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HUMAN PERFORMANCE AND LIMITATIONS

CHAPTER 9 – HYPERVENTILATION AND HYPOXIA

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HYPERVENTILATION AND HYPOXIA

9.1 Hyperventilation

Hyperventilation effectively means over-breathing, or breathing at a rate in excess of that required, to remove carbon dioxide.

Our rate and depth of breathing is controlled by our brain, which reacts not to the level of oxygen in the blood, but the level of CO_2. If the brain detects a rise in CO_2 in the blood, it interprets this as exertion and commands the body to increase the breathing rate and so reduce the level of CO_2 in the blood.

If we suffer some **psychological distress such as fear or anxiety**, we may start to breath too quickly; the result will be the removal of too much CO_2 and the blood will become too alkaline. The person is then said to be suffering from **alkalosis.**

Hyperventilation is not easily distinguished from hypoxia because of similar symptoms. In fact, **hypoxia** can cause hyperventilation. Other causes of hyperventilation are:

- Anxiety (inexperienced pilots in new situations)
- Motion sickness
- Vibration
- Heat
- High "G"
- Pressure breathing.

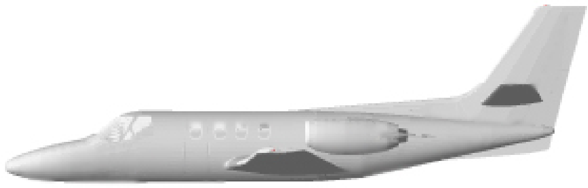
As with the recognition of the symptoms of hypoxia it is also very important that you recognise the symptoms of hyperventilation. Distinguishing **incorrectly** between hyperventilation and hypoxia can have serious consequences.

Signs and symptoms of hyperventilation:

- **Tingling,** especially in the hands, feet and around the lips
- **Stiffening/spasm** of peripheral limb muscles
- **Visual disturbances:** particularly tunnelling or clouding
- **Hot or cold feelings**: hot or cold feelings may alternate in time or site on the body
- **Anxiety:** establishing a vicious circle of cause and effect
- **Impaired performance:** pilot performance can be dramatically reduced by hyperventilation

- **Loss of consciousness:** hyperventilation can lead to collapse but thereafter respiration returns to normal and the individual recovers unless he has hit the ground in the meantime.

At altitudes above 10 000 ft, you should always give Hypoxia the benefit of the doubt and use oxygen and/or reduce altitude immediately.



10 000 ft

At altitudes much less than 10 000 ft, you should:

- Consciously relax
- Concentrate on breathing slowly (and more shallow), although this might be difficult due to anxiety.
- Breathe in and out of a paper bag.

9.2 Hypoxia

9.2.1 Introduction

Hypoxia is the term used to describe the condition, which occurs when the oxygen available to the tissues is insufficient to meet their needs. There are many causes, but in aviation the greatest risk of Hypoxia arises as a result of ascent to altitude with its associated fall in ambient pressure (as described in the previous section).

It is therefore very important that you, as a pilot, be able to recognise the symptoms of Hypoxia because it might just save your life one day and maybe those of your passengers. Even a minor lack of oxygen will result in a substantial deterioration in our performance as a pilot.

When we looked at the subject of hyperventilation, we saw that the brain reacts to the high levels of CO_2 in the body, interprets this as exertion and commands the body to breathe faster. We will experience a lack of oxygen at high altitudes, but the levels of CO_2 will remain steady, so the brain will not command the body to breathe faster. The body has no natural defence against hypoxia.

This table gives a summary of the requirements for oxygen:

Altitude	Oxygen Requirements
0 -10 000 ft	Air only is required, some higher function impairment.
10 000–33 700 ft	Increased percentage of oxygen in breathing gas.
33 700–40 000 ft	100% oxygen.
Above 40 000 ft	100% oxygen under pressure.

9.2.2 Classifications of Hypoxia

9.2.2.1 Hypoxic Hypoxia (The main concern to pilots)

This is a condition where there is insufficient oxygenation of the blood at the lungs due to a **decreased** partial pressure of oxygen (ppO_2) in the alveoli. The blood returning to the heart from the lungs contains less than sufficient oxygen, therefore insufficient O_2 is available for the tissues. In flight, this situation can develop from 8,000 ft and upwards.

