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REVIEW PAPER

Soldier at High Altitude: Problems & Preventive Measures

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ABSTRACT

Due to military and strategic reasons, a large body of troops is being regularly deployed in the snowbound areas throughout the Himalayan regions to guard the frontiers. The mountain environment at high altitude (HA) consists of several factors alien to plain dwellers, which evoke a series of physiological responses in human system. Some of the sea level residents on induction to HA suffer from several untoward symptoms of HA ailments varying from mild-to-severe degrees. Sudden exposure to HA is detrimental to physical and mental performance of the low landers and in certain cases, may even lead to dreaded condition like high altitude pulmonary oedema (HAPO). These may make a man disturbed physically and mentally. So, there is a need to prevent such hazards which is possible if the individual is aware of the problems and preventive measures of HA ailments in advance, before going to HA for a safe and happy living there. Hence, a noble effort has been made to provide guidelines to create awareness about physical and physiological problems of life at HA and the methods of protection against its ill-effects for the soldiers, mountaineers and sojourners conducting scientific trials at HA. In this review, an attempt has been made to describe vital aspects of HA in a popular way, starting with its concept and various environmental factors which exert considerable effects on human body functions, health and performance on exposure to such environment, on the basis of a series of studies conducted at the Defence Institute of Physiology & Allied Sciences, Delhi, over the years. The most important feature of HA (3,000 m and above) is hypoxia or deficiency of oxygen in the body. Other environmental factors are: severe cold, high velocity wind, low relative humidity, high solar radiation, increased ultraviolet radiation and difficult terrain. These factors are responsible for various HA and cold syndromes, viz., acute mountain sickness, HAPO, dehydration, sunburn, snow-blindness, *CO*-poisoning, hypothermia and cold injury of the extremities.

1. INTRODUCTION

Various environmental factors existing at high altitude[1] (HA) exert considerable effects on the physiological functions and physical performance of an individual and contribute to health hazards if the individual does not get acclimatised to that environment. These effects include acute mountain sickness (AMS), high altitude pulmonary oedema (HAPO), frostbite, etc. as well as several other untoward symptoms of HA ailments varying from mild-to-severe degrees which may make a man disturbed physically and mentally. However, it is possible to prevent such hazards/problems if one knows something about these in advance and is also aware of various methods of their prevention. Most of the HA hazards and accidents are avoidable, as these generally take place due to lack of basic knowledge and ignorant behaviour of the individual and/or incompetent leadership. So, firstly one must know what is HA and what are the environmental

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factors responsible for HA ailments, and also the changes that occur in the function of human body on exposure to such environment where people may live permanently.

Due to military and strategic reasons, a large body of troops from the plains is being deployed regularly in the snowbound areas at HA throughout the Himalayan regions in the northern border of our country. Because of the physiological effects of life at HA, the problem of protection against its ill-effects on sojourners from the plains has assumed vital importance for the Armed Forces. To improve the military's ability to deploy troops at high elevations, considerable research on HA problems and mountain sickness has been carried out in India and abroad. The tourists from sea level exposed to HA areas after rapid transport by airplane as well as the mountain climbers moving to great heights will also find this article of significant assistance, even though excellent accounts of biological stresses in HA climbers striving to reach the loftiest summits are available[1-3].

2. CONCEPTS OF HIGH ALTITUDE

HA has no precise definition, but physiologically it is considered to be an elevation of 3,000 m and above because most people develop some symptoms associated with the ascent of mountain areas at this elevation[4]. Even though, as per Army Order[5] No. 110/80, HA is taken as an elevation of 2,700 m or more (Fig. 1). Extreme altitude may be defined as one exceeding 5,800 m where permanent residence is practically impossible[4].

2.1 Symptoms Associated with High Altitude Ascent

The symptoms common in low landers going to high mountains[6] are characterised by headache, dyspnoea, nausea, vomiting, breathlessness, dry nose, dry mouth, tiredness, lethargy, palpitation, stomach-upset (diarrhoea, constipation, etc.) giddiness, insomnia, lack of appetite, disinclination to work, oedema of legs and feet, dry and moist cough, chest and back pain, etc., which generally require little or no treatment and is often relieved by

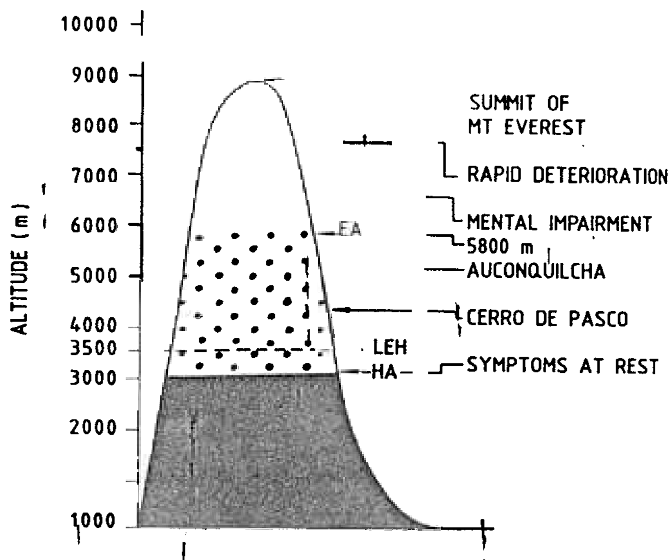


Figure 1. Diagrammatic representation of high altitude and extreme altitude.

bed rest. These are commonly termed as symptoms of AMS. The magnitude of these symptoms is related to the rate of climb and the mode of induction. In most cases, these symptoms pass off within 2-3 days, but in few people who are more susceptible to HA stresses, the symptoms may escalate rapidly into serious forms. Sea level residents (or natives of HA after a stay at low altitude) when ascend to high mountains and undertake substantial physical exertion along with cold exposure, may develop HAPO, which may prove fatal.

2.2 Physical Environmental Factors at High Altitude

The most important environmental factors at HA are: hypoxia, severe cold, high velocity wind, low relative humidity (RH), high solar radiation, increased ultraviolet radiation and difficult terrain. Besides, these areas are also arid in nature with sparse vegetation and potable water, which represent an alien environment and pose additional problems to soldiers, sojourners and mountaineers.

