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Challenges faced by Polar Explorers

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Introduction

People have embarked on polar expeditions for a variety of reasons through the centuries, since the first arctic expedition in the 1500s. Notable examples include John Franklin's final expedition in 1845, with its aim of discovering the northwest trading passage, and the first men to explore to the north and south poles at the turn of the 20th century[1]; to the present day with scientists regularly venturing to the far north and south of our planet. The poles present a delicate "natural laboratory", useful to many different fields of research, such as the LARISSA project[2] which is currently studying global warming and its effects on Antarctic ice shelves, or for the South Pole Telescope[3] which uses the ideal location for its clear view of the stars through the unpolluted sky. In the past, polar expeditions were often fatal; perhaps most famously Franklin's final expedition, and that of Captain Scott to the South Pole[4]. Despite having better knowledge and equipment, there are still many problems to be faced by the modern explorer. Only last year the expedition taken to the Antarctic by experienced explorer Henry Worsley[5] proved fatal, showing that these regions are still as tough and dangerous as they were, and that the harsh climates must be taken extremely seriously and with great care.

Many of the challenges experienced lie around nutrition and hydration problems in the harsh environment, which work to increase the risk of hypothermia and various types of cold injury, and enhance psychological stresses. This paper will begin with an overview of the body's normal mechanisms for coping with exposure to cold, moving on to discuss the various physical and psychological issues around being in these extreme environments, before finally reviewing various methods of coping with these issues.

Physiology

The body detects cold using thermoreceptors: free nerve endings in the epidermis. Temperatures between 10°C and 40°C stimulate cold receptors, and temperatures below 10°C stimulate pain receptors instead.[6]

As a response to a detected temperature decrease, Basic Metabolic Rate is raised to produce more heat, using the methods of non-shivering and shivering thermogenesis. Non-shivering thermogenesis is defined as "increased metabolic heat production from sources other than muscular contraction". It is caused by increased production of thyroid hormone, insulin, catecholamines and adrenocorticoids, all of which increase metabolism and therefore generate heat. There is also evidence that the Central Nervous System increases norepinephrine production from the adrenal medulla, which causes an increase in sympathetic responses in peripheral tissues, causing vasoconstriction of blood vessels. This means blood stays closer to the internal organs and loses less heat to the external environment via radiation. This effect works best with people who have a higher body fat percentage, as this gives more insulation to the circulating blood. This effect is again increased in people who carry weight around their middle, in what is described as "apple shaped". Men tend to carry their fat in this way more than women, who tend to carry weight on their hips and thighs. The increased vasoconstriction leads to a higher peripheral resistance, and so to avoid a dramatic increase in blood pressure the body releases less Anti-Diuretic Hormone (ADH), increasing the need to urinate. This is called cold-diuresis.[7]

Shivering thermogenesis generates heat through fast paced contraction and relaxation of the muscles. This, combined with "pre-shivering" (the general tension of muscles when cold), results in a metabolism of up to 4.2 times the normal human metabolism.[7] This increase in metabolism is how shivering generates heat.

In cold conditions erector muscles of the skin will also raise the hairs on the skin, causing air to be trapped close to the skin. Air is a very good insulator, and so this also decreases the amount of heat lost via radiation.[6]

However, these coping mechanisms are compromised in a person who is chronically externally fatigued, sleep deprived, inadequately nourished or has a reduced tissue insulation (fat), all factors which are more likely in an expedition scenario.[8]

Injury and Management

So, what can happen when these coping mechanisms fail? There are two main ways in which the body may be affected: the body's core temperature (hypothermia) or the body's periphery (cold injuries).

Hypothermia is most commonly defined as the state in which a person's core body temperature drops below 35°C. There are several stages of hypothermia. As a person's temperature begins to decrease, they will start to seem confused and lose co-ordination. If a person fails the classic sobriety test (i.e. unable to walk 9 metres in a straight line), the person is classed as hypothermic. After this the symptoms progress, with

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the patient starting to show signs of depression, difficulty speaking, stumbling and withdrawing. Next, as core temperature falls to around 30°C muscle contraction becomes poor, causing shivering to stop (therefore speeding the rate of temperature decrease) and the patient to experience difficulty standing or walking. Pulse rate and respiratory rate will then drop and muscles will become rigid. As temperature drops to around 26°C consciousness is lost. Because the pulse is very weak at this point, it may appear that the patient is dead, even though they are still alive. This phenomenon sparked the phrase "no one is cold and dead until warm and dead", as they may still recover on warming. As hypothermia progresses, the cardiac cycle lengthens, which causes the oxygen delivery to tissues (including the brain) to be decreased. This goes hand in hand with the decreasing respiratory rate, which decreases its ability to expel carbon dioxide at the regular rate and can therefore cause respiratory acidosis. Eventually pulmonary oedema along with cardiac and respiratory failure will cause death.[7,9]

