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# Medical assessment of fitness to dive. Part I

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## ABSTRACT

*Good physical and mental health is a prerequisite for anyone planning to scuba dive. A fitness to dive certificate for those willing to enter a scuba diving course as well as for active divers, either amateur or occupational, can only be issued if there are no medical contraindications to dive. It is usually within the competence of a diving instructor, a manager of underwater work or a physician to assess a person's mental and physical health and grant them permission to stay under hyperbaric conditions. The legal requirements for issuing a fitness to dive certificate are different for recreational and occupational divers. The part I of this article discusses the issues concerning medical assessment of fitness to dive for amateurs.*

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**Key words: diving, health assessment, medical contraindications**

## INTRODUCTION

In Poland, recreational scuba diving courses are normally organized by privately-owned operators or sporadically by a few state-owned sports clubs affiliated to the Section of Underwater Activities at the Polish Tourist and Sightseeing Society. The training program offered by the state-owned institutions follows the guidelines proposed by the French Confederation Mondiale des Activites Subaquatiques (CMAS) and the Polish National Defense League, whereas scuba diving courses organized by privately owned operators are usually based on the procedures formulated by international diving organizations such as Professional Association of Diving Instructors (PADI), Scuba Schools International (SSI) or International Diving Association (IDA). Scuba diving courses for commercial divers, on the other hand, are organized by a number of state owned companies (e.g. the Polish Vessel Rescue Company, the Polish Register of Shipping and other shipping companies, shipyards or port authorities), by some privately-owned companies as well as by specialist units of the Polish Armed Forces, the Polish National Police and the State Fire Service. Good physical and mental health is a prerequisite for anyone planning to become a diver. A fitness to dive certificate for those willing to enter a scuba diving course as well as for active divers (either amateur or commercial) can only be issued if there are no medical contraindications to dive. However right before a dive, it is normally within the responsibility of a diving instructor, a manager of underwater work or a physician to assess a person's mental and physical health and grant them permission to go underwater. The legal requirements for issuing a fitness to dive certificate are different for amateur and occupational divers [1].

## MEDICAL ASSESSMENT OF FITNESS TO DIVE IN AMATEUR DIVERS

A vast majority of scuba divers are amateurs. Nowadays, recreational diving is popular with people of all ages, including children and the elderly. Regardless of their age, all candidates for scuba diving are obliged to obtain a medical certificate confirming their good physical health and fitness to dive. In the past, entities authorized to issue such medical certificates were health care providers affiliated to sports medicine clinics, the Institute of Maritime and Tropical Medicine in Gdynia as well as military physicians. New

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legal regulations regarding scuba diving requirements (the Regulation of the Minister of Sport of August 17, 2006 on safety rules for practicing scuba diving, Journal of Laws of the Republic of Poland of 2006, item 1103) substantially simplified the procedure for obtaining certificates confirming lack of contraindications to diving [2]. Currently, a person who wants to dive should obtain an appropriate medical certificate, and in accordance with the applicable regulations, such a certificate may be issued by any physician. However, not many physicians are experts in the field of diving medicine; qualifying a person for a scuba diving course by a random and often incompetent physician carries a high risk of diving related accidents. In theory, ever potential diver should undergo a fitness to dive assessment by a medical practitioner before they enter a course. However, in order to promote the sport and increase its accessibility, many clubs and operators no longer require a fitness to dive examination or a certificate. Thus, the complete responsibility for any potential problems or accidents which may occur underwater lies with a diver alone. A physical examination by a medical doctor has been replaced by a self-completed medical questionnaire, which is then analyzed by a diving instructor [3]. On the basis of the information provided by a candidate an instructor will decide whether or not a person can be declared fit to scuba dive [2]. This obviously places great responsibility in the hands of a scuba diving instructor. The instructor should not only be an expert in diving medicine who is fully aware of every single contraindication to scuba diving (like incidents of seizures, loss of consciousness, pulmonary edema) as well as any aspects that would temporarily disqualify a person from diving (e.g. middle ear infections, sinusitis, asthma, bronchitis and respiratory tract infections), but he must also be a skilled psychologist who has the ability to accurately assess a candidate's aptitude for diving before they start training (watch them carefully and look them deep in their eyes). The instructor must also be able to assess the risk of a potential diving accident and be able to recognize all the risk factors which might possibly lead to a diving-related incident, such as: poor physical condition or poor tolerance to exercise of a candidate, insufficient diving training, the presence of underlying health conditions that may aggravate under hypobaric conditions, the potential for a panic attack, poor planning of a diving session and a lack of enough air to complete a dive according to a pre-scheduled plan. As to date, Poland has not introduced effective legal regulations on medical requirements for recreational and sports diving [4]. Anyone interested in recreational scuba diving must rely on individual self-assessment of their health condition. The lack of legislation encourages diving associations to deal with the problems of diving fitness health assessment within their own capacities. In Poland, some diving organizations have been organizing training sessions for medical practitioners in the field of underwater and hyperbaric medicine; such training is offered by the Polish Hyperbaric Medicine and Technology Society and the Department of Hyperbaric Medicine and Maritime Rescue — the National Center for Hyperbaric Medicine at the Medical University of Gdansk. After completing a series of training sessions, participants are certified as diving physicians or club physicians. So far, several hundred physicians have completed the training, which means that anybody willing to start their adventure with scuba diving or those already practicing the sport should be able to consult with a competent diving specialist no matter which part of Poland they live in. A medical certificate stating that a person is medically unfit to dive must never be ignored. Individuals who have been declared 'unfit to dive' may apply for re-examination to the Head of the Diving and Scuba Diving Certification Board at the University Department of Maritime and Tropical Medicine in Gdynia. As a rule, commercial scuba divers are required to undergo a medical examination every 12 months but professionals taking part in scuba diving sports events should have their fitness to dive attested every 3 months [2, 5]. Since scuba diving equipment is easily available to anyone and because formal restrictions for prospective divers are now more relaxed than they used to be in the past, some people fail to get proper training before they go scuba diving and are often completely unaware of the risks associated with this form of activity. From the medical point of view, it seems obvious that each prospective diver should get some insight into certain aspects of diving medicine. This will help them self-assess their fitness to dive and will hopefully reduce the risk of diving-related injuries. Until recently, a vast majority of scuba divers were all young and physically fit individuals, mostly under the age of 30 years. This, however, has changed in recent years. Nowadays, scuba diving is popular with people of all ages. The activity is becoming increasingly popular among teenagers and some scuba diving fans decide to go diving with their children, in some cases no older than 10 years. The requirements for young people willing to engage in scuba diving are the same as for any other age group — they must be in a good physical and mental health and should be free from any contraindications to dive. As was mentioned before, the sport does not only attract the younger generation. In fact, more and more divers are either middle aged or retired people. Some older divers are in good physical health, while others will have certain preexisting conditions. Since a person's general health and level of fitness tends to decrease with age and because ageing is naturally associated with a number of degenerative processes affecting all organs and systems, older divers are recommended to undergo a careful medical examination and extensive diagnostic tests before they start