2.2 *Hypoxia*

As one ascends mountains, the atmosphere is rarefied and due to this rarefaction, the partial pressure of oxygen in the air decreases, resulting in decrease in oxygen in one's breath. Hence, the most important environmental factor of HA is the progressive fall in barometric pressure, which results in the reduction of partial pressure of oxygen in air (Fig. 2). Approximately, the atmospheric pressure diminishes by half for each 5,500 m increase in altitude. With the decrease of partial pressure of the atmosphere, each of its constituent gases also decreases with increasing altitude, although the percentage of oxygen (20.93 per cent) remains more or less[7] constant up to 1,10,000 m. However, gas is compressible which means the number of molecules per unit volume is greater at sea level than at HA. So, contrary to the popular belief, the air at HA does not contain less percentage of oxygen than the air at sea level.

At sea level, air exerts pressure of 1 atm which is 760 mm Hg/cm^2. Accordingly, partial pressure of oxygen at sea level is about 159 mm *Hg*, i.e., (760 x 20.93)/100 = 159.1 mm *Hg*, and the partial pressure of inspired air at sea level is about 149 mm *Hg*, i.e., [(760 – 47) × 20.93]/100 = 149.2 mm *Hg*, where 47 is the water vapour pressure (Fig. 3). This is because when air is breathed into the bronchial tree, it becomes saturated with water vapours, which exerts a pressure of 47 mm *Hg*. Similarly, the barometric pressure at Leh (altitude 3,500 m approx.) is about 493 mm *Hg*, whereas the partial pressure of oxygen is (493×20.93)/100 = 103.2 mm *Hg* and the partial pressure of inspired air is only about 93 mm *Hg*, i.e., [(493 – 47)×20.93]/100 = 93.3 mm *Hg*. Thus, the greater the altitude, the less oxygen is inhaled during normal breathing. Inhalation of this air with reduced partial pressure of oxygen produce hypoxia or oxygen deficiency in the body. As a result, certain physiological symptoms as mentioned earlier, are unavoidable, particularly on rapid ascent, like reaching HA by airplane.

On gradual ascent by road, physiological compensatory mechanisms lead to the process of acclimatisation. Certain individuals fail to acclimatise and become victim of AMS and HAPO, etc. The reduction in air pressure causes very small blood vessels (capillaries) at some regions to leak into the tissues around them. In the brain, this can cause headache etc., in the lungs, it can lead to fluid accumulation.

Oxygen concentration in air is 20.93 per cent, which remains same whether at sea level or on the top of mountains. As one ascends, the barometric pressure decreases with increase in altitude and the atmosphere becomes rarefied, which results in reduced number of oxygen molecules entering into the lungs with each breath and creates oxygen deficiency in the body. Reduced oxygen in the blood and the effect of lowered pressure on body tissues can lead the susceptible persons to acute mountain sickness (AMS). Follow up of certain preventive measures reduces the ailment. Drugs are also available to help.

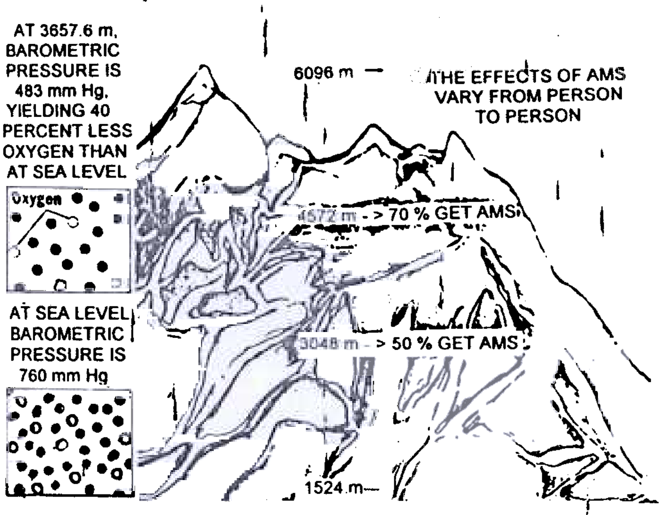


Figure 2. Air both at sea level and high altitude contain same percentage of oxygen (20.93 per cent). However, barometric pressure decreases with increase in altitude. Therefore, the atmosphere becomes rarefied and the number of oxygen molecules in air per unit volume is less at high altitude.

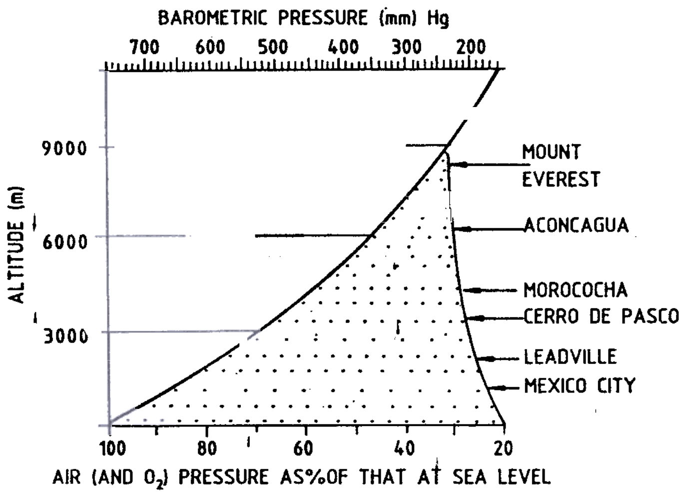
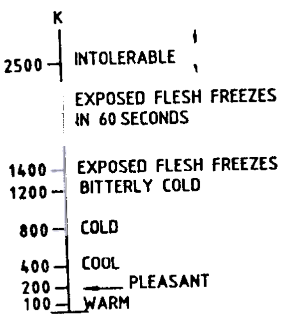


Figure 3. The relation between altitude, barometric pressure and air (oxygen) pressure as percentage of that at sea level. At Leh (3,500 m), the barometric pressure is 493 mm *Hg* resulting a yield 35 per cent less oxygen than that at sea level.

