



THE MEDICAL EXAMINATION OF DIVERS

A Guide for Physicians



Occupational Safety and Health Branch
Labour Department



OCCUPATIONAL SAFETY & HEALTH COUNCIL

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A GUIDE FOR PHYSICIANS

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Introduction

An approved code of practice for industrial diving has been issued by the Labour Department to give guidance on the general duties provisions (sections 6A & 6B) of the Factories and Industrial Undertakings Ordinance as applied to industrial diving. Under the code of practice a diver must be medically examined and should be in possession of a valid Certificate of Medical Fitness to Dive issued by a medical practitioner, preferably with special experience in underwater or occupational medicine, not more than 12 months before the date of the diving operation. A new certificate must be obtained if the diver has been sick for a continuous period of 14 days or more.

The medical examination of divers requires detailed background knowledge in order to be able to make a reasoned judgement of the fitness of an individual to dive. Such knowledge is comprised of not only a sound understanding of diving physiology but also an appreciation of the different aspects of recreational and professional diving. The relevant information is beyond the scope of this pamphlet and can realistically only be obtained from an academic course on underwater medicine or failing that a definitive text on diving medicine (examples can be found in the section on Recommended Reading). This booklet only aims to assist a physician with such knowledge in conducting a suitable examination and making a justifiable decision regarding fitness to dive. The standards discussed generally relate to both professional divers and recreational divers; where a relaxation of the standard for recreational divers is considered appropriate, this will be stated.

The underwater environment is a hostile one for the human organism. Two aspects of fitness to dive must be taken into account:

1. The diver must not suffer from any medical condition which would increase the probability of his safety, or that of other members of the diving team, in the water being compromised.
2. The diver must not suffer from any medical condition which may be aggravated by the act of diving, leading to increased probability of long term health problems.

It is not possible to provide a comprehensive list of medical conditions which may affect fitness to dive; the number of diseases is too great and the degree of severity of any particular condition and the type of diving undertaken by the individual must be considered before a decision is made. The interaction of the pathology of the disease with the alteration of normal physiology in the underwater environment must be taken into account.

Specialist advice on matters concerning diving medicine can be obtained from:

*Occupational Medicine Division,
15th Floor, Harbour Building
38, Pier Road, Central, Hong Kong
Tel: 2852 4041, Fax: 2581 2049*

Physics and Basic Physiology of Diving

Pressure

Pressure is the amount of force applied per unit area and can be measured in a variety of units. The units commonly used in diving are metres of sea water (msw), kilopascals (kPa) and atmospheres absolute (ATA) which is pressure relative to a vacuum. One atmosphere is the amount of pressure exerted on organisms and structures by the weight of the earth's atmosphere and at sea level is equal to about 10 msw and approximately 100 kPa. Pressure therefore increases by 1 ATA for every additional 10 msw depth.

Boyle's Law

Boyle's Law states that for a given mass of gas at constant temperature, the volume is inversely proportional to the absolute pressure. This means that gas volumes contract when the pressure increases (i.e. as the diver descends) and expand as pressure decreases (i.e. as the diver ascends). As the respiratory minute volume is similar at depth and at the surface for the same work rate, it can be seen that the deeper a diver goes, the greater the mass of gas which must be shifted with each breath.

Dalton's Law

Dalton's Law states that the total pressure exerted by a mixture of gases is the sum of the partial pressures that would be exerted by each of the gases if it alone occupied the total volume. As atmospheric air consists of about 80% N₂ and 20% O₂, the partial pressures at the surface are 0.8 ATA N₂ and 0.2 ATA O₂. At pressures greater than about 2.5 ATA N₂, there is demonstrable reduction in diver performance due to nitrogen narcosis and this effect makes diving on air unsafe below 50 msw.

Henry's Law

Henry's Law states that at constant temperature, the amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas over the liquid. This applies to a state of equilibrium in which equal amounts of gas are passing into and out of the solution in contact with it. Therefore, if at sea level a diver's tissues contained x litres of dissolved gas, at 90 msw he would have $10x$ litres of the same gas.

Bubble Formation

If the total pressure of the gas mixture or the partial pressure of a particular gas in the mixture is reduced, then the solubility of that gas will fall in accordance with Henry's Law. If this process is rapid, the tissue may contain more gas than it can hold in solution and bubble formation may occur. In order to prevent this, divers are required to make one or more decompression stops at depth in order to allow time for inert gas to be excreted.

