A U S T R A L I A N   P A R A C H U T E   F E D E R A T I O N

ALTITUDE PHYSIOLOGY

Notes for Level II Coaching Accreditation Course

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ALTITUDE PHYSIOLOGY

OUTLINE

INTRODUCTION

In jumping, we tend to think of altitude in terms of "How much skydiving time does that give us?" Always, we are after more altitude, more value for money, longer freefalls. Every year it seems, we are using aircraft which will take us higher than we could go the year before.

However, there is more to altitude than just being further from the Earth, as any pilot who has struggled through his exams will tell you. Altitude affects all sorts of things, most of them important to flying an aircraft, and some of them important to us as parachutists. With the altitudes we are going to now, it's important to understand some of these effects.

These briefing notes will deal with the important aspects of altitude as it relates to sport parachuting, but not to the special equipment, training and planning necessary for special high-altitude jumps. This is adequately covered by the APF document "High Altitude Descents", which, although a little out of date, is available from the APF Office.

TERMINOLOGY

In jumping, we usually talk about "height", whereas pilots usually talk of "altitude". The difference is that parachutists want to know how high they are above the DZ (height), but a pilot needs something that doesn't vary as he flies cross country. So pilots measure their height above sea level (altitude). Remember the times a new pilot has given you jump runs a few hundred feet below what you asked for? No-one told him to reset his altimeter for the DZ elevation.

Above 10000' altitude, the aviation industry switches to "flight levels", which is more convenient for aircraft at that altitude. Each flight level is equivalent to 100' (approximately), so flight level 150 (FL 150) is approximately 15000'; FL 200 is approximately 20000'.

Since most of the effects that we will be concerned with are caused by altitude, not height, we will be using altitude throughout these notes. For most DZs in Australia, this makes very little difference, but if your DZ is, say, 1000' above sea level, you should take 1000' off all the altitudes to get the height you read on your altimeter. (Eg. We say that 15% of night vision is lost at 8000'. If your DZ is at 1000' above sea level, this means that you will have the same deterioration of vision at 7000' on your altimeter.)

HYPOXIA

Most of the effects of altitude that we are interested in relate to the amount of oxygen the body is getting.

The body is adapted to getting enough oxygen for its needs at sea level or a little above. The Nepalese and other high altitude dwellers may function well at 12000 - 20000', but most Australians can't. We can adapt our bodies to living at high altitudes, but it takes time. The Mexico Olympics demonstrated this: sportsmen used to the altitude and those who arrived in Mexico early enough to acclimatise did well; the others, who weren't acclimatised, generally did poorly.

Effect of altitude on pressure

As we go higher above sea level, the atmospheric pressure falls. Very approximately, the pressure halves for every 18000' of altitude. (ie. at 18000', it is half what it is at sea level; at 36000', a quarter; etc.) Half the pressure means half as much oxygen in each lungful of air.

It might seem that all we would have to do is breathe twice as fast. Unfortunately, it doesn't work like this. Where the oxygen meets the blood in the lungs, a chemical reaction takes place (the oxygen becomes attached to the haemoglobin of the red blood cells). The completeness of the chemical reaction depends on the pressure in the lungs, so that as the air pressure falls, some of the haemoglobin is leaving the lungs without its full load of oxygen.

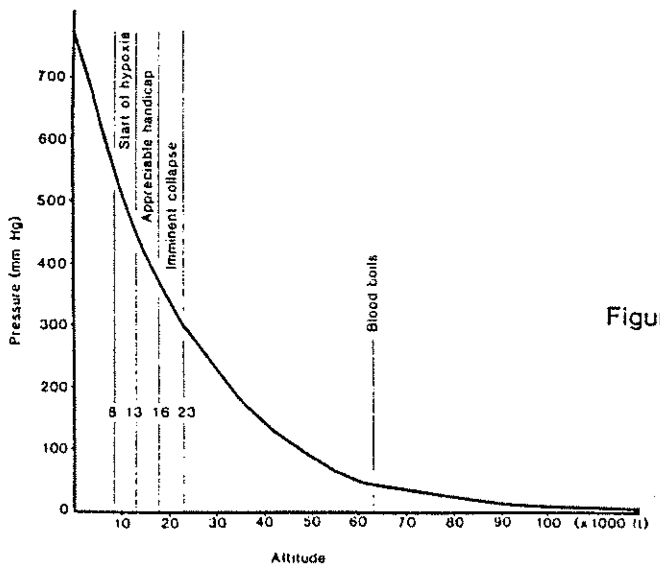
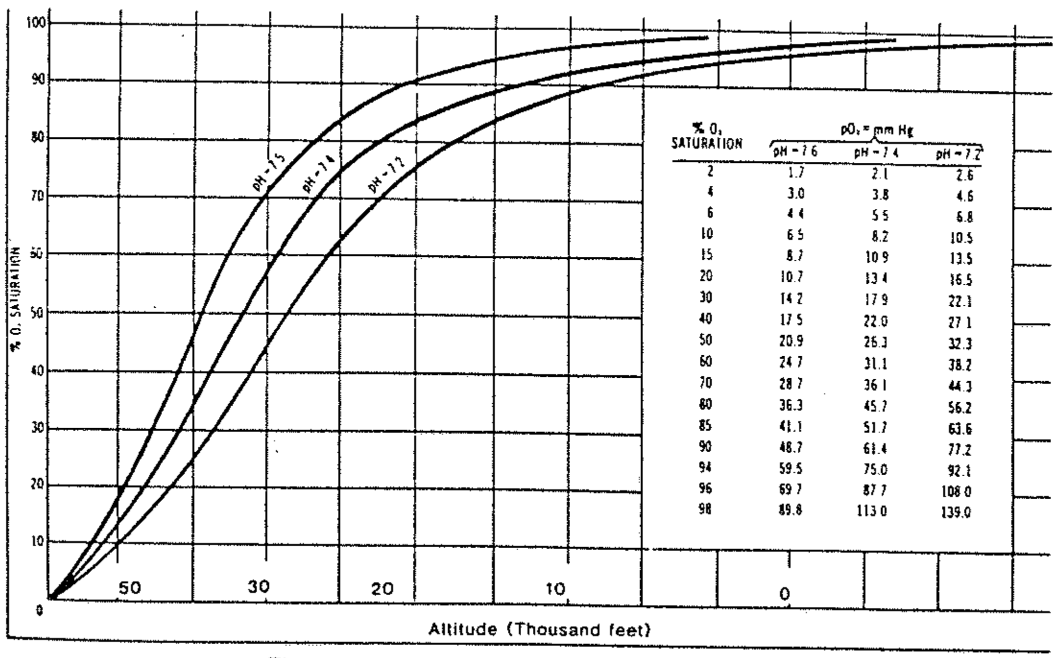