2.2.2 *Severe Cold & High Velocity Wind*

The next environmental hazard that man faces at HA is severe cold. Approximately, a reduction of 1 °C in the ambient temperature is seen for every 150 m elevation in altitude, which is independent of the latitude. Severe cold is a problem by itself, but when chilly winds join in, it can become a killer. Wind movements increase the convectional heat loss, and as a result, the effective skin temperature falls. That is why on windy days of winter, the temperature appears to be much less than the figure quoted by meteorological bureau. It is surprising, but true that an air temperature of – 40 °F without any wind may not produce any ill-effect, whereas an air temperature of 20 °F (– 6.7 °C) with wind velocity of about 72 km/hr can produce frostbite within an hour of exposure. The combined cooling effect of various wind speeds and the environmental temperatures are known as wind chill factors[1] (Fig. 4). The insulating layer of warm air around the skin is blown away by wind, resulting in pathological changes of the exposed tissues. Occurrence of cold



(a)

K 1400 PRODUCED BY	
TEMP. °F	WIND VELOCITY (mph)
20	45
10	18
-10	7
-40	2

(b)

Figure 4. (a) The relation between increasing value of the wind chill factor (K) to various bodily sensations and (b) the combination of temperature and wind velocity. At a K value of 1400 - exposed flesh freezes.

injury, especially frostbite, thus becomes a major medical problem at HA, where cold is superimposed over hypoxic stress.

2.2.3 *Low Humidity*

Another physical stimulus which influences life at HA is the existence of low RH. The combination of low temperature and low humidity can be very unpleasant. Exposed sensitive areas, such as the lips can dry and crack in a matter of hours. The general dehydration resulting from low humidity is believed to be one of the factors responsible for HA illness. Use of lip cream or lipstick periodically can prevent this problem. Frequent and adequate fluid intake will minimise dehydration.

2.2.4 *Solar Radiation*

Paradoxically enough, although temperature falls with increasing altitude, there is increased exposure to solar radiation. At sea level, the average amount of solar radiation absorbed[1] is 230 Kcal/m^2/hr. On the other hand at 5,790 m in clear weather, the solar heat absorbed by the surface of the clothed human body[8] is 350 Kcal/m^2/hr. The solar heat absorbed by the body depends on several factors, such as the clothing and the position of the individual. The clear air of many mountainous areas will more easily permit the passage of solar radiation to the earth's surface. Another important factor at HA is snow, to which man is exposed. It increases the level of solar radiation.

2.2.5 *Ultraviolet Radiation*

Ultraviolet radiation, a segment of solar radiation, is increased at HA. The reflections of solar and ultraviolet radiation are enhanced by snow. Snow can reflect 90 per cent of incident ultraviolet radiation compared to 9-17 per cent reflection from ground covered by grass[9]. Hence, on snowcovered ground at HA, the combination of incident and reflected ultraviolet radiation may be more formidable and may lead to injuries to eyes and skin, if exposed. Use of snow goggles will prevent eye injuries due to snow glare.

2.3 Physiological Effects at High Altitude during Rest

All these physical factors existing at varying altitudes considerably affect the physiological functions, health and performance of a man or woman. Inspite of these, millions of people live permanently at altitudes up to 4,000 m, showing that human body can adapt even to those conditions. The natives of HA achieved a level of physiological fitness and remarkable capacity for performing hard work despite the hazardous environmental conditions, which is impossible for the sojourners from the plains, to achieve even if they stay there for longer periods. The natives appear to have genetic adaptation. Induction of sea level residents to HA evoke a series of compensatory physiological responses to human system for acclimatisation. Most of these responses are beneficial in reducing the ill-effects of hypoxia. The responses that are not beneficial result from over-reactions to HA stress (hypoxic stress). In certain cases, these over-reactions to hypoxic stress can be very unpleasant and may even lead to fatal casualties, particularly during the initial days of acclimatisation.

Biologically, the most important feature of HA is the reduced barometric pressure, which results in reduced oxygen pressure of the air inhaled. Thus, the main physiological feature of exposure to HA is hypoxia (hypoxia is a state of body in which the rate of oxygen utilisation by the cells is inadequate to supply all the energy requirements). Every living organism whose metabolism depends on the consumption of oxygen is naturally adapted, through generations, to the particular partial pressure of oxygen of the ambient air of each habitat. The physiological functions are in a steady state of harmonious integration in these organisms whatever the partial pressure of oxygen may be. This applies to both the animals and men, natives of the plains as well as those of HA. This situation is quite different, however, if organisms from low altitude to which they are naturally acclimatised, ascend to HA where they find a decreasing oxygen pressure with increasing height. As a result of this, certain physiological symptoms are unavoidable on sudden exposure to HA. These symptoms become more severe during exercise than at rest.

2.4 Physiological Adjustments – Acclimatisation

The mode of induction to many of the HA mountainous areas generally takes place by road. With modern rapid transport system and recent proliferation of mountaineering and military activities, people are being inducted to great height by airlift or by quick road transportation, within hours of departure from the plains. Exposure of sea level residents to altitude above 3,000 m evoke a series of compensatory physiological responses involving almost all body systems to alleviate oxygen deficiency in the body, by modifying oxygen transport system and thereby protecting the tissues from the dangerous consequences of hypoxia. These responses are known as acclimatisation responses, most of which are beneficial in reducing the ill-effects of hypoxia and are meant for compensating the severity of oxygen deficiency in the cells. The immediate response to oxygen deficiency is an increase in breathing to raise the minute ventilation (ventilation means the flow of air through the trachea and bronchial tree to the alveolar spaces of the lungs). The term respiration includes: (i) ventilation, (ii) pulmonary diffusion of oxygen, (iii) blood transport, and (iv) tissue diffusion of oxygen. These processes help in the supply of oxygen from atmosphere to the cells. The major physiological adjustments of the body to hypoxic exposure are:

- Increased pulmonary ventilation (hyperventilation)
- Increased cardiac output
- Increased RBC count, haematocrit and haemoglobin concentration of blood (where oxyhaemoglobin saturation percentage decreases)
- Increased unloading of oxygen to the tissues
- Selective redistribution of blood to vital areas (systemic to pulmonary circuit), and
- Economical utilisation of oxygen to release energy at the mitochondria.

The net result of all these adjustments is delivery of larger amount of oxygen from blood to the tissues and its economical utilisation.