scuba training [4, 6]. It is often the case that the initial medical examination may reveal conditions of which a prospective diver has been unaware but which may be a relative or an absolute contraindication to scuba diving. As an example, undiagnosed asymptomatic cardiovascular conditions can unmask or aggravate when a person engages in strenuous physical activity (e.g. during a dive) causing a decrease in blood supply to vital organs. As was mentioned before, the age structure of individuals who practice scuba diving has changed over the past 30 years. This has had a direct influence on scuba diving fatalities statistics. The number of accidents in the 20–29 age group has decreased by a half in comparison to the period of 1987–1989 while, in the 50–59 and 60–69 age groups the percentage of diving-related accidents increased more than 5-fold. Currently, a certain proportion of divers are individuals in their 70s or even 80s; divers in this age category obviously run a much higher risk of a diving related accident or an illness in comparison to younger people. The average age of diving fatalities increased from 39 years in 1989 to over 54 in 2017. According to medical statistics the reason for 25–32% of deaths among divers are cardiovascular conditions. In light of the above, more than ever before, a fitness to dive assessment is of fundamental importance in the process of qualifying a person for recreational diving. Diving fitness health assessment in older divers as well as in divers with preexisting illnesses is a complicated issue. Its purpose is not only to declare all seemingly healthy individuals as 'fit to dive' and all those with preexisting conditions as 'unfit to dive', but rather to assess whether a patient's underlying conditions are a real contraindication to dive and to what extent will they affect a diver's health and safety underwater. The aim of a diving fitness health examination is also to determine safe diving limits for each diver [6, 7]. In the past, good physical fitness was considered to be an absolute prerequisite for scuba diving, more recently however, scuba diving has become popular with all groups of people, even those with physical disabilities. Currently, poor physical fitness alone should not be considered an absolute contraindication to recreational diving, provided that a diver whose level of fitness is lower than normal acts in a reasonable manner and avoids unnecessary risk while staying underwater. Therefore, even people with physical disabilities or those with underlying conditions should be permitted to engage in recreational diving unless it may aggravate their underlying conditions. For many of them scuba diving might be an excellent form of active physical therapy [1].

## RESPIRATORY DISEASES

Fitness to dive examination should primarily focus on the condition of the respiratory system since most diving related incidents and traumas are associated with pulmonary edema caused by a respiratory arrest or abnormal retention of breathing gas in a lung or its part during ascent, even from the depth as low as 1–2 m. This type of traumas may occur at any time, even during the very first dive session when a person is breathing compressed air. Any condition which is likely to increase the risk of air-trapping (i.e., abnormal retention of gas in lungs) during ascent or affect the lung volume during a dive should be considered an absolute contraindication to scuba diving. It is essential that each prospective diver should have a chest X-ray performed prior to their first dive. Amateur diving is contraindicated in patients with airway obstruction or emphysema which is visible on a chest X-ray, patients who are susceptible to spontaneous pneumothorax, patients who have recently undergone a thoracic surgery, as well as those with asthma, bronchitis or pneumonia. Because these conditions change the respiratory mechanics, their presence increases the risk of a pulmonary barotrauma during a dive in response to rapid changes in the intrapulmonary pressure [4, 8, 9]. Medical conditions which are characterized by increased mucus secretion, such as asthma, bronchitis, pneumonia, and bronchiectasis also increase the risk of air trapping. Excessive mucus secretion is also seen in heavy tobacco smokers [1].

**Asthma** is characterized by inflammation of the bronchial mucosa, paroxysmal bronchospasm and over-secretion of mucus in the respiratory tract. Inflammatory lesions cause the so-called bronchial hyper-responsiveness, which increases the risk of a bronchospasm. An asthma attack may be triggered by exposure to allergens or cold air, physical exercise, stress, over-excitement, infections or exposure to air irritants — many of these factors cannot be avoided while scuba diving. Asymptomatic asthma may be associated with persistent subclinical bronchospasm which increases the potential for a sudden asthma attack in case of exposure to any of the above mentioned irritants. Some divers might have had childhood asthma which resolved later in life, others will have allergic rhinitis or seasonal hay fever. All of them run a higher risk of an asthma attack while scuba diving.

Physical exercise alone may be the cause of about 90% of asthma attack cases but breathing dry and cold air from cylinders is also likely to trigger an asthma attack. In order to resolve any doubts, before taking the final decision concerning fitness to dive of a person suspected of bronchial hyper-reactivity, it is recommended to consult a pulmonologist and perform an exercise or a cold air challenge test. Individuals with chronic asthma may be declared fit to dive provided that they are well controlled with steroid drugs and have normal results on the spirometry test.

Owing to the fact that each year there is a growing number of asthmatic divers, British researchers under the guidance of prof. Elliott attempted to study this complex

issue and find a solution to the problem. They have concluded that certain asthmatics can be allowed to scuba dive without running the risk of being exposed to diving-related illnesses or injuries. They have found that the prevalence rate of pulmonary barotraumas in asymptomatic asthmatics was not higher than in non-asthmatics. This led them to a conclusion that asthmatic patients with normal lung function parameters, at rest and post-exercise, may scuba dive safely provided that their forced expiratory volume (FEV) in 1 second on a spirometry test is more than 75% of the predicted $FEV_1$ value – $FEV_1$ > 75%. Elliott [8] also believe that patients with chronic asthma who are well-controlled with steroid drugs may be medically cleared to dive, provided that they have normal spirometry results. In contrast, active asthma constitutes an absolute contraindication to scuba diving. An asthma attack associated with a bronchospasm and overproduction of mucus in the airways prevent normal ventilation and increase the potential for air trapping which in turn increases the risk of a pulmonary barotrauma and cerebral gas embolism.

**Bronchitis and pneumonia** are common respiratory illnesses that are characterized by increased mucus secretion and the presence of inflammatory exudates which increase the risk of air trapping. An active infection definitely disqualifies a person from scuba diving. Occasionally, severe pneumonia may result in permanent changes in the lung structure, such as pulmonary fibrosis, cavities, emphysema, and calcifications. The lesions may obturate the bronchi and impair the lung function and its flexibility. Parts of the affected lung are generally more susceptible to injuries and air trapping. After an episode of pneumonia or bronchitis, a person should not resume scuba diving for at least a month after all the symptoms have disappeared. Before they return to diving they should consult a physician and have a chest X-ray performed. Taking a break from scuba diving will be necessary to recuperate and clear the respiratory tract of the remains of mucus whose presence may increase the risk of small airways obstruction. Susceptibility to **spontaneous pneumothorax** is an absolute contraindication to scuba diving. It is a rare disease (with prevalence rate of about 5 cases per 100,000 people) that is most often seen in younger, healthy men; women are generally at a lower risk of spontaneous pneumothorax. The disease is more common in tobacco smokers. The direct cause of spontaneous pneumothorax is a rupture of pulmonary blebs and a tear in the visceral pleura and the subjacent lung structure. Blebs are usually small and not visible on chest X-ray. Recurrent episodes of spontaneous pneumothorax affect about 50% of individuals. It is well understood that if a prospective diver is susceptible to spontaneous pneumothorax under normal atmospheric conditions they will be even more vulnerable to such incidents under hypobaric conditions. Individuals with a history of **thoracic surgeries**, trauma-induced chest hematoma or pneumothorax should be disqualified from scuba diving. The formation of post-operative or post-traumatic pleural adhesions changes the respiratory mechanics and may impair normal breathing. Although the symptoms may not be clearly visible, changes in the lung volume during a dive, especially when holding one's breath, can cause further damage in the affected lung [1, 4, 8, 9].

## CARDIOVASCULAR DISEASES

A routine fitness to dive assessment may reveal certain cardiovascular conditions. A physical examination, for example, can detect cardiac murmur or arrhythmias, while the electrocardiogram reading can reveal other abnormalities. If a prospective diver is diagnosed with any cardiovascular conditions, they will require further tests. In such cases, it is recommended to perform an echocardiogram, Holter electrocardiogram (a 24-hour test) and possibly a cardiac stress test. Once all the tests have been performed, a prospective diver should be referred to a cardiologist. In general, scuba diving is contraindicated in patients with a cardiovascular condition, patients with poor exercise tolerance, a positive cardiac stress test or any other abnormalities revealed by the standard cardiac tests.

