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FITNESS TO DIVE*

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ABSTRACT

Diving is a recreational sport, which is increasing in popularity world-wide. The risks of diving are significant and medical supervision is required to identify divers with certain medical conditions liable to affect their performance underwater. The UK recently changed the system of medical supervision to a self-administered questionnaire, with support from a national network of doctors with diving medicine experience.

Certain conditions substantially increase the risk of diving, such as epilepsy or recurrent pneumothorax. Divers with conditions such as diabetes and asthma may still be certified fit to dive by if they meet specific criteria. Although most diving incidents are related to technical failure or human error, it is still important to minimise the risk of medical complications in the sequence of events. Divers with patent foramen ovale are at more risk of neurological and cutaneous decompression sickness, although the development of percutaneous closure techniques has allowed such individuals to return to diving.

Key words: diving, decompression sickness, patent foramen ovale, scuba

Introduction

Diving is an increasingly popular recreational sport with an estimated 100,000 active United Kingdom sport divers, and around 8.5 million certified divers in the United States (10). Although diving involves profound physiological changes, divers are not renowned for their physical fitness and medical screening is required to exclude divers with conditions liable to cause injury. Recent surveys suggest that divers are gradually becoming less fit and the prevalence of obesity and smoking is increasing (7). This is disturbing and potentially hazardous given the physical adaptations required during even very shallow dives. So if divers are not elite athletes, what level of fitness is expected? There are very different stresses involved in diving from a boat in the warm waters of the Caribbean, compared with ice diving in the Antarctic. Diving around the coastline of the United Kingdom can be physically and psychologically demanding involving cold water, poor visibility and strong currents. It may be difficult to appreciate the attraction of diving as a sport in these conditions, but it is still possible to experience the magic of weightlessness underwater, and to observe the beauty of another world rarely appreciated from the surface. There are also challenges involved in wreck diving, technical diving (involving exotic gas mixtures to prolong time underwater without resulting in decompression illness), and drift diving where currents are suitable.

Physics of diving

The physiology of diving can be conveniently summarised by the effects of pres-

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sure on the volume of gases (Boyle's law) and the effect of pressure on the solubility of a gas (Henry's law). Boyle's law describes the inverse relationship between pressure and volume - as pressure increases, volume decreases such that a balloon will be compressed to half its original volume when the surrounding pressure is doubled. This effect extends to all gas filled cavities in the body including the lungs, gut and air-filled sinuses in the skull. Henry's law describes the effect of pressure on driving a gas into solution - as the pressure is doubled, twice as much gas will be forced into solution. The converse is also true - when the pressure is halved, gas will come out of solution, potentially forming bubbles.

Dive fitness

In the UK, assessment of fitness to dive is now based on a self-administered questionnaire (see table 1) designed following a survey of almost 3000 divers in the Scottish Sub-Aqua Club (Scot-SAC) (7). The previous system involved routine medical examination by general practitioners without specialist diving medicine experience. The current system aims to detect conditions affecting dive fitness, and such divers may then be assessed by approved diving medical referees supported by the national advisory committee, the UK Sport Diving Medical Committee (UKSDMC). The most up to date medical guidelines can be found on the UKSDMC website (www.uksdmc.co.uk).

Early unpublished analysis of the Scot-SAC safety statistics following the introduction of the new system in April 2000 suggests that the failure rate for new divers has increased and the incident rate has not changed significantly. The actual physical standard of fitness required for diving

