Medical problems of recreational diving*

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RECREATIONAL diving is a relatively new sport and owes its origin to the introduction of self-contained air breathing apparatus into professional diving.

Historically, commercial diving probably began about 2,000 years ago when skin divers, mostly women in the warm seas of the Pacific Islands, earned their livelihood by diving for sponges, sea food, shells and pearls. Indeed they are still doing it to-day using much the same techniques. This is straightforward breath-hold diving which is limited in time to a few minutes and in depth to about 100 feet.

In the latter part of the eighteenth century the standard form of diving developed using the familiar copper helmet, heavy suit and leaden boots, which required a large surface organization to supply air and control from above. This was a cumbersome, limited and expensive method which had little to offer as a recreational activity. During the war however, frogmen breathing closed-circuit oxygen showed that man could become flexible and active under water. The closed-circuit oxygen apparatus was, because of the toxicity of this gas, limited to use in depths not exceeding 30 feet and had certain dangers.

Shortly after the war the self-contained, underwater, air-breathing apparatus rapidly developed. By this means a diver could go underwater taking his air supply with him and breathing through a face mask which, by virtue of a specially balanced valve, supplies air at the same pressure as that of the surrounding water. This brought diving within the reach of everyone who was keen to go underwater for business or pleasure. By wearing fins a fair degree of mobility and speed is achieved with a degree of independence from surface control which is certainly a considerable advantage. This freedom does however place on the shoulders of the diver complete responsibility for his own welfare.

Even without this type of apparatus it is still possible to enjoy short dives in shallow water with the aid of the snorkel tube. This makes it possible to remain on the surface without effort and where required to carry out worthwhile underwater sorties of several minutes. From this stemmed the current exciting sport of spear-fishing, where, armed with a spring loaded gun, fish can be chased and caught effectively in their natural environment. Competitive spear-fishing is a popular pastime although it is not without considerable danger if certain basic principles are not observed which will be described later.

Underwater swimming and diving as a sport should never become directly competitive, as far as speed and endurance is concerned, because the environment is such that to do so introduces unacceptable risks.

The underwater environment

Unlike fishes, man must always be dependent upon a supply of air for breathing either from the surface or from cylinders taken underwater with him. He has no facilities for obtaining dissolved oxygen from sea water. If this air supply is cut off survival is limited to a matter of minutes. Furthermore, as the diver goes underwater he is subject

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to increasing pressure which must affect the air in his lungs whatever type of apparatus he is using.

The pressure of the air on the surface of the sea is about 760 mm Hg (14.7 lbs per sq inch). The changes in this atmospheric pressure due to climatic variations are insignificant as far as diving practice is concerned and it is convenient to regard this pressure as a unit of 'one atmosphere'. This unit is also equal to the pressure of a 33-foot column of sea water so that when a diver reaches this depth he will be subject to a total pressure of 2 atmospheres (2 ats). For every further 33 feet he descends his environmental pressure will be increased by one atmosphere.

As far as the tissues of the body are concerned the effect of this pressure can be ignored but where air is contained, as in the respiratory system, its volume will vary directly with any pressure changes. If the pressure is doubled the volume is halved. Thus if the breath-hold diver (e.g. the pearl diver or snorkel diver), were to enter the water after a full inspiration, i.e. with lungs full of air—about six litres in the average man, he would, by the time he reached a depth of 33 feet, have his lung volume halved i.e. to three litres. At a depth of 99 feet this would become 1.5 litres, which is equal to the volume contained in the lungs at the end of a full expiration. In other words the chest of this diver entering the water in a state of full inspiration will by the time he reaches 100 feet or so be in a state of full expiration without having breathed out any air at all. This depth is the limit to which such a diver can descend without damage to lung tissue.

When a breathing apparatus is used the pressure at which the air is delivered increases in proportion with depth so that at 33 feet it will be delivered at two atmospheres and at 99 feet, four atmospheres, etc. This ensures that the lungs are kept full and normal breathing can be maintained without difficulty or distress at any depth within the range of the apparatus. It will thus be seen that with regard to diving the effects of changes in pressure and volume must be considered.

Furthermore, as air is compressed so will its density be proportionately increased. If the pressure is doubled so is the density. The more dense the air we breathe the more work will be required to move it in and out of the lungs. Thus a second consideration in underwater physiology is increase in density of the breathing mixture.