Hypothermia is a medical emergency, so it is important to get a suffering patient out of the expedition environment and to a hospital as soon as possible. However, if this is not immediately possible there are first aid steps that can be followed. First any wet clothing must be removed. To increase the patient's core body temperature, they must be warmed slowly. This can be done using blankets and another person's body heat. A warm non-caffeinated drink can also be given, providing the patient is not unconscious. If the patient goes into cardiac arrest, CPR should be carried out. Once the patient is in hospital, there are several techniques that can be used to increase their body temperature, the most common of these being inserting a warmed IV fluid, warm water torso immersion and rewarming blankets. Blood glucose, electrolytes and blood gasses should also be monitored.[7,9]

Cold injuries can be classified in two types; cold dry injuries and cold wet injuries. Cold dry injuries, or freezing injuries, range from superficial freezing with no subsequent tissue loss called frost nip, to deep damage to subcutaneous tissue or skin, called frost bite. When the extremities are cooled, the body's initial reaction is vasoconstriction. However, as cooling increases vasodilation occurs in the vessels of the extremities. This occurs in continuous cycles called the "Lewis Hunting Wave". The cold increases cellular permeability, especially in endothelial cells, and this causes fluid release into the tissues resulting in swelling. At 0°C or lower the fluid freezes. On thawing, there is a rush of blood back into the affected extremity, and because the integrity of the cells has been compromised fluid moves into the extracellular matrix. Blood stagnates and the tissue dies and turns black. When exposed to extreme cold, frostbite can occur in only a few minutes. Treatment for these injuries consists of removal of any constrictive clothing and a rapid rewarming of the affected area up to the last salvageable point. Because of the damage to the vascular bed, skin grafting is not an option, so the dead skin must be surgically removed.[7,9]

Cold wet (or non-freezing) injuries occur when an extremity is exposed to a wet but not freezing environment for a long period of time. These too are categorised on a scale, with the injury developing from chilblain to pernio to trench foot. The first sign of chilblain is an itching caused by vasodilation and subcutaneous oedema. This is followed by redness, swelling, tenderness and heat. In the case of chronic chilblain, feet may change colour to a purple/red, become painful and form blisters. Pernio is a more serious form of chilblain, where patches of skin become necrotic and slough off. As the depth of tissue death increases due to increased exposure, the injury develops to trench foot. Trench foot occurs when an extremity is exposed to temperatures below 10°C for more than 12 hours. With trench foot, skin may change colour to blue or black and become numb. It can also result in long term problems, such as Raynaud's syndrome (where extremities become painful or numb on cooling due to poor circulation). To treat these cold wet injuries, wet clothing must be removed and feet must be dried carefully, massaged and then elevated. In hospital, pain medication may be given, along with dextran or heparin in an attempt to improve blood flow. If a patient develops a fever, amputation may be necessary.[7,9]

Cold can also damage the respiratory tract, as when cold air heats up it increases its capacity to hold moisture, and so water and heat are lost from the respiratory tract. This can cause a burning sensation in the throat and dehydration. This is best combated with a balaclava, to avoid loss of expired water and to heat air before it enters the respiratory passage.[8]

Clothing and Equipment

As laid out above, there are many reasons that it is vital to protect the body from the extreme cold. Therefore, it is so important to have the correct equipment when on an expedition, particularly warm clothing. Air is one of the best insulators, so clothing worn in layers gives good protection from the cold. This also applies to clothes containing poultry down,

as it traps layers of air between feathers. A way of categorising the importance of various items of clothing is using the Clo values. 1 Clo is the amount of insulation a person requires to maintain thermal equilibrium in a 21°C environment. Using this unit can give an estimation of how important each item of clothing is. For example, a normal long sleeved t-shirt has a Clo value of 0.25, where a down jacket has a Clo value of 0.55. A hat is an extremely important item as an estimated 30-40% of heat is lost through the head.

frost bite. Below is a graph created by the National Weather Services to show the effects of wind chill.[10]

Hydration and Nutrition

It is also very important to think about nutrition and hydration, as being dehydrated or malnourished are risk factors for both hypothermia and frostbite.[7] During an expedition, the combination of exercise and cold temperatures means the need for food greatly increases as shivering and pre-shivering can use a