Table 1. *The UKSDMC self-administered questionnaire*

1. Have you suffered at any time from diseases of the heart and circulation including high blood pressure, angina, chest pains and palpitations?
2. Have you at any time had chest or heart surgery?
3. Have you suffered from or had to take medication for asthma?
4. Have you ever had collapsed lung or pneumothorax?
5. Have you ever had any other chest or lung disease?
6. Have you suffered at any time from blackouts, fainting or recurrent dizziness?
7. Have you had regular ear problems in the past ten years?
8. Do you have an ileostomy, colostomy or ever had repair of a hiatus hernia?
9. Have you ever had epilepsy or fits?
10. Have you had recurrent migraines?
11. Have you ever had any other disease of the brain or nervous system (including strokes or multiple sclerosis)?
12. Have you ever had any back or spinal surgery?
13. Have you any history of mental or psychological illness of any kind, fear of small spaces, crowds or panic attacks?
14. Have you any history of alcohol or drug abuse in the past five years?
15. Do you have diabetes?
16. Are you currently taking any prescribed medication (except the contraceptive pill)?
17. Are you currently receiving medical care or have you consulted the doctor in the last year other than for trivial infection or minor injury?
18. Have you ever been refused a diving medical certificate or life insurance or been offered special terms?
19. Have you ever had, or been treated for, decompression illness?

is not formally regulated except in a few specific circumstances. This includes divers recovering from cardiac revascularisation or myocardial infarction who are required to complete at least 9 minutes or equivalent of the Bruce protocol exercise test. All new entrants to diving undertake a basic swimming test and rescue simulations implying at least a reasonable level of physical fitness. There is no current requirement to subsequently test this level of fitness throughout a diving career. Subjects with disabilities such as limb amputation are allowed to dive although this is usually with a higher level of supervision from diving instructors if the disabled diver cannot act as a rescuer in an emergency situation.

Children and diving

Children as young as 14 years are able to dive with some of the major diving organisations although Scot-SAC will not permit SCUBA training until the age of 15 years. It is worth noting that other organisations worldwide specifically target very much younger children, age 8-9 years, for specially designed introductory programmes. There are concerns in allowing children to dive including the nature of informed consent and a degree of parental supervision may be required. The other concerns though are medical and are based on physiological observations. Adult divers are found to have venous gas bubbles in their circulation after even very shallow dives and these can be detected by Doppler ultrasound (11). In children these bubbles theoretically may cause damage to the bone growth plates, spinal cord, brain and lungs. Such damage has not been demonstrated in children but conclusive research is unlikely to be possible because of the ethical considerations involved. Post-mortem studies suggest that silent spinal cord damage is common in adult divers (1) and this would be of concern in children who have not yet reached physical maturity. The other issue is that the decompression tables were designed for adults, often as the result of military research, and do not take into account the very different body composition, metabolic pattern and thermal properties of children.

High-risk conditions

Many of the cases of decompression illness observed in the UK are due to inadequate decompression or rapid ascents as the result of diving malpractice rather than pre-existing medical conditions. There are various other factors that can influence a subject's fitness to dive, and subsequent susceptibility to decompression illness. Some are preventable, but others are less obvious and may not be detected until after an event. The Scottish Sub-Aqua Club is unique in the UK because all of the medical forms are stored centrally and have been analysed annually since 1992 to monitor the medical system and to look for changes in the incident pattern. Around 30% of the medical referrals in Scotland are for the assessment of divers with asthma, although this often reflects a childhood history rather than active symptoms. Asthmatics are at risk of pulmonary barotrauma during the ascent because of air trapping in the lungs. As the diver ascends the surrounding pressure decreases and trapped air expands to cause damage and eventually rupture of the alveolar space. Gas bubbles may then leak into the arterial circulation leading to cerebral arterial gas embolism with a high risk of death or permanent injury.

Divers with asthma are required to have exercise testing performed if there is any suggestion of exercise induced symptoms and they are also required to monitor their peak flow rate (PFR) during the diving season. If there is a drop in PFR of more than

10% of their best result then diving is contraindicated. This approach appears safe based on analysis of the diving incident reports although conclusive prognostic studies have not been performed (2, 5).

Some doctors might be surprised to learn of the conditions that are no longer regarded as a contraindication to diving. For example, divers with insulin dependent diabetes can now be officially approved. This is a relatively recent development following an initial randomised, controlled pilot study (4) and a continuing long-term audit of divers with controlled insulin-dependent diabetes. Motivated diabetics can dive safely with appropriate precautions and their involvement in educating dive club branches is an important part of the process. This has highlighted the ability of diabetics to take part in other sports at very high levels.