**Congenital heart defects** that allow the blood to flow between the right and left chambers of the heart are an absolute contraindication to scuba diving. A person with the above mentioned conditions may only be allowed to dive provided that these defects have been corrected surgically in childhood, they report no cardiovascular symptoms and the results of cardiological and pulmonary tests show no abnormalities. Patients with asymptomatic **valvular incompetence** may be allowed to scuba dive, provided that they have normal results of electrocardiography and echocardiography. In older patients, it will be necessary to check whether valvular incompetence has not resulted from a more serious heart condition. If such a condition is confirmed by the echocardiogram the individual cannot be declared fit to dive. Any form of **valvular stenosis** disqualifies an individual from scuba diving. Individuals with asymptomatic **mitral valve prolapse** (a condition which affects approximately 5–10% of the global population) may be declared fit to dive unless they have reported symptoms such as palpitations, arrhythmias, chest pain or syncope, in such cases scuba diving will not be possible. It is important to remember that the presence of **patent foramen ovale** (PFO, a failure of the foramen ovale in the atrial septum to close) may significantly increase the risk of diving-related illnesses and affect diving safety. Although the condition is quite common and affects between 20% and 34% of the global population, prospective divers are not routinely screened for PFO and its presence

is not considered a contraindication to scuba diving. Diving with PFO carries a certain level of risk — if the right atrium pressure exceeds the left atrium pressure during a dive, especially if a diver has not followed the recommended decompression procedures, gas bubbles are released into the arterial circulation causing arterial gas embolisms.

**Abnormal electrocardiogram** does not always mean that a patient has developed a cardiovascular disease, in some individuals it can signal sinus bradycardia or right bundle branch block.

**Bradycardia**, i.e., heart rate below 60 beats per minute is a condition associated with exercise-induced adaptation of the heart muscle. In athletes, bradycardia is normal and should not be considered a contraindication to scuba diving. In older patients, especially those who are not physically active, bradycardia is rather a signs of a heart condition and/or the effect of using cardiovascular medications. Such individuals should be consulted by a cardiologist and the decision concerning their fitness to dive should be taken with caution.

**Right bundle branch block** and **incomplete right bundle-branch block** is commonly seen in young physically active individuals and is not normally considered a contraindication to diving. The conditions are not associated with any heart disease and cause no signs or symptoms. In some patients, the ECG may reveal a brief resolution of the block when performing the Valsalva maneuver or during exercise. Patients with complete or incomplete right bundle branch block can safely engage in diving activities, but before they are medically cleared to scuba dive they need to be referred for an exercise tolerance test. **Left bundle branch block** is common in older people. The presence of left bundle branch block is indicative of a cardiovascular condition and is associated with a higher risk of a cardiac event; therefore it is considered an absolute contraindication to scuba diving. **Wolff-Parkinson-White** (**WPW**) **syndrome** is a condition associated with episodes of paroxysmal tachycardia, i.e., supraventricular tachycardia, atrial fibrillation or atrial flutter. WPW syndrome is an absolute contraindication to diving; a tachycardia attack under water may result in a loss of consciousness which, in consequence, may lead to drowning. For the same reason, candidates for divers with a history of paroxysmal supraventricular tachycardia (regardless of its cause) cannot be declared fit to dive. Individuals under 35 years of age may be conditionally allowed to scuba dive providing they have never fainted during a tachycardia attack, they have not been taking any cardiac medications and have not had an attack in the last six months. **First-degree atrioventricular** (**AV**) **block** is quite common in professional sports people as well as in some healthy individuals. A candidate diver with first degree AV block should first consult with a cardiologist; such patients can be declared fit to dive, provided that the results of the cardiac stress test and echocardiography show no abnormalities. **Second-degree and third-degree AV block** is always a sign of a cardiac condition and therefore it is an absolute contraindication to diving.

**Ischemic heart disease** (**IHD**) is the leading cause of premature mortality for both men and women and of excess mortality for middle-aged men. The most dangerous consequence of IHD is myocardial infarction (MI). A history of a MI, angina or cardiac arrhythmias which have resulted from IHD are an absolute contraindication to diving. IHD is often associated with dangerous arrhythmias, which in 20% cases are responsible for the so-called 'sudden cardiac death'. IHD was found to be the largest single cause of sudden cardiac death in scuba divers. When assessing fitness to dive of individuals in their 40s or older, special attention should be given to IHD risk factors (high total cholesterol level, past history of IHD, family history of IHD, MI or sudden cardiac death in parents or siblings, arterial hypertension, diabetes, significant obesity). Prospective divers over the age of 40 with IHD risk factors or a history of a cardiac condition should have a cardiac stress test performed before they are declared fit to dive. If the test result is negative and a diver can reach a work rate of 13 metabolic equivalent level, which is approximately 45 mL $O_2$/kg/min, they can be considered fit for recreational diving. In doubtful cases, further non-invasive cardiac evaluation will be necessary, including echocardiogram and exercise scintigraphy. The presence of cardiac symptoms, exercise intolerance, a positive result of the cardiac stress test or any abnormalities revealed by cardiac tests disqualify a person from scuba diving. Other cardiac contraindications for scuba diving include: pacemaker implantation, artificial heart valves insertion, a history of coronary angioplasty or coronary artery bypass grafting. A diver who has had a MI should not return to scuba diving for 12 months after the cardiac event. After this period, a patient will need to undergo a thorough cardiovascular evaluation to assess his exercise tolerance and long-term complications of the infarction. In general, an episode of MI decreases a diver's tolerance to exercise, stress and cold. A diver who effectively controls his blood pressure with medication and has normal exercise electrocardiography results can re-apply for a fitness to dive certificate. In some cases additional cardiac exams, such as echocardiogram or coronography will have to be performed. Complications associated with MI such as electrical conduction abnormalities may disqualify a person from scuba diving. Also pacemaker implantation is a contraindication to resuming any diving-related activities. Because they will require chronic anticoagulation treatment, patients with artificial heart valves should not be medically cleared to return to scuba diving. It must be

remembered that the diving reflex may aggravate the existing arrhythmias and conduction abnormalities. The recent advances in medicine have enabled surgical treatment of coronary arteries. Although angioplasty and coronary artery bypass grafting significantly improve tolerance to exercise and general condition in patients with coronary artery disease or after MI, clearing such persons to return to scuba diving carries a certain level of risk due to the progressive atherosclerotic process.

Approximately 45% of people aged between 45 and 64 suffer from **arterial hypertension**. In candidates for diving it will be necessary to check whether or not arterial hypertension has caused permanent damage to the heart, kidneys and the fundus of the eye. The presence of left ventricular hypertrophy or left ventricular dilation disqualifies an individual from scuba diving. Individuals whose condition is effectively controlled with anti-hypertensive medications can be declared fit for recreational diving. However, if blood pressure cannot be normalized, a patient should not be medically cleared to scuba dive. Physical effort, stress and cold water exposure during a dive may potentially cause a significant increase in blood pressure. The risk of a stroke or a heart attack is much higher in those divers who are at an older age and have been diagnosed with arterial hypertension; therefore, such candidates should be disqualified from scuba diving.