In normal breathing on the surface, although man is dependent for the oxygenation of his tissues on the chemical union of oxygen with the red blood cells, there is nevertheless a proportion of oxygen which dissolves directly in the fluid of the blood. This is also true of the nitrogen content of the air which is breathed. In other words there is an equilibrium between the pressure of air which is breathed and the amount of its component gases in solution in the blood. A similar equilibrium must exist between gases dissolved in the blood and the tissues which the blood supplies. As pressure increases so will the amounts of oxygen and nitrogen dissolved in the blood and tissues increase. As both these gases may be harmful their toxicity must also be taken into consideration.

Finally when the diver returns from depth to the surface the pressure is reduced and a situation arises where the blood and tissues contain excess amounts of nitrogen and oxygen in solution. In order to restore the pre-dive equilibrium these gases must come out of solution and escape through the lungs. If the release of pressure is rapid (and it must be remembered that it is felt not just in the pulmonary lining but throughout the body) the gases may possibly come out of solution in the blood stream or tissues as bubbles which themselves can be damaging to the individual. It is thus of great importance to consider also risks of surfacing or decompression.

The physiological problems of diving may thus be considered under the following headings:

1. Changes in pressure and volume
2. Increase in density
3. Excess oxygen in solution
4. Excess nitrogen in solution
5. The effects of decompression.

In addition to these physiological hazards are the physical hazards of failure in the breathing apparatus and dangers from underwater obstructions, the environment itself.

In this particular field the psychological adaptation which is necessary if diving is to become an acceptable recreation is of great importance. Man is essentially a land animal used to a two-dimensional existence. In the water he becomes virtually weightless, vision is reduced and distorted, hearing abnormal and postural sense limited. Perhaps one of the reasons why diving has been a late starter as an adventurous pursuit is due to the strength of this psychological barrier in which man is reluctant to return to the dark unknown depths where life itself began.

A further risk is that of drowning which is by and large the end result of any underwater accident. On land when a man is injured and loses consciousness he is not engulfed by his environment but is able to continue breathing until help arrives. In water unless rescue is immediate drowning is inevitable.

Causes of underwater accidents

Changes of pressure and volume

Where breathing apparatus is used—unless this fails—pressure and volume changes are self-adjusting. It is the snorkel diver, the spear fisherman, who is particularly vulnerable. The time he can spend underwater is limited by his breath-holding ability and he must resist the temptation to increase this by hyper-ventilation before the dive. This by lowering the carbon dioxide content of the lungs delays the breaking point of breath-holding. It may even double the time the breath may be held. While breath is being held the oxygen content of the lungs is decreasing particularly if there is also continuous muscle effort, as in chasing fish or competing in underwater swimming. The urge to hold the breath may be further increased by emotional stimulus if during the chase the quarry is in sight or in an attempt to break an underwater swimming record. The oxygen content of the alveoli may in such cases reach a dangerously low level. When the breath-holding limit is reached and surfacing becomes essential, this final act may itself further reduce the intra-pulmonary oxygen pressure to such a degree that consciousness is lost. If this is so, drowning is likely. Over the years a large number of spear fishermen have died from this cause. Thus the practice of pre-dive hyper-ventilation cannot be too highly condemned. Diving practice should not take place where there are no facilities for immediate rescue should loss of consciousness occur.

A further danger under this heading may affect the diver who is using a breathing apparatus. If, for example, this develops a fault which necessitates immediate surfacing without the apparatus the air which remains in his chest will, as he surfaces and pressure is reduced, expand. If he is well-trained, relaxed, and allows the expanding air to escape freely in a prolonged expiration he will come to no harm. If, on the other hand as indeed happens all too often, he becomes frightened and tries to hold his breath the expanding air cannot escape. It will in this situation stretch lung tissue and ultimately tear it, so that when he finally reaches the surface and breathes out some air will escape back through the torn lung tissues into either the mediastinal tissues, the pleural cavity or indeed into the pulmonary circulation itself. This last occurrence which introduces air bubbles into the circulation may produce the rapidly fatal condition of air embolism blocking the cerebral or coronary circulations. The only possible life-saving treatment

for this mishap is immediate recompression and subsequent staged decompression at a slow rate. It is for this reason that the practice of 'free ascent' as a training measure should never be carried out unless there is immediately to hand a therapeutic pressure chamber.