Types of Diving Commonly Practised in Hong Kong

SCUBA Diving

Self Contained Underwater Breathing Apparatus consists of cylinders of gas (usually compressed air) which are worn on the back of a free swimming diver. Gas is supplied to the diver via a reducer and a mouthpiece with a demand valve. This type of diving is practised by recreational divers and by certain professional divers. It has the advantage of mobility but the disadvantages of limited endurance and lack of hardwire communications to the surface.

Surface Orientated Diving

This form of diving has much greater endurance than SCUBA as the breathing gas is supplied to the diver via an umbilical that can also supply hardwire communications. The gas (most commonly air) is usually from a surface compressor and may be supplied free flow or via a demand regulator.

Saturation Diving

Saturation diving is a highly specialised form of diving using mixed gases which is usually carried out in deep water. It is not practised in Hong Kong as the local waters are not deep enough to justify the technique. Examination of these divers is very specialised and should not be undertaken without specific training in diving medicine. The medical standards for saturation divers will not be considered in this booklet.

Requirements for the Medical Examination

Equipment

Apart from the basic clinical equipment such as a stethoscope, neurological kit, otoscope and ophthalmoscope and urine testing sticks, a diving medical examination requires the use of the following:

- A spirometer
- Equipment for exercise testing
- An electrocardiograph

There must also be access to:

- Haematological testing
- Radiography

Frequency of Medical Examinations

All persons wishing to dive should have a medical examination before they commence diving training. This is particularly true of those who wish to become professional divers as the training of professional divers is both arduous and expensive. The initial medical examination of the professional diver should be rigorous and a high standard of medical fitness is required in order to facilitate long term employment and prevent the development of health problems.

All divers should have a medical examination at least annually. Elderly divers may require more frequent examinations at the discretion of the doctor.

Additional examinations are required for those returning to diving after injury or illness, particularly if this is diving related.

The diver must meet the medical standards at the time of the examination in order to be considered fit to dive. Successful treatment for short term problems should not be anticipated and fitness to dive status granted, or fitness status conditional to successful treatment granted. In such circumstances it is appropriate to make the diver temporarily unfit and review them after a suitable period of treatment.

Restrictions on type of diving, depth, time, environment or duration of certification of fitness to dive may be imposed at the examining doctor's discretion.

General Considerations

Any form of diving is a potentially hazardous activity and a high standard of medical fitness is required for all divers, whether recreational or professional. The professional diver is, however, expected to perform work underwater as well as dive and the minimum standards of physical and mental fitness expected of this group are consequently greater than those of recreational divers. Higher standards should be applied to instructors of trainee divers than to ordinary recreational divers as instructors have responsibility for the safety of their students and may need to conduct a rescue in an emergency situation.

Age

Provided divers are able to satisfy the medical standards, there is no upper age limit for either professional or recreational diving. The older diver will by necessity have to maintain greater than average fitness for his age group. Suggested minimum ages are 15 for recreational diving and 18 for professional diving as a degree of physical and emotional maturity is required for diving to be conducted safely.

Gender

In general, the same fitness criteria should be applied to both sexes. The effects of pressure on the human foetus are not known and because of this diving should not be undertaken in known or suspected pregnancy.

Morphology

The size of a diver should not compromise mobility and agility. Those with a Body Mass Index (weight [kg] / height [m]²) greater than 30 should have assessment of body fat content. A body fat content of more than 30% should lead to temporary unfitness until sufficient fat has been lost.

Previous Medical History

A thorough account of the previous medical history must be elicited. Specialist reports may be required in some cases before the medical examination can proceed.

Medications

Medical fitness to dive under medication is dependant on:

- The type of diving
- The underlying pathology which requires the use of medication
- The interaction of medication and diving physiology
- The effects of medication on response to emergencies requiring sustained physical effort
- The effect of abrupt cessation of medication

Smoking

Divers should be discouraged from smoking.

Alcohol, Drug or Substance Abuse

Current abuse is incompatible with diving. A history of abuse gives rise to doubts about fitness to dive, particularly in the case of professionals. A lengthy period of stability without medication should be regarded as a minimum requirement.

Psychiatric Illness

Professional divers should be free from significant mental illness, past or present. Significant illness would include that leading to functional occupational impairment, or requiring hospitalisation or protracted medication.

Recreational divers with a history of acquired psychosis (anxiety or depression) may be allowed to dive after a suitable period of normality without therapy. Psychiatric opinion should be sought in all cases.

Personality disorders, schizophrenia and bipolar affective disorder are incompatible with any form of diving.