2.5 Hyperventilation

Hyperventilation replaces more of the alveolar air by freshly inspired air, thus elevating the oxygen pressure in the alveoli in the lungs. Pulmonary hyperventilation in a newcomer to HA occurs within a few hours of arrival and increases rapidly during the first week[10]. Hyperventilation is the major systemic adjustment to the tolerance of hypoxic stress at HA and can be considered as the first and the most effective mechanism of acclimatisation to HA. Initial hyperventilation during acclimatisation is the result of stimulation of peripheral chemoreceptor[11]. Hyperventilation improves blood oxygenation in two ways: (i) by increasing the availability of oxygen in the alveolar air, and (ii) by providing adequate ventilation to all the alveoli including those, which are poorly ventilated during normal breathing. Hyperventilation causes an imbalance in driving out CO_2 from the blood, thus causing alkalosis (a condition in which the blood becomes alkaline). Nevertheless, this is corrected through the kidney during initial acclimatisation period at HA. It is believed that these disturbances might be partly responsible for HA sickness.

2.6 Sleep Disturbance

Disturbance of sleep is a common complaint of the sojourners at HA, which is more marked during initial days of stay. Periodic breathing may occur at night. This is an adaptive mechanism to prevent accentuation of hypoxaemia resulting from sleep-hypoventilation. Those who fail to show this adaptive response and have normal synchronised sleep may suffer[12] from AMS. Sleeping pills should never be used during initial days of acclimatisation to HA, because it will interfere with normal acclimatisation process and worsen the symptoms. Cardiovascular system may also influence the supply of oxygen to the tissues by changes in the cardiac output and in the distribution of blood flow in the body[13,14]. The heart beat rate increases with an increase in cardiac output. On exercise, cardiac output increases disproportionately. A moderate elevation in blood pressure as well as some adjustment in the responses of autonomic nervous system are also observed[15,16]. These changes increase the speed of oxygen transport in the blood.

The transport of oxygen from the lungs to the tissues is a function of the cardiac output, the quantity of oxygen in the systemic arterial blood and the affinity of haemoglobin for oxygen, allowing the gases to pass to the tissues. Thus, haemoglobin concentration is of considerable importance. At HA, there is an increase in the number of erythrocytes and haematocrit. During the first few days at HA, there is a quick rise in haemoglobin along with red cell mass and this increased haemoglobin re-establishes the oxygen contents of the arterial blood. The iron turnover rate increases at HA. The oxygen-haemoglobin-dissociation-curve is shifted to the right, maintaining relatively high partial pressure of oxygen in the capillaries to aid diffusion of oxygen into the tissues. The final area in which respiratory acclimatisation to HA takes place is the tissue diffusion.

2.7 Mal-Acclimatisation

Inspite of all these adjustments, certain susceptible individuals fail to acclimatise and may become victims of AMS and HAPO–the two dreaded conditions of the ill-effects of HA. Some people suffer from chronic mountain sickness as well. The exact etiology of these disorders is not completely understood. However, it is true; the basic cause is hypoxia, since all these three ill-effects are cured when the person is brought at sea level atmosphere (i.e. hypoxia is withdrawn). However, one of the interesting findings is that the susceptible individual has less efficient chemical sensors (chemoreceptors), which monitor the oxygen deficiency, and therefore, fail to respond adequately to oxygen deficiency and become victims of AMS and HAPO[17]. All the above disorders generally occur during the initial phase of HA acclimatisation only (first 3-7 days).

3 PHYSIOLOGICAL CHANGES DURING EXERCISE

Even after the initial acclimatisation the physical work capacity is reduced at HA. The limiting factors for work capacity at HA are:

'all in arterial oxygen saturation

Decrease in maximal heart rate

Reduction in maximal oxygen uptake capacity

Increased anaerobic metabolism

Increased accumulation of lactic acid

'all in oxygen debt capacity, and

,imits in maximal ventilation.

After prolonged stay at 3,500 m, the sea level residents have shown gradual improvement in physical work capacity but it still remained lower than their physical work capacity at sea level[18].

Since there exists no means of shortening the process of acclimatisation, and since the absence of acclimatisation in new arrivals at HA precludes the execution of jobs involving heavy physical performance, the deployment of troops at HA poses serious problem. Troops from the plains rapidly transported to HA cannot be deployed immediately for patrolling, entrachment, combat or other physically-taxing duties. Present stage of knowledge therefore dictates a deployment, which makes for some degree of acclimatisation prior to heavy physical duties. Recent studies at this Laboratory[19] indicate that gradual and staged movement of troops from sea level to HA by road, with 3–4 days of acclimatisation halts at a series of intermediate altitudes, definitely reduces the incidence of HA sickness. Alternately, troops moved directly by airlift to 3,500 m must be given allowance for their illness and relatively low activity for about first five days of residence[19].

4 IMMEDIATE EFFECTS OF HIGH ALTITUDE EXPOSURE

4. Acute Mountain Sickness

The immediate effect of sudden exposure to HA is AMS, which occurs in many people with different severity. Low air pressure triggers mountain sickness. The commonest of the symptoms reported in acute mountain sickness are: headache, dyspnoea, nausea, vomiting, anorexia, breathlessness, dry nose, dry mouth, lack of appetite, tiredness, giddiness, palpitation, tachycardia, dry and moist cough, insomnia, stomach-upset (diarrhoea, constipation, etc), inability to concentrate, lethargy, disinclination to work, oedema of extremities, impairment of judgement and occasional discomfort, pain in chest and back (Fig. 5). The condition generally appears within 6–72 hr, but the maximum severity is seen within 18–48 hr. It gradually subsides/disappears within 5–6 days without much medication, but with

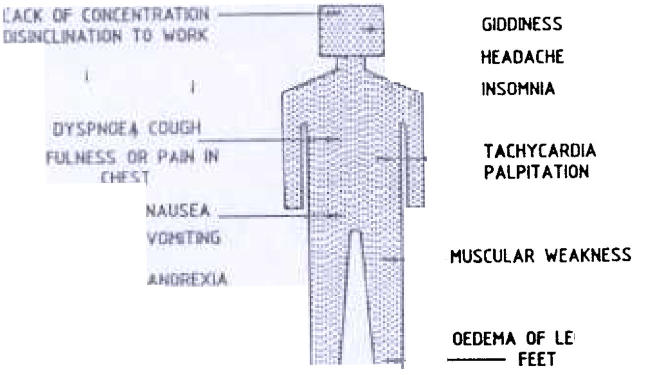


Figure 5. Some commonest symptoms of acute mountain sickness.

proper rest and acclimatisation. The onset is definitely hastened by physical exertion and cold exposure. Mild symptoms of AMS abate in a few days but severe AMS can be a forerunner to HAPO[20].