Figure 1

Effect of pressure on blood oxygen concentration

See figure 2. This shows the maximum amount of blood that will leave the lungs carrying a load of oxygen at different altitudes. Up to about 8 or 10 thousand feet, the body copes fairly well. There is a decrease in the amount of oxygen carried by the blood, but it's not very marked. Above about 10000 ft, the capacity of the blood falls off rapidly. There has been the assumption that this means that increasing altitude has no effects below 10000 ft, but this is a false assumption. It's just that the effects are not so obvious.

Normally, at sea level, the blood leaves the lungs for its trip around the body carrying about 98% as much oxygen as it theoretically could. At 10000', because of the lower pressure in the lungs, this figure falls to 87%. At this level of oxygen in the blood, the body can still function reasonably well. Once it falls below this, however, the workings of the body (the brain in particular) become impaired to an extent which can be noticed and measured.



% O_2 SATURATION	pO_2 = mm Hg		
	pH - 7.6	pH - 7.4	pH - 7.2
2	1.7	2.1	2.6
4	3.0	3.8	4.6
6	4.4	5.5	6.8
10	6.5	8.2	10.5
15	8.7	10.9	13.5
20	10.7	13.4	16.5
30	14.2	17.9	22.1
40	17.5	22.0	27.1
50	20.9	26.3	32.3
60	24.7	31.1	38.2
70	28.7	36.1	44.3
80	36.3	45.7	56.2
85	41.1	51.7	63.6
90	48.7	61.4	77.2
94	59.5	75.0	92.1
96	69.7	87.7	108.0
98	89.8	113.0	139.0

Figure 2 Oxygen dissociation curves for human blood

Times of useful consciousness

The impairment becomes worse the higher we go and the longer we stay there. So, at 18000', we have 20 - 30 minutes of useful consciousness before lack of oxygen affects us so badly that we are incapable of doing anything about it. Going higher, the time

Times of useful consciousness

Altitude	Time of useful consciousness at rest
18 000 ft	20-30 minutes
22 000	10
25 000	3-5
30 000	1-2
35 000	30 seconds
45 000	9-12

Note that these times are for a fit person, at rest. "Useful consciousness" means the ability to put on an oxygen mask. Symptoms of hypoxia will be evident well before the loss of useful consciousness.

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of useful consciousness halves approximately for every extra 3000'. So, we have 10 - 15 minutes at 21000', 5 - 7 minutes at 24000', ... and only a few seconds at 40000'. Note that this does not mean that at 18000' we will be perfectly OK for 20 - 30 minutes and then keel over. It means we will get progressively worse until, after 20 - 30 minutes, we are mentally and physically incapable. After even a few minutes at this altitude, our mental state will have deteriorated and will continue to get worse until we become unconscious.

Pressurisation and the use of oxygen to prevent hypoxia

The aviation industry has used two methods to overcome the problem. The first, used in passenger aircraft, is to pressurise the entire cabin. Usually the pressure is arranged to be equivalent to about 8000' - comfortable enough for the passengers and crew and not working the compressors too hard. The other method used is to breath oxygen rather than air.

Only one fifth of air is oxygen. The rest is mostly nitrogen, which goes into and out of the lungs unchanged. Breathing oxygen rather that air means that the oxygen pressure in the lungs is effectively five times as great, and the body will function normally while this oxygen pressure is at least as great as it normally is when breathing air at sea level. As an example, breathing oxygen at 34000' will keep the same level of oxygen in the blood as breathing air at sea level. Breathing oxygen at 40000' is equivalent to breathing air at 10000'.

Signs and symptoms of hypoxia

When the blood is leaving the lungs less than saturated with oxygen, the condition is known as hypoxia (hypo = low, oxia = oxygen). The effects of hypoxia vary according to just how unsaturated the blood is, and they vary from un-noticeably slight effects to death.