Malignancy

Any malignant condition should be assessed on an individual basis. Specialist reports will be required and medical examination may have to be conducted with greater frequency.

HIV Infection

A positive HIV test does not disqualify an individual from diving but a re-assessment of fitness must be carried out if secondary problems arise. It is unlikely that any person who develops AIDS would be fit enough to dive.

Communicable Diseases or Other Infections

Divers suffering from infections should be considered temporarily unfit to dive and should be reviewed after resolution of the problem.

The Systemic Medical Examination

Dermatology

The integument should be functionally intact and without increased susceptibility to infection.

Prolonged immersion in water may exacerbate pre-existing dermatoses and these may cause unfitness in professional divers. Acute or chronic infections and unhealed wounds are a cause for temporary unfitness until resolved.

Otorhinolaryngology

Hearing should be of a level which permits normal conversation to be understood. The vestibular function of the ear must be normal. The diver must be able to equalise pressure in both ears. There must be no increased susceptibility to infection of the ears.

Surgical procedures are sometimes effective in diver candidates with poor Eustachian function.

Clinical examination of the ear with an otoscope should confirm that both tympanic membranes are intact and visual confirmation of Eustachian function should be obtained. In some cases, this may require the removal of wax. The canal should likewise be free of occlusive exostoses or signs of infection.

The nasal airway should be free from signs of obstruction. There should be no evidence of sinus disease.

For professional divers it is strongly recommended that audiometry in the range 0.5 kHz to 8 kHz should be conducted at the initial examination. The examination should be repeated after significant aural barotrauma and in accordance with a hearing conservation programme.

Respiratory System

The chest should be anatomically normal. Clinical examination of the respiratory system should be normal. The gas exchange capability and structural integrity of the lungs should not be compromised. There should be no reduction of exercise capacity.

A history of spontaneous pneumothorax or penetrating chest injury resulting in pleural adhesions or pulmonary scarring is incompatible with diving.

Persons who have had a traumatic pneumothorax or thoracic surgery should be carefully evaluated and specialist opinion sought about the likelihood of pulmonary barotrauma in a diving situation.

There should be no evidence of obstructive or restrictive airways disease. Spirometry must be conducted at all examinations. Divers whose FVC or FEV₁ are below 80% of established predicted values for a person of the same race, sex, age and height or whose FEV₁ / FVC is less than 70% (75% at initial examination for professional divers) should be referred for specialist opinion as should those whose values have changed significantly since the last examination.

Full plate PA chest radiographs in inspiration and expiration should be obtained at the initial examination and subjected to specialist reporting. Repeat radiography need only be undertaken at the examining doctor's discretion.

Asthma

Diving with asthma needs to be very carefully evaluated and in professionals is normally considered a contraindication to diving.

The regular use of bronchodilator drugs, or a history of asthmatic attacks provoked by cold, exercise, hypertonic saline or a wide range of stimuli are contraindications to diving.

Infrequent and mild attacks only in response to specific stimuli unlikely to be encountered in the diving environment are not necessarily a contraindication. In all cases specialist opinion including the results of bronchial testing for cold, exercise and hypertonic saline should be obtained.

Dental

Due to the requirement for SCUBA divers to grip the mouthpiece and the possibility of dental barotrauma due to caries or poor fillings, all divers should be subject to examination, preferably conducted by a dentist.

Divers should be encouraged to have regular dental check-ups.

Cardiovascular System

The medical examiner must be satisfied that the cardiovascular system of the diver can meet the following requirements.

- Capacity to sustain strenuous muscular activity at depth
- No increased risk of loss of consciousness
- Peripheral circulation capable of maintaining adequate perfusion even in cold conditions

Blood pressure should be recorded at each medical and a maximum diastolic pressure of 90 mm Hg (80 mm Hg for professional divers at initial examination) is recommended. No upper limit for systolic pressure is recommended as it tends to rise with age. Antihypertensive drugs can cause variations in the response to and capability for physical exercise and the only use permitted is that of low dose diuretics in recreational divers.

An ECG should be performed initially for all divers and annually for professional divers and at the doctor's discretion for recreational divers. Abnormal tracings should be discussed with a cardiologist.

Murmurs at initial examination, or not previously noted at auscultation or worsening should be the subject of specialist opinion. Any form of organic heart disease is incompatible unless considered by a cardiologist to be haemodynamically unimportant. Patent Foramen Ovale should only be sought in the cases of unexplained neurological DCI.