4.2 High Altitude Pulmonary Oedema

In certain cases, the above conditions can progress and may lead to HAPO due to accumulation of fluid in the lungs, which is a serious clinical problem and is very dangerous. Hypoxia is the initiating factor for AMS and HAPO. Oliguria and redistribution of blood also is of importance in the development of AMS[20]. Paintal[21] is of the opinion that the increased pulmonary arterial pressure, increased plasma volume and increased cardiac output which occurs in subjects at HA, especially on exercise, produce pulmonary congestion and pulmonary hypertension, which in minority of cases, progress to HAPO[21]. HAPO is characterised by: (i) shortness of breath, (ii) chest pain, (iii) mild fever, (iv) lethargy, (v) severe cough with blood-tinged sputum, (vi) crepitation sound at the time of respiration, and (vii) cyanosis in the lips and at the extremities.

HAPO patient must immediately be given oxygen and transferred to the nearest hospital. The treatment is primarily aimed to gain relief from hypoxia. Prompt descent to lower altitude or at a simulated lower altitude in a re-compression chamber gives dramatic relief. Temporary relief from hypoxia can be achieved by breathing oxygen and bed rest. Carbohydrate rich diet and mild diuretic like acetazolamide or spironolactone may be beneficial. Acetazolamide can produce a number of side effects. Standard dose is 250 mg, 2 or 3 times daily, but the Himalayan Rescue Association Medical Clinic recommends 125 mg, 3 times daily to reduce side effects without loosing effectiveness. Prof. Ronchin[22], in his study with drug called *Tanakan*, produced from the leaves of *Ginko* tree, revealed that it can prevent mountain sickness and may have lesser side effects compared to acetazolamide. Recent study showed inhalation of 50 per cent oxygen and 15 ppm nitric oxide is helpful in the treatment of HAPO[23]. Inflatable HAPO bags (developed by Defence Bio-Engineering & Electro Medical Research Laboratory, Bangalore) have been proved as a life saving device during evacuation of HAPO victims to lower altitudes. Without treatment, HAPO becomes extensive, causing greater impairment of blood oxygenation, mental confusion, loss of consciousness, coma and death. The deterioration is very rapid. Worldwide, about 20 deaths in a year occur due to HAPO. On the other hand, if it is treated adequately, the prognosis is excellent since the condition is totally and rapidly reversible[24,25] HAPO is rare at elevations below 3,000 m.

A person is said to be acclimatised to HA when he can sleep well, eat well and work well. It appears from author's personal experience that the best single index of acclimatisation to HA is one's ability to maintain the body weight. For this, nutritionally balanced, warm and palatable diet prepared from fresh items acts as a protector from HA hypophagia. Increased palatability and variety in the menu, supplemented with pickles, papads, green chillies/raw onions, etc. accelerate hunger and saliva secretion. This greatly helps in adequate food consumption and better maintenance of body weight.

5 PREVENTIVE MEASURES FOR HIGH ALTITUDE AILMENTS

Generally, the most effective principles of the prevention of AMS and HAPO during ascent and on arrival at HA include:

(a) Slow and gradual ascend to HA, allowing time for acclimatisation. This minimises HA illness. There is a common saying that 'Mountain must always be approached with respect'. The golden rule at altitude is, 'Don't go too fast, too high'.

(b) Avoidance of physical exertion as well as cold exposure on arrival at HA. Popular saying is, 'In the land of *LAMA* don't try to be a *GAMA*'.

(c) Allowing sufficient rest is a must for sojourners to HA, at least for the first 72 hr of induction.

(d) Acute inductees by airplane or by rapid road transportation must undergo thorough acclimatisation.

(e) Plenty of fluids (water, tea, coffee, soup, beverage, etc.) must be taken daily to avoid dehydration, dryness and constipation.

(f) High carbohydrate and low fat diet is beneficial for better adaptation. More fibers should be taken in the food (vegetables and fruits). If symptoms of constipation appear, *Isabgol* may be taken.

(g) Restrain from overeating, late-night dinner and consumption of alcohol.

(h) Avoidance of day sleep and staying lightly active keeps one's respiration up.

(i) Drugs that depress central nervous system and control breathing must be avoided during initial days of acclimatisation. This includes alcohol, tobacco, barbiturates, tranquilisers and sleeping pills.

(j) Not every individual is susceptible to the occurrence of HAPO. Very few people (0.03 – 0.05 per cent) are highly prone to this condition, whereas others show good resistance. In most cases, re-assurance by companions and experienced associates, preventing psychological apprehension and adequate rest are sufficient to prevent or curtail the symptoms of AMS and HAPO.

5.1 People Most Vulnerable to High Altitude Illness

(a) The low landers, who ascend rapidly to HA by air or by fast road transportation and then engage themselves in strenuous physical activity along with exposure to cold.

(b) Both low and high landers, who return to HA after spending a short period at plains (re-inductees).

It is a common observation that persons become more vulnerable to HAPO on re-ascent than those who are inducted to HA for the first time. This is probably because re-inductees are overconfident and disinclined to take sufficient rest during initial days of their subsequent visit to HA and do not adhere to acclimatisation schedule. Hence, every time a person is going to HA, he must consider himself as a fresh inductee and undergo thorough acclimatisation. The staging acclimatisation (i.e. gradual acclimatisation of varying days at different heights) minimises most of the ill-effects of HA. Persons once adapted to a particular altitude pose no risk of HAPO later at that altitude, provided they continue staying there. However, ascending to higher elevation or re-induction to the same altitude after a period of leave at the plains, again introduces full risk of AMS and HAPO. Therefore, acclimatisation schedule must strictly be adhered to by all the inductees (both fresh and re-inductees) on return from sojourn at plains. After the initial acclimatisation, the other mild and severe problems which the man may encounter at HA are: dehydration, snow blindness, sunburn, carbon monoxide poisoning, hallucination and effects of severe cold like hypothermia and cold injuries of the extremities, which may occur at any time during the stay at HA.