It is the effects in the middle of the range that interest us as parachutists. The signs that a parachutist would notice as the effects of hypoxia begin are usually different and characteristic for each person, and with a little experience it is possible for each person to recognise his own personal signs of hypoxia as soon as they begin.

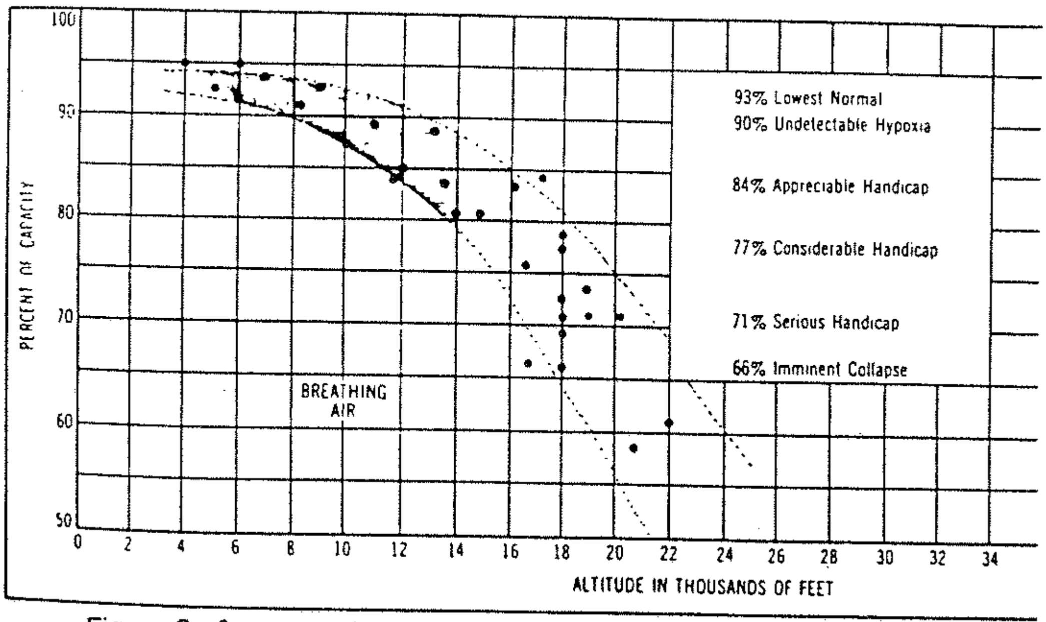


Figure 3 Oxygen saturation (% of capacity) of arterial blood and range of performance in subjects breathing air

The signs that a parachutist would notice in himself could be any or all of these:

- Blurred or spotty vision
- Tunnel vision
- Tingling in the fingers and toes
- Numbness
- Hot and cold flushes
- Dizziness
- Nausea
- Fatigue
- Headache
- Apprehension
- Hunger for air

The symptoms that other people might notice in someone suffering from hypoxia could be any or all or these:

- Increased breathing rate
- Cyanosis (blue tinge in the skin, especially finger tips and lips)
- Mental confusion
- Loss of muscular co-ordination
- Poor judgement
- Belligerence
- Unconsciousness
- Euphoria

All these are rather gross effects. Recent research is showing that there are other, more subtle effects of mild hypoxia. These relate to fine motor tasks and intellectual skills and they appear at lower altitudes than the gross effects. In other words, before a person goes blue, starts panting or noticing spots before the eyes, his judgement and ability to make precise movements is already impaired.

It used to be thought that the effects of hypoxia were temporary, but researchers are now finding some evidence of brain damage resulting from long-term hypoxia. No long-term effects of mild hypoxia have been found.

Two of the symptoms of hypoxia, hunger for air and euphoria need some more explanation.

. Hyperventilation

The rate and depth of breathing is normally controlled unconsciously, though the conscious part of the brain can take over at times. Normally, breathing is controlled through sensors which measure the amount of carbon dioxide in the blood. This will normally keep the blood well topped up with oxygen. The body needs to keep the amount of carbon dioxide in the blood fairly well controlled between narrow limits, because if it goes up or down too much, the pH (acidity or alkalinity) of the blood will go out of the range necessary to keep the body (especially the brain) working properly.

However, there are also sensors which respond to the amount of oxygen in the blood. These become active when the oxygen concentration falls to a low level, such as might happen at an altitude of 12000 - 15000 ft, and their activity causes the rate of breathing to increase.

This increase in breathing rate does not actually increase the amount of oxygen in the blood, because its low concentration is not caused by slow breathing, but by the inability of haemoglobin to take up much oxygen at the low atmospheric pressure.

The deeper and faster breathing reduces the amount of carbon dioxide in the blood. The blood becomes less acid, and the body reacts, showing symptoms of dizziness, muscular spasms and unconsciousness. At an early stage, the victim becomes aware of the beginnings of these symptoms, becomes anxious, and breathes even faster, compounding the problem. Once unconscious, the breathing stops, the carbon dioxide level increases and victim recovers. However, if the conditions that produced hyperventilation in the first place are still present, the cycle will start again.

