - a disease of the limbs associated with cold-wet exposure (32 - 50°F) for a period of 12 hours or more. Results in damage or tissue death.

For further information, consult references 1,3,4,5,6.