5 *Dehydration*

The HA ascent is always associated with moderate-to-severe dehydration. Dehydration takes place due to loss of body fluids. The high rate of fluid loss from the lungs, associated with increased ventilation in the dry cold air makes it necessary to consume 5–7 litres of fluid every day. With much water loss by humidification of inspired air (up to 7 l/day), the resulting haemoconcentration might quickly become hazardous, since it causes increased blood viscosity, hyper-coagulability of the blood, decreased oxygen transport capacity and disturbed microcirculation with an impaired heat supply, especially to the acral tissue. General dehydration resulting from low humidity is believed to be one of the factors responsible for HA illness. Various effects of dehydration are: strong thirst, vague discomfort, loss of appetite, tingling in arms, legs, head, etc, incapacitation, spastic muscle, shriveled skin, inability to swallow, dim vision, dryness and cracking of sensitive skin areas of lips, etc. For prevention, one must take plenty of fluids (water, tea, coffee, soup, beverage, etc.) and try to maintain body temperature. Avoid alcohol and cigarette. Soothing cream like vaseline should be applied on the sensitive skin areas to prevent cracking.

5.2 *Snow Blindness*

This is a severe form of conjunctivitis and a condition of temporary blindness due to the effect of ultraviolet light in snowy conditions. It occurs in snow areas due to the direct fall of reflected sunlight in eyes. In this, the patient reports for blindness. The eyeballs become red and he feels sensation of sand particles and acute pain in the eyes and it is impossible to open the eyes against light, hence the term blindness. For precaution, one must always use dark sun goggles while on snow areas. In the absence of snow goggles, the patient may use a piece of paper, clothes or even one's own hair which should cover the eyes.

In the event of disease:

Close the eyes of the patient immediately and keep him away from the light.

Apply eye pad/bandage and call for the doctor or evacuate the patient to the hospital.

5 3 *Sunburn*

Ultraviolet and infrared rays cause skin burn in the exposed parts of the body in the snow bound areas of HA. Hence, it is advisable to cover the exposed parts of the body. Body oil should be preserved by avoiding excessive application of soap. Male members should sprout and preserve their beard to protect the face against sunburn. Applying vaseline or any other anti-sunburn cream, will also give soothing effect.

5.1.4 *Carbon Monoxide Poisoning*

HA inductees and mountain climbers have been seen to faint or complain severe headache when they sleep with all the doors of the hut or tent closed. When the *bukharies*, lanterns, patromaxes, candles, stoves, etc. are left lighted inside the tent or hut, which has no proper ventilation, carbon monoxide poisoning starts playing with the lives inside. Hence, proper ventilation should be provided in the living tents/huts.

5 5 *Hallucination*

This condition is observed mostly at extreme altitude only. It may be visual, auditory, pertaining to smell (olfactory), pertaining to taste (gustatory) and connected with the sense of touch (tactile). Those connected with hearing or smell may purely be psychological in nature while those of sight, touch and sometimes smell may have an organic basis. With hallucination, the mind gets a jolt and gropes in the dark. This follows impairment of judgement and control. Every effort should be made to control this situation.

6 EFFECT OF SEVERE COLD: HYPOTHERMIA & COLD INJURIES

HA is always associated with low temperature. Low temperature combined with high velocity wind increases the wind chill factor. Human body loses heat by conduction, convection, radiation and evaporation. Wind movement increases convectional heat loss to surroundings. Evaporation of sweat leads to loss of heat in the transfer of energy required to change sweat to vapour (Fig. 6).

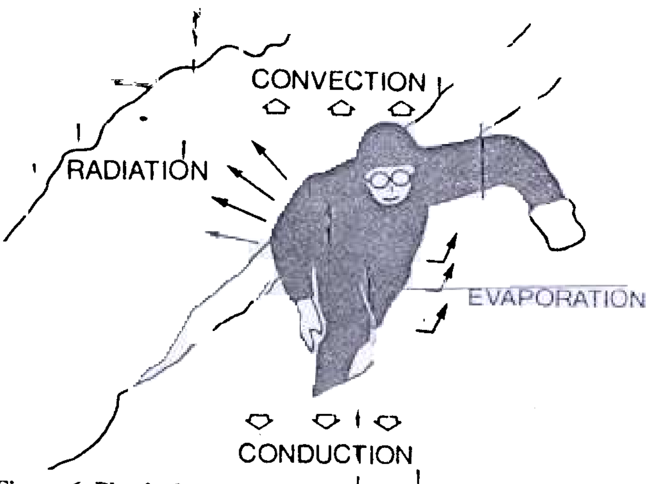


Figure 6. Physical processes by which human body loses heat to its surroundings on exposure to cold.

This process is facilitated by low humidity of HA. Wet clothes, on exposure to cold at HA, can be dangerous. On exposure to cold, body has to fight against it to retain its warmth and also to increase heat production by way of increased metabolism, shivering and hormonal secretion. Body also gains heat by absorbing solar radiation, which is pronounced in the clear skies at HA and is exaggerated by reflection from snow.

The pathological effects of intense cold stress are manifested in the form of hypothermia and cold injury. Hypothermia, which is a fatal condition, can be prevented to a great extent by wearing proper insulated clothing, adequate footwear and covering the extremities warmly. However, because of the geometrical shape and anatomical reasons, the extremities are comparatively less protected and thus are badly affected on exposure to severe cold. Man's immediate response on exposure to severe cold is peripheral vasoconstriction leading to reduction in blood flow, especially to the extremities. Moreover, the extremities have limited muscle mass and their capacities for heat production are also very less. As a result, the peripheral tissues cool faster than the central tissues, on exposure to severe cold. In the cold areas of HA, the problem becomes more intense, since hypoxia is superimposed on cold stress and this can result in further reduction of extremity blood flow, which make these areas more vulnerable to cold injuries. Among the various types of cold injuries, chilblain is the least severe while frostbite is the most severe form. In severe winter, susceptible individuals suffer from chilblain. Fingers and toes begin to itch, turn red and become very painful within a couple of days. Sometimes, chilblains end in blister and ulceration. The prime cause of this is defective circulation to the extremities. There is no proper remedy for chilblain. One can only protect the hands and the feet by keeping them warmly covered. Besides chilblain, the injuries caused by cold include: trench foot, immersion foot, shelter foot and frostbite. However, the most serious and dangerous effect of severe cold is frostbite, which is responsible for the loss of a large number of fingers and toes of our young soldiers operating in the snowbound areas of HA. Thus, it is a major health hazard and a serious medical problem for the Armed Forces.