Treatment for hyperventilation: The best practical treatment for hyperventilation is descent to a lower altitude, where the atmospheric pressure allows the blood to take up more oxygen. Alternatively, the oxygen concentration of the blood can be increased if the victim breathes oxygen instead of air. A crude but effective treatment is to raise the carbon dioxide concentration of the blood by having the victim breathe in and out of a bag, so that he or she is inhaling his own exhaled carbon dioxide. It is necessary to let him/her get a lungful of fresh air every fifteen of twenty seconds.

- Euphoria

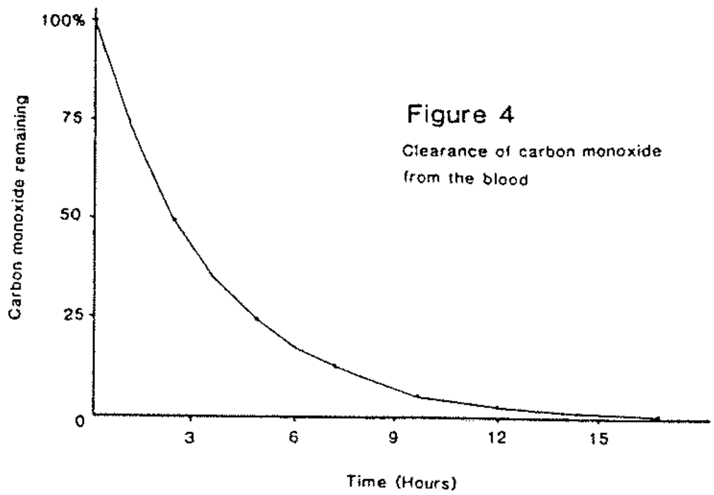
Being a little bit hypoxic is like being a little bit drunk. The victim feels good, but the "critical assessment" part of the brain, which would normally warn of other symptoms such as lack of co-ordination or slower reaction times, is often switched off. Very often it is possible to see the signs of hypoxia in everyone but oneself.

This is dangerous because the victim feels he is performing well, perhaps even better than usual, when in fact he is performing less well than normal. He may be encouraged by his feeling of well being to take additional risks, which he is actually less capable of handling.

Factors which aggrievate hypoxia

- Smoking

Smoking (tobacco or any other substance) produces carbon monoxide which poisons the haemoglobin in the red blood cells, so that they cannot take up as much oxygen. The effect is temporary, but it takes many hours after the last cigarette to clear the blood entirely of carbon monoxide. (The half-life of carbon monoxide in the blood is about 200 minutes: that is, every 200 minutes, half the carbon monoxide in the body will be eliminated.)



A moderate smoker may have 5 - 10% of his haemoglobin poisoned with carbon monoxide. This means that the oxygen-carrying capacity of the blood is reduced to what it would normally be at 5000 - 8000'. A heavy smoker may have his oxygen-carrying capacity reduced to the equivalent of being at 10000 - 15000'.

These figures refer to the oxygen-carrying capacity at sea level: as soon as the parachutist starts gaining altitude, his blood will be able to carry even less oxygen. Having smoked a few cigarettes is equivalent to being a few thousand feet higher.

. Blood donation and other blood loss

A standard blood donation involves the extraction of about 500 ml of blood, about one tenth of the body's supply. The liquid is replaced fairly quickly, but the haemoglobin in the red blood cells take about a week to recover. Until it is replaced, the body is getting only as much oxygen as it would normally if it was several thousand feet higher than it really is.

This applies to any form of blood loss, of course. Most people would not be parachuting soon after an accident causing this sort of blood loss, but a heavy menstrual flow can cause a significant reduction in the oxygen-carrying capacity of the blood.

. Drugs

Many drugs reduce the amount of oxygen that the blood can carry. This includes legal and illegal drugs, and both prescribed and over-the-counter drugs. Common examples of such drugs include alcohol and narcotics such as codeine.

In addition to the effect of the drug on the oxygen-carrying capacity of the blood, the reduction of oxygen with altitude often also increases the effect of the drug on the body. For example, at altitude, alcohol has a greater inebriating effect, and anti-histamines cause a greater degree of drowsiness.

The exact effects of altitude on many drugs is not known, and parachutists would be wise to treat all drugs with great caution. Do not assume that because there are no noticeable effects on the ground, there will be none at altitude.

. Blood pooling

Blood pooling is the name given to what happens when a person is sitting still for a period. The body tissues do not need as much oxygen, so the heart responds by slowing down and beating less strongly. The pressure in the blood vessels is quite low - still high enough to circulate the blood around the essential parts of the body, but not high enough to drive the blood back from the feet and legs. When the blood in these parts of the body becomes quite stale and very short of oxygen, we get the sensations of pins-and-needles and numbness.

In effect, this blood pooling reduces the amount of blood in circulation, and isn't a problem while a jumper is sitting still in the aircraft. However, activity and a shot of adrenaline on jump run makes the heart beat more strongly and faster, sending the pooled up blood back into circulation. The mixed blood is short of oxygen, and this deficit takes some time to make up. Thus we have another effect which can decrease the amount of oxygen available to the brain at the time of exit.

Blood pooling can lock up a quite significant proportion of the blood, and can impair performance for at least a minute after the parachutist becomes active.

Fortunately, blood pooling can be overcome. This is done by alternately tensing and relaxing the muscles of the legs and feet. Two methods are useful: the first is to tense the thigh muscles for about one second and then relax them for the same time. The second is to rock the feet backward and forward so that first the heels, then the balls of the feet are in contact with the floor. The muscular movement increases the pressure in the blood vessels enough to keep the blood moving back to the heart. The second method may not be available to a parachutist sitting in a crowded aircraft, but the first method will be useful. Getting ready to exit at least a minute or two before actual time of exit will help too.

