Science Spot

THE MEDICAL EFFECTS OF SPACEFLIGHT

Some readers will have heard my talk about NASA's Skylab space station, and my involvement in the project during the 1970s (crowaptok.com/mike/skylab.htm). Members of the Bosham WI will have the chance to hear the talk on September 5th, 2012. However, when talking to a general audience, I don't go into the details of the effects which the spaceflight environment has on the human body. This article aims to rectify that deficiency.

Most people know that there is no apparent gravity within an orbiting spacecraft, and the astronauts are thus exposed to 'zero-g' (more correctly called 'microgravity'). The absence of gravity affects three body systems—(1) the muscles and bones; (2) the heart and circulation, and (3) the balance organs and brain.

1) When we are 'on earth', gravity acts on every part of us, and our muscles have to produce sufficient force to move our body and limbs. Constantly using the muscles in this way keeps them strong. In zero-g, very little muscle effort is needed to move around, and the muscles shrink and become weaker, as in the well-known phrase 'use it or lose it'! In moving our limbs and bodies around, the forces from the muscles are transmitted through the bones. Just as the muscles respond to the amount they are used, so do the bones. If you stop applying substantial forces to the bones, they become lighter and less strong—a clinical condition known as osteoporosis, which is common in older people, especially women. The measurements we made on Skylab showed that without any countermeasures, nine months in zero-g would lead to 'clinical' osteoporosis. Astronauts typically try to protect their muscles and bones by doing resistive exercises, against strong elastic 'bungee-cords'. It is not known how effective these countermeasures are. The calcium and phosphorus lost from the bones is excreted in the urine, which increases the risk of developing renal calculi ('kidney stones'), although as far as we know, no astronauts have suffered this complication.

2) The effect of spaceflight on the heart and circulation is shown in the diagram. In earth's

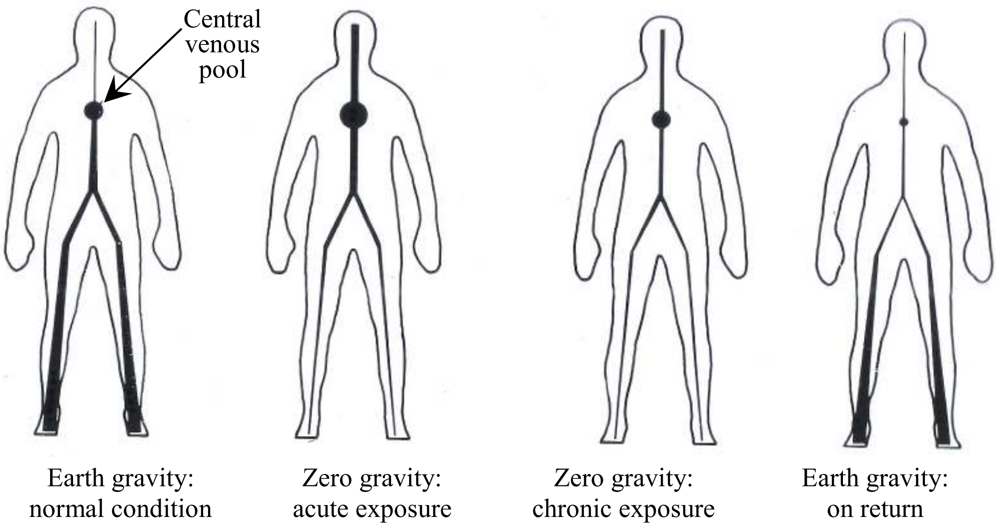

Diagram to show the amount of blood in the veins, in different parts of the body gravity, the weight of the blood in the veins pulls it down to the lowest part of the body. When standing up, there is a lot of blood in our legs, and very little in the head and neck. To minimise this effect, the veins of the legs are quite elastic; those higher up the body are not. When an astronaut is exposed to zero-g, the blood no longer weighs anything, and the elasticity of the veins in the legs pushes it up into the head, neck and chest. During the first day or two in orbit ('acute exposure' in the diagram), the astronauts complain that their heads feel 'full', and their noses are stuffed up. Photographs show that their faces are rounder and more 'florid' than normal, and the veins of the neck are very prominent. The veins in the chest (known as the 'central venous pool') also contain more blood than usual. The body closely monitors the size of this central venous pool, and tries to keep it at its 'normal' size. The increased volume in zero-g triggers a mechanism to reduce it, by increasing the excretion of water, through the kidneys. During the first 24 hours in orbit, the astronauts produce about 1½ litres (2½ pints) more urine than normal, most of which consists of water, taken from the bloodstream. This has three effects: a) their body weight reduces by 1½ kg (3 lb), the weight of the water removed; b) the blood becomes more 'concentrated', as the same number of red cells are then contained in a smaller volume of fluid, and c) the feeling of congestion in the head and neck becomes reduced, although not totally eliminated ('chronic exposure' in the diagram). The increased concentration of red cells in the blood then has a further effect: the body decides that there are too many red cells in circulation, and the production of them is shut down, until the concentration is 'back to normal'. This means that the total number of red cells in the circulation gradually reduces. This observation had been made in earlier spaceflights, but it had been wrongly ascribed to breathing an oxygen-rich atmosphere.

These adaptations to zero-g (reduced blood volume and reduced numbers of red cells) are perfectly appropriate so long as the astronauts remain in zero-g. However, when they return to earth, the blood is once again pulled down into the legs, and the size of the central venous pool becomes inappropriately small ('on return' in the diagram). This causes the astronauts to come close to fainting when standing up, and to be very thirsty. They drink a lot, the body weight increases by 1½ kg, and 1½ litres of water re-enters the blood stream, diluting the red cells to the point that the astronauts become temporarily anaemic!

3) The third effect of weightlessness, that on the balance organs and brain, I experienced myself, in a flight on the zero-g aircraft (known, for good reason, as the 'vomit comet')! As soon as gravity is removed, the balance organs of the inner ear decide that you are upside down. The fact that the floor and ceiling are in their usual positions convinces you that the whole room (actually an aircraft fuselage) is upside down. Added to the lack of input from force sensors in the joints and muscles, the brain experiences serious disorientation, which is at least partly responsible for the motion sickness experienced by almost everybody who goes into space. (In the 'vomit comet', the up and down motion of the aircraft contributes even more strongly to the motion sickness!) The sickness experienced by the astronauts disappeared in around 24 hours, after which they were extremely resistant to motion sickness (when taking part in a very sick-making experiment), although two of them were seasick on the recovery ship, after their return to earth! 'Space sickness' remains one of the unsolved problems of spaceflight.

Nor are these the only hazards to which the astronauts are exposed—they may also be exposed to high 'g' forces during takeoff and landing, and to radiation from particles streaming out from the sun. Mind you, I'd still go, if given the chance!