Preparing for Cold Weather Exercise

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For many, the coming of winter marks a season where we reluctantly confine ourselves to our homes, offices, malls, cars, or any other enclosure that can generate enough heat to keep us comfortable. Too often the simple phrase, "It's too cold out," is the first uttered when the notion of winter exercise creeps into our thoughts. For most of us, the inability to tolerate the cold is due more to a lack of preparation, than it is to an inability to stay warm. A basic understanding of how the body generates, retains, and dissipates heat can assist us in preparing for winter's worst, and help us to take advantage of a host of unique outdoor activities. As is the case with hot weather activities, exercise in the extreme cold carries with it physiological consequences that must be understood and addressed in order to maximize performance and ensure a safe exercise experience.

Production of Heat During Exercise

Like all machines, the human body is not 100% efficient. In fact, during walking, cycling, and running, the body only uses about 20-30% of its energy output for mechanical work, with the remaining energy expenditure being liberated as heat[3]. Depending on environmental conditions, the body tries to either retain or dissipate this heat, in order to keep the body core temperature at a constant 37°C. Heat is removed from the body by a combination of the following mechanisms:

Table 1

Mechanisms of Body Heat Loss

Mechanism	Explanation
Conduction	Heat transferred from a warmer body to a cooler body through direct contact
Convection	Removal of heat from a body by movement of air or water over the body, thus replacing warmed air or water molecules with cooler ones
Radiation	Electromagnetic transmission of heat from a warmer body to a cooler body
Evaporation	Water vaporizing from the skin (sweating) and through respiration

Conduction

Heat exchange by conduction involves transfer of heat between molecules that are in direct contact with one another. These molecules can be present in the form of liquid, solid, or gas. For example, muscle tissue that becomes heated from the friction of contraction will transfer this heat through adjacent structures via conduction to the skin, where air molecules in contact with the skin are then heated, thus resulting in heat loss.

Convection

Once air molecules in contact with the skin are heated via conduction, they must be replaced by cooler air molecules for effective heat transfer to the environment to continue. If warm air molecules are not exchanged, which is desirable during cold weather, they act as an "insulating layer" and prohibit further conductive cooling. Convection describes the process by which these warm air molecules are replaced by cooler air molecules. Exercise on a windy day, during running or cycling, or stationary exercise in a room with a fan will result in a greater heat loss since cooler air is constantly replacing the warm air molecules that are in contact with the skin.

Radiation

Heat loss by radiation describes the emission of electromagnetic waves to cool solid objects in our surrounding environment. In the same way that our bodies receive heat from the sun through radiation, our bodies emit heat to our surroundings. Similarly, if the objects in our surroundings are at a higher temperature than our bodies, we will absorb heat that is radiated from those objects.

Evaporation

The major mechanism by which heat is removed from the body during exercise is evaporation. Water is continually vaporizing from the skin and respiratory passages, thus transferring heat to the environment. Evaporation of sweat has a cooling effect on the skin, which in turn cools the blood in the skin via conduction.

Effects of Cold on Exercise Performance

Whether exercise performance in the cold is compromised is dependent on a multitude of factors, such as air temperature, wind chill, clothing selection, body composition, and type of exercise. Generally exercise performance will not be compromised, unless a significant amount of energy is expended on shivering, which can significantly increase oxygen consumption during exercise. This is particularly the case during swimming, where heat is removed from the body more rapidly through conduction in the water (about 25 times faster than air). Exercise in cold water produces greater oxygen consumption than exercise of identical intensity in warmer water[2]. Heat loss via convection is also increased during swimming, as water molecules in contact with the skin are continually being replaced as the individual moves through the water.

Moderate intensity land-based exercise typically generates enough heat to maintain the body's core temperature in environmental temperatures as low as -30°C (-22°F), without the need for excessive heavy clothing, or increased shivering[3]. Furthermore, individuals who posses a higher amount of body fat will retain a greater amount of body heat than leaner individuals[4]. Therefore, leaner individuals will typically require greater insulation in the form of clothing than those with a greater degree of body fat.

In addition to the issue of heat loss during cold weather exercise, a significant water loss can be incurred through sweating, and respiration. Air is typically very dry in the winter months, and this air is warmed and humidified in the bronchial passages during inspiration. This constant humidification of incoming air often results in dryness and irritation of these passageways. Wearing a scarf or facemask over the nose and mouth during exercise will trap heat and water vapor in the fibers during exhalation, which will in turn serve to assist in warming and humidifying the next incoming breath.

Clothing Selection for Cold Weather Exercise

The primary function of clothing is to assist the body in maintaining a core temperature of 37°C, regardless of environmental conditions. During hot weather, clothing serves to prevent radiant heat gain from objects in the surrounding environment, while during cold weather it serves to prevent heat loss through convection and conduction. Clothing provides a barrier of air between the clothing and skin, as well as a physical barrier to the surrounding environment. Wearing multiple layers of thin clothing creates a larger air barrier above the skin, which is optimal for preventing heat loss. Furthermore, wearing multiple thin layers, as opposed to one thick layer, gives one the option of removing individual layers to adjust the level of insulation during exercise.