The dangers of increased density

The additional effort required to breathe air at increased density in diving does little harm but inexperienced divers unaware of this problem may be disturbed by the apparent respiratory distress. At 100 feet the breathing effort is doubled and it is easy for the inexperienced to become alarmed by this experience and even panic. Increased density does in fact lead to some carbon dioxide retention which may summate with other pre-disposing factors and result in an underwater accident. Divers must learn to accept this additional respiratory load and be discouraged from extreme exertion under water. It is for this reason that competitive underwater activities should at all times be discouraged.

Effects of excess oxygen

Even at atmospheric pressure continuous breathing of oxygen for two days or more produces a chronic irritation of the lungs with dry cough and some respiratory distress. If, however, it is breathed at two atmospheres of pressure it may need as little as 15 minutes to produce the symptoms of acute oxygen poisoning where, following twinges of various muscle groups particularly the lips, a generalized convulsion develops. This occurring in the water could lead to drowning. Thus the use of pure oxygen for diving purposes is not acceptable. Even air, which contains only 21 per cent oxygen, when used at depth gives increased oxygen partial pressure until at 124 feet the effect is the same as breathing oxygen at the surface. At a depth of 300 feet there may be risk of acute oxygen poisoning. Oxygen poisoning is thus one of the limiting factors in using air for deep diving.

Excess nitrogen

Nitrogen has a narcotic effect if it is breathed at increased pressures. This is a progressive condition first giving the sensation of light-headedness, disorientation and mental instability progressing to a complete loss of consciousness. In diving these effects are liable to occur from depths of 180 feet onwards. Experienced divers who do achieve some adaptation to this condition cannot proceed beyond 300 feet without gross effect.

Effects of decompression

Decompression sickness is the divers ever present menace and is due to a too rapid surfacing from a working depth or too rapid decompression in a chamber. It is caused by a bubble formation in the tissues causing local pressure or embolisms in peripheral arterioles particularly the end-arteries.

The clinical picture varies, according to the severity of the decompression effect, from mild skin irritations, itches and rashes through joint pains (the most common presentation or 'bends') to gross involvement of the central nervous system with severe paralysis and even death. Decompression sickness can invariably be prevented by a close adherence to the well established decompression tables which are recommended for use. When decompression sickness has occurred treatment necessitates recompression followed by a prolonged period of steady decompression with, in severe cases, oxygen breathing in the later stages. These routines of treatment are well established and instructions are to be found in the diving manuals of the various underwater organizations.

Accidents in general

Although the conditions described are fundamental problems of diving medicine

and in general responsible for the majority of accidents, it is found in practice that most mishaps result from a summation of various adverse situations and are in 75 per cent of cases due entirely to lack of experience, inadequate training or gross neglect on the part of the individual diver. These incidents include drowning through flooding of the face mask and panic, parting of improperly secured life lines and diving without facilities for rescue or proper control. Accidents are rare in the professional organization where training is of the highest order and safety precautions strictly applied.

One factor which must not be overlooked is the question of illness in the water. Any illness causing sudden loss of consciousness could lead to drowning. There are many examples of divers who have drowned as a result of epilepsy, coronary thrombosis and acute virus pneumonia developing while they have been in the water.

Medical examination for diving

It would be wrong to consider diving as a sport only available for supermen. Except in the specialized research projects most recreational diving is a relatively gentle pastime, demanding no greater degree of physical fitness than any other worthwhile activity. Thus anybody who is reasonably fit should be able to dive.

The only additional requirements are that particular attention should be paid to the ears and respiratory system. It is absolutely essential for anybody going underwater to be able to equalize the pressure of the middle ear with that of the outside water by clearing the eustachian tube. This is a knack which in the absence of any chronic catarrh can be easily mastered with practice.

As far as the respiratory system is concerned any disease of the lung, tumours, cysts, infections etc., which could cause trapping of air in the alveoli during decompression could be a prelude to serious pulmonary barotrauma or burst lung. Would-be divers therefore should have periodic medical examinations and an annual chest x-ray is recommended.

Perhaps the most important medical advice that can be given to the recreational diver is that never under any circumstances should diving be carried out if there is any evidence of an upper respiratory tract infection. The changes in pulmonary ventilation and blood flow which follow with the variations in underwater posture and pressure are such that any infection would spread extremely rapidly. There have been many cases where a common cold has become a widespread pulmonary infection in a very short time simply as a result of going underwater.

In conclusion it should be emphasized that diving has a great deal to offer as an active sport equally available to men and women and with no upper age limit. Would-be divers are strongly advised before attempting any underwater activity to join one or other of the established underwater clubs and take heed of the important and proven regulations which experience has shown to be essential for safe and satisfying diving.