**Arterial and venous diseases** are another major contraindication to scuba diving, because they are known to limit the physical capability of a diver. The exposure to cold water causes constriction of blood vessels and a reduction in blood supply to muscles. Arterial insufficiency in the lower limbs is a condition which will have a negative effect on a diver's swimming efficiency. Varicose veins are not considered to be a contraindication to scuba diving, provided that the condition is not associated with venous insufficiency or thromboembolism. Until only a few years ago, cardiovascular conditions were considered an absolute contraindication to dive. Currently, it is not uncommon for diving specialists to consult older divers with underlying heart conditions, which have developed as a result of many years of diving. An experienced physician should be able to determine safe diving depth limits for those who begin scuba diving at an older age. A large number of prospective divers are over 40 years old, sometimes even older than 60. Divers in this age category will be more likely to have an underlying heart problem or hypertension in comparison to younger divers. Unless they have a serious cardiovascular disease, people over the age of 50 cannot be declared unfit to dive solely because of advanced age. Divers at an older age are likely to have lower physical fitness and exercise tolerance in comparison to younger divers. This, coupled with cardiovascular conditions may lead to a sudden aggravation of the underlying diseases and increase the risk of a sudden cardiac death in water, drowning or sustaining a diving-related injury. Elderly candidates with pre-existing cardiovascular conditions must be made aware of the risk of sudden cardiac death which may occur while scuba diving and of the potential risk for their dive buddy — in emergency situations a younger diver will have to risk his own life in order to save his older partner. When assessing their fitness to dive, a physician will not only have to consider the risk of a sudden aggravation of an underlying cardiovascular disease, but also the effects of immersion itself, stress, physical effort and cold temperature on the functions of the cardiovascular system. It cannot be assumed that every elderly diver will only engage in recreational diving, i.e., swim at a slow to moderate pace at shallow depths. During any dive, difficult conditions and circumstances can arise which may require vigorous exercise. In case of an emergency, a diver may be pushed to their limits in order to save himself or help his dive buddy, for example, he may have to swim against a strong current or a tide, he may become entangled in a fishing net, come across dangerous marine animals or have to deal with a failure of scuba diving gear. All these unforeseen circumstances rapidly increase the physical and mental strain, and may potentially turn out life-threatening for an elderly diver. Each diver should have sufficient cardiovascular reserves to be able to cope with unexpected emergencies without risking complete exhaustion or loss of consciousness. It is important to note that as they grow older people become more sensitive to temperature changes. Therefore, older divers will be more susceptible to dehydration when travelling to tropical regions or hypothermia when diving in seemingly warm waters. Both dehydration and hypothermia affect the function of the cardiovascular system and may trigger a cardiac event. Additionally, the stress associated with diving increases blood pressure and can cause tachycardia, which in patients with cardiovascular risk factors may result in acute MI leading to a sudden cardiac death. According to the statistics, as much as 25–32% of diving-related deaths in divers at an older age are associated with cardiac events [1, 4, 8–13].

## DISEASES OF THE EAR AND PARANASAL SINUSES

Chronic otitis media or sinusitis, marked stenosis of the auditory canal, permanently perforated tympanic membrane or any recent surgeries of the ear constitute absolute contraindications to scuba diving. The presence of the above listed conditions will make it difficult or even impossible for a diver to equalize pressure in the ear and in the sinuses. Diving in a wet suit with perforated eardrum may lead to irritation of the labyrinth and disorientation under water. Eustachian tube dysfunction and edema within the nasopharynx are usually caused by frequent infections of the

upper respiratory tract or by otitis media. The abnormalities increase the risk of the barotrauma of the ear or paranasal sinuses. Other common risk factors for barotrauma include: allergies, tobacco smoking, overuse of nasal sprays or nasal drops, polyps or other abnormalities within the nasal cavity. All these conditions may prevent normal ventilation of paranasal sinuses. People with childhood history of acute otitis media may have difficulties in normal ventilation of the ear at an older age which will increase their potential for an ear barotrauma. Congenital defects, such as cleft palate or bifid uvula are often associated with anomalies of the Eustachian tube. Surgical correction of the defects does not necessarily restore the function of the Eustachian tube. Patients with the above defects should be tested for the patency of the Eustachian tubes before they are medically cleared to scuba dive. If a diver had suffered **perforation of the tympanic membrane** they can only be allowed to resume diving after it has reattached and the ear function has returned to normal. Diving in a dry suit protects the middle ear from flooding and because it prevents the labyrinth from exposure to thermal irritation it allows a diver to stay underwater even if the eardrum ruptures. A history of the **mastoid process or the auditory ossicles surgery** disqualifies a candidate from diving due to a high risk of damage to the inner ear. People who often develop **inner ear infections** or **Meniere's disease** which manifest with dizziness should not be allowed to undertake scuba diving. Dizziness is often accompanied by nausea and vomiting and may potentially lead to drowning. Some divers may experience **dizziness** during the ascent because of asymmetric pressure equalization in the middle ear. If dizziness occurs on each ascent, or if it is severe, recreational diving should be discontinued. A sinus X-ray and a consultation with an otolaryngologist might be useful when assessing fitness to dive in prospective divers with a history of illnesses of the ear, nose or sinuses. However, the final decision can be left to the divers themselves. If they have problems with equalizing pressure during their first diving session or develop a severe headache or an earache while diving in shallow waters they are very likely to discontinue scuba diving anyway. A fitness to dive assessment in divers who have suffered a middle ear or inner ear barotrauma should be performed by an otolaryngologist. Such patients may be allowed to return to scuba diving provided that the tympanic membrane has healed and vestibular disorders (irritation of the inner ear) have resolved. If a diver is to dive in a dry suit only, he may conditionally be allowed to return to scuba before the eardrum has healed [1, 4, 6, 14, 15].

## EYE DISEASES

Good visual acuity and normal field of vision are essential for maintaining safety and sense of direction underwater. Having good eyesight is essential to read the screen of a dive computer, a depth gauge, a watch, a compass or decompression tables. The visibility underwater is often limited because of water pollution or because there is not enough sunlight. Color blindness should not be considered a contraindication to scuba diving, as it has no direct influence on a diver's safety. There are some ocular conditions, however, which will disqualify a candidate from scuba diving. These include any severe inflammatory conditions of the eye or its protective apparatus manifesting with pain, disturbed visual acuity, diplopia or photophobia. If such conditions occur, a prospective diver cannot be declared fit to dive until the disease is cured and all symptoms subside; such individuals will need to consult an ophthalmologist before they can be declared medically fit to dive. **Visual acuity disorders** are increasingly common nowadays. A growing number of young scuba diving candidates have some vision defects which have to be corrected by wearing prescription glasses or contact lenses. Vision defects are found in nearly all candidates over the age of 50. When consulting individuals with decreased visual acuity, it will be necessary to determine whether scuba diving will be safe in their case and decide which forms of scuba diving activities can be recommended to an individual person. There are several ways to improve visual acuity underwater. A diver might, for example, wear soft contact lenses or use a special scuba mask fitted with corrective lenses.

Since the eyeball and the fluid within are not compressible, the eye is not affected by pressure changes. An injury to the eye or rupture of the cornea may only occur with facial barotrauma, i.e., a mask squeeze which occurs if a diver fails to exhale all the inhaled air during a descent. For this reason, a history of **eye surgery** is not a contraindication to recreational scuba diving. In general, individuals who have had an eye surgery are not recommended to go scuba diving for 2–3 months after the surgery or until the cornea has healed. People who have undergone a surgery to the eyelids, conjunctiva or eye muscles should be discouraged from scuba diving for 2–3 weeks after the surgery. Divers at an older age are more likely to have serious vision problems or eye diseases, such as **cataracts** or **glaucoma**. In fact, glaucoma is quite a common condition in middle aged and elderly people. The above conditions are not normally considered to be an absolute contraindication to scuba diving, unless the loss of vision is so profound that it could threaten diving safety. Divers who have had a glaucoma or cataract surgery can be allowed to resume scuba diving 3 months after the operation. Divers who have had any visual disturbances following an episode of a decompression sickness or arterial gas embolism should be strongly discouraged from further diving [1, 4, 6].

## NEUROLOGICAL DISEASES

A history of **seizures** with a **syncope** as well as a history of **transient ischemic attack** or a **stroke** is considered to be absolute contraindications to scuba diving. The presence of the above listed conditions creates a significant risk for the safety of a diver himself as well as people around him. A typical tonic-clonic seizure which is associated with respiratory arrest creates a high risk of drowning or pulmonary barotrauma. During a pre-dive assessment particular attention should be paid to: a past history of head trauma, concussion, post-traumatic intracranial hematoma, skull fractures, loss of consciousness or memory disorders lasting more than 24 hours, severe infections presenting with seizures. In patients with a history of febrile seizures, the risk of non-febrile seizure recurrence has been estimated at 13%. Such patients will require a pre-diving assessment by a neurologist and an electroencephalography test. If the test reveals no abnormalities, a patient can be medically cleared to dive recreationally. The assessment of divers who have experienced a **head trauma** but would like to return to scuba diving is a separate issue. Whether or not a person may be cleared to resume diving will primarily depend on trauma severity and the presence of residual neurological symptoms. Post-traumatic seizures occur in approximately 90% of patients who suffered a head injury. In such cases scuba diving should be discontinued. Divers who have suffered a mild head injury which has caused a brief loss of consciousness and memory loss may return to scuba diving after a minimum of 6 weeks after the injury provided that the neurological assessment reveals no deficits, their electroencephalography is normal and they do not require anticonvulsants. If head trauma results in a loss of consciousness lasting a longer period and a memory loss of more than three weeks, a person should not resume diving for a minimum of 12 months after the injury.