The acceptability of a diver who has undergone transluminal surgery is dependant on the underlying condition and the operative result. An history of angioplasty or the current use of anticoagulants are contraindications to diving.

A diver with a pacemaker will require extremely careful assessment regarding the type of diving intended and the type of pacemaker fitted. The clinical indication for the fitting of the device is more important than its presence.

As diving is known to affect the microcirculation, conditions known to be associated with impaired organ or peripheral circulation should be considered contraindications to diving.

Exercise Testing

Underwater work is often strenuous and a professional diver or instructor must be capable of conducting a rescue on a colleague. For professional divers or instructors, exercise testing should be conducted at initial and annual medical examinations. Examples of tests are:

- **British Army Physical Fitness Test:** The candidate steps up and down at a rate of 30 times per minute from 0.43m step for 5 minutes. The pulse is counted from 1 to 1.5, from 2 to 2.5 and from 3 to 3.5 minutes after cessation of exercise. The sum of the pulse counts must be less than 190.
- **Bicycle ergometer or treadmill:** Minimum values suggested by various authorities include 200 Watts for 6 minutes or a value of 13 METs or VO_2 max. of about 2.8 litres per minute.

Central Nervous System

As the CNS is so often affected by decompression illness and is so important to underwater safety, a detailed examination is required at every diving medical. This should include cranial nerves, motor and sensory system, balance, co-ordination and gait.

The CNS should be clinically and functionally normal. Any deviation from normal should be elicited and the diver informed as it may be similar to a symptom of decompression illness.

Any condition predisposing to impairment of consciousness, convulsion, disturbances of speech, vision or motor control or disturbances of orientation or balance is not compatible with diving. Intellectual and psychological function should be intact.

A history of head injury with depressed skull fracture or intracranial haematoma or unconsciousness or post traumatic amnesia greater than 30 minutes is not compatible with diving. A history of intracranial surgery is likewise incompatible. Specialist opinion should be sought in cases of more minor head injury and temporary unfitness to dive must be applied for at least 4 weeks.

Musculo-skeletal System

All divers should have sufficient mobility, dexterity and strength to be able to swim and use their equipment safely. Professional divers additionally need to be able to cope with the demands of heavy underwater work and both they and instructors must be strong enough to lift another diver from the water.

Divers with a history of back or cervical pain require careful assessment because of the risk of sudden incapacitation or referred pain mimicking decompression illness.

The risk of dysbaric osteonecrosis in persons who do not do saturation diving is so low that the radiation exposure from routine long bone X-rays is not justified. Such radiology should only be undertaken if clinically indicated.

Gastro-intestinal System

Gastrointestinal function should be normal with no increased tendency to vomiting, dyspepsia, reflux, bleeding, perforation, diarrhoea or pain. Use of H₂ blocker therapy for the control of dyspepsia and heartburn in recreational divers is permitted.

Current peptic ulceration is not compatible with diving. There must be objective evidence of resolution of peptic ulceration or a long asymptomatic period without the requirement for medication before a diver can be considered fit.

Hepatic and pancreatic function must be normal.

Abdominal wall hernias are incompatible with diving as bowel gas in a loop may expand on ascent causing strangulation. Successful repair must be conducted before diving is permitted.

The presence of a stoma is not a bar *per se* to diving but the underlying condition leading to the presence of the stoma must be taken into account.

Genito-urinary System

The function of the renal tract and urinary system should be normal and free from increased susceptibility to infection, pain or obstruction. Specialist reports in persons with a history of nephrolithiasis or renal colic should be obtained.

Persons with active venereal disease are unfit to dive until successfully treated.

Dipstick urinalysis for blood, protein and glucose must be carried out at all medical examinations. Any positive results should be investigated.

Endocrine System

Due to the physiological and exercise demands of the underwater environment, it is unlikely that a person suffering from an endocrine condition resulting in significantly impaired thermoregulation, cardiac impairment or muscular insufficiency could be considered fit for any form of diving. A proven or suspected endocrine abnormality requires detailed investigation.

Patients with stable thyroid disease who have no cardiovascular complications may be considered fit for restricted certification.

Diabetes Mellitus

For professional divers, insulin dependant diabetes mellitus or non-insulin dependant diabetes mellitus requiring control by oral hypoglycaemic agents are contraindications to diving. Assessment on an individual basis should be made for those with non-insulin dependant diabetes mellitus controlled by diet alone, taking into account the type of diving undertaken. Restricted certification is often applied in these cases.