There are conditions that are absolute contraindications to diving such as epilepsy or recurrent pneumothorax. The risks involved are excessive for a recreational sport and while divers may state that they are willing to accept individual responsibility for their condition, the nature of diving requires individuals to take responsibility for their diving partner too. This is known as the buddy system.

There are other situations where the impact on diving fitness may be less obvious. One example is hereditary haemorrhagic telangiectasia (HHT) and this can be used to illustrate some of the important issues in assessing fitness to dive. HHT is a relatively rare condition although this may be because of underdiagnosis (8). The most common presentation is with epistaxis, and this in itself is a problem for divers. The bleeding may be enough to obscure vision by filling up the diving mask, and can lead to hypotension due to blood loss, or spurious haemoptysis, which can be confused with pulmonary barotrauma when surfacing. The telangiectasia in HHT may be present in various organs including the spinal cord and brain, and bleeding in either of these sites would cause neurological signs that could be confused with neurological decompression illness. Prolonged recompression therapy may then be initiated and this would cause unnecessary delay in receiving standard medical treatment. HHT is also associated with pulmonary arteriovenous fistulae and these could allow paradoxical embolism of venous gas bubbles into the arterial circulation. Such bubbles may deposit in tissues such as the brain, spinal cord and skin and increase the risk of serious neurological decompression illness. For all of these reasons, subjects with HHT are not permitted to dive.

Paradoxical embolism of gas bubbles may be the mechanism of decompression illness in a significant proportion of divers who develop problems within the recommended limits. An underlying patent foramen ovale (PFO) is found in approximately 60% of divers with neurological DCI or skin bends who present with symptoms developing after a short latent period following surfacing (typically around 5-10 minutes) (14). A link between PFO's and migraine with aura has also been demonstrated (3, 13), and there is limited evidence to suggest an excess incidence of migraine in divers with neurological decompression illness. There is no indication at present for screening divers for PFO at the start of their diving career because other factors appear to influence individual susceptibility to decompression illness. In addition around 20-25% of the population have PFO's at autopsy (9) and barring one quarter of the population from diving is unreasonable.

PFO's can be detected by transthoracic echocardiography with second harmonic imaging (a method for improving the image quality) following the injection of agi-

tated saline containing small air bubbles. These bubbles are too large to pass through the pulmonary circulation and therefore detection of bubbles within the left heart is diagnostic of a right to left shunt. Late detection of bubbles in the left heart may reflect passage of contrast through a pulmonary arteriovenous fistula as found in HHT (above). It is possible to close PFO's percutaneously and the limited follow-up information suggests that this reduces the risk of subsequent decompression illness (12, 15).

Extreme breath-hold diving

Extreme breath-hold diving is the one form of diving that can be regarded as an elite sport as it requires exceptional levels of fitness. The risks of breath-hold diving as a sport are excessive however and no responsible authority would endorse its conduct. Historically some communities relied on their breath-hold divers for financial prosperity, and there are historical accounts of individuals regularly diving to depths as great as 70 metres. To put this in perspective, recreational diving with SCUBA equipment rarely exceeds 50 metres. The current sport record is 150 metres, and physiological research has demonstrated profound haemodynamic changes during such dives including profound bradycardia (around 20 beats per minute), hypertension (for example 290/150 mmHg), hypoxia, hypercapnia and lactate accumulation (6). The extreme breath-hold divers strive to avoid unnecessary energy expenditure and use a weighted pulley to drag them to the target depth before using buoyancy aids to help them regain the surface. Syncope is common and the risk of serious mishap is considerable.

Conclusion

Recreational SCUBA diving does not require exceptional levels of physical fitness but carefully directed medical supervision is required to exclude specific conditions that increase the risks of diving. Such risks can be predicted theoretically using the gas laws but evidence based studies are lacking and are unlikely to be performed because of ethical considerations. The medical system for the evaluation of divers in the UK changed recently to a self-administered questionnaire designed to select divers requiring assessment by approved diving doctors. The full effects of this change have still to be appreciated.

Note

Stephen Glen is the Scotish Sub-Aqua Club medical advisor and secretary of the UK Sport Diving Committee. The personal views expressed here do not necessarily reflect Scottish Sub-Aqua Club policy or UKSDMC consensus.

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