9.2.2.2 Anaemic or Hypaemic Hypoxia

This type of hypoxia occurs when there is a decrease in the amount of red blood cells (RBCs) available for O_2 transport. It may be because of blood loss from severe bleeding (internal, or external), blood donation, from menstruation, chronic infection, or an iron deficiency in the diet causing anaemia. It can also occur in cases where there is an abnormally high carbon monoxide presence in the blood, reducing the haemoglobin's capacity to carry oxygen.

9.2.2.3 Stagnant Hypoxia

This condition can occur where there are heart or circulatory problems. The blood may have normal haemoglobin and oxygen levels, but poor circulation results in less oxygen than required reaching the tissues. This can be found in cases of shock, where there is a drop in the total effective circulating blood volume (the muscular walls of the arteries relax, which effectively widens them) as well as certain medical problems with the blood circulatory system.

9.2.2.4 Histotoxic Hypoxia

Histotoxic means 'cell poison'. This happens when some agent prevents the cells from taking in oxygen. **Alcohol** and **cyanide** are two such agents.

9.2.3 Causes and Symptoms

Hypoxia in aviation is caused mainly by the reduced partial pressure of oxygen available to the lungs. The first symptoms of hypoxia are usually associated with eyesight and mental functions, owing to the fact that eye and brain tissues are very sensitive to a lack of oxygen. The rate at which the effects occur depends upon the altitude.

It is possible even at 8,000 ft to observe signs of mental impairment, particularly if the person is active or under stress. Generally, healthy persons should not be noticeably affected below 10,000 ft. From 10,000 ft upwards the effects become more noticeable and symptoms similar to the effects of alcohol consumption may be seen.

The effects of oxygen deprivation vary from person to person and will become apparent at different cabin altitudes. However, eventually all people will be affected. At about 14,000' (with no oxygen) performance will be very poor. By 18,000, the ppO_2 is about **half** that at sea level and some people may already be unconscious.

The red blood cells (haemoglobin) in the blood would prefer to carry carbon monoxide, rather than oxygen. This means that a person who smokes has less oxygen circulation through their body system, compared to the non-smoker. In a smoker, the symptoms of hypoxia will therefore commence at a lower altitude.

Classical signs and symptoms of hypoxia

- **Sensory Impairment**: peripheral vision and night vision are first affected, followed by day vision, colour vision, touch and hearing. The optic nerve is very sensitive to oxygen deprivation. In general, night vision will be affected above 4,000'.
- **Euphoria and Personality Change**: Change in outlook and behaviour with euphoria or aggression and loss of inhibitions. This happens quite early and makes the recognition of hypoxia symptoms difficult.
- **Muscular Impairment:** Finely coordinated movements become difficult through slow decision-making and poor fine muscular control.
- **Memory Impairment:** Short-term memory is lost early, making drills difficult to complete unless trained into long term memory.
- **Impaired Judgement:** Loss of self-criticism with the individual unaware of reduced performance. It is also due to euphoria.
- **Cyanosis:** The skin becomes pale and a bluish tint may become noticeable, particularly the finger nail beds, the lips, ears and nose. This is called Cyanosis, which is caused by the de-oxygenation of the haemoglobin.
- **Impairment of Consciousness:** As Hypoxia progresses the individual's level of consciousness drops until he/she becomes confused, then semi-conscious, and unconscious. Unless he/she is rescued he/she will die and high altitude death can occur within a few minutes.

9.2.4 Time of Useful Consciousness (TUC)

The time available to a pilot to recognise the development of hypoxia and to do something about it is termed the **time of useful consciousness (TUC)**. This time period is typically:

- 30 minutes at 18 000 ft
- 2–3 minutes at 25 000 ft
- 45–75 seconds at 30 000 ft
- 20–30 seconds at 40 000ft
- 12–15 seconds at 45 000 ft.

This is not the time to unconsciousness but is the rather shorter time from a reduction in adequate oxygen tension until a specified degree of impairment, generally taken as when the individual can no longer take the necessary steps to help himself.

The figures are fairly representative of the various times of useful consciousness for a normal, healthy person. It should be noted that, in the case of an abnormal depressurisation of an aircraft cabin, the pilot will be engaged in a high level of activity and stress. TUC will be affected accordingly.