Additionally, the layer of clothing closest to the skin should be made of a material that "wicks" moisture away from the skin to the next layer of clothing for subsequent evaporation. Natural fibers such as silk and wool, and synthetic fibers like polyester and polypropylene, do an excellent job of wicking moisture away from the skin, drying quickly, and insulating well. Absorbent materials such as cotton are a poor choice as first layer, as they will lose their insulating properties if they become wet through sweating, and will actually increase conductive heat loss. Wool does an excellent job retaining its insulating properties even when wet, and makes a good choice as an outer-layer garment as well. Several manufacturers make undergarments of fabrics that are a silk and wool blend, which serve as an excellent first layer. Because of wool's insulating properties, a wool hat is a very good choice during cold-weather exercise, as 30 – 40% of body heat is lost through the head.

A combination of a polypropylene sock liner and a wool sock is a good choice for stop-and-go activities such as hunting, where the feet may sweat considerably during walking, then become much cooler when sitting for extended periods. In this situation cotton is a poor choice for socks, as they will lose their insulating properties when wet, and result in rapid heat loss from the feet by conduction. Consideration should also be given to the weight of a garment relative to its insulating properties. For example, a fleece outer layer may have insulating properties similar to wool, but less weight, making it a more efficient garment overall.

It should be noted that prevention of air exchange between the environment and the warm air barrier created by clothing is a primary determinant of the clothing's insulating effectiveness. Because warm air rises, turtlenecks do a good job of preventing a chimney effect, and subsequent loss of body heat via convection. Baggy, loose fitting clothing generally provides more opportunity for air exchange with the environment. During exercise where a high degree of pumping of the arms and legs occurs, a "bellows effect" is created, and warm air can be forced out through the large openings provided by loose clothing.

Table 2

Clothing Recommendations for Cold-Weather Activity
First layers constructed of "wicking" materials such as polyester, polypropylene, silk, or wool.
Multiple thin layers provide better insulation and greater comfort control than a single thick layer.
Clothing should be snug fitting to prevent air exchange with the environment (chimney & bellows effects)
Wear a hat. 30 – 40% of body heat is lost through the head.
Sock and glove liners should be a synthetic material such as polyester to ensure wicking of moisture from the extremities, which are most susceptible to frostbite.
Chemical heat packets can be stuffed wherever necessary to provide immediate auxiliary heat.

Warning Signs for Cold Related Injuries

The most common type of cold related injury is frostbite, which occurs when the temperature of the extremities falls to dangerously low levels. This is most likely to happen when a person is participating in stationary activities such as ice fishing or hunting, where body heat production is relatively low. If one's clothing does not adequately maintain core temperature during these types of activities, blood flow to the extremities will drop dramatically, resulting in skin temperatures that can become dangerously low. The toes are especially susceptible to frostbite if one's feet get wet either through sweating or poor footwear, which significantly increases conductive heat loss. Early warning signs of frostbite include numbing or tingling sensations that typically occur in the fingers, toes, nose and ears.

Providing some type of external heat to the torso[1] or directly to the extremities is an excellent way to prevent frostbite during stationary activities. Disposable chemical heat packs are a safe, convenient, and inexpensive way to keep warm during cold weather activities. When exposed to air, these heat packs reach a temperature of approximately 104°F, and will operate for up to 18 hours depending on size.

Summary and Recommendations

The body loses heat through the mechanisms of evaporation, conduction, convection, and radiation. Moderate levels of activity generally produce enough heat to maintain a constant body core temperature. However, stationary or stop-and-go activities can pose a significant risk of cold related injury. During cold weather exposure, our best defense against heat loss is clothing, and proper selection of clothing relative to the activity at hand is essential to ensure a safe, enjoyable outdoor experience. One must recognize that different activities will require different clothing selections, with the degree of required insulation generally being inversely related to the intensity of the exercise performed. Multiple thin clothing layers provide a larger air-insulating zone between the skin and environment, and allow one greater control over the degree of insulation than a single thick layer. Layers immediately adjacent to the skin should be constructed of materials that wick moisture to outer layers for evaporation. This is especially true for socks, where frostbite is a primary concern.

Winter weather provides a multitude of opportunities for one to participate in unique outdoor experiences. Whether these experiences are enjoyable or disastrous, is primarily dependent on preparation for the activity. A basic understanding of how the body regulates temperature, combined with the knowledge of how to make wise clothing choices, will ensure a safe and enjoyable cold-weather exercise experience.

References

1. Brajkovic D, Ducharme MB, Frim J. (1998). Influence of localized auxiliarly heating on hand comfort during cold exposure. *Journal of Applied Physiology, 85(6)*:2054 – 2065.

2. Craig AB, Dvorak M. (1968). Thermal regulation of man exercising during water immersion. *Journal of Applied Physiology, 25(1)*:28 – 35.

3. McArdle WD, Katch FI, Katch VL. (2001). *Exercise Physiology: Energy, Nutrition, and Human Performance (5th ed.)*. Lippincott, Williams & Wilkins: Baltimore, MD.

4. McArdle WD, Magel JR, Gergley TJ, Spina RJ, Toner MM. (1984). Thermal adjustment to cold-water exposure in resting men and women. *Journal of Applied Physiology, 56(6)*:1565 – 1571.

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