. Other factors

Anaemia (shortage of haemoglobin) makes a person more susceptible to hypoxia. One cause of anaemia is poor diet, specifically one short of iron. (Haemoglobin contains iron.) This type of anaemia is more common in vegetarians than in meat-eaters.

Low temperature reduces the body's tolerance to hypoxia.

An unfit person, or one who is fatigued, or short of sleep, is more susceptible to hypoxia than a fit person, and almost any illness or disease will increase the effects of hypoxia.

. Cumulative effects

Although, say, a couple of cigarettes may not have a very large effect on performance, a small contribution from each factor may add up to a significant reduction in performance and safety.

A smoker with a hangover who is taking cold tablets and has been sitting still in a slow climbing aircraft will have a much reduced performance level compared to a jumper who hasn't been subject to all these factors.

Variation between individuals

Just about everything that has been described in this article applies to the average person, to the mythical "average man". However, real people are all different. Some people will suffer symptoms of hypoxia at a lower altitude than some other people; some will react more strongly to some drugs than other people.

What this means is that even if we stay within the set guidelines for maximum exit altitude or maximum time at altitude etc, we still need to be alert for those people who are more susceptible and may have problems while other people are fine.

The significance of hypoxia to parachutists

So what does all this mean in practical terms? Does this really need to concern us as parachutists?

The answer to the second question is "Yes!" We have not seen a lot of problems in the past, and this has led us into a false feeling of security. However, things have changed: we do have to think about it now.

It is only in the last few years that exit heights above 12000' have become common. It just wasn't practical to go above this in a small Cessna or a DC-3. However, with the use of turbine engined aircraft such as the Twin-Otter, it's easy and economical to go regularly up to or higher than the legal limit (FL140 or about 14000' without oxygen). At this height, the effects of hypoxia are starting to become evident in many people. Luckily, the aircraft that can get to these heights economically will also get there fast, so the time-of-exposure, and consequently the severity of the effects, will be less.

This height (12-14000') is fairly close to the altitude at which we can expect to start to find problems. In the past, we've been immune from problems by our enforced staying below the limit. However, now we have the capacity to get to altitudes that will cause problems.

Consider the case of a go around at 14000' because of cloud or other aircraft traffic. Another few minutes exposure, and very probably an extra couple of thousand feet: the problems compound rapidly.

Out of the door at this height, the jumpers are losing altitude rapidly, and falling into a more hospitable atmosphere. By the time they land, none of them will be showing any marked signs of hypoxia.

But back to the initial few seconds of the skydive. A skydive which started with a bit of extra height because it's a special attempt to build a big freefall formation. The early waves are under pressure to put their bit together quickly for later waves to build on. All are suffering from slight, unnoticed, hypoxia. Not enough to have any very marked effect on their performance, but enough that they are all thinking and reacting just a little slower than normal. One of them is just a bit slow in getting there, and there's a lot of people behind him relying on him to perform. He puts on a bit more speed, flares before docking ... but too late, and he takes the base out ... or worse.

Every skydive is a calculated risk. We accept this and live with it. What we don't need is to add an uncalculated risk. A "she'll be right" attitude is an uncalculated risk. Each experienced jumper needs knowledge of the risks associated with the jump before he gets involved in it. Each DZSO or Instructor needs to know the risks before planning jumps for students or novices.

Skydiving is a mentally demanding sport: we need all our wits about us. When the brain is working close to the limit of its capacity, as it is when we are undertaking a difficult task, then even a small diminution of our mental capacity will cause a mental overload. And in conditions of mental overload, we do surprising things. Things which we normally find easy become difficult, things which are almost habitual get forgotten, tunnel vision increases. All or which add up to increased danger.

AFF students, especially, need to be performing at their very best possible. We know about sensory overload, which is a psychological effect. Hypoxia can only increase sensory overload, and generally depress the student's performance.

There are implications for competition teams, too. For competition, you need to be performing at 100% of your capacity. 95% doesn't win medals. At exit height, eight-way teams <u>are</u> experiencing hypoxia and their performance <u>is</u> diminished, even if only slightly. There may be a case for these teams to breathe oxygen for a few minutes before exit to eliminate any traces of hypoxia and get their bodies and brains working at full efficiency.

UNDER-WATER DIVING AND SKYDIVING

There are many parachutists who also participate in under-water diving. They will be aware of the risk of the bends caused by too rapid decompression during a dive.

The bends (or decompression sickness) is a painful, incapacitating and sometimes lethal disorder caused by nitrogen bubbles forming in the blood as the pressure is reduced during ascent from a dive. These bubbles may accumulate in the joints, causing pain and stiffness, or in the blood vessels of the heart and lungs, with the risk of death. It's a problem only on those dives where air is breathed underwater (SCUBA or hookah dives): snorkel dives do not pose any risk.

However, some underwater divers do not realise that the decompression tables are drawn up on the assumption that the diver is going to remain at sea level after his dive.

If the pressure is reduced to lower that sea-level pressure (by flying), the onset of bends is more likely. Note that it is the actual reduction of pressure that has the effect of causing the bends, not the length of time at altitude. Even a very short flight might be dangerous.