Under certain circumstances, persons with diabetic control dependent on medication may undertake recreational diving. The disease must be well controlled (though it must be remembered that the better the control, the more likely the attacks of hypoglycaemia)

and completely free of complications. The treatment regimen must not have altered within the last year and the diver should only undertake relatively undemanding diving. They must dive with a non-diabetic buddy who can administer oral glucose or give an intramuscular injection of glucagon. These should be carried whenever the diabetic diver is in the water. It is recommended that diabetics take extra glucose to boost blood sugar levels before diving. The diver must be made fully aware that both diabetes and diving can cause problems with the microcirculation. It must be remembered that whatever the regimen, diving with diabetes involves some added risk.

Haematology

Any disorder leading to impaired oxygen transport capacity is a contraindication to diving. Recommended levels of haemoglobin are:

- Male 13 - 18 g/dl
- Female 11.5 - 16.5 g/dl

Sickle cell disease or thalassaemia are contraindications to diving. Carriers of sickle cell trait and thalassaemia trait can be considered fit to dive as hypoxic conditions are not routinely encountered during diving, and if they are then there are far more urgent matters than haemoglobinopathies.

Diving is not recommended in persons who have glucose-6-phosphate dehydrogenase deficiency as high oxygen tensions may cause significant haemolysis.

Significant impairment of clotting is a contraindication to diving.

At preliminary examination a full blood count should be performed for all divers. Any abnormal result requires further investigation. Electrophoresis, sickle cell testing or testing for glucose-6-phosphate dehydrogenase deficiency or clotting disorders may be performed at initial medical examination if thought indicated.

Vision

Visual acuity with or without correction should be adequate for the type of diving e.g. reading of watches and pressure gauges. For professional divers additional tasks such as boat handling and underwater demolition may require greater acuity and good colour vision.

Optical correction may be achieved by using a prescription faceplate or by the use of soft, gas permeable contact lenses. Hard impermeable lenses are unsuitable unless fenestrated. Many divers prefer the use of disposable soft lenses.

Diving after ophthalmic surgery should be assessed on an individual basis and with access to specialist reports. Certain surgical procedures may involve instillation of gas into the globe or may result in a reduced ability to tolerate trauma or other pressure change.

Medical Certificate of Fitness to Dive

From: Code of Practice - Safety & Health at Work for Industrial Diving

Initial (Pre-training) Examination

Initial medical examination should be conducted before a diver has commenced training by a medical practitioner, preferably with special experience in underwater or occupational medicine. Investigations conducted during the examination should include:

- a. chest X-ray, PA full inspiration and expiration
- b. full blood count, including haemoglobin and haematocrit
- c. audiometry
- d. lung function tests including FVC and FEV
- e. exercise testing
- f. electrocardiography
- g. dipstick urinalysis
- h. long bone radiographs which need only be taken at initial examination for those divers working at depths exceeding 50 metres and which should only be repeated at the discretion of the examining medical practitioner
- i. additional investigations which may be ordered at the discretion of the examining medical practitioner and specialist referral is appropriate in the case of abnormal results

Annual Medical Examination

At annual medical examination, investigations (c.) to (g.) of the above section should be completed. Additional investigations may be ordered at the discretion of the examining medical practitioner and specialist referral is appropriate in the case of abnormal results.

Certificate of Medical Fitness to Dive

The medical certificate issued after the examination should contain:

- a. name of person
- b. date of medical examination
- c. date and result of chest X-ray taken at first medical examination
- d. date and result of long bone radiographs, if applicable
- e. results of investigations conducted
- f. any limitation on diving
- g. name, qualification, address and telephone number of the medical practitioner issuing the certificate
- h. signature of the medical practitioner issuing the certificate

Recommended Reading

The following textbooks and documents are recommended reading for doctors wishing to conduct medical examinations of divers. They provide required background information on diving physiology and techniques and the legal requirements of industrial diving in Hong Kong:

The Physiology and Medicine of Diving

Peter Bennett and David Elliott

W B Saunders Company Ltd.

London

ISBN 0-7020-1589-X

Diving and Subaquatic Medicine

Carl Edmonds, Christopher Lowry and John Pennefather

Butterworth-Heinemann Ltd.

Oxford

ISBN 0-7506-2131-1

Diving Medicine

Alfred Bove and Jefferson Davis

W B Saunders Company Ltd

Philadelphia

ISBN 0-7216-2934-2

Code of Practice - Safety & Health at Work for Industrial Diving

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