Another group of patients who should not be medically cleared to scuba dive are those who are more susceptible to **syncopal episodes** triggered by exposure to stress. Such individuals are likely to experience weakness, dizziness, excessive sweating, hot flushes and hypoglycemia when confronted with a stressful situation. Because it is essential that a diver remains conscious underwater at all times, re-current episodes of stress-related syncope are considered an absolute contraindication to scuba diving. Patients with a history of a **stroke**, even if it was mild and with minor residual symptoms only, must be disqualified from recreational scuba diving. If a stroke has been the effect of a vascular disease, there will be an increased risk of a vascular, cerebral or cardiac event during a dive. In very rare cases, a patient with a past history of a stroke episode may be cleared to take up less demanding scuba diving activities (only recreationally) provided that the risk of a recurrent stroke has been ruled out by specialist tests and that they have adapted to their functional limitations.

**Chronic radiculopathy** and **degenerative disc disease** are conditions commonly seen in the middle-aged and the elderly people. They usually present with chronic pain at multiple sites. If the conditions are not associated with any physical disability, they should not be considered a contraindication to diving. However, it must be remembered that swimming in cold water as well as lifting and carrying heavy objects, such as scuba gear, may cause recurrence of pain. In such a case, a person should discontinue diving until the symptoms have subsided. Patients who required surgical treatment of the above conditions should not resume scuba diving for a minimum of 2 to 3 months after the operation [1, 4, 6, 16, 17].

## MENTAL DISORDERS

Mental disorders which are regarded as absolute contraindications to scuba diving include: a history of **psychotic episodes**, **anxiety** or **personality disorders**, **intellectual disability**, **alcohol addiction and substance abuse**. Because there is no legal requirement for prospective divers to undergo a comprehensive fitness to dive assessment before they go scuba diving, some candidates may turn out to have an underlying mental disorder. In such cases, it will be up to a diving instructor to decide whether or not an individual is fit to dive. The instructor will be the only person who can judge the behavior and personality of a prospective diver and assess whether he is likely to make progress. Close supervision of candidates during their initial dives (their behavior, the way they handle equipment and react to the challenges involved in the training and unforeseen difficulties) will provide valuable information on their general diving aptitude. An experienced scuba diving instructor will usually be able to evaluate a person's diving fitness and aptitude during the very first training session. Candidates who are emotionally unstable should be discouraged from further training or any diving related activity. Those who exhibit anxiety or depression-related behaviors require close supervision during their preparatory training. If they are unable to control their fear and move to the next, more difficult stage of the training, they will be more susceptible to a panic attack while staying underwater. People with anxiety disorders often suffer from phobias, of which claustrophobia, i.e., the fear of confined spaces, is the most common. Other phobias which might be seen in prospective divers include: the fear of diving, the fear of water, the fear of depths, the fear of open spaces or of marine fauna and flora. When a diver experiences strong fear, he is more likely to lose self-control and panic. This can have grievous consequences as panic is the leading cause of death for scuba divers. On the other side of the spectrum, there is a group of natural risk-takers, people who are over-

confident, self-centered and stubborn. Such candidates are likely to underestimate the danger associated with scuba diving and disregard the diving safety procedures. As a result, they will be more likely to experience a diving-related accident than other groups of divers. In addition, candidates who are too confident tend to ignore their diving buddy or the problems they may have during a dive, which can have tragic consequences. It should not be difficult for a diving instructor to identify such a person, as they are likely to brag about their past achievements, accidents or injuries. Unfortunately, it may be more difficult to dismiss such a candidate from a dive course. Once they have decided to complete the course, it will be difficult to dissuade them from doing so. In such situations, the only thing that the instructor can do is to supervise the 'unpredictable' candidate and ensure that he follows all the scuba diving safety regulations.

Most patients with **psychosis** (**schizophrenia**, **bipolar disorder**) experience periods of symptoms exacerbation and remission. During the period of remission they manifest no worrying symptoms and are likely to conceal their illness from other people. A detailed medical interview focusing on medications taken regularly, the family situation and work environment might be helpful in such cases. Patients on psychotropic medications cannot be medically cleared to scuba dive because the drugs impair a diver's performance underwater and exacerbate the symptoms of nitrogen narcosis. Quite a large number of recreational scuba divers report a regular use of medications; the most common include tranquilizers and anti-anxiety drugs. It must be emphasized that abuse of alcohol or of any antipsychotic medications is an absolute contraindication to scuba diving. Alcohol impairs judgment, delays reaction time and affects a diver's motor coordination. Diving under the influence puts a diver at a significant risk of having an accident or sustaining an injury; it also increases the risk of a barotrauma. Therefore, it is important that divers avoid alcohol not only immediately before a dive and in between the diving sessions but also the night before they go scuba diving (e.g. at team-building parties organized before a diving session). Similarly, drug addiction is considered an absolute contraindication to diving. The use of narcotic drugs endangers the safety of a diver and people around [1, 4, 6, 18, 19].

## DENTAL PROBLEMS

A prospective diver needs to have all his front teeth to able to hold the scuba mouthpiece. Having a dental bridge or a dental prosthesis is not a contraindication to scuba diving, provided that they are firmly attached because a loose denture creates a risk of airway obstruction in case of an emergency. All prospective divers are recommended to visit a dental practitioner to have all their teeth fixed and filled before they start diving. Root canal treatment and loose fillings increase the risk of dental barotrauma. Multiple missing teeth and advanced caries lesions are considered a contraindication to scuba diving [1].

## GASTROINTESTINAL DISEASES

Gastrointestinal system is the area of the body where gas can easily get 'air trapped'. Vomiting is a common symptom of some digestive tract disorders or illnesses; gastrointestinal conditions which are associated with an increased risk of vomiting and air trapping are an absolute contraindication to scuba diving. Vomiting underwater may potentially lead to drowning and the expanding gas trapped in the intestines may cause barotrauma.

Scuba diving, especially in a head-down position, promotes air swallowing, while the state of apparent "weightlessness" underwater has a negative effect on peristalsis, and may aggravate underlying gastrointestinal conditions. **Gastroesophageal reflux disease** is a significant contraindication to scuba diving because it puts a diver at risk of aspiration of the gastric contents. In mild cases, a patient may be conditionally cleared to scuba dive but he must be aware of the fact that scuba diving may cause aggravation of symptoms. **Hiatal hernias** which are asymptomatic do not disqualify a person from scuba diving. A major sliding hiatal hernia is considered an absolute contraindication to scuba diving as it increases the risk of distention and injury to the part of stomach displaced to the mediastinum (during ascent). Conditions associated with spasm of the cardia or pylori create a similar risk and therefore disqualify a candidate from diving. All factors which prevent gas being released from the stomach during ascent may cause gastric distention and rupture. For the same reason, obstruction of the small or large intestine is another contraindication to scuba diving. Patients with **gastritis**, **gastric** or **duodenal ulcers** or **cholecystitis** cannot be medically cleared to scuba dive until their condition has been successfully managed and all symptoms have resolved. **Cholelithiasis** is not a contraindication to dive. All hernias of the abdominal wall disqualify a candidate from diving until they are managed surgically. Lifting and carrying heavy objects, such as scuba gear increases the risk of hernia expansion and strangulation. Additionally, the presence of a hernia increases the risk of air trapping, with well-known consequences to the loop of the intestine filling the hernial sac. Patients who have had a hernia repair surgery can safely return to scuba diving after the post-operative wound has healed completely [1, 4, 6, 20].