The rules for flying (or parachuting) after diving are mostly rule-of-thumb, and differ considerably according to who issues them. There seems to be no procedure that is guaranteed to prevent bends.

An AIC (Aviation Information Circular) No C04/1985 published by DoA recommends the following restrictions on flying after underwater diving:

a. Diving which does not require decompression stops may be followed by flying after a rest at sea level of 4 hours;

b. Diving which requires decompression stops and is of less than four hours duration may be followed by flying after a sea-level rest of 12 hours;

c. Diving which requires decompression stops and is of more than four hours duration may be followed by flying after a rest of 48 hours.

The Hyperbaric Medicine Unit of the Royal Adelaide Hospital has recommended that people should not fly <u>at all</u> within 24 hours of <u>any</u> diving activity, and, if people are going to fly and SCUBA dive in the same weekend, then they should do the flying first.

The bends is a serious, sometimes fatal, problem, and these precautions should be adhered to strictly. The symptoms of bends are:

Itchiness or other sensations in the skin
Painful swellings under the skin
Exhaustion, sweating, shivering
Pains in the joints or muscles
Respiratory troubles
Nervous troubles (developing into paralysis)

A case of bends must be referred to medical treatment immediately. Treatment usually entails a spell in a recompression chamber to dissolve the nitrogen bubbles, then a slow decompression to allow the nitrogen to pass out through the lungs.

NIGHT VISION

Night jumps may be the exception rather than the rule, but it is important to recognise that the eyes function differently at night in ways that are important to the parachutist.

Each eye really incorporates two different systems - a day vision system and a night vision system. In bright light, the night vision system is virtually turned off, and in dim light, the day vision system is turned off. There is a certain period of twilight when both systems are working, but neither at their greatest efficiency. These two systems work and respond differently, and since we tend not to use the night vision system much, it is easy to get caught out.

The day vision system is the one most people are most familiar with. Its sensory cells are called cones and they are sensitive to colours, but only in bright light. There are a great number of cones, concentrated in the centre of the visual field, so they are able to resolve fine detail, but only in the centre of the field of view. At the edge of the field of view details become hazy.

The night system, on the other hand, is colour blind - it sees only in black-and-white. Its sensory cells are called rods, and they are found where the cones are not - ie. in the peripheral areas of the retina, but less in the centre. They are not as closely packed as the cones, so they cannot resolve fine detail. They are very sensitive to light and can only work properly in dim light.

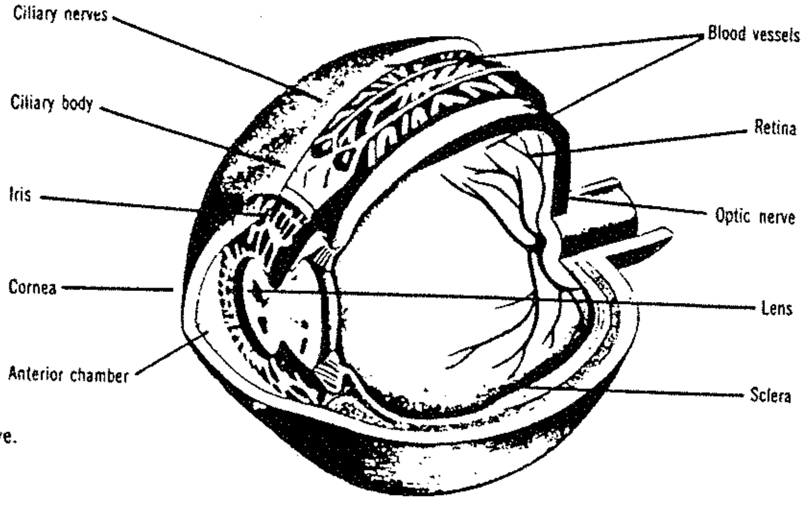


Figure 5
Sectional view of the eye.

Acclimatisation to darkness

The rods (night vision) take about 30 minutes to recover from bright daytime light: everyone knows that you can be blind for several minutes after walking from sunlight into a dark room. In a natural situation, the light intensity changes fairly gradually at dawn and at dusk, giving the two systems time to adapt to the different light systems. The day vision system recovers much more quickly: we may be temporarily blinded when we walk out of a dark room into sunlight, but it takes only a few minutes to recover fully.

When skydiving at night, the jumper needs his night vision system working at its optimum. While it is possible to light altimeters and landing area brightly enough for the day-vision system to work, the skydiver needs to be able to see, for example, other skydivers and canopies, and other ground features. It is necessary to illuminate altimeters and other jumpers sufficient to allow them to be seen by the night-vision system but not enough to destroy it. Red light has a rather less damaging effect on the night-vision system than other colours so there is a case for using this colour for altimeter lights.

Skydivers should avoid bright areas for at least half an hour before jumping, and should fit up their lighting systems <u>after</u> their eyes have become adapted to the dark, and should mask their lights to reduce the intensity needed, but no higher. It is important to realise that once adapted to the dark, the skydiver should not expose himself to bright light, even momentarily, because the adaptation back to night vision is a slow process. Where is is essential to use a bright light, it is advisable to do so with one eye closed, thus retaining the night-vision capability of that eye.