Frostbite is caused by freezing of the skin and subcutaneous tissues of variable depths, which invariably leads to tissue loss. Circulatory insufficiency also leads to thrombosis, which aggravates anoxia and leads to necrosis. The effected parts become pale and lusterless. Within 2–3 days, large blisters appear and after another 1 or 2 weeks, the part becomes black and either drops off on its own in about 4–5 weeks or has to be amputed. In mild frostbite, only the skin and subcutaneous tissues are involved while in severe types, deeper tissues like muscles and bones die and are cast off.

6.1 Causation of Cold Injury

The factors responsible in the causation of cold injury[26] are:

(a) Atmospheric temperature (severity of cold)

(b) Duration of exposure to such environment

(c) High velocity wind–hasten tissue cooling

(d) Moisture (wetness) in the atmosphere adds to the severity of the problem.

(e) Hypoxia of HA adds to this due to increased vasoconstriction resulting in slowing down of capillary blood flow.

Beside these environmental factors, other important factors which may accelerate the cold injury are:

(a) Poor quality of protective clothing and foot wear

(b) Lack of physical activity

(c) Previous cold injury

(d) Lack of adequate nutritious diet

(e) Physical exertion, fatigue, fear and anxiety

(f) Hunger and insomnia

(g) Lack of personal hygiene

(h) Individual susceptibility

(i) Lack of cold acclimatisation

(j) Consumption of alcohol and excessive smoking

(k) Age, race, and geographic origin

(l) Working in snow/water for long duration

(m) Wet socks/clothes

(n) Touching metal bodies without gloves. (Exposed parts of the body, such as, ears, nose, cheek, chin, fingers, toes and feet generally suffer from cold injuries, but the commonest site of the injury is the feet) (Fig. 7).

6.2 Clinical Symptoms of Frostbite

The consecutive stages in the development of frostbite are:

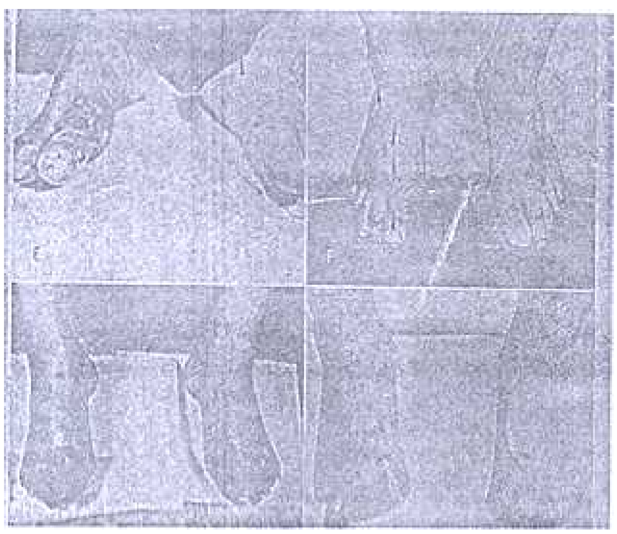


Figure 7. Frostbite of feet

(a) Painful feeling of coldness, tingling and itching of the numbed finger/toe tips are the signs and symptoms of cold injury. (Warm the part immediately by body warmth or in a water bath/tea decoction medium at about 37–39 °C and dry it).

(b) In the next stage, affected parts become anaesthetised, allowing the injury to settle.

(c) Third stage occurs as the patient warms up, with reappearance of painful phenomenon, followed by oedema and bulbs. Necrosis appears at a much later stage.

6.3 Preventive Measures for Cold Injuries

Frostbite, once occurred, its treatment is not very satisfactory, particularly when there is a delay in starting the therapy. Hence, prevention appears to be the best method of saving the extremities during military operations, mountaineering and polar explorations. Good hygiene and intelligent field operations are important measures in the prevention of frostbite.

Basic factors in the prevention of cold injury re

(a) Heat production capacity of the body and

(b) he measure to conserve this heat.

Useful preventive measures of frostbite are:

Physical well-being and adequate nutritious food.

Keeping the body warm with proper insulative clothing. A multilayer clothing, which can be removed or added and which has the possibility of being opened or closed easily at the neck to eliminate excess heat or conserve it, is the ideal clothing to wear in cold. Between layers, air is trapped which gives added insulation, since air is a bad conductor of heat. The inner layer should preferably be of insulation material like wool. The wind and waterproof top layer is very useful in open cold areas. An essential quality of a good garment is that it should be able to perspire. The type of clothing should vary with temperature, wind, amount of sunshine and level of activity.

Limit the period of cold exposur o the possibility of not causing cold injury.

Maintain proper hydration by taking plenty of fluid.

Keep the parts of body, especially extremities, dry and free from abrasion.

Heavy socks, well-fitting boots and wind-proof insulative mittens/gloves should be worn with woollen gloves inside.

Boots and socks should be removed twice a day. Feet should be washed, dried, massaged and warmed.

Extra pair of socks (dry) and gloves should always be carried.

Wet socks, boots, gloves, etc. should be removed immediately and dried. Feet should be kept out of water, snow and mud (Water conducts heat 23 times faster than air).

In night camp, elevate feet, if possible, and keep toes and feet moving.

Modern mountaineering boots with a plastic outer shell and inner detachable boot of artificial fiber are better for HA than leather boots.

Sleep with dry feet.

Do not get hands wet with kerosene or petrol.

Never touch metallic objects with bare hands in extreme cold as skin will stick to metal and would cause loss of tissue (Metal conducts heat very fast).

Wind and HA must always be approached with respect. Never be in hurry.