## OTHER CONTRAINDICATIONS

A number of active or prospective divers might have **diabetes**. The clinical course and the severity of the illness vary between individual patients. The main risk associated

with diabetes is a sudden loss of consciousness due to hypoglycemia. Diabetic patients who manage their condition with diet and medication and have not reported any past episodes of hypoglycemia may be permitted to scuba dive. Patients who receive insulin therapy or those treated with oral medications but with a history of hypoglycemia must not be cleared to scuba dive.

**Pregnancy** and **obesity** are considered relative contraindications to recreational scuba diving. In general, pregnant women should be temporarily discouraged from any diving-related activity. Women who have had a natural birth are not recommended to go scuba diving for at least 4 weeks after they have given birth, while women who have had a Cesarean section should not scuba dive for 8–12 weeks after the delivery. Obesity does not only decrease general physical fitness but it may also increase the risk of a decompression sickness due to a high content of total nitrogen in the body (nitrogen is more soluble in fat than in other tissues). Candidates for scuba diving with any chronic conditions are recommended to have a fitness to dive examination before each dive. A candidate's fitness to dive will depend on the severity of their condition and how well it is controlled [3, 21].

In recent years, scuba diving has been increasing in popularity with people in their 50s. This is undoubtedly associated with a rapid growth in tourism globally, especially scuba diving tourism. Older people should be strongly recommended to undergo a careful medical examination and a fitness to dive assessment before they go diving. Candidates for recreational scuba diving must be made aware that the responsibility for their life and safety lies with themselves. It would be particularly dangerous if they tried to withhold any important information relating to their past or present medical history. It is the role of a physician, a specialist in diving medicine, to inform a patient of the conditions which are relative or absolute contraindications to scuba diving and of the potential health risk factors associated with this sport. Exposure to extreme environmental conditions (cold stress, underwater conditions, increased hydrostatic pressure, increased volume of respiratory gases) causes physiological and systemic changes which may unmask or aggravate certain pre-existing conditions [4, 9–13, 22, 23].

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# Medical assessment of fitness to dive. Part II

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## ABSTRACT

*Good physical and mental health is a prerequisite for anyone planning to scuba dive. A certificate of fitness to dive for those willing to enter a scuba diving course as well as for active divers, either amateur or occupational, can only be issued if there are no medical contraindications to dive. It is usually within the competence of a diving instructor, a manager of underwater work or a physician to assess a person's mental and physical health and grant them permission to stay under hyperbaric conditions. The legal requirements for issuing a certificate of fitness to dive are different for recreational and occupational divers. The part II of this article discusses the issues concerning medical assessment of fitness to dive for professionals, and divers in uniformed services. It also discusses contraindications to scuba diving and guidelines for medical assessment of fitness to dive in divers with a history of a diving-related condition.*

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**Key words: diving, health assessment, medical contraindications**

## MEDICAL ASSESSMENT OF FITNESS TO DIVE FOR OCCUPATIONAL DIVERS

Because of the difficult working conditions and exposure to increased hydrostatic pressure, a candidate for a professional diver has to be in perfect health, both physically and mentally. Occupational divers are required to undergo a regular health assessment to check their fitness to work underwater. Divers themselves should be interested in maintaining full physical fitness in order to be able to cope with the physical and emotional strain of their job and their work environment. Taking good care of their own physical and mental health will allow them to stay professionally active for a longer time, and will help reduce the negative health effects of the job.

In 2003, the European Diving Technology Committee (EDTC), in cooperation with experts, set new standards for medical assessment of occupational divers [1]. The EDTC guidelines include standard record forms for medical assessment of working divers; they discuss all diagnostic tests which must be performed, and list all contraindications to scuba diving, grouped by organs and systems. In compliance with the European Union legislation, the guidelines have been adopted in Poland and have been outlined in the Regulation of the Minister of Health of 2007 [2]. Under the Regulation, all candidates for divers are obliged to undergo a preliminary health assessment, while professional divers must undergo a periodic medical examination. Medical assessment of fitness to dive can be carried out at the University Center for Maritime and Tropical Medicine in Gdynia, regional healthcare providers run by the port authorities and other medical facilities designated for this purpose. Medical assessment of fitness to dive can be also carried out by physicians certified by the Polish Hyperbaric Medicine and Technology Society and the National Center for Hyperbaric Medicine.

After the initial medical check-up, candidates for commercial divers are issued a certificate of fitness (or lack of fitness) to work as a diver. Professionally active divers, on the other hand, receive a certificate confirming a lack of contraindications to work as a commercial diver or a certificate

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of temporary or permanent disability to work underwater. After a fitness to dive assessment is complete, occupational divers are issued with one of the following documents:

— a certificate confirming a lack of contraindications to continue work as a commercial diver;
— a certificate limiting the maximum diving depth to 18 m;
— a certificate of temporary disability to work as a commercial diver;
— a certificate of permanent disability to work as a commercial diver.

A preliminary health assessment for prospective divers includes: a general medical examination, ear, nose and throat examination including an audiometric and a balance test, a neurological examination, an eye test, as well as multiple diagnostic tests such as: a chest X-ray, electrocardiogram (ECG), a blood test, urinalysis, a test for syphilis. If there are no medical contraindications to work as a commercial diver, candidates are referred for pressure tolerance test in order to assess their response to changes in the atmospheric pressure of no less than 0.3 MPa (an equivalent of 30 m of water column). Routine medical re-assessment of commercial divers is performed every 12 months, if their maximum depth limit is 18 m, or every 6 months, if they their allowable depth limit is more than 18 m. A special diving health re-assessment is carried out after a break from diving lasting longer than 3 months, a diving-related illness or injury, or right before a dive session if a diver reports of any health problems. Although the risk of diving-related illnesses or injuries is similar for all types of scuba-diving (occupational, sports, recreational), it may differ depending on the technology and equipment used by individual divers. Proper training, practice and modern equipment reduce the risk of diving-related illnesses and injuries. The basic criteria for determining fitness to dive in commercial divers are as follows:

— the absence of medical contraindications to work as a commercial diver (i.e. having good swimming skills and communications skills, being responsible and mentally competent);
— the absence of illnesses or disorders which could potentially put a diver or any member of a dive team at risk (e.g. a history of syncope, disorientation, a tendency to panic);
— the absence of conditions which might result in deterioration of a person's health condition (i.e. conditions which increase the potential for a barotrauma);
— the absence of conditions which increase the risk of diving-related illnesses, e.g. patent foramen ovale (PFO), a history of a diving-related accident (since the risk of developing a decompression sickness [DCS] is low in divers with PFO, diagnostic tests for this condition are generally not recommended in recreational divers; however, because occupational and military divers may be exposed to a much higher decompression stress, candidates should, in our opinion, be tested for PFO).