Because the rods of the night-vision system are distributed mostly around the peripheral parts of the retina, the central part of the field of vision is relatively blind at night. This is the opposite to the day-vision system, where the centre of the field of view is the most sensitive. This makes tunnel vision doubly dangerous at night - not only is the jumper looking only straight ahead of himself, but also he can't see what he is looking at very well! Keeping the eyes moving, scanning the entire area of interest will prevent vital information being lost in the central area of low sensitivity.

The distance-judging part of the eyes and brain works less efficiently in the night-vision system. This means that a parachutist may err in judging his distance and closing speed with the ground or another jumper. This skill is regained after several night jumps, but a non-current night jumper should be aware of the possibility of errors in this area.

Effect of altitude

The two visual systems - day vision and night vision - react very differently to the reduced amount of oxygen during the ascent. During the day, vision is not seriously affected by oxygen lack. However, the night-vision system *is* very sensitive to oxygen shortage. The figures generally quoted are that the acuity of night vision is reduced by about 15% at 8000 ft and by about 25% at 12000 ft compared to night vision at ground level. This is a substantial reduction and one that should not be ignored by, say, a night relative worker. When combined with other factors, such as smoking, the loss of acuity can well amount to a dangerous hazard.

Percentage loss of night vision with altitude

Altitude	Loss
4000'	5%
6000	10
8000	15
10000	20
etc	

OTHER EFFECTS OF LOW ATMOSPHERIC PRESSURE

During the climb to height, the atmospheric pressure falls. This has the effect of allowing any gasses trapped within the body to expand and press against the surrounding tissues. We need to consider the effects of this in several areas of the body.

Intestinal gasses

Gasses in the stomach and intestines can find their way out of the body quite easily and rarely cause any problem other than temporary discomfort. However, an uncomfortable stomach distension during climbout and exit could make a marginal difference in competition and should be avoided.

Stomach gas is produced especially by hurried eating, carbonated drinks and by chewing gum (it leads to air being swallowed), so these should be avoided for say half an hour before take-off.

Intestinal gas is produced especially by heavy eating and by various items of diet. Most people are aware of the particular foods that cause them problems. In addition, the intestine becomes more sensitive to being inflated by expanding gasses when it or the body has been maltreated. After a heavy night, the intestine is not only brewing more gas than usual, it is also more sensitive to it.

Problems with teeth

Gas trapped in teeth can cause real pain as it expands. An imperfectly filled cavity, or a patch of decay within a tooth or an abscessed tooth can be the cause of the gas. The gas expands with altitude, and since it cannot escape, it presses on the surrounding nerves, causing the same sort of pain that a dentist's drill causes.

Generally the pain appears at between 5000 ft and 15000 ft during the ascent, and for a particular tooth will often be very consistent in the altitude at which it appears. The pain may or may not become more severe or may disappear as the altitude increases. In the short term, descent is the only effective way to bring relief. In the long term, a visit to the dentist is usually called for.

However, it should be borne in mind that new fillings, especially those of amalgam material, may take some time to stabilise, and altitude pain in a recently filled tooth may decline and disappear over a few weeks.

Evidently it would be advisable for a competitor at an important competition or training camp not to take dental problems with him/her, but to get treatment several weeks before the event.

Tooth pain at altitude should not be ignored: if it is due to an abscess in the root area of the tooth, there is a possibility that the pressure changes could lead to a serious spread of the infection

Sinus problems

The sinuses are air-filled areas within the bones of the head. Most people become aware of them only when they have some sort of head cold. Normally the pressure inside the sinuses is equalised with atmospheric pressure through small openings into the nose. When the head is stuffed up with a cold, the openings may become plugged with mucus and the pressure may not equalise.

There may be excess pressure which cannot be vented from the sinuses during ascent, or the gas may escape during ascent, and equalisation not happen during the descent. Both conditions may lead to pain which may be mild or intense.

Various drugs are available, either on prescription or over the counter, to reduce the amount of mucus in the sinuses. However, any drug, even though it appears to have no side effects at ground level, should be viewed with suspicion in a situation where peak mental and physical performance is called for. Anti-histamines, especially, do not mix with skydiving. They blunt the reaction time to some degree, and have a greater sedating effect at altitude.