Keep your tetanus booster uptodate.

- Don't smoke or use alcohol excessively.

There is a popular belief that consuming alcohol is a good warmup method before venturing out in the cold. This is a misconception. Alcohol must be avoided before going out in winter as it increases the blood supply to the skin and limbs. Though this may produce a feeling of warmth, it will also result in greater heat loss from the body on exposure to cold. If the exposure is prolonged, this heat loss can be reached to the extent of lowering the body temperature and produce hypothermia, which is very dangerous. Rather, alcohol works better after cold expdsure when one returns home and is well-protected. The best way to resist cold is to wear adequate clothing. The golden rule in cold is to remain active, move the hands, feet and wriggle facial muscles frequently during exposure to cold.

However, supplementary to all the preventive measures the possibility of prevention by certain drugs and vitamins acquire importance. Experiments have been conducted[27] at this Laboratory to evaluate the preventive role of certain drugs and vitamins. Tolazoline hydrochloride and xanthinol nicotinate were found to be effective in the peripheral vascular response and thereby reduce the extent of cold injury. Administration of high dose of vitamin C (1–3 g) prior to cold exposure for long periods, maintained higher rectal temperature during severe cold exposure and helped to reduce the incidence of frostbite[28].

Since the application of various preventive measures may become difficult under field conditions, particularly during war or accidental situations, such as sudden storm or prolonged outdoor exposure due to unforeseen reasons, possibility of getting cold injury could not be avoided completely. Further in field situation, there is always a delay in evacuating the frostbite victims from field to the rear areas in the hospitals, due to various logistic problems. The time lag between the occurrence of frostbite and the initiation of therapy plays vital role in the curative process. The purpose of treatment is to re-establish the stagnant circulation, to prevent sedondary effect, to attain recovery as quickly as possible and to avoid amputation The treatment must, therefore, be immediate, intense and above all, as conservative as possible.

6.4 reatment

Apart from the conventional treatment in the hospital, simple procedures for the treatment of frostbite in field conditions have been tried at this Laboratory. The first step in this is to stop exposure to cold and apply rapid rewarming at 37–39 °C. Recent study by the authors illustrates the synergistic effect of vitamin C in amelioration of cold injury, if coupled with rapid rewarming at 37 °C in tea decoction. Rapid rewarming in decoction of Indian tea maintained around normal body temperature (37 °C), followed by high dose of vitamin C (50 mg/kg b w) for 15 days is very effective as an immediate treatment of frostbite[29]. The use of rewarming in tea decoction is already in vogue in the local residents of HA as a therapy for cold injury.

The most encouraging and highly beneficial result was obtained by the treatment of rapid rewarming in tea decoction maintained at 37–39 °C immediately after cold exposure, followed by combined therapy of aspirin (5mg/kg) and pentoxifylline (40 mg/kg) along with vitamin C (50 mg/kg), twice daily for seven days. Rewarming was applied for 30–35 min, once daily for two successive days. Silver sulfadiazine, an antiseptic cream was also applied externally to prevent secondary infection, which is the major contributory factor in determining the severity of the injury.

These findings in rats call for clinical studies for confirmation of beneficial effects of the above combination therapy in man. Positivity of the findings in human subjects, will help to formulate a simple procedure of treatment, which will be self-applicable in the field situation, by the victim himself, immediately on recognition of the cold injury and will be a real boon to the humanity, particularly to our Armed Forces, operating in the snowbound areas of HA. Pentoxifylline, a dimethylxanthine derivative and metabolites have been proved to be effective in chronic peripheral arterial diseases, increasing blood flow to the affected microcirculation by decreasing blood viscosity and enhances tissue oxygenation[30]. Aspirin acts at the cyclooxygenase level, preventing conversion of arachidonic acid to prostaglandin, thus inhibiting thrombus formation. Vitamin C is an antioxidant. Increased metabolism and thermogenic properties of vitamin C helped in restoring general body warmth by increasing extremities blood flow. Vitamin C also helps in collagen synthesis and is known for its use in accelerating wound healing process.

6.5 Some Do's and Don'ts on Recognition of Cold Injury

(a) Remove tight shoe soc etc

Warm the injured parts by giving body warmth (not by direct fire heat f m *bukharies*, room heaters, blowers etc.)

(c Cover the body with blankets

(d) Provide rest and plenty of hot drink

over blister with dry dressin

f) Treat the victim a stretcher patient

tl

(h) Do not massa e or rub the parts/d ap direct fire heat

Do not apply ointment

rink alcc

(k) Transfer the patient to hospital at the earliest for further treatment.

6.6 Some Do's and Don'ts at High Altitude

Footwear should be just fit–neither loose not tight. Heavy woollen/feather stuffs should only be used when required. But it does not mean that the ascender should wear very light clothing as in the low temperature area where the weather changes at very short intervals.

(b) Plenty of fluid must be taken with regular interval for proper appetite, avoidance of dehydration, dryness and constipation, Avoid excessive use of alcohol and cigarette.

There is no need of taking regular bath, but the body must be kept cleaned with the help of sponge, wet towel etc. Dryness is common at HA. Some lubrication of all the body parts including the hidden part is nece

(d Aspirin may be taken fo relie g headache Sleeping pills should not be aken

Everybc at I m exercise

)ark n gogg must be while on

Members should not mind each other's gossip and comments, as at HA area, the body and mind sometimes do not function properly and mental irritability may occur.

(h) All members should endeavour to do their best in their allotted task so that the leader may not be taxed unnecessarily.

i) Sometimes food or equipment runs short because of some accident or logistic problems. In such situations, the whole party should share rest of the food and equipment in a very cooperative manner.

(j) In case of an accident, everyone should put one's full effort to help evacuation of the injured.

(k Life at HA is studded with challenges, adventure and opportunities. So healthy and constructive men of the society not only keep themselves hale and hearty but also create similar environment around them. This principle is very important at HA.

(l) In case of an expedition or in extreme forward camps at HA, or in posts at the glacier regions, every member is equal. There should not be any difference of rank, toughness, climber and non-climber, fighter or non-fighter, so on and so forth. Everyone is important in one's own capacity. Leader is, therefore, the central stone of the arch, but side stones of the arch are also equally important.

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