The task of a dive doctor performing a diving health assessment is to disqualify each person who has medical contraindications to scuba diving, using their own experience and the recommended medical guidelines for assessing a person's fitness to dive. A preliminary health assessment for commercial divers must be very careful. Disqualification from scuba diving before the training starts will be less stressful for a candidate than disqualification shortly after the completion of training or at the beginning of a career. The primary purpose of each diving health assessment is to improve diving safety as much as it is possible. A thorough preliminary evaluation of candidates will reduce the risk of major injuries as well as the risk of death from pre-existing conditions which might occur during a dive session. Manifestation of an underlying condition under water is dangerous for a diver himself as well as for his buddy and other members of a dive team. The aim of periodic re-examination is not only to determine a person's fitness to continue work as a commercial diver but also to detect any conditions or abnormalities which might have resulted from exposure to hyperbaric conditions in order to minimize the negative health effects of scuba diving which may affect a diver later in his life. When a diver retires, his complete medical records might be used to determine the extent of work-related personal injury for the purposes of an insurance claim. A reliable medical assessment of fitness to dive requires close cooperation between a patient and a doctor, which is based on mutual trust. During an interview, a diver must provide the physician with accurate and complete information about their health condition and inform the physician of any illnesses or injuries which had occurred in between successive re-examinations that resulted in a temporary disability to scuba dive. The fitness to dive examination and assessment form should be completed in the presence of a patient. A physician must make sure the patient fully understands the questions concerning their past and present medical history. An interview is an excellent opportunity to observe patient's behavior and assess their mental condition and communication skills. Before a dive doctor issues a certificate of medical fitness to dive, he or she will have to analyze the results of the diagnostic tests and get acquainted with the opinion of other specialists. The medical examination form must be signed by both the doctor conducting the examination and the diver. The medical records should be available for review by any other physician if necessary. If possible, it is highly recommended that all subsequent fitness to dive re-examinations should be carried out by the same physician. This way, it will be easier to identify even the slightest changes to a diver's health.

A certificate of fitness to dive should include the following information: the type of scuba diving a person is cleared to engage in, the maximum depth limit and the term of its validity. If an individual is declared 'unfit to dive' or 'fit to dive with restrictions', the reasons for such a decision must be clarified to the diver. If a diver is not cleared to scuba dive, he should have the right to appeal against the decision to a superior institution.

European Diving Technology Committee recommends to distinguish between: a preliminary diving health assessment of candidates for occupational divers (during which a maximum depth limit is established), periodical medical assessment and special medical re-assessment to resume diving after a diving-related illness or injury, including DCS. According to the EDTC guidelines, a periodical health re-assessment does not require such comprehensive tests and procedures as the initial examination. However, it is recommended that a diver is interviewed by a dive physician on a yearly basis. If the information obtained during the interview suggests any abnormalities, a diver should be referred for diagnostic tests. EDTC recommends that an in-depth health re-assessment is to be performed every 5 years. Divers who have suffered a diving-related condition or injury or those who have recently had a surgical procedure will require a special medical re-assessment including the analysis of the existing health problem and its consequences for continuation of occupational diving. This type of examination needs understanding and knowledge of the job as well as its physical demands and hazards in order to be able identify potential restrictions [3].

## MEDICAL ASSESSMENT OF FITNESS TO DIVE FOR UNIFORMED SERVICES

In Poland, the most stringent regulations concerning medical assessment of fitness to dive apply to the military personnel. This can be explained by the fact that soldiers must at all times be ready to work under extremely dangerous conditions, often in operational settings, and might be involved in exceptionally challenging missions and tasks, such as offshore rescue operations (including submarine rescue operations), planting explosives, sabotage or subversion missions. To accomplish such difficult tasks, military divers may be required to dive using highly specialized equipment, e.g. a semi-closed or closed circuit breathing apparatus as well as an oxygen or mixed breathing apparatus [3].

The latest provisions regulating medical assessment of fitness to dive in military personnel were specified in the Regulation of the Minister of National Defense of 2015 [4], the provisions form the basis for qualifying or disqualifying prospective and active divers from occupational diving. According to the eligibility criteria, the age of a candidate should range from 18 to 30 years. In compliance with the provisions, a candidate for a military diver must be in perfect health and should demonstrate a high level of physical fitness. In order to determine his health status and fitness level, a prospective diver is referred for an initial assessment of fitness to dive by a board of specialists. The preliminary evaluation of candidates includes a series of diagnostic tests (e.g. ECG, echocardiogram, radiography of the chest, paranasal sinuses and the epiphysis of the long bones, blood test, urinalysis) as well as multiple consultations with specialists: a psychologist, a neurologist (electroencephalography [EEG] test), an ophthalmologist (fundus examination), otolaryngologist (audiometric test), internal medicine specialist (a spirometry test), a surgeon, a dermatologist and a dentist. During the initial assessment of candidates, particular attention is paid to their body build. In doubtful cases, exercise ECG and spirometry test results are used to determine the physical fitness of candidates. Excessive body weight (obesity), underweight and asthenic body build are considered absolute contraindications to occupational scuba diving in the Polish Armed Forces. ECG and echocardiography (ECHO) tests are performed to exclude those candidates who suffer from a heart condition. During contrast ECHO a candidate for a diver performs the Valsalva maneuver. The ECHO test performed in this way makes it possible to detect the PFO in the interatrial septum. If such a condition is diagnosed, a candidate is declared unfit to become a military diver because of a high risk of developing a severe decompression sickness. Radiography of the chest and paranasal sinuses is performed in order to disqualify any candidates with respiratory system pathologies. Radiography of the long bones epiphysis is performed during the first 3 years of service, before a diver leaves the service as well as after each diving related accident. The aim of the preliminary radiography is to disqualify any candidates with aseptic osteonecrosis, while the tests which are performed after accidents or when a person leaves the service are aimed at identifying any possible long-term health effects associated with scuba diving or the extent of work-related personal injury. Because of the nature of the underwater environment, it is essential that military divers have excellent eyesight and good color vision. Also, they should present with no dental problems or conditions. The proportion of the missing teeth cannot exceed 45%; however, none of the front teeth can be missing, otherwise a candidate will not be able to hold the scuba mouthpiece. Also, a prospective military diver cannot have any chronic, allergic or purulent dermatoses. The assessment of the mental state of a prospective diver is a key element of the initial evaluation of fitness to dive. Psychological consultation is aimed to assess the emotional state of a person and their tolerance to stress. Psychological assessment of military divers is performed before they start service, shortly before they leave

the service as well as after each diving-related accident. All types of neuroses or phobias (e.g. claustrophobia) are considered an absolute contraindication to scuba diving in the military. However, the final decision whether or not a person may be medically cleared to become a military diver is taken after the analysis of the hyperbaric chamber test results. The hyperbaric pressure tolerance test and oxygen tolerance test are performed to determine a person's sensitivity to the effects of hyperbaric oxygen. A routine reassessment of military divers' fitness to dive is normally carried out every 12 months. A number of diagnostic procedures, including radiography of the long bones, EEG test, fundus examination and audiometric test are performed as part of the initial assessment of candidates. The same tests are routinely performed in all active military divers during periodic medical re-assessments at least every 3 years; the tests are performed in order to identify any negative health effects associated with scuba diving.

The following medical conditions disqualify a person from becoming a military diver or continuing service as a military diver: chronic infections of the upper respiratory tract, especially chronic or recurrent paranasal sinusitis, perforation of the tympanic membrane, chronic otitis media, a past history of the inner or middle ear surgery, inability to equalize middle ear pressure, chronic pulmonary illnesses, cardiac diseases, arterial hypertension, peptic ulcer, hernias (until surgically managed), epilepsy, a history of severe head trauma or craniocerebral surgery, disorders of the central nervous system, severe hearing or vision loss, obesity, diabetes, mental disorders, urinary tract abnormalities, alcohol or substance abuse.

A large number of tasks and missions which were previously carried out by military divers or members of the national scuba diving clubs have been taken over by the Polish National Police and the State Fire Service. The regulations on medical assessment of fitness to dive in police officers and firefighters have been specified in the Regulation of the Minister of Health of 2007 [2] and the Regulation of the Minister of Internal Affairs and Administration of 2014 [5]. Under these Regulations, candidates for divers recruited from among the ranks of the Polish Police or the State Fire Service must show perfect physical and mental health and a good level of fitness, as is the case with military divers. The tasks executed by members of the two services are usually carried out under difficult conditions and in dangerous waters. The task of a physician responsible for certification of medical fitness to dive is to determine each candidate's fitness to dive and disqualify all candidates with any underlying health conditions on the basis of the applicable guidelines as well as their own experience. The initial medical assessment of fitness to dive is extremely important and has to be very careful. The purpose of routine fitness to dive examinations, on the other hand, is not only to declare a person fit or unfit to dive, but also to identify any illnesses or conditions which might have resulted from exposure to hyperbaric conditions and which may potentially have a negative effect on a diver's health later in his life. After conducting all the recommended tests and procedures a medical board declares whether a given candidate is fit to become a diver. Prospective divers are selected on a voluntary basis. All amateur or professional divers should hold a current medical certificate confirming their fitness to dive and stating the date of their last fitness to dive assessment. In order to become a good diver, a candidate must enjoy the activity, feel safe underwater and be confident with the equipment he is using [3].