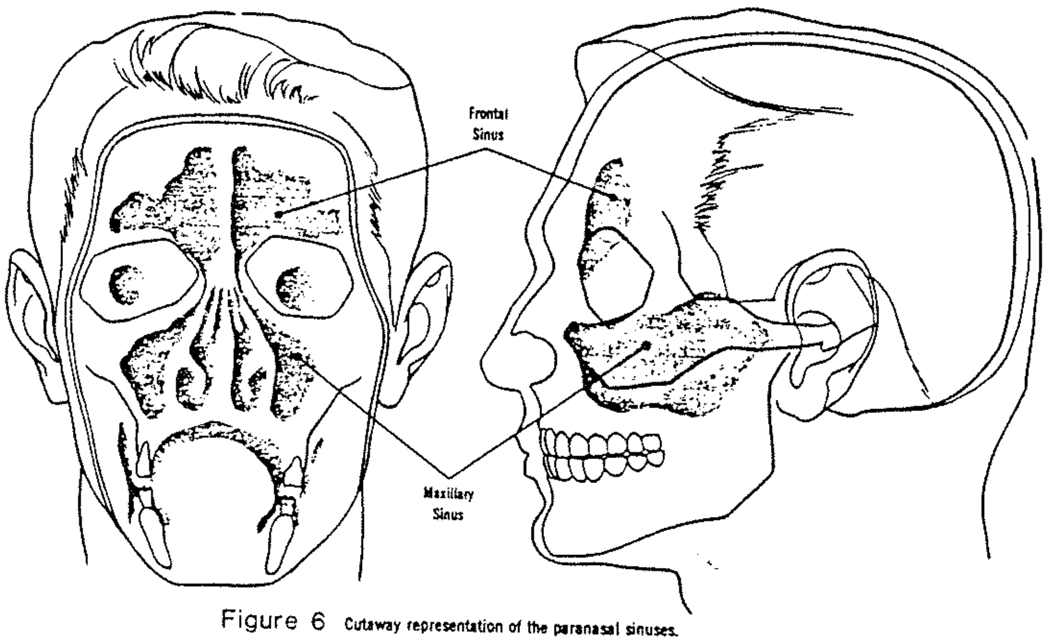


Figure 6 Cutaway representation of the paranasal sinuses.

The best advise to skydiver with hay fever or a cold is to stay on the ground. However, a parachutist who has landed with sinus pains will probably get some relief by yawning, swallowing, or blowing the nose.

Jumping with blocked sinuses can be more than just uncomfortable: it is fairly common for the pressure changes within the sinuses to suck infected mucus into the sinus, causing what was a simple cold to develop into sinusitis.

Ears

The ear mechanism consists of three distinct parts: the outer ear, which ends at the eardrum, the middle ear, which is a small air-filled cavity within the skull, and the inner ear, a fluid-filled cavity containing the actual sense organs of hearing and balance.

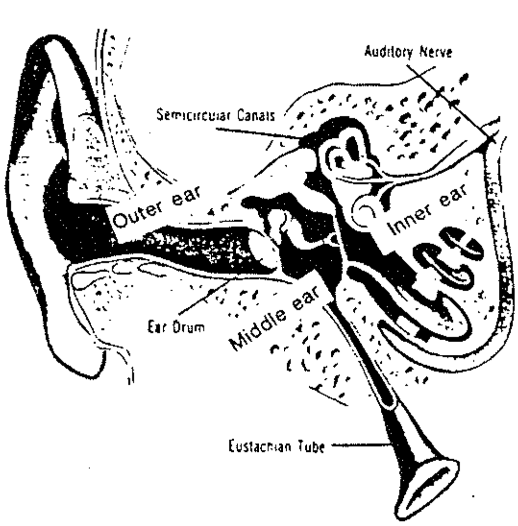


Figure 7 Cutaway representation of the ear.

It is primarily the middle ear that concerns us here. Like the sinuses, it is air-filled, and has a small connection to the atmosphere through the Eustachian tube, a narrow passage opening onto the back of the throat. The eardrum, which separates the middle ear from the outside atmosphere in the outer ear, is a thin membrane about one tenth of a millimetre thick. Figure XX shows the relationship of these parts.

During ascent, the reduced atmospheric pressure outside the middle ear allows the air within to expand. Normally, this air automatically squeezes out through the Eustachian tube. If the ascent is rapid, this expansion and release of gas is often noticed as a feeling of fullness in the ear followed by the feeling of relief as the gas escapes.

However, during descent, the opposite process is not so efficient. Air does not get back into the middle ear through the Eustachian tube as easily as it gets out. This is because the Eustachian tube acts somewhat like a flutter valve - excess pressure outside tends to close the opening of the tube.

Most skydivers are familiar with ways of "clearing the ears" - getting air at outside pressure through the Eustachian tubes. Useful techniques include the following: closing the mouth, holding the nose and raising the air pressure in the mouth and throat using the muscles in the tongue and floor of the mouth (this effectively forces air past the valve at the base of the Eustachian tube); yawning, swallowing or rotating the lower jaw (these tend to distort the opening of the Eustachian tube and allow air to pass through).

Practice at these clearing techniques will help to allow a faster rate of descent to be borne without discomfort, so parachutists should be encouraged to practise the techniques. Ones which do not involve using the fingers to pinch the nose are the most useful as they allow the pressures to be equalised without, for example, taking the hands off the steering toggles.

Practice makes clearing the ears easier: few experienced skydivers complain about trouble clearing the ears except when they have a cold. However, students have not had the practice of clearing the ears over hundreds of skydives. AFF students may well suffer discomfort if they are not advised of methods for clearing the ears before take off.

Head colds, hay-fever and the like make the clearing of the ears more difficult. In mild cases, this leads to discomfort and diminished hearing ability, and the possibility of forcing infected mucus into middle ear. However, a pressure change of less than 0.4 atmospheres (equivalent to a skydive from 14000 ft) can be enough to cause serious pain and has occasionally caused the delicate eardrum to rupture. Occasionally, a drop of only 4500 ft without equalisation is enough to burst an eardrum, or even less if it is already damaged or diseased. Although it will usually heal by itself without complications, a ruptured eardrum is not to be taken lightly, as there is risk of infection of the middle ear.

The same drugs that dry up the sinuses can be used when the ears are blocked, but they have the same effects. Again, the best advice for a parachutist with ears blocked by a cold is to stay on the ground.

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