Wind Chill Chart

Wind (mph) \ Temperature (°F)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph) *Effective 11/01/01*

Much more insulation is needed during rest. As an example, at -20 degrees, 1.6 Clo units of clothes are required to keep a heat equilibrium, but while sleeping this goes up to 10.6 units. As water conducts heat 25 times faster than air, it is extremely important not to let clothes get wet, as they will lose up to 90% of their insulating properties. This means it is also important to make sure clothing is ventilated, so that it does not become saturated with sweat when exercising. 8 Explorers have known this for years, and Inuits traditionally wear loose fur clothing to reduce sweat.[4] A ski mask and a balaclava protect the face and guard against snow blindness, caused by the sun reflecting off the snow.[9]

It is also important that clothing is wind-resistant, as wind chill can have a drastic effect on body temperature, and increase the likelihood of getting

huge amount of glucose, and can cause hypothermic patients to be hypoglycaemic[7]. Explorer Ben Saunders described needing 6000 calories worth of food a day.[11] In the past it was common for explorers to get scurvy, though a good way of avoiding this was eating seal and penguin meat which, unknown at the time, contains Vitamin C. This was an idea picked up from the indigenous peoples of the Antarctic who had an almost exclusively carnivorous diet.[4] In the modern day, freeze dried meals can provide a lot of nutrition, as well as being light and compact and therefore easy to carry, although a stove is required to create hot meals.[11]

Transportation

As a mode of transport, people have been using skis and sleds for a very long time. At the beginning of the 20th century, the first explorers to reach both the north

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and south poles used skis and dog pulled sleds.[4] For explorers that choose to make the journey unaided, sleds containing all the vital food and supplies can be dragged.[11] These are methods still used today due to reliability. Modern equipment such as GPS and radios make it much safer and far decrease the risk of simply disappearing, as so many early expeditions did. It is also now possible to arrange for air drops of supplies, or to be air lifted out if things go wrong.[5]

Psychological Factors

As well as all the physical factors making expeditions in the Polar Regions challenging, there are many psychological factors that must be considered when surviving in the environments of our polar climates. It is extremely important to keep up motivation and organisation, as a lack of either can be fatal. Because of sudden changes in conditions, such a sudden 'white out' where snow is blown up in a sand-storm fashion and obscures vision, it is vital to know where all kit is at all times. It is also important to make sure every night that nothing has been left where it might get blown away or covered in snow. As mentioned earlier, getting clothes wet greatly reduces their insulating properties and having wet gloves, socks or shoes can induce cold wet injuries. For these reasons, anything wet must be removed before sleeping and dried, particularly boots. To avoid trench foot, massaging of feet at night is important, and this must also be kept up when exhausted. None of these things sound particularly difficult, but after dragging a 200kg sledge through the snow all day it is easy to see how organisation could slip, and simple mistakes could be easy to make.[7,11,1]

Knowing one's limits is also key. Walking beyond the point of exhaustion is very dangerous, as it can lead to being too tired to be as organised as is necessary, and again sleep deprivation and physical exhaustion are risk factors for hypothermia.[8]

Effective team work is also extremely important. This involves keeping morale high, and looking out for signs of illness in team members. Often hypothermia is not easy to spot, especially for the person who has it. They may just seem irritable and unsociable, which is why it is important to have a team looking out for each other and recognising these early stages.[7]

For scientists staying in the polar regions for many months "polar nights" may become a problem. A polar night is defined as when the sun does not rise for over 24 hours. At the north and south poles, the longest the sun stays down for is 179 days.[12] Sun is a natural anti-depressant, so this dark period could lead to mental health problems for some people. At the launch of his recent book "Empire Antarctica: Ice, Silence & Emperor Penguins" Gavin Francis who had acted as a doctor in the British base in Antarctica in the summer months described how people who lived there year round found the lack of sunlight in the winter very strange, and had been overwhelmed with joy to see the sun coming back. So, depression may prove to be a significant problem for people staying long term.

Conclusion

To conclude, completing an expedition in the polar regions of the globe presents a host of unique challenges to the modern scientist or explorer. The need to stay hydrated and adequately nourished is greatly increased whilst the task of achieving this is made far more difficult. An extreme mental challenge is also presented, as thinking rationally, being well organized and planning ahead are all vital, even when exhausted. Understanding the basic factors and systems that lead to injury and illness in the cold can help explorers to identify early signs and understand how to prevent them.

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