## FITNESS HEALTH ASSESSMENT AFTER DIVING-RELATED ILLNESSES

Whether it will be possible to return to diving after having had a diving-related accident or a diving illness will much depend on the nature of the incident or the condition itself and the risk of deterioration or recurrence of symptoms. The criteria for medical assessment of fitness to dive in individuals with a history of a diving related-illness vary depending on the institution or types of services which employ the diver, in other words, they will be different for the military and for commercial companies. Each time a diver has suffered a diving-related injury or illness, they will be obliged to undergo a careful medical examination. The purpose of such an examination will be to assess a diver's general health condition and the extent of the injuries. Such an examination will also be necessary if an injured diver claims for compensation or a disability benefit. Before declaring a person fit to dive, a physician needs to consider whether this person will continue to dive occupationally (either for a commercial company or as a member of the uniformed services) or only for recreational purposes [3].

### DECOMPRESSION SICKNESS

When a diver exhibits signs of a DCS, the role of a physician is to determine whether the condition has resulted from inadequate decompression or if it has been the result of individual risk factors which could increase the chance of DCS occurrence. The primary cause of a decompression sickness is shortening the decompression time. However, in some cases the disease may occur even if a diver has followed the recommended decompression procedures and adhered to the diving tables limits; in such cases, the decompression sickness is usually associated with cerebral or cutaneous manifestations. The incidence of DCS in divers is relatively low, ranging from 0.01% to 0.095% depending on the diving environment and the type of diving activity. A study involving a relatively small group of divers with

a known PFO has shown that the incidence of decompression sickness in such individuals ranges from 0.5% to 1.8% [6, 7]. During a longitudinal study of a group of recreational divers who had received recompression treatment for decompression sickness, study subjects received a variety of psychometric tests as well as the electronystagmography test (electronystagmography is a diagnostic test which records nystagmus in response to stimuli and helps diagnose the causes of vertigo). A total of 50% of the study group showed abnormal tests results after 1 week of completing the treatment, after 3 weeks of the treatment only 10% of the patients had abnormal tests results, which indicates that the neurological signs and symptoms of decompression illness persist for a minimum of 1 month. Therefore, divers are not recommended to return to scuba diving for at least 4 weeks after hyperbaric treatment [1, 8–11].

A mild form of a decompression sickness is relatively easy to manage. Some specialists even believe that if recompression treatment is effective and all signs and symptoms subside, a person can safely return to scuba diving after a minimum of 24 hours of the treatment. A lot of researchers, however, consider such an approach too risky. In compliance with the United States (US) Navy recommendations, a person who has suffered a mild form of a decompression sickness and met the criteria for recompression treatment specified in the US Navy Treatment Table 5, can safely return to diving after a week of hyperbaric treatment, provided that all signs and symptoms have subsided. Divers who meet the criteria listed in the US Navy Treatment Table 6 may be allowed to return to scuba diving after a week of successful hyperbaric treatment, whereas those with a severe form of a decompression sickness manifesting with neurological, pulmonary or circulatory signs and symptoms who have been treated in compliance with the criteria defined in the US Navy Treatment Tables 4 or 7, can only be allowed to return to scuba diving after they have had a medical assessment of fitness to dive by a specialist physician and no earlier than 3 months after completing recompression treatment. Individuals who have experienced a severe form of a decompression illness with residual neurological symptoms should not be allowed to return to occupational diving at all. A medical assessment of fitness to dive in individuals with a history of a decompression illness should include a complete neurological and psychological examination as well as a computed tomography or magnetic resonance imaging scan of the brain and the spinal cord as well as the evoked potential test [8, 9].

It is not uncommon that commercial or military divers conceal or dissimulate their symptoms for fear of losing their job. It is, therefore, important that a physician makes them realize that diving with any residual neurological symptoms increases the potential risk for further brain damage, which may eventually lead to a permanent neurological dysfunction. According to the general recommendations, divers may be medically cleared to return to diving 1–4 weeks after successful hyperbaric treatment. Not all diving specialists, however, agree with the proposed guidelines. The reason for this is the fact that the results of imaging tests performed in patients with a history of a severe form of a decompression illness have shown that the central nervous system damage was far more extensive than the presence (or absence) of residual symptoms. Some diving specialists believe that every single episode of a decompression illness manifesting with neurological symptoms should be considered an absolute contraindication to commercial or professional diving. In our opinion divers with a patent foramen ovale, atrial septal defect or intracardiac or intrapulmonary shunts should not be cleared to return to commercial scuba diving after they have experienced an episode of a decompression illness. In some cases, one might consider limiting professional activity to more conservative diving in order to reduce the risk of venous gas bubbles forming and passing through the PFO to the left part of the circulatory system. This can be achieved by: shortening the dive time to the limits of a no-D dive, limiting the diving depth to less than 15 m, performing only one dive per day, using nitrox, deliberately extending the safety stop or the duration of shallow decompression stops, avoiding any exercise or any unnecessary effort for at least 3 hours after diving. Percutaneous PFO closure may also be considered; performing the procedure eliminates the risk of DCS [12]. As for recreational divers, only those with the atrial septal defect and a history of a severe decompression illness manifesting with neurological symptoms should not be permitted to resume scuba diving. Divers with osteonecrosis revealed by a routine X-ray examination can be medically cleared to return to commercial or professional scuba diving [8–10].

## PULMONARY BAROTRAUMA AND ARTERIAL GAS EMBOLISM

Medical assessment of fitness to dive in individuals who have suffered arterial gas embolism (AGE) resulting from a pulmonary barotrauma (PB) or those who have experienced a PB with or without accompanying neurological symptoms is a more complicated issue. Experts disagree as to whether such patients may be medically cleared to safely return to scuba diving. It is generally accepted that individuals who have had any of these conditions may be more prone to the recurrence of symptoms because once a lesion has occurred, lungs become more susceptible to injury. For this reason, before a patient with a history of AGE or PB might be declared fit to return to scuba diving, he will need to undergo a series of specialist pulmonary tests. When consulting a diver who has suffered a PB it is

important to establish whether the condition has been the result of a diver's mistake or whether it might have been caused by some underlying conditions or the presence of pathological lesions within the lungs which increase the potential for pulmonary parenchymal damage. If a diver has not had a quick and uncontrolled ascent and has not reported a respiratory arrest during a dive, the reasons for air-trapping must be looked for elsewhere. The common causes of a diving-related barotrauma might include: a recent respiratory infection, air bubbles trapped at lung apices or interstitial scarring. Because minor lesions may not be visible on a standard chest X-ray, in some cases it might be necessary to perform more accurate diagnostic tests (e.g. computed tomography scan). If the test reveals any abnormalities in the lungs, a patient cannot be medically cleared to return to scuba diving. In rare cases, divers who have received treatment for AGE may develop neurological residuals (although the symptoms are generally more common in patients with a PB). In such cases, divers with a history of AGE will have to undergo the same tests and procedures as those who have had a decompression illness. It will be necessary to perform tests to detect a patent foramen ovale or intracardiac or intrapulmonary shunting. According to the United Kingdom Diving Medical Advisory Committee, any person with symptoms of AGE (with or without the signs of pulmonary damage) as well as any person with signs of a lung injury should be declared as permanently unfit to scuba diving. In exceptional cases, and only if a patient shows a complete recovery from a PB or AGE, divers may be medically cleared to return to scuba diving after a minimum of 3 months [8–10, 13].

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