~~**Note:** Take particular note of how the time above 20 000 ft shorten dramatically. Time of Safe Unconsciousness (TSU) is the time a person can remain unconscious without the risk of brain damage due to lack of oxygen—about 4 minutes.~~

As you can see time plays an important role with Hypoxia and you need to take some countermeasures against it. The principal action is to add an increasing percentage of oxygen into the breathing gas. This must be done until a point is reached at which the pilot is breathing 100% oxygen to maintain an alveolar partial pressure equivalent to that found when breathing air at sea level

To keep yourself safe in the air you need to, as far as possible, reduce your susceptibility to hypoxia. This may be done by taking cognisance of the following:

- **Altitude:** The greater the altitude the greater the hypoxia and the more rapid its progression. A faster rate of climb will result in quicker onset of symptoms.
- **Time:** The longer the time the greater the effect.
- **Exercise:** Exercise while flying increases the demand for oxygen and hence increases the degree of hypoxia. A regular exercise programme on the other hand will make the pilot slightly less susceptible to hypoxia.
- **Cold:** Cold makes it necessary to generate more energy, which in itself increases the demand for oxygen and hence increases the degree of hypoxia.
- **Illness:** Similarly, illness increases the energy demands of the body.
- **Fatigue:** Fatigue lowers the threshold for hypoxia symptoms.
- **Stress:** Stress will increase the body's demand for oxygen and any lack of oxygen will result in the onset of hypoxia symptoms.
- **Drugs/Alcohol:** Alcohol has very similar effects on the body as hypoxia and therefore reduces tolerance to altitude. Many other drugs have adverse effects on brain function and therefore further impair functions under hypoxic conditions.
- **Smoking:** Carbon monoxide, produced by smoking, binds to haemoglobin with a far greater affinity than oxygen and therefore has the effect of reducing the available haemoglobin for oxygen transport, exacerbating any degree of Hypoxia.
- **G Force Exposure:** High 'g' reduces circulation and cardiac efficiency. The human body evolved under the influence of 1 'g', so has limited tolerance to deviations from this standard.

9.2.5 Methods to Deal with Hypoxia

There is very little that will reduce a person's susceptibility to hypoxia. To reduce the onset of hypoxia, we must:

- Provide an adequate **supply of oxygen.**
- In the case of loss of pressurisation or the failure of the oxygen supply, the only remedy is to **descend immediately.**
- Some minor benefit is obtained by maintaining a healthy and efficient cardio-vascular system.

People in good physical condition, between 25 and 50 years and pilots who fly regularly in mild hypoxia conditions have a **slightly** higher tolerance to the effects of hypoxia. **However, the effects of hypoxia are inevitable.**

9.2.6 Pressurisation

Modern large jet powered aircraft rely on high altitude operation for good performance. The thinner air results in less drag. Depending on the aircraft type, aircraft pressurisation systems provide a cabin pressure of about 9 psi greater that the outside air pressure. Flying at 30,000’ will result in an internal environment equivalent to approximately 6,000’ and at 40,000’ aircraft altitude, cabin altitude would be around 7,000’

Should an aircraft lose this pressurisation, the internal cabin altitude will rapidly increase, subjecting the crew and passengers to the problems of hypoxia, as well as many other problems including barotrauma, shock, anxiety, DCS and possibly physical injury.

The cabin altitude may also reach an altitude greater than the aircraft altitude because of a phenomenon known as **venturi effect**.

Loss of this pressure, in seconds is termed a **rapid decompression**; in milliseconds is an **explosive decompression**.

9.2.6.1 Rapid decompression

Observations:

- Noise
- Sudden and extreme drop in temperature
- Rapid air movement (towards the opening in the fuselage)
- Flying debris (may cause physical injury)
- Cabin misting (as temperature drops and relative humidity rises)
- Cabin altitude higher than outside (Venturi Effect)
- Possible extreme fear and panic amongst the passengers
- Hypoxia
- Forced Exhalation
- Expansion within the body (leading to flatus) } **Pain**
- Decompression sickness.

9.2.6.2 Slow decompression

Passengers may not notice. Symptoms will be progressive drowsiness, yawning, euphoria, sleep, unconsciousness, coma and eventually death.

9.2.6.3 Actions

Crew and passengers must put on your oxygen masks immediately. Flight crew should commence an emergency descent following company standard operating procedures.